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Design of Ultra-sonication Pre-Treatment System for Microalgae CELL Wall Degradation

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Abstract

Cell walls of microalgae consist of a polysaccharide and glycoprotein matrix providing the cells with a formidable defense against its environment. Anaerobic digestion (AD) of microalgae is primarily inhibited by the chemical composition of their cell walls containing biopolymers able to resist bacterial degradation. Adoption of pre-treatments such as thermal, thermal hydrolysis, ultrasound and enzymatic hydrolysis have the potential to remove these inhibitory compounds and enhance biogas yields by degrading the cell wall, and releasing the intracellular algogenic organic matter (AOM). This paper preproposal stage investigated the effect of different pre-treatments on microalgae cell wall, and their impact on the quantity of soluble biomass released in the media and thus on the digestion process yields. This Paper present optimum approach to degradation of the cell wall by ultra-sonication with practical design specification parameter for ultrasound based pretreatment system. As a result of this paper presents, a microalgae system in a wastewater treatment flowsheet for residual nutrient uptake can be justified by processing the waste biomass for energy recovery. As a conclusion on this result, Low energy harvesting technologies and pre-treatment of the algal biomass are required to improve the overall energy balance of this integrated system.

Key words: *Ultrasound, Sonication, Microalgae, Algae, Cell Wall, Pre-Treatment, Cell wall degradation, anaerobic digestion.*

1. Introduction

Algae are a group of eucaryotes that are capable of photosynthesis. Algae vary in size from microscopic

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plants as small as 10micro meter up to seaweeds that can be 50 m long. All algae require the inorganic nutrients carbon, nitrogen, and phosphorus and an adequate supply of sunlight.

The metabolism of algae that often regulates the concentrations of nitrogen and phosphorus in natural systems. Most algae live in fresh or sea water where they can either be free-floating (planktonic) or attached to the bottom. Some algae can grow on rocks, soil or vegetation as long as there is enough moisture. A few algae form very close partnerships with fungi to form lichens. Unusual algal habitats are the hairs of the South American Sloth and Polar bears.

All algae contain a pigment called chlorophyll a (other types of chlorophyll such as b, c and / or d may also be present) and they make their own food by photosynthesis. The chlorophyll is contained in the chloroplasts and gives many algae their green appearance. However some algae appear brown, yellow or red because in addition to chlorophylls they have other accessory pigments that camouflage the green colour.

Diatoms a type of algae, are found floating in the phytoplankton of the seas. Their cell walls contain a hard substance called silica. When the diatoms die they sink to the floor. Their soft parts decay and the silica cell wall remains. Over time the pressure of the seawater pushes the silica together to form one large layer. This silica is mined from the seabed, crushed and used in abrasives and polishes such as toothpaste.

Algae are differentiated primarily according to pigmentation that is green, brown, red, yellow green, etc. These classifications come from the different pigments and/or different ratios of pigments found in various groups of algae. The excessive algal growth can degrade water quality but some types of algae can troublesome than others. Green algae generally pose few problems in water systems, whereas other forms of algae can generate toxins. The blue-green algae, which we shall classify as procaryotic, are well known for their effect on water quality in this regard.

This paper describes in details of microalgae cell wall and How to degrade the cell wall using Ultrasound based water pretreatment methods. Also this paper describes the detailed HW design details and system specification of Ultra-sonication based pretreatment system.

2. Microalgae Cell Wall

Algae are the plants with the simplest organization shown in Figure 1. Many of them are single-celled, some have no cell wall, others do though its composition and structure differ strongly from that of higher plants. They are good specimen for tracing back the evolution of the cell wall. Primitive cell walls do not fulfil the same requirements as that of higher plants.

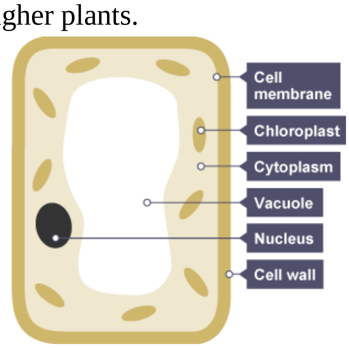


Figure 1. Algae Cell Organization

The main structural elements of all plant cells are polysaccharides. Differences in their chemical composition cause fundamentally different physical properties. No plant cell wall consists only of one class of molecules. The interactions of the different molecules produce properties that allow to distinguish the cell walls of certain classes.

In many classes of algae is cellulose already the main structural element of the wall, though remarkable variations of the fibrillary structure exist. Reliable X-ray analytical data prove that is mostly crystalline in cells of algae, too. Differences in the type of the flexor reflexes hint at the fact that cellulose could aggregate in many more or less uniform crystalline structures. Such reflexes are a measure for periodic distances at the molecular level, which may differ considerably from species to species and are specially large in Rhodophyta.

In some classes of algae exist only disperse textures, while others (specially many Chlorophyta-species) have a higher degree of organization (layers of parallel microfibrils). Such layers do usually alternate with layers of an amorphous material. No clear difference between primary and secondary cell wall exists in most algae. Where such a distinction is possible, differ the causes usually from that in higher plants.

3. Cell Wall Degradation Pre-Treatment

The strong cell walls of the algae cell prevent easy rupturing for lipid extraction. The cell wall degradation methods are classified into two categories: mechanical and non-mechanical.

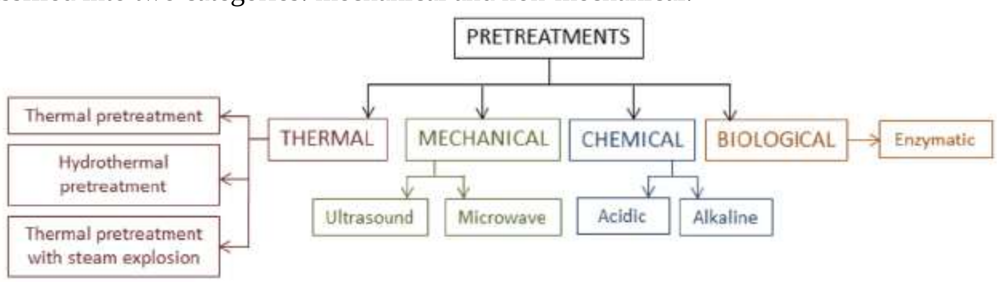


Figure 2. Microalgae Cell Wall Degradation Pre-Treatment Methods

Mechanical methods include bead/grind milling, high-shear mechanical process, high pressure homogenization, ultra-sonication, etc. Non-mechanical methods includes thermal treatment, Acidic/Alkaline Chemical treatment, and enzymatic biological treatment. Enzymatic degradation method is high cost and low effectiveness.

The positive benefits of ultrasound for cell disruption is use of less energy consumption in comparison with high shear forces. Ultrasonic devices can be scaled up and operated on a continuous basis. This is in contrast to limited size laboratory scale devices such as a French press. Also, Cost reduced extraction provides benefits in terms of time, energy, and volume of solvent.

4. Ultrsound Pre-Treatment

The main aim of ultrasound pretreatment being to destroy the cell wall of microbes and to release the intracellular materials to the aqueous phase, the quantitative evaluation of the effects of the pretreatment becomes much valuable in providing useful data for the design and process optimization of an ultrasonic system.

Ultrasound is a mechanical acoustic wave with the frequency range from roughly 10 kHz to 20 MHz. It imparts high energy to reaction medium by cavitation and secondary effects. Microbubbles containing solvent vapors are generated that grow and undergo radial motion as acoustic energy propagates through the liquid medium.

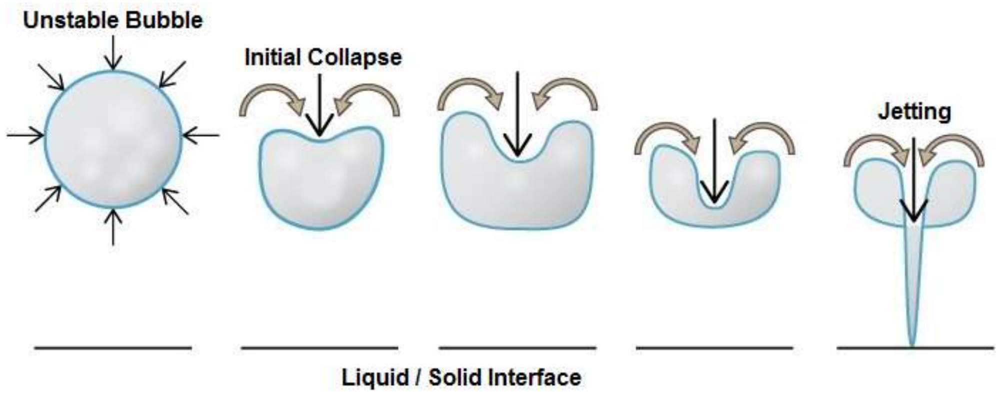


Figure 3. Ultra-sonication of Algae Cell Wall

With low acoustic intensity, the radii of microbubbles periodically and repetitively expand and shrink within several acoustic cycles. When the resonant frequency of bubbles exceeds that of ultrasonic field, the bubbles collapse within several nanoseconds, which creates special physical and chemical effects and enhances thermochemical/biochemical reactions or treatment. Cavitation is the main key for ultrasound intensification. The key to efficient application of ultrasound is control and selection of the energy intensity and population of active cavitation.

5. Ultrasonication Pre-Treatment

The Ultrasonication module design involves Vibrator design, Horn design, Ultra sound Sensor design, Oscillator design, Oscillator signal Amplifier, and vessel design. This section gives real-time Ultrasonication module design for pretreatment with specifications.

Ultrasonic pretreatment systems Vibrator and Horn design details shown in Figure 4.

(a) (b)

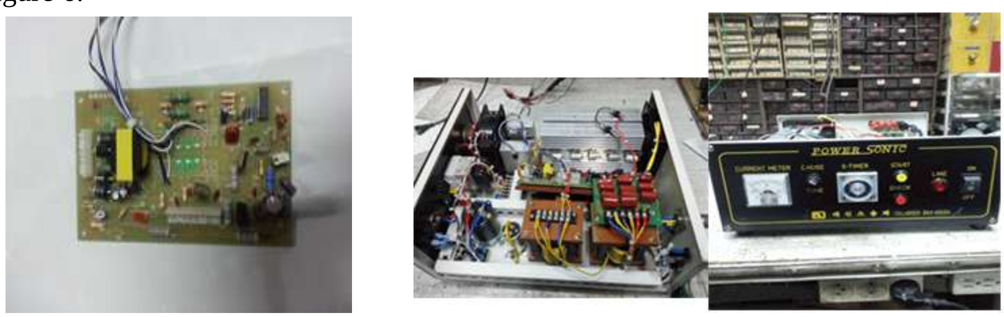
Figure 4. (a) Ultrasound Vibrator Design (b) Ultrasound Horn Design

Ultrasonic pretreatment systems ultrasonic sensor module details shown in Figure 5.

(a) (b)

Figure 5. (a) Ultrasonic Module Internal Circuit (b) Ultrasonic Module Interface Circuit

Ultrasonic pretreatment systems Oscillator Circuit design and Oscillator Amplifier circuit design details shown in Figure 6.



(a) (b)

Figure 6. (a) Ultrasonic Oscillator PCB (b) Ultrasonic Oscillator Amplifier

Ultrasonic pretreatment systems, Multi-wavelength Ultra-sonication water submerged vessel Mechanical Design details shown in Figure 7.

(a) (b) (c) (d)

Figure 7. (a) Vessel Drawings (b) Outer Vessel (c) Vessel Closer (d) Vessel Internal Structure

6. Conclusions

Ultrasonic energy has a special place in meeting the challenges of processing recalcitrant, multicomponent and heterogeneous biomass materials. The introduction of an ultrasonic field can provide an extremely severe physicochemical environment that is difficult to realize with other engineering methods. Sonication does not remarkably change the chemical mechanism of biomass pretreatment and reactions, but the reaction kinetics is remarkably accelerated as the result of ultrasonic cavitation and the secondary effects, and therefore enhances the efficiency and economics of the biomass conversion process. Therefore, it can be concluded that ultrasound offers a successful and beneficial option for rupturing of algal cells. Sonication favors the cultivation, harvesting, component extraction and conversion of macro and microalgae to wastewater, sugars, ethanol, bio-hydrogen and biodiesel. The state of art of Microalgae CELL Wall Degradation using Ultrasound based design is verified on real-time scenario.

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