ALGAE: AN OPPORTUNITY TO OBTAIN PRODUCTS WITH HIGH VALUE, TO CONTRIBUTE TO THE REDUCTION OF ENVIRONMENTAL POLLUTION AND TO ACHIEVE ENVIRONMENTAL SUSTAINABILITY

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Abstract

In view of the serious problems affecting humanity (energy, hunger, global warming, etc.) and to completion of their previous researches aimed to their mitigation, the authors dwell on the contribution that the cultivation of algae can give.

They highlight the significant advantage that the algae can give because of their ability to provide high use value products and high market value, based on recovery and on the storage of anthropogenic CO_2.

In countries with optimal environmental parameters for the algae cultivation, it would also have the opportunity to market their "green certificates.

The authors hope a growing interest of the governments in respect of products and industrial processes that can be realized through the use of CO_2, including those derived from algae themselves, in order to obtain an economic value through the use of CO_2 derived from industry.

Riassunto

In considerazione dei gravi problemi che interessano l'umanità (energia, fame, riscaldamento globale ecc) e a completamento di loro precedenti ricerche finalizzate alla loro mitigazione, gli autori si soffermano sul contributo che la coltivazione di alghe può dare.

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Essi sottolineano il significativo vantaggio che le alghe offrono in considerazione della loro capacità di fornire prodotti ad elevato valore d'uso e alto valore di mercato, basato sull'impiego e conseguente stoccaggio di CO_2.

Nei paesi con i parametri ambientali ottimali per la coltivazione di alghe, si avrebbe inoltre l'opportunità di commercializzare i "certificati verdi" di cui gli stessi sono portatori.

Gli autori auspicano un crescente interesse dei governi in materia di prodotti e processi industriali che possono realizzarsi attraverso l'uso di CO_2, compresi quelli che derivano dalle alghe medesime, ciò al fine di dare valore economico alla CO_2 di origine antropica.

Keywords: Algae and utilization of CO_2, Algae and direct and indirect products obtained, Algae and storage of CO_2.

Introduction

As is known among the problems of modern society are to be considered the pollution and the need to pursue manufacturing procedures that safeguard the natural heritage, especially in the case of non-renewable resources. This is in order to stand in line with the concept of sustainability as defined in the Report of the Environmental Commission of the United Nations (1).

This concept, which combines the social and economic needs with the needs of environmental protection and of conservation of exhaustible resources, is particularly significant in a situation of serious and growing environmental problems (greenhouse effect, acid rain, ozone hole etc.) (2), of increase of world population and its needs, of the growing gap between rich and poor countries and so on (3). It is also widely agreed that Science, Technology and Innovation should be regarded as fundamental resources for humans (4).

The demonstration of their importance is confirmed by the determinations of economic policy taken in 2000 in Lisbon by the Council of Europe (5).

The auspice is that to use knowledge and to introduce innovation in the various human activities in order to respect the environment and not impoverish the exhaustible resources, namely to put into practice the philosophy of the sustainable economy (1). Particular attention must have reposed to the CO_2 emissions as they are the main cause of the greenhouse effect, and are closely linked with the use of the fossil fuels.

In an earlier paper we have been identified the possible industrial uses of CO_2 in order to obtain economic value from it (production of goods and adoption of more secure innovative processes) and, simultaneously, pursuit a mitigation of the greenhouse effect (Table 1) (6).

The purpose of this paper is to extend the study also to the biological field, in particular to the production of algae and their derivatives.

TABLE 1

LIST OF THE MAIN USES AND INDUSTRIAL APPLICATIONS OF CO_2

Products / Processes	**Purity CO_2**	**State**
Production of urea	> 99.7%.	Gas
Production of methanol in processes where CO is not used	> 99.7%.	Gas
Production of polymers: polycarbonates, polyurethanes and polyureas)	>99 %	Gas
Production of Soda (Solvay process)	>99.7%	Gas
Production of carbonates and hydrocarbonates of NH_4, K and Ba	>99.7%	Gas
Increase in production of fuel oil in oil wells: it increases the pressure and favours extraction	< 90 %	Gas
Neutralisation of alkaline waste waters	>99%	Gas
Carbonation of waters for industrial use: hinders calcareous deposits	>99%	Gas
Cleaning of pipes containing inflammable gases	>95%	Gas
Movement of liquids that are inflammable or degradable	>99%	Gas
Stabilisation and 'inertization' of stockpiles or freight containing dangerous fluids	>95%	Gas
Control of reaction temperature as an intermediate means of removal of heat, in nuclear reactors, seeing that it does not become significantly radioactive	>99.99%	Gas
Refrigerating fluid in general	>95%	Liquid
Rubber finishing operations: hardening and removal of possible burrs	>95%	Liquid/ Solid
Maintenance of an inert atmosphere during electrical welding	90% mixture He + N	Gas

continue

Products / Processes	Purity CO_2	State
Hardening of fusion moulds and shapes in smelting processes	>99.7%	Gas
Tempering of certain alloys of Al and nickel steels	>99.7%	Gas
Cooling of mechanical pieces in the metallurgical industry	99%	Solid
Gas lasers	Pure	Gas
Fire-fighting fluid in fire extinguishers	>96%	Gas
Refrigeration of food and drinks	>99%	Solid
Preservation of foodstuffs	>99.99%	Gas
Production of fizzy drinks	>99.7%	Gas
Increasing stability in pressurised containers	>96%	Gas
Carbonation with magnesium carbonate and serpentine	>90%	Gas
Production of vegetable biomasses in greenhouses	>95 %	Gas
Production of microalgae in photobioreactors	>95 %	Gas

Algae and cultivation system

Algae are a large and diverse group of simple organisms, typically autotrophic, ranging from single-celled forms to giant multi-cellular forms (Kelp reaches also 65 meters in length) (7).

Algae, which in the traditional sense also include the blue-green algae (cyanobacteria) such as Spirulina, are in the waters of lagoon-seas, lakes and rivers, free or anchored to the ground. Existing varieties are numerous and all have one thing in common: they contain photoreceptors pigments (including chlorophyll), and, like all plants, are able, to use CO_2 to produce glycides, using the sun's energy. They have the advantage of using large volumes of water existing on the planet, rather than to be bound to the surface, as in the case of terrestrial plants. They have a higher biomass production for surface unit. Therefore have remarkable ability to capture and store of CO_2.

The algae take nutrients (nitrogenous and minerals) from the water through the surfaces in contact with it. In particular also the CO_2 emissions from industrial plants can be used, once purified by unwanted components. In this case, the CO_2 becomes a resource which can increase the production of biomass, in the same way of traditional fertilizers (8). They are easily adaptable to the different climatic conditions, to the chemical properties of

water. Then the algae are a great opportunity, especially if aimed at making sustainable the industrial processes that release CO_2. Furthermore, countries where conditions are optimal for their production can further benefit from the intensive cultivation of algae for trade with other countries the so-called "green certificates.

For algae it is possible to forecast an important future success in terms of quantity produced, in view of the prerogatives that make them unique: for example they do not require the use of large areas (but volumes of water), do not require herbicides and pesticides and so on (9).

In view of the estimates of their quantitative growth is expected to increase in importance of the artificial production systems of cultivation. These are geared towards the use of natural light and to a high yield per hectare, also to minimize the costs associated with the operating expenses and of amortization of the equipment. Depending on the technology, the location of the plants, the type of algae, the production per hectare varies between 40 and 80 tonnes of dry matter, with tendency to exceed 80 t (10).

The main artificial systems of production are:

- *open cultivation systems* ("raceway ponds"): These are easy closed-loop channels (deep 25-30 cm) in which the water is kept in movement by paddle wheel.
  This open systems of cultivation are subject to the effects of climate, pollution and predators.
- *closed cultivation systems*: they use transparent plastic tubes in which algae are exposed to natural light. The systems are more expensive, but solved many of the problems of open systems as they are less influenced by the environment.
- *sea-based cultivation systems*: they are intensive systems of cultivation of algae of sea (of hundreds of hectares), near to the coast, in low water.

Algae and products obtained

The number of products that can be obtained from the algae is virtually unlimited, because there is a great variety of species (calculated in half million about) and the variation of growing conditions can influence their composition.

Today they are commercialised only a few products derived from algae, so the possibilities offered by this resource are unused. Many industries that could benefit of they remain without their input.

Algae have great interest in the production of industries such as the energy, the alimentation of man and animals, in the chemical industry, in the health, in some manufacturing industries etc. Below we report this cases (Figure 1).

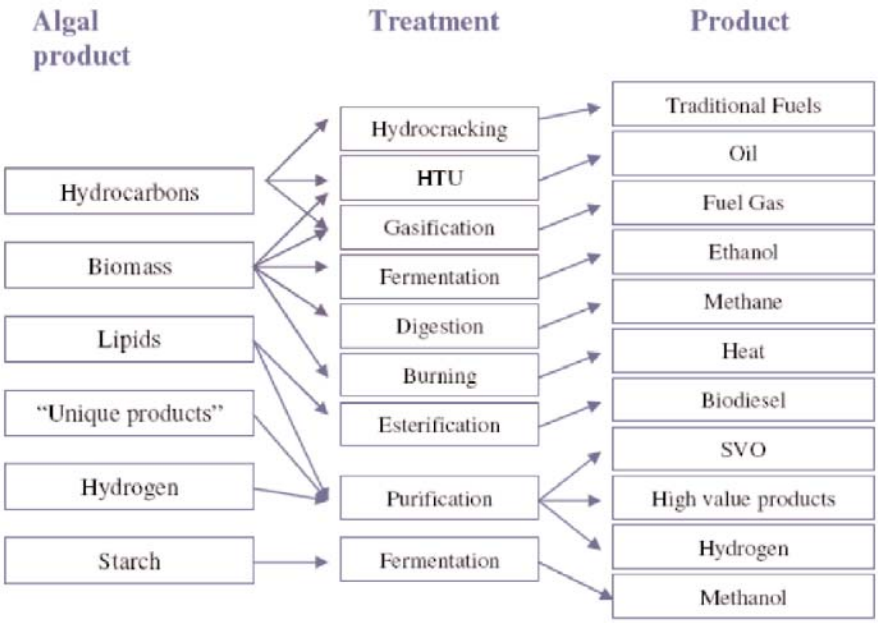

Fig. 1 - Overview of algae-to-energy options

Bio energy

The need to 1) combat climate change, 2) improve energy security, 3) do not dissipate the limited resources of fossil fuels, encourages the use of bio fuels production (eg in transport). Today as feed stocks to produce bio fuels are used agricultural products (first generation), that might instead be better directed to the human or animal nutrition. In this respect it is more appropriate produce bio fuel of second generation, by means of the use of cultivated algae (they do not require pesticides). Now we provide an indication of bio fuels that can be obtained from algae (11).

Biodiesel. Algae can come to have a total lipid concentration major of 80% when they are grown in special conditions (eg insufficient amount of nitrogen) (rapeseeds 6%). Under these conditions the yield per unit of

area is lower but the production of biodiesel is particularly satisfying. One hectare of sunflower or rapeseed can produce 700-1000 kg of oil per year, while the algal cultures usually may exceed the 20 tons of oil per hectare per year (in closed reactors) and have a potential of 30 tons in tropical countries.

Hydrocarbon. *Botryococcus* (grow in freshwater and saline water) does not produce lipids, as above pointed out, but longer chain hydrocarbons which can be fractionated in different compounds in a process similar to the production of fuels from fossil oil. This genus of algae has slow growth, but lives in freshwater and in saline water.

Ethanol. Ethanol is commonly produced from feedstocks containing starch. It is been reported some algae contain over 50% of starch. This polysaccharide can be used as a feedstock in a process similar to cellulosic ethanol production, with the advantage that algae rarely contain lignin.

Biogas. Anaerobic digestion converts organic material into biogas that contains about 60%-70% bio methane, while the rest is mainly CO_2, which can be fed back to the algae.

Hydrogen. Some algae produce hydrogen, but the yield needed to be increased for have industrial interest.

Bioelectricity. Algae can also be co-combusted in a power plant. For this production, the biomass needs to be dried. This process is thus interesting only if the biomass is required to be dried in order to extract a valuable co-product.

Algae-based product for human consumption

Is known that the use of algae in the human alimentation goes back to very remote times (12) and algae are added in foods in small amounts in many countries, to enrich the diet of compounds of great biological value (proteins, vitamins, minerals etc).

Less known is the variety of algae-derived ingredients (fats, polyunsaturated fatty acids, dyes, sugars, pigments, antioxidants, bioactive compounds, emulsifiers etc.) that are used in the alimentary industry (noodles, beverages, snacks, candy bars or gums, breakfast cereals, cookies etc.) (13).

Food. Most of the algae can not be directly used in human food because the cell walls are not digestible. However, the large number of

existing species and the selection made have permitted to overcome the problem and now the algae that are used by man are some hundred.

The growth of population and the billion people who suffer from hunger are a powerful incentive that will allow the algae to serve the world more effectively. Many algae are employed directly in human food without requiring any processing or from simple treatments such as cleaning and drying. Instead, other algae require actual processes for deliver active ingredients of great industrial interest (not just food) (14).

The direct use of algae for man goes back several millennia ago.

This use has concerned and continues to concern mainly the Asian populations of China, Japan, Philippines, Thailand, Malaysia etc. but also Oceania, New Zealand and also some Northern European countries. Among the many species that are used most commonly, we mention the genus *Ulva* and *Monostroma*, for green algae, while among the red algae we remember the *Rhodymenia palmata*, *Gracilaria compressa, Iridaea edulis, Chondrus crispus* and so on. Algae once collected, can be eaten as they are, how common salads and other vegetables, or as happens for example in Japan, dried and reduced to sheets ("hoscinori" or "nori") derived from algae of the genus *Porphyra* or in other forms then used for various food preparations.

Among the products on the Asian market, in addition to the “nori”, we remember the "kombu", consisting of several species of *Laminaria*, the "wakame", originated from the processing of *Undaria pinnatifida* etc.

As for Europe, but with refer to traditional sweets we remember some products (eg. jams) prepared in Sweden and Norway from *Chondrus*, *Gelidum*, *Porphyra*, and *Rhodimenia* or the "bread of Goemon" of the Breton coast.

Besides the mentioned seaweeds, great interest has the intention to contribute significantly to the proteic needs of the humanity, using green algae microscopic of freshwater.

Together with the *Chlorella*, the *Spirulina* is certainly the kind of alga that has the greatest importance. It was already consumed by the people of Chad, Mexico and Peru for the quality and easy digestibility and the high protein content: 63% on dry weight basis. In addition to the direct uses, algae are used in the food (and not only) with the their extracts.

With reference to the European Union (15) the algal derivatives are used for their properties emulsifiers, stabilizers, thickeners and gelling: E400 (alginic acid), E401 (sodium alginate), E402 (potassium alginate), E403 (ammonium alginate), E404 (calcium alginate) and even E 406

(Agar-Agar), E407 (Carrageenans). These derivates can be used in a long list of different foods. Of these extracts we talk afterwards.

Products for health and drugs. The use of algae in the sectors of health (life sciences) is traditionally prevalent in populous eastern countries where it has importance in the prevention of diseases and during therapy. The uses are extended to the west, in some branches of medicine such as thalassotherapy, phytotherapy etc.

The first applications in the health field have taken place in China with the use of Sargassum and Laminaria in the prevention and treatment of goiter and other glandular diseases, and, most recently in circulatory diseases, bronchial and pulmonary (14).

To the west is Hippocrates to that has talked of the use of algae in medicine and Pliny the Elder has described the use of laxative Chondrus crispus.

With reference to more recent times it is recalled as the Pharmacopoeias of Europe gave particular emphasis to the jambs dried of Laminaria (Laminaria digitata) in surgery, as a means of expansion of the channels or injury or as a result of hydration of algae. Important are the studies conducted by the Japanese researchers and aimed at the identification of active and useful substances to be used in pharmaceutical preparations and medicine.

With regard to the health effects algae are considered re-mineralizing, strengthening the immune system, stimulating the exchange metabolic and of the endocrine glands etc. And for this are recommended in cases of general fatigue, lymphatic, demineralization, loss of appetite, convalescence, nervous disorders, disorders associated with senescence and also have some specific principles useful in the treatment of obesity, cellulites, illness of puberty and menopause, inflammation, allergies, arthritis, chronic nasopharyngitis, thyroid disorders, goiter, disorders of the circulation, hemorrhoids.

From the studies that have been made in the medical field it is shown that they include the following actions: antihypertensive, ipocolesterolemica, antibiotic, anthelmintic, and antiviral. With regard to the uses of major algae derivatives (agar, carrageenate, alginic acid and derivatives) we refer later.

With more specific reference to therapeutic disciplines it is necessary to remember that the algae are used in the allopathic medicine, homeopathy, herbal medicine, oligotherapy, aromatherapy, thalassotherapy and seaweed, oysters and mud therapy, hydrotherapy.

In many countries, particularly in France, there are different centers, such as thalassotherapy, algae move that to use an important turnover.

a) Pigments. In addition to chlorophyll, which is the main compound photosynthetic, micro-and macro-algae contain other pigments correlated with the light.

The most important are the phycobiliproteins and the carotenoids. Dunaliella sp. are microalgae rich in beta-carotene (more than hundred times higher than any other vegetable: carrots, melons, apricots, etc.).

Their presence greatly increases the ability of defence against the diseases, particularly against certain types of cancer. Carotenoids have many applications in the market.

Beta-carotene is one of the most important ingredients of our diet for its antioxidant action and because it is a precursor of vitamin A. Many pigments of algae can also be used as natural food colorants, for example, in the orange juice, chewing gum, sorbets, ice, candy, soft drinks, dairy products and wasabi paste but also to give colour to the flesh of farmed fish (astaxanthin from Haematococcus) or to the skin of birds (lutein, zeaxanthin) (13).

b) Polyunsaturated fatty acids (PUFAs) and other bioactive algal products. Health professionals continue to stress the importance of essential fatty acids in nutrition and in therapy. The essentiality of these nutrients is linked to the inability of the human body of synthesize them.

Also known as vitamin F, the essential fatty acids (in the strict sense) are two: linoleic acid (founder of ω6, which reduce the concentration of cholesterol and triglycerides) and α-linolenic acid (founder of ω3, which lower plasmatic levels of the triglycerides, the aggregation of platelets, the risk of coronary heart disease and thrombotic, and increases blood flow). It is therefore necessary to introduce them in the diet in correct quantities and in appropriate ratio. This ratio (ω3/ω6) should be between 1:2 and 1:4. Their deficiency produces immune deficiency, growth retardation, infertility, fatigue, dry skin. The fat fish is the most important food giving PUFAs. However, fish do not produce PUFAs accumulated in their body, but by eating algae (or other algae-eating organisms).

Algae are the true source of these essential nutrients. The PUFAs industrial production from algae has been developed only in the last decade and has advantages in comparison with fish: Lacking unpleasant odour, reduced risk of chemical potential contamination and better purification (16). This helps us to understand the advantages that the direct consumption of PUFAs from algae have on the men's health.

c) Other bioactive products content. In the algae there are the vitamins. The algae represent a valuable source of almost all vitamins (e.g., A, B1, B2, B6, B12, C, E, nicotinate, biotin, folic acid and pantothenic acid) (17).

In *Chlorella* species, the most important compound from a medical point of view is beta-1,3-glucan, an active immunostimulator, a free radical scavenger and a blood lipid reducer. Efficacy of this compound against gastric ulcers, wounds and constipation, preventive action against atherosclerosis and hypercholesterolemia, and antitumor action have also been reported (13).

Algal extracts for food preparations and other products

The most important algal extracts are the macro algal polysaccharides: agar, carrageenans and alginates. Their value is due to their thickening and gelling properties. These are important for a lot of products and, in particular, specially for alimentary and pharmaceutics industries.).

Agar. Agar is made from seaweed and is used in a wide range of applications. In the food, in Europe with the letters E 406, is used in many products: ice cream, various confectionery products, fruit syrups, milk-based products (0.5%), puddings, canned meat etc. (1%), confectionery, canned fish etc. (2%). In the medical / pharmaceutical field it is used as a laxative and slimming treatments, in the preparation of capsules, tablets and suppositories containing active substances to be released gradually etc. In the manufacturing is also used in the industries of paper, of adhesives, of textile printing/dyeing etc. (18).

Carrageenan. In Europe carrageenans are listed in the ingredients as E407. Carrageenans are a water soluble group of polysaccharides that are more widely used than agar as emulsifiers and stabilizers in numerous foods (especially milk-based). Carrageenans are especially used, for their thickening and suspension properties (usually in a quantity less of 0.5%),in chocolate milk, ice cream, puddings, jellies, jams. Several potential pharmaceutical uses of carragenans have also been indicated (like antitumor, antiviral, anticoagulant and immunomodulation activities).They also have a tranquilizing action, lowers cholesterol in the blood, have anticoagulant action and are considered an anti ulcer (14).

Alginate. Alginates in the EU are listed in the ingredients from E400 to E405, depending on the chemical form of alginate. Alginate (or alginic acid) is produced by brown seaweed. Its gelling capabilities make

it of considerable technological importance. It is widely used in the food and pharmaceutical industries due to its chelating ability and its capability to form a highly viscous solution. It's also used in the textile industry for sizing cotton yarn (18).

Algae for livestock consumption

The use of algae (micro-algae) as food for animals is relatively recent. It is due to the high content of nutrients, especially proteins, that have normally and naturally in the algae. Initially, the uses have involved the poultry (to replace feed fishmeal-based or soy-based), especially because algae improve the yields of meat, flavour, the colour of the skin, shanks and egg yolks. Toxicological and nutritional evaluations have demonstrated the ability of algae to replace conventional sources of protein (fishmeal, rice bran, soybean meal, etc..) as a feed in different animals (cows, bulls, horses, birds, fish). It was in fact found that algae-based feed-stuffs give a better immune response, fertility, weight, skin, and then meat, milk and eggs, that have a lower content of saturated fat acid (13) (19).

Algae for fish and shellfish

Algae (microalgae in particular) are obviously great utility for aquiculture. They are essential during the processes of hatchery and nursery of bivalves, shrimp, finfish and some cultures. Microalgae are used also to produce zooplankton (typically rotifers) which is feed for the carnivorous fish freshly born (20).

Like for humans and livestock, protein and PUFAs are of main importance. Fresh algae are used in fish breeding, but this may cause problems. But they are solved by alternatives such as frozen and microencapsulated algae, as well as a concentrated algae pastes (13).

For market needs, in the preparation of feed, we may add algal pigments which may render the flesh of farmed fish of the same colour of the meat of the animals that live in open water (salmon, trout etc.).

In aquiculture, this can be corrected by adding astaxanthin to fish feed. Astaxanthin is mostly produced synthetically. But there is a growing market for astaxanthin derived from algae-based Haematococcos pluvialis.

Options non-food use of algae

As know algae have many different uses and application fields. Here we describe a few cases.

Chemical industry. At present the chemical industry is strongly linked to the nature of fossil energy resources and especially to oil. In fact, it is said that the petrochemical industry is the foundation of the chemical industry and it is linked to industry of the fuels for transport (land, sea and air) and to electricity production. All this is governed by a giant tangle of economic interests, that exceed the borders of nations and that it is difficult to scratch.

This makes difficult a large utilization of raw materials of biological origin in the chemical industry, partly because the prices of these materials are greater than fossil combustibles. However, it is expected that the trend of the bio fuel market and the importance that the algae may have in this market is to facilitate their entry into the chemical industry. Novel bio-based processes require significant R & D. These activities will focus initially over the algae feed stocks.

Already many exist developments, including large quantities of bio-based chemical already produced (for 2009 capacity is estimated to be over 5 million tons) (11).

In some cases the algae may already be competitive in specific applications like polyols and, possibly lactate acid, succinic acid and ascorbic acid. Some multinational companies already have used algal materials for the production of ethanol and butanol (DuPont and Dow Chemical Company). All this represent a good perspective for the future uses of algae in the chemical industry.

Cosmetics. For over two decades in developed countries the cosmetics industry is having a great development, as a result of the spread of fashion but also of the results of research in the cosmetology laboratories. In this context, the products based on algae, and their extracts, have contributed to skin care both in terms of prevention and for the restoration of the conditions of welfare (skin, subcutaneous tissue and hair).

The cosmetic use of algae is to be found in the properties and in the effectiveness of their extracts to stimulate, revitalize and nourish the skin (14). Algae in fact contain a high concentration of vitamins. They can be assimilated by the skin, such as vitamins D, K, E and carotenoids. Also B-complex vitamins are present. The high quantities of vitamin C rend the extracts suited for the preparation of sunscreen.

They have a high percentage of certain minerals (especially iodine and sulphur), amino acids and proteins of low molecular weight, easily absorbed through the skin and effective in the treatment of cellulite, of the fat and of the facial blackheads.

Colloidal seaweed extracts (agar, carrageen, alginates and derivatives) are highly moisturizing action.

These extracts provide consistency to the cosmetic preparations, to which give texture and desired viscosity, although used in small percentages (1-5%). They have functions emulsifiers, stabilizers, and thickeners and therefore have widespread use. They have the property to give film, to be washable, so that they are used in creams as well as in the preparation of hair products (fixers) and toothpaste.

As a result of these important properties, the tissues outside, properly treated, have a better resistance to weather and to the external environment. This is made possible for the following their actions: stimulant, tonic, balancing and detoxifying.

That said, here are indicated the preparations of algae found on the market: bags of dried thalli (bathroom); dense paste, semi-liquid and liquid (bathroom); dust, (bathroom); gel for massage or bath; moisturizing creams, slimming (massage etc.); sun milk detergent (after bath); paste for beauty masks; emulsions; lotions; shampoo; toothpaste; soaps (hygienic soap and toilet).

To get an idea about the market size and development taken by the algae in the cosmetics industry is of aid the copious list of products found on the French market, leader in cosmetics field.

Fertilizers. As is know algae have been used as a fertilizer in coastal territories for their capacity to retain water in the soil and their content of minerals.

As it is possible to predict for the future a considerable increase in demand for fertilizers, the uses of algae-based fertilizers have great potential of success, also to counter the negative environmental impacts associated with fertilizer produced by the chemical industry.

In fact, algae (macro and micro) contain substances that promote germination, flowering and then the harvested. In fact, algae (macro and micro) contain substances that promote germination, flowering, and then the harvest, because exercise a protective action against plant diseases (16).

Paper industry. As we know the consumption of different types of paper has increased over time, and everything suggests a similar trend for

the future, so that the algae are able to enter this industrial sector in the preparation of cellulose pulp used by paper industries.

Yet they are still to be overcome certain problems related to the fact that while most plant cells consist of cellulose, the coverings of the cells of the algae are different and vary depending on the species (21).

Paper industries have nevertheless interest that research of commercial products continues even considering the high costs of traditional cellulosic materials and the growing shortage of cellulose on the world market, in the face of growing demand for various types of paper.

Conclusion

Given 1) the problem of hunger, which affects 1.2 billion people, 2) the energy problem, of which suffers much of the world, 3) the environmental problem and in particular the increase of concentration of CO_2 in the atmosphere, with the resulting climate change (the CO_2 has exceeded 380 ppm, 270 ppm compared to the start of the 900 '), given 4) the prediction of population growth (8.2 billion people in 2025, compared to 6 in 2000), 5) the fact that aquatic plants have higher productivity per unit area of the common plants and then capture larger amounts of CO_2, we can say that the cultivation of algae, together with the other opportunities mentioned in our paper (6), can give an interesting contribution to the mitigation of problems related to the greenhouse effect.

In addition we have the advantage of getting products of high use-value and high economic value.

In this way, with the use of solar energy and factors of eutrofizzazione used by the production of the same algae, we get the result of giving economic value to the CO_2 and store it in important products of the market (this is not always for short periods time). In addition, when algae are used to obtain energy, they allow the savings of fossil fuels. Therefore, it calls a greater governments interest to the industrial cultivation of seaweed, as for the other possibilities indicated in the Table 1.

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REFERENCES

(1) UN, "Our Common Future", *Report of the World Commission on Environment and Development 1987*. Annex to General Assembly, Document A/42/427, August 2, 1987.

(2) WWF, Living Planet Report 2010, www.wwf.it; 1-117.

(3) G. Santoprete, J. Wang, *Energy and environment. Possible options for continually growing populations* (in Italian), ETS, Pisa, 2009.

(4) G. Santoprete, M. Santoprete, *Science and technology for society. A review of the main achievements of man* (in Italian), ETS, Pisa, 2001

(5) EUROPEAN COUNCIL, "The Lisbon Special European Council (March 2000): Towards a Europe of Innovation and Knowledge", 23-24 March 2000.

(6) G. Santoprete, P. Berni, "The significance of industrial uses of CO_2 (processes, products and goods) as instrument for the attenuation of the greenhouse effect and for the obtaining of economic values", *J. Commodity Sci. 2009*, 48 (II), 5-18.

(7) S. S. Kumar, S. Seema, *A textbook of algae*, Campusbooks, XII, 460 pp, 2008.

(8) D. Botkin, J. Janak, J.Wallis, "Estimating effect of carbon fertilization on forest composition by ecosystem simulation", *Brookhaven Symp. Biol.1973*, (30), 328-344.

(9) L. Brennan, P. Owende, "Biofuels from microalgae-A review of technologies for production, processing, and extractions of biofuels and coproducts", *Renewable & Sustainable Energy Reviews 2010*, 14 (2), 557-577.

(10) R. Wuffels. et Al., "Microalgae for the production of bulk chemicals and biofuels", *Biofuels, Bioproducts and Biorefining 2010*, 4 (3), 287-295.

(11) FAO- ACQUATIC BIOFUEL WORKING GROUP, "Alagae-based biofuel: applications and co-products", 1-107, Rome, 2010.

(12) C.K Tseng, "The past, present and future of phycology in China.", *Hydrobiologia 2004*, 512 (1-3), 11-20.

(13) P. Spolaore et Al., "Commercial applications of microalgae.," *Journal of Bioscience and Bioengineering 2006*, 101(2), 87-96.

(14) G. Santoprete, "Alghe e loro derivati una panoramica delle utilizzazione medico-farmaceutiche, cosmetiche ed alimentari", *Minerva Mesoterapeutica*, Vol. 1, n.2, pp 89-99, 1986.

(15) EC, Directive 95/2/EC of the European Parliament and of the Council of 20 February 1995.

(16) O. Pulz, W. Gross, "Valuable products from biotechnology of microalgae", *Applied Microbiology and Biotechnology 2004*, 65(6), 635-648.

(17) A. Richmond, *Handbook of microalgal culture: biotechnology and applied phycology.* Blackwell science, Oxford, 2004.

(18) K.H.M. Cardozo, T. Guaratini et Al."Metabolites from algae with economical impact", *Comparative Biochemistry and Physiology C-Toxicology & Pharmacology 2007*, 146(1-2), 60-78.

(19) E.W. Becker, "Micro-algae as a source of protein", *Biotechnology Advances 2007*, 25(2), 207-210.

(20) J.R. Benemann, W.J. Oswald, "Systems and economic analysis of microalgae ponds for conversion of CO_2 to biomass", Final report: Size: 214 pp. 1996.

(21) K. Okuda, "Structure and phylogeny of cell coverings", *Journal of Plant Research 2002*, 115(1120), 283-288.