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A CONCEPTION OF A GEOTHERMAL APPLICATION IN COMMON MICROALGAL DEVELOPMENT IN BALKAN COUNTRIES

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Abstract

A very intensive development of micro-algal biomass production is currently going on worldwide. This is related to the wide range of algal application in medicine, cosmetics and agriculture.

The quality and economic efficiency of this production is site specific and highly dependent on climate, water CO_2 content and overall composition, environmental conditions, know-how technology, as well as the existing local traditions for algal applications. The use of geothermal waters in algal technology provides a high optimization of the cultivation process and considerable reduction in production costs.

There are extremely good conditions for algal technology development in the Southern Balkan region in terms of the above mentioned major factors required for this activity. More efforts should be made for a wider use and management and that could be achieved by the joint efforts of Bulgaria, Greece and Macedonia. The first step has already been made with the Bulgarian-Greek project for Spirulina cultivation in the Nigrita geothermal field (N.Greece).

The conception of geothermal application in microalgal development proposed herein is based on:

- A fully developed know-how technology at an up-to-date level for cultivation of Chlorella in SW Bulgaria for more than 35 years of plant operation in the Rupite area (South-West Bulgaria), as well as various forms and types of applications in Bulgaria and accumulated export experience.
- Four years of Spirulina cultivation in the Nigrita area (Northern Greece) and some experience in its management and export.
- A good water resource base for successful cultivation and possibilities for application in F.Y.R. Macedonia.

Many spas in the three countries could be also a good choice for setting up an algae development in them. Algae's proven curative properties for many diseases could be successfully combined with their direct use in cosmetic services at the same spas. A health center using algae products is already in year round operation in Bulgaria (Albena resort, the Black sea).

The complex use of geothermal energy and thermal waters at the existing sites will expand the field of algae application and make their production cost effecttive.

It would be a good chance for the three countries to take advantage of microalgae rehabilitation and treatment as this is considered to be the medicine of the future.

Another profitable utilization could be a complex algae cultivation at the sites of existing greenhouses as CO_2 is required for both applications. The highest percentage of geothermal energy use in Greece and Macedonia belongs to greenhouses.

The purpose of this paper is to provide a general analysis on the existing conditions in this Balkan region and point out the hydrothermal fields suitable for mircoalgal development. The results obtained may become the basis of a future algal technology project of mutual interest to the three

Balkan countries. They could combine their knowledge in hydro-thermal resources and results achieved already in micro-algal cultivation, technology and marketing.

1. INTRODUCTION

Direct geothermal energy use for agri-business applications (aquaculture and agri-culture) is very attractive (Lund,1999), but for the time being only 10 % of the world geo-thermal energy application belongs to this type of use.

Microalgae are very promising aquacultures that attract developers' interest with the chance of controlled biomass production. Microalgal biomass has a very high protein con-tent (more than 50%) with well-balanced amino acid composition, rich mineral content (Fe, Se, Zn, Ca, Mg, etc), vitamins, antioxidants (carotenoids), phycobiliproteins, essential fatty acids and polysaccharides. It is used for either of the following: stimulation of the immune system, support for the cardio-vascular system, raising the content of the "healthy " cholesterol, improvement of the gastro-intestinal and digestive tracts, improvement of the natural purgation and detoxification, reducing the risk of cancer through antioxidant protection, solving of dermatological problems (Cifferi, 1983, 1985; Dilov, 1985; Becker,1994; Richmond,1986; Jassly, 1988).

Microalgae can be grown in environments normally not used for agricultural purposes; they are a rapidly renewable food source as they produce more biomass than any other food source per unit of time; they are the most nutrient-dense food currently known; they are an as yet untapped source of biochemical compounds (Richmond,1986; Shelef, Soeder, 1980; Stadler et al.,1988; Borowitzka and Borowitzka,1988; Becker,1994; Cefferi, 1983; Kay,1991).

The quality and economic efficiency of this production is site specific and highly dependent on climate, environmental conditions, developed know-how technology, as well as the existing local tradition of its use.

Thermal waters, geothermal energy and CO_2 use in algology strongly increase micro-algal production and reduce its cost (Fournadzieva et al.,1993,1999).

The purpose of this paper is to provide a general analysis of the existing conditions in the Balkan region and to point out the hydro-thermal fields suitable for micro-algal development. The results obtained may become the basis of a future algal technology project of mutual interest to the three Balkan countries. They could combine their knowledge in hydrothermal resources and results already achieved in microalgal cultivation, technology and marketing.

2. BASIC FACTORS REQUIRED FOR MICROALGAL CULTIVATION

Microalgal cultivation is based upon the logic of the photosynthetic process: solar energy is used for the synthesis of organic compounds out of non-organic substances.

The amount of microalgae produced depends mainly on the genus/species, photoperiod and total amount of light, temperature, pH, rate of removal of cells from the medium, turbulence and nutrient composition of the medium, CO_2-supply (Richmond,1986; Borowtzka and Borowitzka, Becker,1994) and others.

The quality and quantity of the biomass produced depend on the complex relationship among the above-mentioned factors, as presented in Fig.1.

Different methods of algal technology optimization by geothermal energy, CO_2 and thermal water application have been discussed by Fournadzieva et al.(1993, 1999). They consist of:

1. Use of geothermal CO_2 and energy for optimizing photosynthesis.
2. Use of geothermal water for nutrition algal media preparation.
3. Use of geothermal energy for algal biomass drying.

According to the parameters of the different geothermal sources either of the above mentioned applications could be realized.

CO_2 is the inorganic carbon substrate for photosynthesis. The right quantity of CO_2 provided to the algal cells can guarantee an intensive photosynthesis, a good physiological state and low contamination.

The production cost analysis for 1 kg of biomass according to Becker and Venkataraman (1980) is as follows:

Fully equipped plant	- 100%	Ponds	-12.8%
Centrifuges	- 13%	Fertilizer	- 12.3%
Dryer	- 12.5%	Labor	- 18..4
CO_2	- 27.4%		

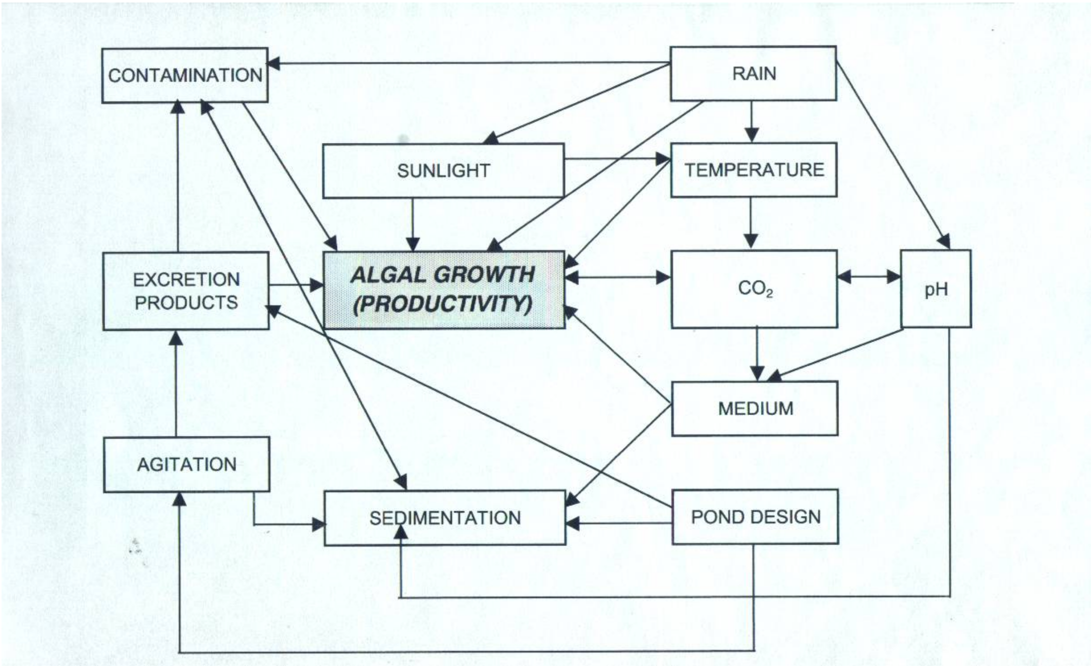

Fig.1. Influence of some of the main climatic and technological factors on the productivity of large-scale algal cultures

These data as well as the results obtained in our practice undoubtedly confirm the economic advantages of CO_2 application in this type of cultivation.

The optimization of the temperature and radiation regime, respectively photosynthesis, through water suspension heating realized in Greece and partially in Bulgaria showed a 30% yield increase, Fig.2, (Fournadzieva et al.,1999). At the same time the duration of the cultivation period is increasing and lasts from March till October.

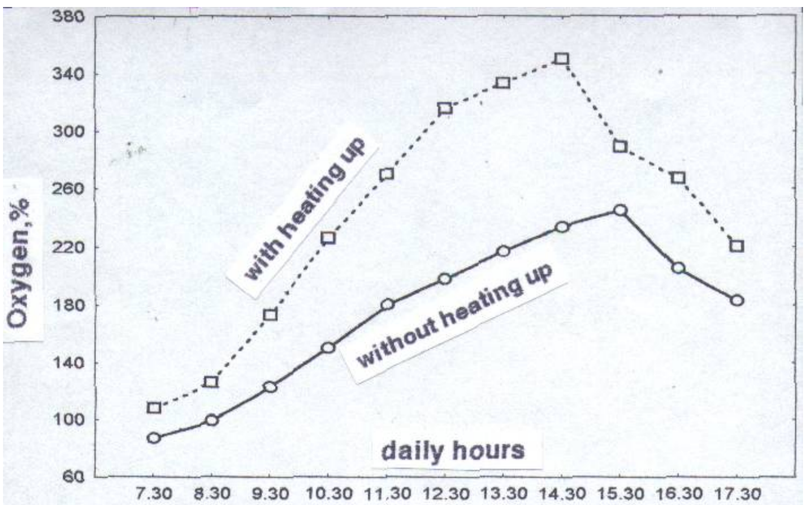

Fig.2. Photosynthetic intensity of Spirulina (with and without heating up)

Geothermal waters are rich in macro and micro elements and are used for preparation of nutrition media required for different algae species. Our research (Fournadzieva et al., 1993) aimed at modifying the nutrition media accounting for the minerals already present in the mineral water showed 5-10% growth increase and reduced cost for mineral salts. It should be emphasized that if the geothermal water contains toxic heavy metals or other components accumulating in the algal cells, such water should not be used directly for algal cultivation.

Geothermal energy can be successsfully used for algal biomass drying especially when algal slurry obtained after centrifugation has a high density (as it was observed for Spirulina cultivation, Nigrita field, N.Greece)

3. BASIC CRITERIA FOR OUTLINING PROMISING AREAS

This article aims to formulate the major requirements for selecting a set of parameters and point out the promising areas for a successful microalgal cultivation, production and marketing in the respective countries.

There are extremely good conditions for algal technology development on the Southern Balkan region in terms of the following factors:

- Climatic conditions

The region under study is located between 44^0 and 40^0 Northern latitude and 20^0 to 28^0 Eastern longitude. A long sunshine period of about 240 days is typical of the whole region.

The Balkan region under consideration satisfies the climatic requirements for open microalgal cultivation.

- Hydrogeological background

The hydrogeological conditions of the discussed area are characterized by abundance of thermal water sources of temperature from 30ºC to more than 100ºC. Water sources of temperatures exceeding 40ºC have been selected for this study.

They are characterized by various chemical composition, TDS from 0.25 g/l to more than 25 g/l and a high HCO_3 content in some of them: Rupite, Bulgaria - 1321.6 mg/l (Karakolev,1990), 2233 mg/l - Therma-Nigrita, Greece (Andritsos et al,1994) and 2 534.5 mg/l in Kumanovo, Macedonia (Kotevski, 1999).

The freely released CO_2 to the atmosphere reaches about 99.5 % in Rupite, Bulgaria (Karakolev,D,1990), up to 99.2 % in Therma-Nigrita field, N. Greece (Andritsos et al.,1994), and 95% - in Istabanja, Macedonia (Kotevski, 2000)

As only some of the criteria are fulfilled for some of the geothermal sites we split them in two groups: group (A), covering all factors and group (B) - covering only some of them. Usually the second group (B) comprises thermal waters of high temperature, application free flow rates and of missing CO_2 (HCO_3) content. They also could be used, but at à higher costs due to the considerable CO_2 expense.

We also concentrate our interest in sites of some geothermal application looking for process optimization. Some other cites of no application but of higher CO_2 (HCO_3) content have also been pointed out.

The data analysis shows that very few geothermal fields in the country meet all requirements for microalgal cultivation. Most of those that cover the criteria for group B are located to the north of the country and close to highly populated and polluted industrial areas.

The Rupite geothermal field is a typical example of a successful choice of geothermal field and microalgal cultivation and production. The Rupite base (Fig.3) was established by the Bulgarian Academy of Sciences and has been in exploitation for more than 35 years. The plant is used both for cultivation and processing of algae biomass by well developed know-how and technology. The cultivation installations have a total area of 3000 sq.m. and produce about 5-6 tons/year of dry product. The development nowadays includes a wide variety of products and applications, such as: production of pills enriched in Ca and Mg and delivered to the local market, various types of creams, shampoos, etc.

There are better conditions for microalgal cultivation in Greece compared to Bulgaria in terms of hydrothermal resources and climatic conditions.

The Nigrita base (Fig.4) for open cultivation of Spirulina has been in operation for four years.

It covers an area of 2000 sq.m. The production amounts to about 2000 tons/ year and is used in the form of capsules.

4. BULGARIA

Table 1

Selected geothermal site suitable for microalgal cultivation - Bulgaria

(Sources: Petrov et al.,1998, Karakolev,1990)

N	Location	Lat.N,Long.E.	Temp.	Flow rate	HCO_3	CO_2	TDS	Application
		Deg	deg C	l/s	mg/l	mg/l	g/l	
	Hydrocarbonate waters							
	Sofia basin							
	Class A							
1	Rupite		74	15	1321	900	2.1	aquaculture, public bath
	Class B							
2	A.Voikov	42, 23	40	2	2001	no	3.1	public bath
3	Gniljane	42, 23	42	0.9	1904	no	3.1	public bath
4	Trebich	42, 23	50	1	1831	no	3.8	hot tap water
5	Chepintsi	42, 23	50	6	1347	no	2.1	public bath
	Sliven-Straldja basin							
6	Sliven mineral baths	42, 26	44	18	869	no	2.0	public bath
	Acidic-Hydrocarbonate waters							
	Sofia basin							
7	Iljantsi	42, 23	45	3	1975	505	4.5	no
8	Mramor	42, 23	42.6	1.5	2415	469	3.4	public bath

Note: *Class A*- fully satisfied requirements for microalgae cultivation
Class B - partially satisfied requirements for microalgae cultivation

Fig.3. The Rupite base for algal cultivation and biomass downstream processing.

5. GREECE

Table 2

Selected geothermal sites suitable for microalgal cultivation - Greece
(Sources: Fyticas et al,1995,2000)

N	Location	Lat.N,Long. E deg	Temp. max deg C	Flow rate total m3/h	TDS g/l	Main dissolved solids	Application
	Class A						
Macedonia							
1	Agistro		47	100	<0.3	Ca, Na, HCO_3	balneology
2	Nigrita	41, 23.5	64	400	2.5	HCO_3,Na,Ca,Mg, CO2(h)	balneology grennhouses aquaculture
3	Sidircastro	41, 23.5	75	150	1.5	Cl, Na, HCO_3	balneology greenhouses
4	Nea Appolonia	40.5, 23.5	56	400	1	SO_4, HCO_3, Na, CO2(m)	space heating balneology
5	Nymfopetra	40.5, 23.5	45	200	1	SO_4,HCO_3,Na,CO_2(m)	greenhouse
6	Langadas	40.5, 23	40	300	1	SO_4, HCO_3, Na, CO_2(l)	greenhouse
Thrace							
6	Neo Erasmio		60	400	1	Cl, Na, HCO_3	space heating greenhouse
7	Nea Kessani	41, 25	80	350	6	Na, Cl, HCO_3, CO_2(h)	no
	Class B						
Sterea Hellas							
8	Soussaki	38, 23	80	200	39-42	Na-Cl, CO_2(h)	no

Note: l - low content, m - medium content, h - high content
Class A- fully satisfied requirements for cultivation
Class B- partially satisfied requirements for cultivation

Fig. 4. The Nigrita base for Spirulina cultivation

6. F.Y.R. MACEDONIA

Table 3.

Selected geothermal sites suitable for microalgal cultivation - Macedonia (Popovski,1999; Georgieva,1999; Kotevski,1999)

N	Location	Lat.N, Long.E. deg	Temp. deg C	Flow rate l/s	HCO_3	CO_2 mg/l	Application
	Class A						
1	Strnovec (Kumanovo)		40	46.7	?	2534.5	balneology
2	Istabanja(Kochani,Vinitsa)		65	73	70	1462.0	greenhouse
3	Bansko (Strumitsa)		70	50	16	112.9	Integrated geoth.project
4	Smokvitsa (Gevgelija)		65	120	11	30.8	greenhouse
5	Kosovratsi (Debar)		48	60	33	375.4	balneology
6	Banishte (Debar)		40	100	31	891.6	balneology
	Class B						
7	Katlanovo (Skopje)		50	13	83.6	no	balneology
8	Podlog (Kochani)		75	300	81	no	greenhouse
9	Banja (Kochani)		40	63.2	61.5	no	balneology
10	Kezovitsa (Stip)		60	20	?	no	balneology
11	Negorci (Gevgelija)		50	80	10	no	space heating balneology

Note: *Class A*- fully satisfied requirements for microalgal cultivation
Class B- partially satisfied requirements for microalgal cultivation

For the time being there are no aquaculture applications available in F.Y.R. Macedonia, although there are good hydrothermal conditions for their future development. Other important factors are the existing various uses of geothermal waters and the accumulated experience in their development. The micro-algal biomass could receive a very attractive application in spas both in cosmetics and for treatment.

Based on the data selected for the three countries a common project region consisting of three hydrothermal fields could be outlined: Rupite (Bulgaria) - Nigrita (Greece) and Bansko (F.Y.R. Macedonia). They are located close to the common borders. This selected region meets the requirements for favorable climatic conditions and suitable hydrothermal reservoirs. It also includes the two bases currently in operation.

This region also comprises parts of the countries that are environmentally clean and poorly developed thus creating a good basis for algal technology implementation as well as more employment.

At the same time the population of the three countries is more or less familiar with algal products and their qualities. This fact could facilitate the product realization on the local markets.

The common project will promote an exchange of experience, technology, production, application and marketing provided on a mutual basis for the partners.

The published data focus widely on the opportunities of geothermal energy use for aquaculture development, microalgae being a part of them. We have not found out data on carrying out similar projects elsewhere except in Bulgaria and Greece. The results obtained in our practice give us reasons enough to draw the conclusion that microalgal cultivation is an important ergonomic application of geothermal waters and geothermal energy.

CONCLUSIONS

- The complex natural factors required for microalgal cultivation have been analyzed.
- A selection of hydrothermal fields located in Bulgaria, Greece and Macedonia suitable for algal technology has been presented.
- A proposal for a common project for a region consisting of geothermal fields located in the three countries has been outlined.

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