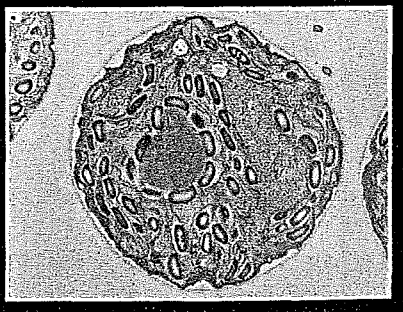
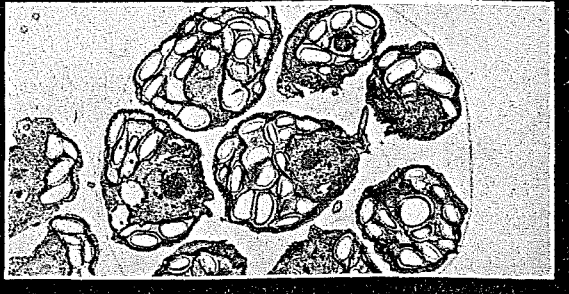
ALGAE THE MODERN MANNA?

In the U.S., blue-green algae for human nutritional use are found growing naturally in beautiful pristine Upper Klamath Lake. This mountainous lake, as shown in the photograph, is situated in a high valley in the Cascade Range at over 4,000 ft above sea level. It is located near Klamath Falls, Oregon, just to the north of California. Today, Klamath Lake remains an ecological haven as it has for years—unpolluted by man and his technologies. During the warm summer days, nutritionally healthful blue-green algae grow abundantly in the lake. And, they are being harvested by a nonpolluting method which leaves the lake in its natural state. Since the algae grow rapidly, removing some for our use does not disturb the natural ecology of the area.

Blue-green algae for human use are also grown in the U.S. in large (100,000-gal) covered growth chambers as shown. They are grown throughout the entire year and yield about 75 dry tons/acre-year compared with 2 to 4 tons/acre-year for conventional crops. During sunlight hours, they are removed from the growing medium by microsieving, washed twice with pure water, centrifuged to obtain a thick paste, and flash-frozen. The harvesting and processing of the algae takes less than two hours to complete. The algae are freeze-dried to preserve their energy-giving qualities (Controlled Growth Factor).



The lead picture is a photomicrograph of filamentous blue-green algae and was taken on a Zeiss photoscope with an ultraviolet exciter light source. The contained cell energy is shown by the vivid glow of the red fluorescence emitted from the high concentration of green cellular chlorophyll. The three major sources of blue-green algae, as found growing naturally, are Upper Klamath Lake (USA), Lake Texcoco (Mexico), and Lake Chad (Republic of Chad, Africa).



Dawn. During the night, photosynthesis and growth stopped. The cell survived by consuming food it had produced and stored during the day. Note the paucity and small size of white carbohydrate globules compared to those shown in photos taken later in the day.

Midmorning. After several hours of photosynthesizing, the cell becomes "ripe" with the food it has generated. Note the abundance and larger size of white carbohydrate globules. The cell itself has also considerably increased in volume.

By Dr. Victor H. Kollman
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Then the Lord said unto Moses, Behold, I will rain bread from heaven for you; and the people shall go out and gather a certain rate every day, that I may prove them, whether they will walk in my law, or no . . .

And when the dew that lay was gone up, behold, upon the face of the wilderness there lay a small round thing, as small as the hoar frost on the ground.

And when the children of Israel saw it, they said to one another, It is manna, for they wist not what it was. And Moses said unto them, This is the bread which the Lord hath given you to eat.

Exodus, Chapter 16

Since this dramatic episode, scholars have been intrigued by manna. Some believe manna might have been coriander seeds, others a type of lichen common in Africa and Arabian deserts.

However, what manna may have been is not so important as what the Biblical account represents: man's age-old dream of a miraculously provided food so perfect that it would satisfy all human needs.

If the yearning for manna was strong 3 millenia ago, it is even stronger today. The spectre of starvation stalks millions of the world's mounting population. The high hopes placed in the Green Revolution, which seemed so promising in the '60s, are fading as mounting costs of petroleum, the basis of modern fertilizers essential to the Green Revolution, threaten to make fertilizers unavailable to poorer nations.

Man needs a modern manna. The call for science to respond was aptly put by James Kendrick, Jr., University of California vice president for agricultural sciences:

"One hundred years ago, greater agricultural production was a pressing need for our rapidly growing society, and farmers needed the help of science to achieve it. Now, as we face the next 100 years, we have that same pressing need for production . . . and the help of science is needed more than it was before . . .

Research

"Major limits to production growth for the rest of this century will not be physical, but man's ability to discover new knowledge . . .

"The time has come for more resources to go into nutrition research, new food technology, and ways to increase productivity per acre. We need to explore ways of capitalizing on photosynthesis and making better use of the sun's energy . . ."

Answering this appeal in a variety of innovative ways is a group of scientists, engineers, and technicians in the United States who have made significant advances in this area and are confident they have opened a new era in the fields of nutrition, health, and environmental quality. This group, working both independently and together, may have touched on modern manna. Interestingly, it would have its roots in one of the earth's oldest, most overlooked, yet most efficient high-energy life forms: ALGAE.

Algae exist everywhere in thousands of varieties. While resembling bacteria, some of which can photosynthesize, algae have cell walls and are far more efficient photosynthesizing organisms. Some algae grow in colonies, resembling plants. Best known of these are the sea kelps, some of which can attain lengths of several hundred feet. However, algae such as these differ from true plants in not having root, circulatory, and other complex transport systems. Each cell is self-sufficient; break a piece of sea kelp off and it will retain its viability.

Algae are generally, if not entirely satisfactorily, classified by color: green, blue-green, red, and brown. However, regardless of camouflaging

pigmentation, all contain green chlorophyll for photosynthesis.

Mineral

Algae may be found wherever there is water, or even moisture: in the ocean (where they are a major constituent of plankton), lakes, rivers, streams, ponds, hot springs with a high mineral content, and short-lived rain puddles. They may be found living on the ground or beneath the earth's surfaces, on the bark of trees, on rocks, and even within the bodies of higher plants and animals.

Primitive as algae may seem (and have been labeled as such by scientists), most are highly efficient photosynthesizers (more so than green plants). They use light energy, greater than 10 percent conversion efficiency, carbon dioxide from the air, and hydrogen and oxygen from the water to synthesize a high-energy form of proteins, carbohydrates (starches and sugars), lipids (fats), nucleic acids (DNA and RNA), vitamins, cofactors, chlorophylls and pigments.

A few strains, of special interest to nutritional researchers, rapidly metabolize molecular nitrogen from the air to proteins and other nitrogen-containing biomolecules. In addition to nitrogen, algae require phosphorus and micro quantities of certain metals to grow. The trace metals appear in the algae along with essential vitamins.

And algae grow rapidly. A few cells in a pond, under optimum conditions, can reproduce to cover the pond with thick scum in but a few hours. Exceptionally fast-growing varieties have cell-generation times of from two to three hours; a single cell splitting at this rate could produce algae covering the earth within a very short time. Obviously, there are limiting factors.

Delicacy

Some types of algae have been used as a food source for centuries. A few primitive tribes have gathered algae for food. In the Orient, sea kelp is today used in a few areas, and, in the Western world, dried and powdered sea kelp is sometimes used as a dietary supplement. One form of algae, when mixed and seasoned with other foods, is considered an exotic delicacy in isolated Asian areas.

A species of blue-green algae and green algae, freeze-dried and powdered, is available now in some health food stores in the U.S. Green algae are available in Japan at high prices. Some survival manuals contain instructions

for making "pond scum" into an edible broth.

But except in these minor ways, the immense nutritional and energy-health potential of algae has not been used or even recognized by most humans since the destruction of the Aztec empire. Algae are simply not in the cultural nutritional patterns of most of the human race.

This being so, there has been no incentive for farmers to grow algae, especially during a fast-receding era when high-technology/low-energy containing foods were abundant and inexpensive.

But with the impending world "food energy" shortage, all this may change as the need for energy-positive food supplements mounts. The crescendo of change will become deafening when the qualities of a few varieties of *fresh water algae* become known.

Powder

Blue-green and green fresh water algae, when grown, harvested, and processed for human consumption, have a dark green color and are a fine-grained or fluffy powder depending on the processing methods used. They have no odor and are described by many as having a mild natural flavor—unlike that associated with the sea algae (kelp). They are packaged in bulk powder, tablets, capsules, and as soft drinks for use. The average chemical composition of blue-green algae *(Spirulina or Anabaena)* and green algae *(Chlorella* or *Scenedesmus)* is:

AVERAGE CHEMICAL ANALYSIS
(PERCENT DRY WEIGHT)

Constituent	*Blue-Green Algae*	*Green Algae*
Protein	65	55
Chlorophyll	5	4
Lipid	4	4
Carbohydrate	9	22
Minerals	13	8
Moisture	3	4
Crude Fiber	1	3

Spectrographic analysis by atomic absorption spectroscopy shows that the complexed-chelated minerals present are boron, calcium, chromium, cobalt, copper, iron, magnesium, manganese, potassium, phosphorus, sodium, sulfur, titanium, vanadium, and zinc. Selenium is present as an organically complexed ion when it is present in the growth solution.

And, analysis shows that algae are rich in the necesssary known vitamins. The vitamins present in the average daily adult intake of 2 grams of algae are:

Vitamin	*Blue-Green Algae*	*Green Algae*
Provitamin A (β-carotene)	1400 USP Units	1200 USP Units
Thiamine B_1	0.04 mg.	0.05mg
Riboflavin B_2	0.10 mg	0.11 mg
Pyridoxine B_6	0.08 mg	0.04 mg
Cyanocobalamin B_{12}	4.00 mcg	2.14 mcg
Ascorbic Acid C	6.65 mg	9.00 mg
Niacin	0.73 mg	0.48 mg
Choline	9.31 mg	5.60 mg
Pantothenic Acid	0.07 mg	0.04 mg
Inositol	0.70 mg	N.D.A.
Folic Acid	1.00 mcg	0.97 mg
d-Ca-Pantothenate	22.00 mcg	16.00 mcg
Biotin	0.80 mcg	3.36 mg
α-Tocopherol E	0.40 mg	0.30 mg
Vitamin K*		

mg = milligrams; mcg = micrograms; N.D.A. = No Data Available

*Vitamins E and K are synthesized in the mammalian body from the phytol moiety of the chlorophyll molecule.

While blue-green and green algae, on the whole, are good sources of vitamins, they contain no vitamin D and have a highly variable ascorbic acid content which is dependent on the environment in which they are grown. Lesser amounts of ascorbic acid have been reported for yeast, and no reports were found for the ascorbic acid content of bacteria. Even when compared with eggs and milk, which are known to be rich food sources, algae are an excellent nutritional value.

APPROXIMATE COMPOSITION AND VITAMIN AND MINERAL CONTENT OF MILK, EGGS, AND ALGAE

Approximate Composition	*RDA for Adult Males*[a]	*Cows Milk*	*Chicken Eggs*	*Algae*
Protein, g	56	28[b]	49[b]	51
Carbohydrate, g		32[b]	3[b]	27
Fat, g		28[b]	44[b]	7
Fiber, f		0[b]	0[b]	6
Minerals, g		6[b]	4[b]	9
KCal/g[c]		5.2[b]	6.2[b]	3.6[d]
Vitamins, mg				
Thiamine	1.4	0.2[b]	0.4[b]	1.2
Riboflavin	1.6	1.4[b]	1.1[b]	3.0
Niacin	18.0	0.8[b]	0.4[b]	10.4
Pyridoxine B_6	2.0	0.4[e]	0.4[e]	0.2
Folic Acid	0.4	4.7[e]	16.3[e]	3.4
Cyanocobalimin B_{12}	3.0	3.2[e]	7.6[e]	25.0
Ascorbic Acid C	45.0	8.0[b]	0[b]	40.0
Panthothenic Acid		2.4[e]	0.4[e]	0.7
Biotin		–	–	26.0
Carotenoids, IU	5000	1110[b]	4500[c]	156,000
Vitamin E	15.0	–	–	2.6
Minerals				
Calcium, g	0.8	0.93[b]	0.21[b]	0.2
Phosphorus, g	0.8	0.74[b]	0.78[b]	1.8
Calcium/Phosphate	1.0	1.27	0.37	0.2
Magnesium, g	0.4	0.10[b]	0.42[b]	0.6
Sodium, g	–	0.40[b]	0.46	0.1
Potassium, g	–	1.14[b]	0.49[b]	0.8
Sulfur, mg	–	–	–	187.0
Iron, mg	10	Trace[b]	9.0[b]	31

[a]Recommended dietary allowances, 8th Ed. Nat'l. Acad. Sci., 1974.
[b]Composition of Foods, Agr. Handbook No. 8, U.S.D.A.
[c]KCAL/g = Kilocalories per gram.
[d]Calculated from median values for approximate composition of algae.
[e]Food Composition Tables for Use in East Asia, U.S. Dept. HEW and FDA, 1972.

The mineral content of algae can be adjusted to the desired amounts and ratios by changing the growth solution. Median values for phosphorus, magnesium, sulfur, and iron, as found in algae, are generally higher when compared with comparable dry weights of milk and eggs. The resulting low calcium-to-phosphate ratio in algae can be altered by changing the growing medium.

Although fresh-water algae have been eaten by man for centuries, only recently have they been touted by scientists and anthropologists (Furst, P.T., Human Nature *1*, 60 (1978)) as the group of high-protein containing organisms most likely to provide man with sufficient amounts of nutriments for the future.

But the real benefits which fresh-water microalgae can provide to modern man, when eaten on a daily basis in one to three gram amounts, is not in its protein food value, but instead is in a "Controlled Growth Factor"—designated as CGF by Japanese biochemists to describe the combination of molecules that provide the large increase in sustaining energy when certain types of algae are eaten by man in the freeze-dried form (one to three grams daily).

Amino

Yet, the amino acid profile of the protein contained in algae is adequate to sustain life. Algae contain all the essential and nonessential amino acids; and, if more highly processed than drying, they can provide a protein concentrate of greater than 90 percent consumable amino acids. However, during the protein concentration process, the CGF is entirely lost and, thus, the energy enhancement qualities are gone.

The processing of algae is just as important as the product itself. Considering the health and energy-giving qualities of algae, it must be recognized that the method used to dry the algae after it has been grown and harvested is critical if the beneficial factors (CGF) are to be retained.

The Kanembu natives of the Lake Chad region of Africa have traditionally harvested and eaten algae. They use a processing method similar to that used by the Aztec civilization to remove the alga, *Spirulina*, from Lake Texcoco.

The algae are gathered from the lake in porus cloth bags and allowed to drain. It is then formed into large flat cakes on the sand and dried in the sun. As the blue-green algae gels, it is smoothed by hand and marked off into squares. When most of the water has evaporated or seeped into the sand, the squares are pulled up, dried further on mats, and cut into brittle cakes. The Kanembu then eat the algae which is called "dihe," after it is cooked in a sauce of tomatoes, chili peppers, and various spices. The algae sauce is then poured over millet. Unfortunately, much of the chlorophyll and other factors are lost by the hot sun/sand drying.

Drying

Two drying methods for processing algae are currently in use; they are:
1) spray drying which involves the use of high temperatures (500 to 600 degrees F), and
2) freeze-drying which employs low temperatures (32 degrees F) and reduced pressure (absence of air). Due to the higher costs of freeze-drying, this process was largely abandoned for processing algae until our efforts to provide a product with all the "beneficial factors" dictated its use.

As far back as 1921, Robert McCarrison, M.D., F. J. Pottengern, M.D., D. G. Simonsen, PhD., and W. A. Price, D.D.S., demonstrated the destructive processes involved when foods are processed at high temperatures. They also showed the degeneration of primitive peoples that adopted "civilized" diets, and demonstrated a correlation between societal decay and diet.

With such factors as poor soils producing low-quality/low-energy crops, heat-processed and refined food, and even the lack of food, algae, which have been grown in sunlight and natural water, is perhaps the most significant and feasible way to dramatically improve any diet on earth.

While photosynthesis takes place in algae, a complex of chemical compounds is synthesized simultaneously along with the carbohydrates, lipids, proteins, nucleic acids, and vitamins. The exact compounds of this complex have not yet been determined by scientists but, because of its growth-promoting factors, is called "Controlled Growth Factor" (CGF).

The "Controlled Growth Factor" found in certain types of fresh-water microalgae is water-soluble and is easily extracted. CGF is separated into four fractions, each having specific effects on enhancing the growth of certain microorganisms. CGF has the following chemical properties: It has maximum optical absorption in the ultraviolet region (260 nm) of the electromagnetic spectrum; it is a mixture of sulfur-containing nucleotides (nucleic acids are larger units of nucleotides), and peptides (small

proteins) which are chemically complexed into units. The nucleotide portion of the CGF consists mainly of the important nucleic acid bases adenosine and cytidine. The molecular weight of the nucleotide-protein complex, which we believe provides the long-term energy stimulation when eaten by man and animals, is less than 15,000. The most effective ingredient of the algae *Anabaena, Spirulina, Chlorella,* and *Scenedesmus* is the CGF. And, it has been shown to ensure the proper vital cellular metabolism and functions in man.

Fresh-water microalgae, when grown under closely controlled conditions of sunlight, water, carbon dioxide, and some elements, contain a balanced human nutritional profile and contain as high as 65 percent pure consumable protein.

Since blue-green and green algae contain high amounts of lysine and arginine and other basic amino acids; they improve the nutritive value of rice and wheat flour and other grains when they are mixed, or included in the diet. Algae have been shown to be helpful in increasing the assimilation and utilization of proteins when on a vegetarian, microbiotic, and/or strictly raw food diet.

When algae, or a water-soluble extract of it, are added to a suspension of *Lactobacillus,* lactic acid production is accelerated. Using an extract of the green algae, *Chlorella,* the Yakult Company (Taiwan and Japan) has manufactured a soft drink called "*Chlorella* Yakult." The growth of the so-called "friendly bacteria" is accelerated in the gut of humans when algae are eaten daily.

Animals which were fed a diet of whole-dried algae have shown accelerated growth rates when compared to those raised on normal laboratory rations. Yamagushi and his coworkers observed greater weight increases and a higher percentage of viable offspring in mice, rats, swine, chickens, and silkworms. One study from a sample of Japanese school children who had been given two grams of algae every day for 112 days, indicated that this dietary supplement provided weight and height increases greater than in the control individuals. And reports from Japan indicate babies love algae as a food supplement when consumed as a liquid.

Published reports involving the clinical and biomedical use of algae are few; however, those that have been completed in controlled situations show encouraging results. Most of the clinical studies performed to date have been done in Japan and have appeared in Japanese journals; thus, the results of their work have gone virtually unnoticed by Western physicians.

Practice

Several U.S. medical practitioners do presently use algae in their practice, with excellent results with the administered cases. The algae are given to the patient as a dietary food supplement in the form of capsules, tablets, powder, or liquid. No claims can be made in the U.S. regarding the efficacy of algae for treatment of disease or metabolic dysfunction.

Today, about five million pounds of microalgae are produced in the world. Most of the world's production and consumers are in Japan and/or Taiwan. Mexico and the U.S. are minor producers. The total world's production, which is essentially consumed in total by Japan, provides a dietary supplement for about six to ten million Japanese and Taiwanese. Little wonder that with the wonderful energy-giving properties of algae these two societies play such a dominant role in shaping world markets and policies. □