INCREASING BIOMASS FOR FUEL PRODUCTION BY USING WASTE LUKE-WARM WATER FROM INDUSTRIES

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Summary

Waste luke-warm waters of many industries do not often contain enough calories to be recuperated with a good [yield/investment] ratio by techniques such as : heat pumps, heat exchangers...

On the other hand, it is known that when algae are moderately warmed in the laboratory, the rate of photosynthesis increases, and hence biomass accumulation.

So it seemed interesting in temperate zones to grow algae in waste luke-warm waters at temperatures between 20 and 35°C, in order to recuperate the calories by increasing the yield of biomass. This was shown to be possible with filamentous and microscopic algae.

1. Cultures made in lagoons utilize the polluted water of the Meuse river, the temperature of which is increased by circulating through the 3rd cooling circuit of the Tihange nuclear power plant. The temperature of the water is 12°C higher than that of the river. Cultures of filamentous algae like Hydrodictyon or Cladophora exhibit a yield increase of 50 to 200 % in the luke-warm water. In that way, it has been possible to harvest in Belgium 12 to 15 tons of dried algae/ha/year.

2. It is also possible to use polluted warm water of industrial origin to regulate the temperature of unicellular algae cultures. This can be performed by means of appropriate heat exchangers.

This new concept appears now to be the basis of a "depolluting bio-industry" to be developed in temperate industrial countries. Even after extraction of high-value substances from the biomass, the residue is still the source of fuel through methanisation, or of energy by direct combustion.

1. INTRODUCTION

The culture of algae is an interesting method of accumulating biomass. Depending on the climatic conditions and on the species 10 to 150 tons (or even more) dry biomass are harvested per year and per hectare. The organic matter produced by the algae is an excellent substrate for anaerobic fermentation. Naveau, Nyns et al have shown that 0,3 l methane are produced per one g volatile matter, which is 50 % of the maximum, theoretical yield (0,55 l/g volatile matter; 1,2).

2. CULTURE OF ALGAE ON LUKE-WARM WATERS FROM INDUSTRIES

In Belgium, the mass culture of fresh-water algae yields 10 to 30 tons dry biomass/ha/year depending on the temperature of the summer and on the species. It has been shown that the temperature of the water is an essential factor for the control of the growth rate. Fig. 1 gives the form of the dependance of photosynthesis on water temperature in Scenedesmus quadricauda. Such a curve represents also the temperature dependance of biomass accumulation as a result of photosynthetic activity. It illustrates the fact that the algae make a better use of solar energy when the temperature is raised by some degrees between 20° and 30°C.

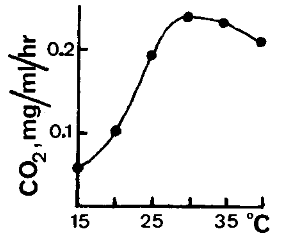

Fig.1: Temperature dependance of photosynthesis in Scenedesmus quadricauda.

Luke-warm waters are available in industrial countries. In Belgium the case of the Meuse and Sambre valleys is typical. These rivers collect warm waters from many factories of different kinds. This provokes an appreciable perturbation of the ecological equilibrium. By growing algae on the rejected waters, one increases the biomass yield, and one contributes to the river depollution by cooling and by cleaning the water before rejection in the river. This concept seems particularly adapted to electrical power plants which furnish a great amount of wasted calories and relatively clean warm water (3,4). Our experiments have shown that in this particular case, the algae biomass yield increases substantially. The harvested biomass is suitable for feeding herbivorous fishes in warm waters; very fast growth rates of fishes have been obtained in this way (5,6).

Several industries introduce mineral salts or organic matter in the warm waters (siderurgy, food industry, textile industries, etc...). The culture of algae allows to recuperate part of the salts, as well as organic matters together with the calories. The carbon dioxide from industries, especially from fermentation industries, may be used to increase the biomass yield and the depolluting activity of the algae.

3. WARMING ALGAE CULTURES

a. Macroscopic algae

Fig. 2 is a scheme of the lagoon system constructed recently in Tihange by the Photobiology Laboratory of the Liège University. The depth of the lagoons is 30-40 cm. Luke-warm water circulates as indicated in the scheme. The water comes from the river Meuse. It is warmed by the nuclear electric power plant of Tihange I, the temperature of the water increasing by about 12°C above that of the Meuse. This allows to increase the biomass yield appreciably. Table I gives the dry weight of filamentous algae (essentially Hydrodictyon reticulatum) collected from May to July 1979 in warm water, and in August-September 1979 in non-heated water. Table II gives the composition of the collected biomass. Mineral salts are accumulated in the biomass, showing that the culture is also an excellent method for recuperating salts from the river. Thus the system depollutes the water chemically and thermically. It utilizes the wasted calories for increasing the efficiency of photosynthetic conversion of solar energy, and it replaces an expensive chemical cleaning of the pollu-

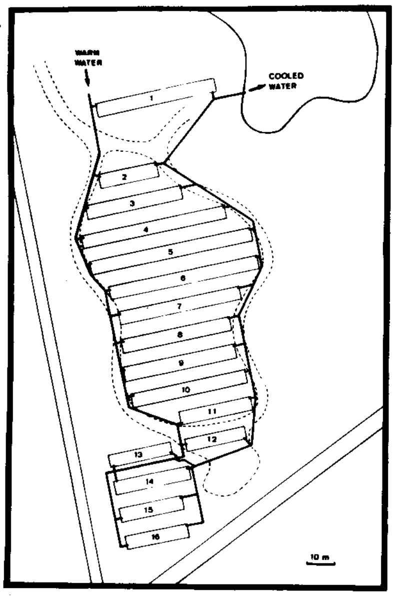

Fig. 2 : The lagoon system in Tihange (Belgium).

ted water by a non-expensive photobiological cleaning.

It has been shown by Naveau, Nyns et Asinary that 1 g of the dry matter collected in Tihange produces about 0,1 liter methane gas (1).

TABLE I

Hydrodictyon harvested in 1979 in Tihange (Kg dry algae/400 m2 of lagoons).

Month	Dry weight	Mean daily water t°
May	85	20-20
June	79	26-30
July	85.5	25-27
August	53.6	18-20
Septem.	30.5	19-20
October	45	23-30

TABLE II

Hydrodictyon composition (% dry weight)

Carbon	28.4
Hydrogen	3.3
Nitrogen	2.6
Sulfur	1.5
Ashes	35.7
Carbon (as carbonates)	5.1

b. Microscopic algae

Microscopic algae (Scenedesmus, Chlorella) are grown either in ponds in which the suspension is more or less moved continuously, or in a circulating thin layer, as the one shown in fig. 3. In both cases part of the suspension is removed from time to time for harvesting the algae; the clarified water is recycled. In the case of the thin-layer cultures, a heat-exchanger has been conceived in Liège for transferring heat from water warmed at a temperature between 40° to 60°C, to the culture medium.

Fig. 3 : View of 1 exposed surface for growing microscopic algae at the Photobiology Laboratory in Liège (Belgium).

The general concept is the following. The suspension of algae flows along a surface which exposes the algae to light. It is collected into a reservoir at the bottom of the exposed surface. A pump recycles the suspension to the top after saturation with CO_2. The heat-exchanger which has been conceived by Delvaux and Tran "Laboratoire de Génie chimique", Liège University (7) with the collaboration of Piron* consists in a series of metal tubes in which the warm water is circulated as shown in fig. 4. The number of the tubes and the input of warm water vary according to the temperature of the latter. The warm water is cooled very rapidly in such a heat-exchanger and therefore its flow must be very rapid. For a very fast input, the water is still warm at the output of the exchanger. It is then introduced into lagoons where filamentous algae are grown.

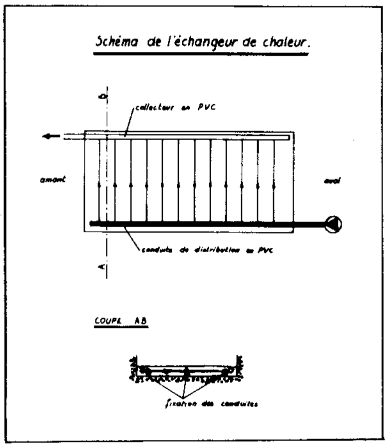

Fig. 4 : Heat exchanger for the installation described in fig. 3.

In Liège, a culture of Chlorella or Scenedesmus may produce 20 to 30 tons of dry algal biomass per effective year (6 month) if it is not warmed. We hope to be able to increase the yield by a factor of 50 to 100 % by circulating 40° to 60°C warm water through the heat-exchanger.

The collected biomass, or even better the residue collected after extraction of usefull chemicals, may be used as fuel. It produces about 0,3 to 0,4 liter methane per g volatile matter (8). When grown on wastes containing a certain amount of organic molecules Scenedesmus and Chlorella cultures assimilate organic matter from the medium. We hope to be able to increase in this way the biomass content in volatile matter, and consequently to increase the methane yield.

4. DEPOLLUTING BIOINDUSTRIES

When one takes the costs of conventional thermal and chemical depollution into account, the real cost of the algal biomass produced as indicated in § 3 becomes rather low. This is still more true if the biomass furnishes

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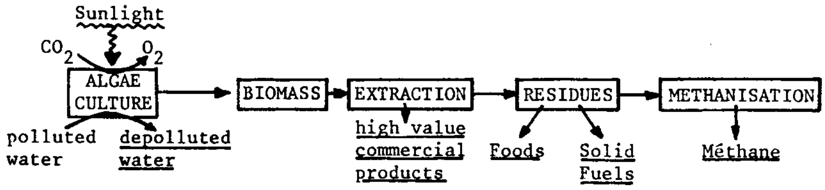

Fig. 5 : The general concept of a depolluting bioindustry.

interesting high-value commercial products. The extraction residues may be processed into food for animals and man, or may be used to produce either solid fuels, or methane. The ashes or the fermentation residue are good fertilisers for traditional agriculture and for the algae cultures. Depolluting bioindustries may be developped on this general basis (fig. 5).

(E.E.C. Contract n°ESD/021/B).

5. ACKNOWLEDGMENTS

We thank the INIEX for chemical analyses and Mr S. Sougné for technical assistance.

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ENERGY FROM BIOMASS

1st E.C. Conference

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APPLIED SCIENCE PUBLISHERS LTD
LONDON

Proceedings of the International Conference on Biomass held at Brighton. England, 4–7 November 1980.

APPLIED SCIENCE PUBLISHERS LTD
RIPPLE ROAD, BARKING, ESSEX, ENGLAND

British Library Cataloguing in Publication Data

Energy from biomass.
1. Biomass energy—Congresses
I. Palz, W. II. Chartier, P.
III. Hall, D. O. IV. Commission of the European Communities
662'.6 TP360

ISBN 0-85334-970-3

WITH 198 TABLES AND 210 ILLUSTRATIONS

Organization of the conference by: Commission of the European Communities, Directorate-General Research, Science and Education, Brussels in co-operation with the Department of Energy, London

Publication arrangements by: Commission of the European Communities, Directorate-General for the Information Market and Innovation, Luxembourg

EUR 7091

Printed in Great Britain by Galliard (Printers) Ltd, Great Yarmouth