Funded by the
Erasmus+ Programme
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ENERGY SAVING SYSTEMS

University of Klaipeda

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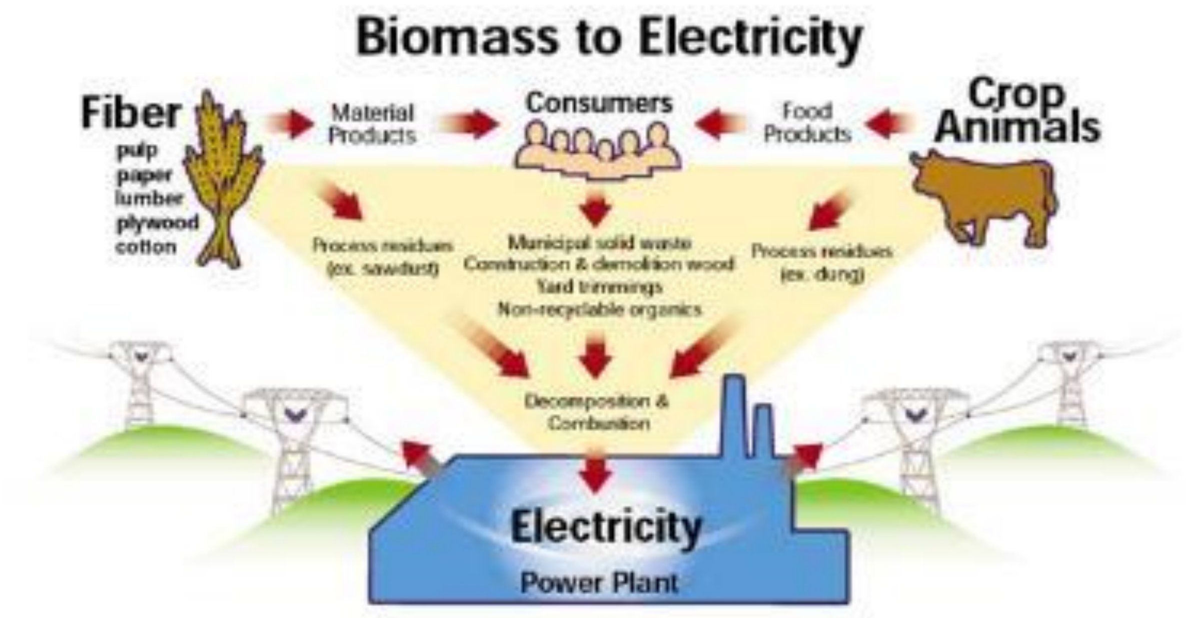
Part 1

Bio-based electricity:

How biomass resources can support renewable energy?

Biomass may be used to generate low-carbon energy compared to fossil fuels



Introduction

Nowadays there is increase in fossil fuel consumption. Due to that demand, fossil fuel reserves are depleting very fast, so there is a need for ***alternative fuels****. Many scientists are focusing on* ***biofuel*** *production from* ***biomass.*** *Many technologies can convert biomass to biofuels. One of them is* ***pyrolysis****. Most promising biomass is considered algae because they grow very fast and do not need any investments.*

Batch reactor is used for pyrolysis process. This reactor is compact used in chemical laboratory and small scale industries.

*Pyrolysis process is an attractive for production of 3 products like **liquid fuel**, **gas** and **char**. This technology is cost effective due to recirculating system when produced gasses are used as heat carriers. This technology do not need external heat source to heat up biomass in the reactor.*

*In this study, **algae** and **algae mixture** with **waste plastic** were used as raw material in slow pyrolysis process. Pyrolysis process was held at 400^{o}C with different proportions of raw material used.*

After collection of liquid product from pyrolysis process, distillation can be done in that liquid product.

The distilled bio-oil was conducted several property test: ***density****,* ***viscosity****,* ***ash test****,* ***gas chromatography*** *and* ***elemental analysis.***

Results show that by adding waste plastic in algae, pyrolysis process the liquid product yield is increased and also distillated bio-oil from waste plastic and algae gives better property test. Best liquid product properties obtained when 400^oC t^o.

The main aim of research

To investigate the possibilities to produce bio-oil from macro-algae and plastic waste mixtures

Objectives

- To examine the possibilities to increase the yield of pyrolysis oil by using different raw material mixtures like macro-algae and HDPE plastic waste in the batch reactor
- To analyze the possibilities to separate the hydrocarbon fraction from pyrolysis bio-oil in the distillation unit under vacuum pressure
- To determine the properties of hydrocarbon mixture like viscosity, density, ash content and elemental composition
- To identify the individual hydrocarbons and its amount by using gas chromatography

Generations of bio-fuels from different raw materials

Generations	Raw materials	Products	Description
First generation	Wheat, barley, corn, potato, soybeans, sugarcane	Bioethanol or butanol by fermentation of starch. Biodiesel by trans-esterification of oil crops	The source of carbon for the biofuel is sugar, lipid or starch directly extracted from a plant. The crop is actually or potentially considered to be in competition with food
Second generation	Straw, wood, grass, sugar crops such as jatropha, cassava or miscanthus	Bioethanol and Biodiesel produced from conventional technologies. Bioethanol, biobutanol, syndiesel produced from lignocellulosic materials	The biofuel carbon is derived from cellulose, hemicellulose, lignin or pectin. For example this may include agricultural, forestry wastes or residues, or purpose-grown non-food feedstock
Third generation	Micro-algae, Macro-algae	Biodiesel, bioethanol, hydrocarbons, hydrogen	The biofuel carbon is derived from aquatic autotrophic organism (e.g. algae). Light, carbon dioxide and nutrients are used to produce the feedstock "extending" the carbon resource available for biofuel production

Comparison of Micro-algae and Macro-algae

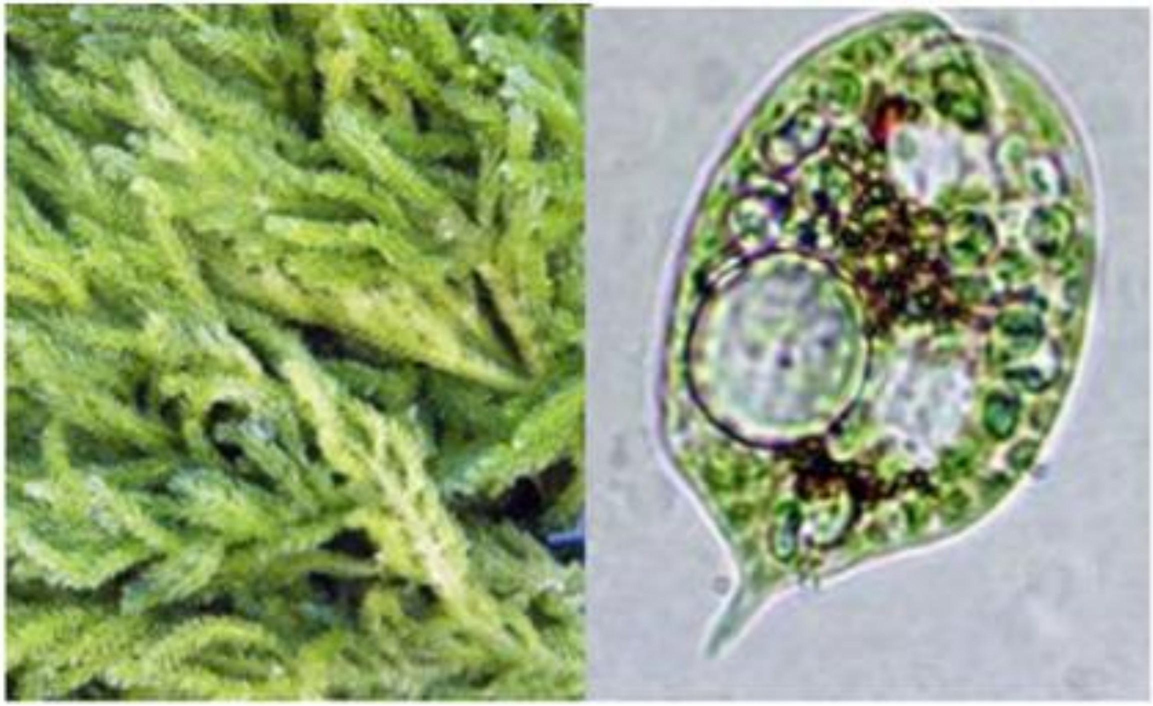
Algae are organisms that grow in aquatic environments and use light and carbon dioxide (CO_2) to create biomass.
There are two types of algae:

macro-algae
micro-algae

macro-algae are the large (measured in inches), multi-cellular algae often seen growing in ponds. These larger algae can grow in a variety of ways. The largest multi-cellular algae are called seaweed; an example is the giant kelp plant which can be more than 100 feet long

micro-algae are tiny (measured in micrometers), unicellular algae that normally grow in suspension within a body of wate (Zhiyou Wen, 2009)

Micro-algae and Macro-algae (Spolaore et al. 2006)



Oil yields based on crop type (Christi, 2007)

Crop	**Oil yield (gallons/acre)**
Corn	18
Soybeans	48
Canola	127
Jatropha	202
Coconut	287
Microalgae	6283 – 14641

Types of algae

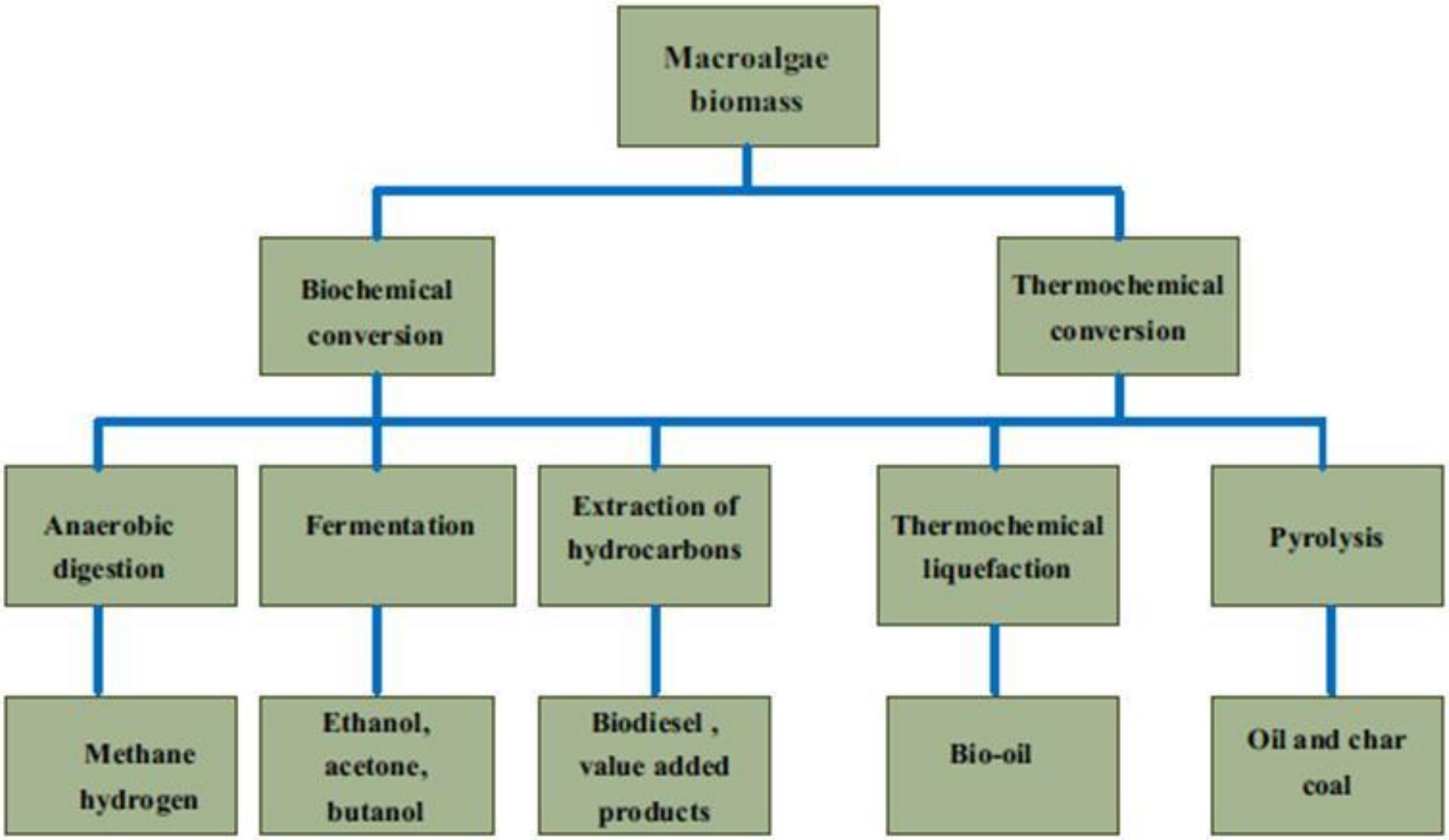
Paeophyta (brown algae)

Rhodophyta (red algae)

Chlorophyta (green algae)

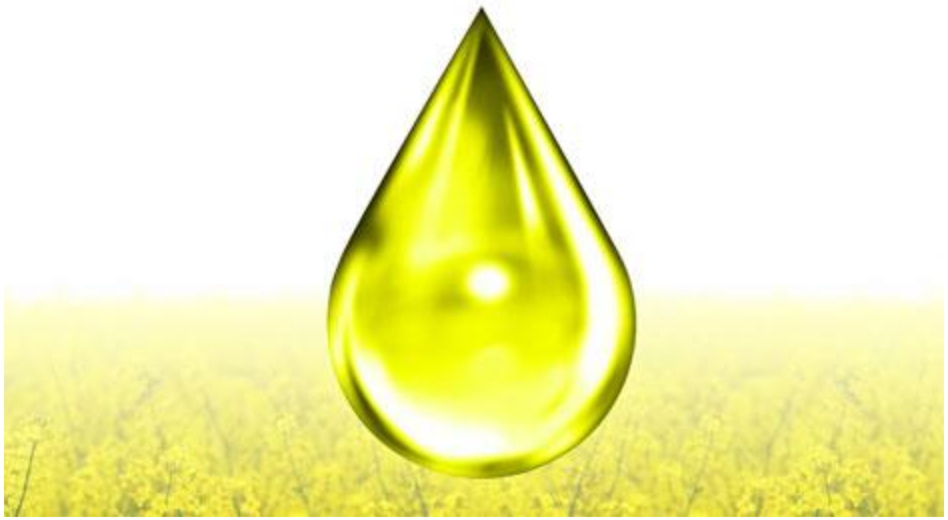
Biochemical and thermochemical biofuel conversion processes from macro-algae

(Coppola, 2008)



Types of Biofuels from Macro algae

- ***Bioethanol*** Macro-algae have high content of carbohydrates and little lignin and thus are suitable to be used as substrate in fermentation process for bioethanol production after hydrolysis process



Types of Biofuels from Macro algae

- ***Biodiesel*** Macro-algae are considered for making biogas and bioethanol rather than biodiesel. Macro-algae is usually converted into bio-oil (lipids and free fatty acids), and then the lipids are separated for biodiesel production

Effect of pyrolysis parameters on the product distribution

Pyrolysis ***temperature*** (t^o) is the most important parameter affecting the product yields. The basic role of t^o is to provide necessary heat of decomposition to fragment biomass linkages. Modifications in the products composition measure the capability of t^o to decompose the biomass.

Effect of pyrolysis parameters on the product distribution

Particle size is another parameter that affects product distribution. Influence of particle size is considered important on the yield and properties of liquid oil produced and to minimize heat transfer problems (Akhtar, 2012).

Effect of pyrolysis parameters on the product distribution

Increasing ***atmospheric pressure*** has been found to increase oil viscosity. On the other hand, reduced pressure (often associated with vacuum pyrolysis), has been found to reduce secondary reactions in the gas phase, by reducing volatiles residence time; this would tend to increase oil yield.

The definition of ***residence time*** differs in various studies: in *fast pyrolysis* or continuous pyrolysis process, it refers to the contact time of the plastic on the hot surface throughout the reactor.

In a *slow pyrolysis*, long residence time encourages the carbonization process and produces more tar and char in the products (Karaduman, 2001).

The pyrolysis conditions, residence time and target products *are given below:*

Process	Heating rate	Residence time	Temperature (°C)	Target Products
Slow carbonization	Very low	Days	450-600	Charcoal
Slow pyrolysis	10-100K/min	10-60 min	450-600	Gas, oil, char
Fast pyrolysis	Up to 1000K/s	0.5-5 s	550-650	Gas, oil, (char)
Flash pyrolysis	Up to 10000K/s	<1 s	450-900	Gas, oil, (char)

Feedstock characterization

Terrestrial biomasses contain fewer minerals than seaweeds. This is due to mineral accumulation in seaweeds. The amounts of ash found in the present study were in agreement with previous results (G. Qupere 2002). The mineral content of seaweeds depends on ***location***, ***oceanic residence time*** and ***season*** as well as on the ***individual seaweed species***.

Chemical Composition of Macro-algae

Macro-algae contain generally only 10–15% dry matter. The dehydrated macro-algae consist of large amounts of carbohydrates (approximately 60%).

Chemical Composition of Macro-algae

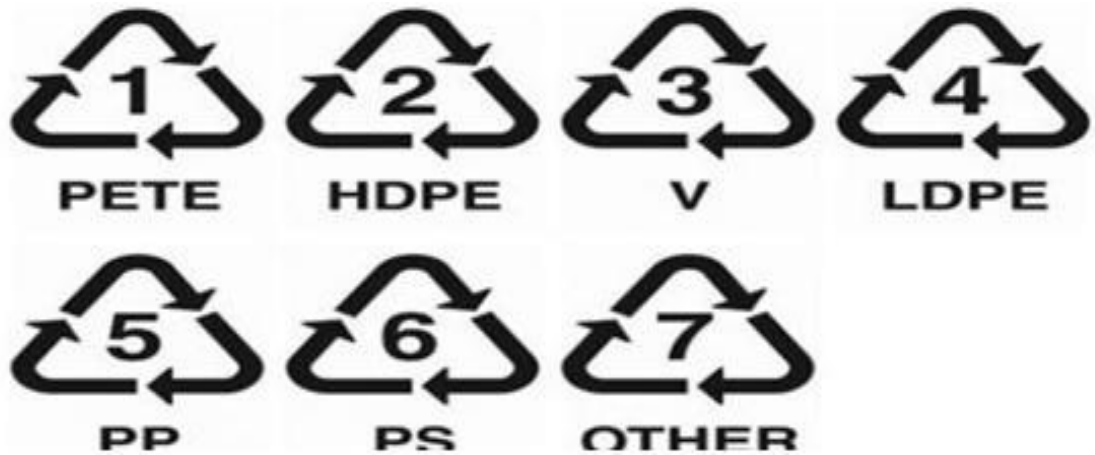
Cell wall components of macro-algae are the major sources of carbohydrates. Macro-algae have relatively higher alkali metals and the halogen contents (0.5–11%) than those of terrestrial biomass (1–1.5%). The nutrient content (N, P) depends primarily on macrophyta morphology and then on environmental nutrient pollution (Roesijadi, McHugh, 2010)

Plastic

Plastic is a standout amongst the most normally utilized materials as a part of day by day life which can be arranged from multiple points of view, for example, in light of its concoction structure, blend procedure, thickness, and different properties. Keeping in mind the end goal to help reusing of the waste plastic, Society of Plastic Industry (SPI) characterized a tar recognizable proof code framework that partitions plastics into the accompanying seven gatherings in view of the compound structure and applications are exhibited below

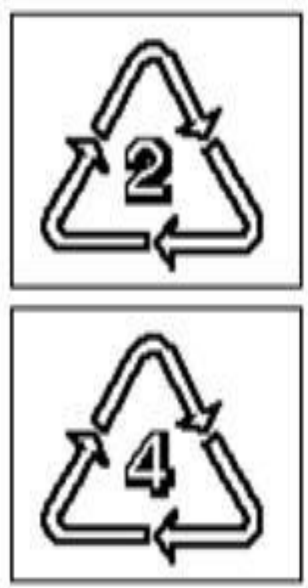
The seven types of plastics are marked on various plastic products as follows

1. PETE (Polyethylene Terephthalate)
2. HDPE (High Density Polyethylene)
3. PVC (Polyvinyl Chloride)
4. LDPE (Low Density Polyethylene)
5. PP (Polypropylene)
6. PS (Polystyrene)
7. Other



Types of Plastic products

Polyethylene (PE)

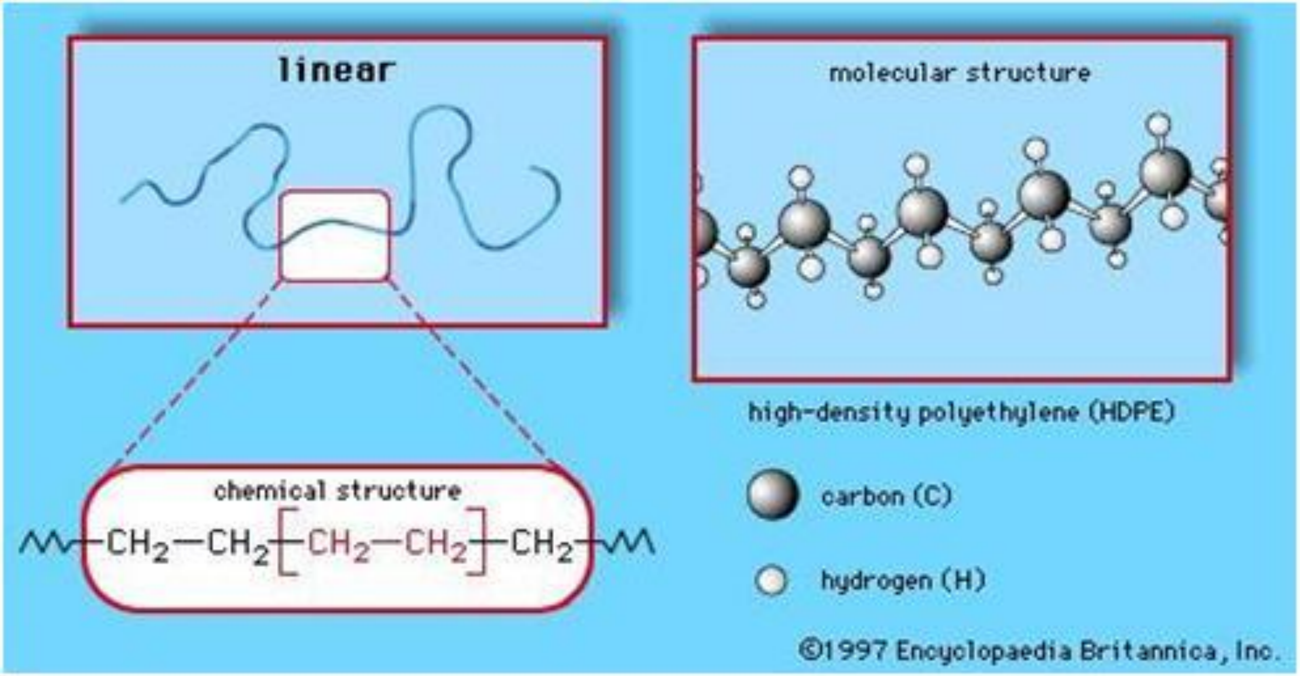


HDPE - High Density Polyethylene: plastic milk containers

LDPE - Low Density Polyethylene: 6-pack rings, food wrap

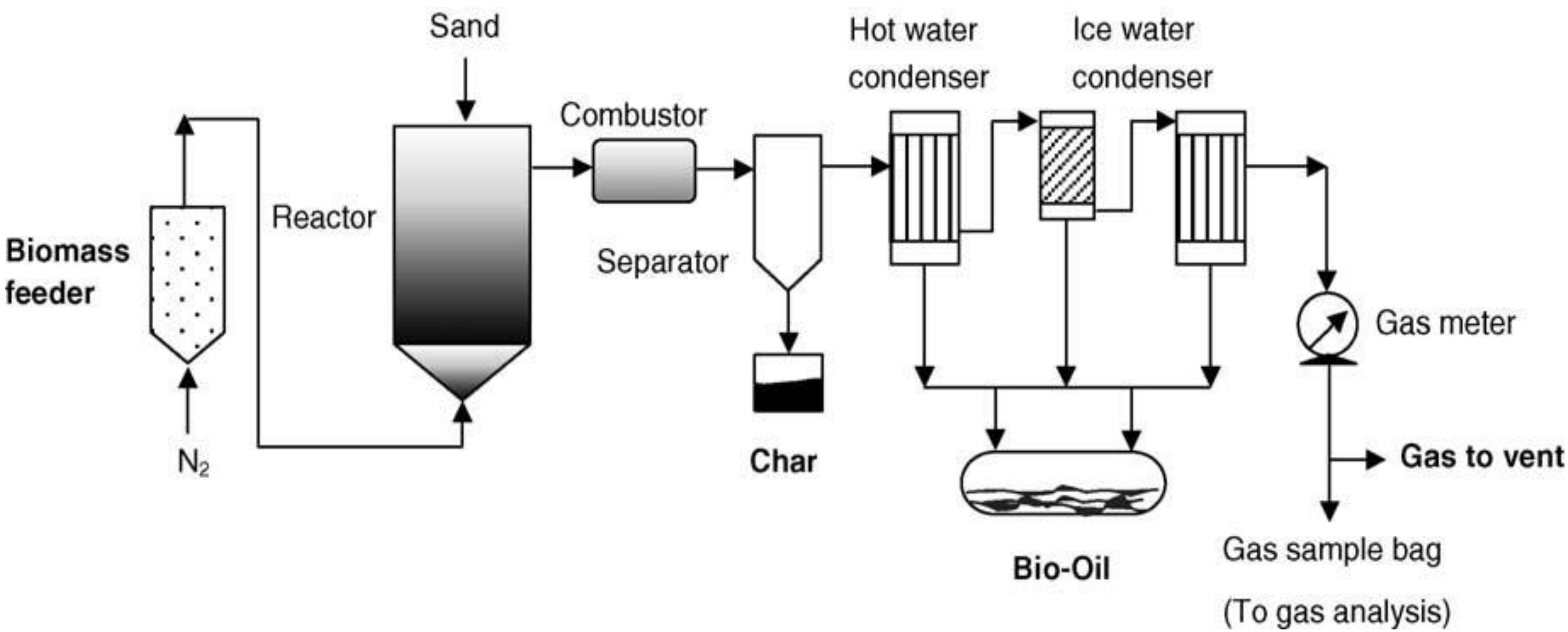
Types of Plastic products

High Density Polyethylene (HDPE)



Structure of HDPE (Mansur, Abdullah, Michael, Anderson, 2001)

Different technologies
Fast pyrolysis



Fluid bed fast pyrolysis system

Bio-fuel Production from Algae by Slow pyrolysis

An algae was fed into in a fixed-bed reactor made of stainless steel with a height of 21 cm and a diameter of 6 cm. Nitrogen gas was fed at a flow rate of 30 ml min-1 for 30 minutes to remove the air in the reactor before testing. The test was started by heating up the reactor at a rate of 8^{o}C min-1 until the temperature reached a set temperature between 450 – 600^{o}C. Then, the reactor was kept at a constant temperature for 60 minutes. The gas yield leaving the reactor was condensed in two water-cooled condensers and was kept in liquid form in two collected flasks while the solid residue (bio-char) remained in the reactor. The condensed liquid was bio-oil, and its properties were tested. The slow pyrolysis of algae in this study could produce bio-oil and bio-char products.

Pyrolysis process for bio-oil production

Pyrolysis is a thermochemical decomposition of organic material at elevated t^{o} in the absence of oxygen. It involves the simultaneous change of chemical composition and physical phase, and is irreversible.

A pyrolysis study on a species of brown algae Saccharina japonica was carried out in a fixed-bed reactor. The yields of bio-oil and bio-char obtained at 450^{o}C were 47 % and 33 %, respectively. The raw S, japonica, ethanol and acid pretreated samples and the resulting pyrolysis products were also characterized with respect to proximate and ultimate analysis, and higher heating value. The higher heating value (HHV) of HDO bio-oil product was close to those of conventional gasoline and diesel.

Types of reactors

Batch Process

The batch reactor is the generic term for a type of vessel widely used in the process industries. Its name is something of a misnomer since vessels of this type are used for a variety of process operations such as solids dissolution, product mixing, chemical reactions, batch distillation, crystallization, liquid/liquid extraction and polymerization.

In some cases, they are not referred to as reactors but have a name which reflects the role they perform (such as crystallizer, or bioreactor).

A ***typical batch reactor*** consists of a tank with an agitator and integral heating/cooling system. They are usually fabricated in steel, stainless steel, glass-lined steel, glass or exotic alloy.

Liquids and solids are usually charged via connections in the top cover of the reactor. Vapors and gases also discharge through connections in the top. Liquids are usually discharged out of the bottom.

Fluidized bed reactors

The fluidized bed reactor has been used in most commercial plants in which gaseous products or inert gas flow through an expanded bed of feedstock and other bed materials, forming bubbles or eddies.

The advantages of fluidized bed reactor are the homogeneity of both t^o and composition. Heat and mass transfer rates are much higher than the fixed bed thus the low thermal conductivity in fluidized bed reactors is no longer a problem.

Experimental and Methodologies

Object

It is now widely accepted that macro-algae and plastic waste are promising candidate feedstock for biofuel production.

In this work, biofuels and their chemical and physical properties of selected macro-algae and plastic waste were investigated. According to the ASTM standard methods were implemented to examine the properties of macro-algae and plastic waste

Experiment and Equipment used

Macro-algae: This is the green growth gathered from Baltic Sea in the summer season from June to September. These gathered green growths contain some water, so it can be utilized to dry for once in a while. After that green growth can be smashed into little sizes, since it effectively fits into the reactor.

Wet Macro-algae

Experiment and Equipment used

Polyethylene (HDPE): It is only plastic milk holder which can be accessible in business sector. It was cut into little piece for effortlessly fit into the reactor.

Milk container and its pieces

Experiment and Equipment used

Batch Reactor: One of the best reactors for pyrolysis is accessible in Klaipeda University Laboratory. It is utilized to break a Macro algae and HDPE (Polyethylene) to give us a pyrolysis fluid and gas. The flare gas is not essential: it lets go.

In this reactor, first unadulterated green growth has been pyrolyzed and second, both green growth and plastic combined can be pyrolyzed with various proportions.

Procedure:

1) The samples are filled into the assembly of reactor and the chamber with great stuffed ensures that there is no spillage.

2) Switch on the reactor and wait for couple of min, then switch on the cooler to cool the gas port to change over into fluid.

3) At the same time, water stream is racing to keep the chamber to cool, to get some flare gas, these can be terminated.

4) Simultaneously, take note of the reactor t^o for at regular intervals, in the wake of getting first drop of fluid in the compartment, note reactor t^o every 5 minutes.

Distillation

Vacuum distillation is simply distillation at pressures at below one atmosphere. Reduced pressure permits vaporization at reduced t°.

The sample to be evaporated is present in the evaporator flask. Depending on the thermodynamic properties of the sample, it was evaporated by a suitably selected combination of the heating bath t° and the vacuum. The settings are made on the control panel of the base unit. The drive unit provides a rotation, which reduces the risk of boiling evaporation and accelerates the evaporation process by increasing the surface area of the sample. The sample vapor reaches the condenser, the vapor tube is condensed and then flows into the receiving flask

Ash Test

This test method covers the determination of ash in the range of 0.001-0.180 mass %, from distillate and residual fuels, crude oils, lubricating oils, and other petroleum products.

The test method is limited to petroleum products which are free from added ash-forming additives, including certain phosphorous compounds (ASTM standard D482).

Crucible and Muffle furnace

Procedure

1) Heat the evaporating dish or crucible that is to be used for the test at 700 to 800^{o}C for a minimum for 10 min. Cool to room t^o in a suitable container, and weight the crucible

2) The crucible is weighed and loaded with samples; in this test having 4 different mixtures of samples, 4 samples are filled in the four crucibles

3) The samples in the crucible need to burn up to last drop in the crucible. Then the crucible is moved to the heater, it ought to be kept for pretty much 60 min

4) The crucible is taken off from the heater, it will be kept in room t^o to get cool, and then measure the crucible with ash

Calculation

calculate the mass of the ash as a percentage of the original samples as follows

$$\text{Ash, mass} = (w/W) \times 100\ \%$$

where:

w = mass of ash, g,

W = mass of sample, g.

Viscosity

This test method specifies a procedure for the determination of the kinematic viscosity of liquid petroleum products by measuring the time for a volume of liquid to flow under gravity through a calibrated glass capillary viscometer (ASTM Standard D445)

Procedure

- Take a glass container filled with full of water warm up to 40^{o}C. Ensure that the entire water ought to be keeping up at 40^{o}C
- The u-shaped capillary tube is loaded with enough measure of sample to figure the running stream
- Then the capillary tube is fitted inside the water with the assistance of stand to keep warm
- After a few minutes the globule is utilized to suck the sample. The stream of sample ought to past the begin mark
- Then take stopwatch to ascertain the seconds from the begin imprint to stop mark. The reiteration of trial will give great results

Calculation

The viscosity of the sample is calculating with gravity of free fall,

$$\nu = C \cdot t \ mm^2/s$$

Where:

C – viscometer calibration constant, mm^2/s;

t – average flow time, s.

Density test

This test method covers the determination of the density or relative density of petroleum distillates that can be handled in a normal fashion as liquids at test t^o between 15^oC to 35^oC. The equipment which is used for density test is given below

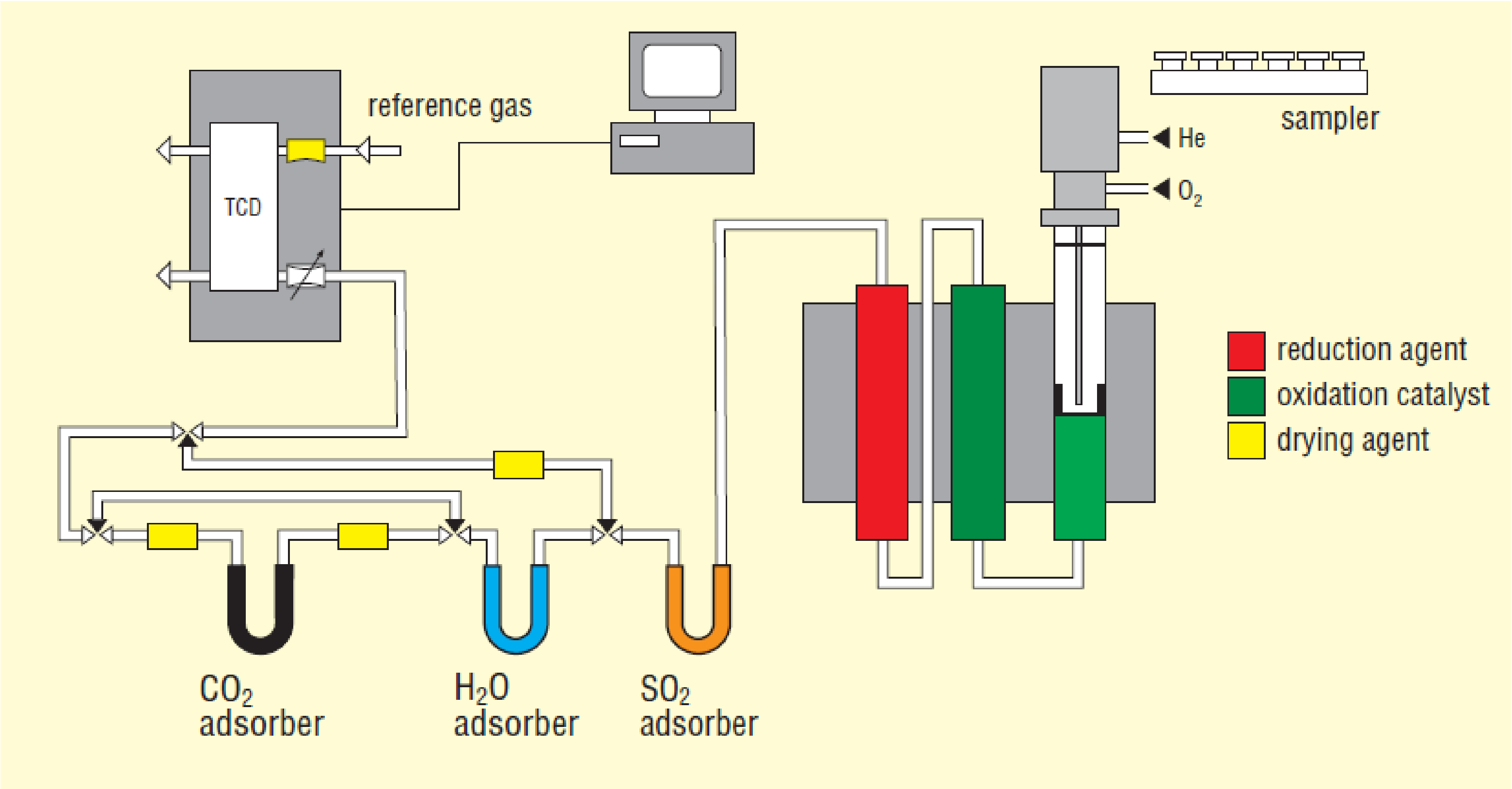
Procedure

- Find the mass of the empty graduated cylinder
- Pour the sample into the graduated cylinder to the 10ml level
- Find the mass of the graduated cylinder with 10ml of sample
- Calculate the weight of the oil in the container by subtracting the weight of the empty cylinder from the weight of the container containing the sample

Gas Chromatography Analysis

GC has the benefits of high segment proficiency, high affectability, quick investigation speed and simplicity to be joined with other expository techniques (e.g. Mass Spectrometry). In this way, it is broadly used to dissect raw petroleum and its items.

Elemental Analysis Fuel is a complex material whose chemical composition is difficult to determine. The fuel elements forming divided into combustible and incombustible. Flammable ones are carbon C, hydrogen H and sulfur S, incombustible - nitrogen N, oxygen O, the ash A and humidity W.



Copper MACRO elemental analyzer principal scheme

Results and discussions

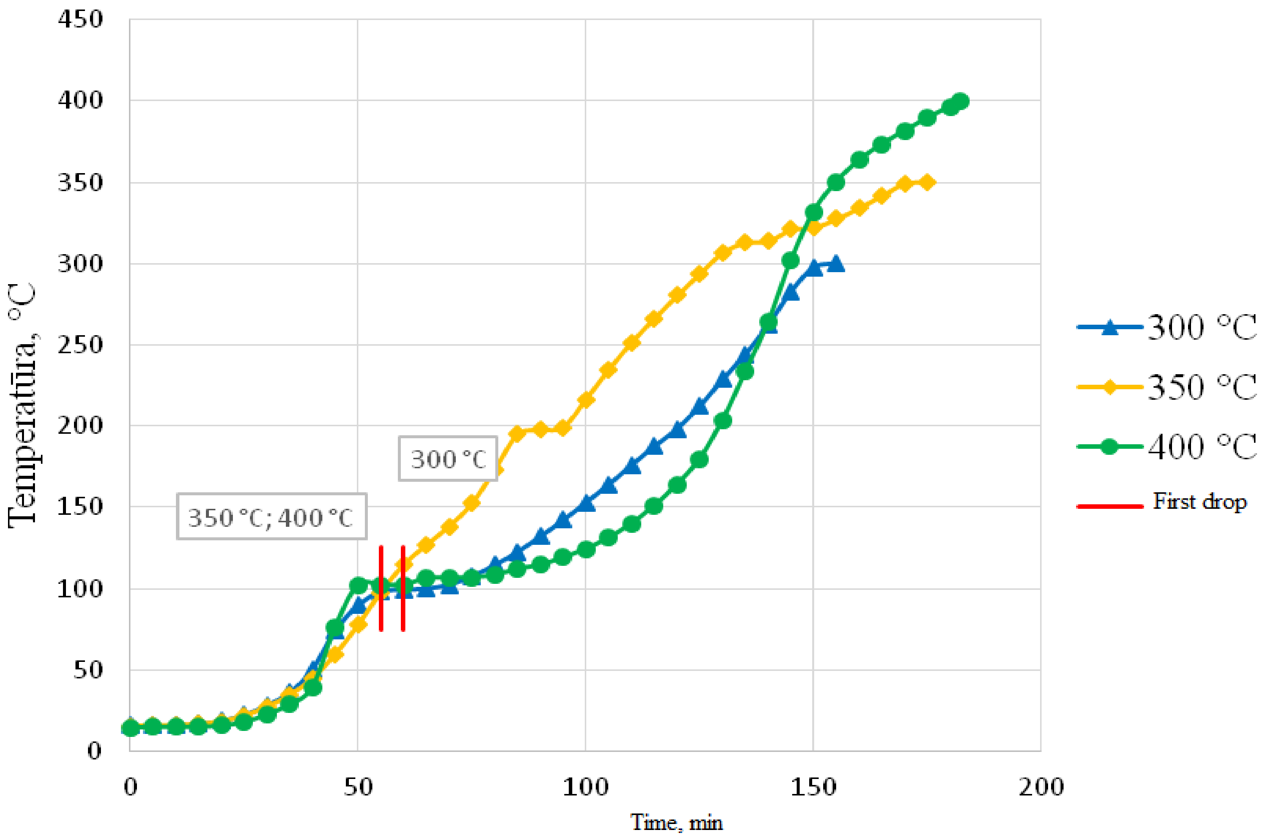
This part incorporates pyrolysis yield, refining of pyrolysis oil, and examination of physical and chemical properties

Pyrolysis from macro-algae and HDPE

The first stage was pure macro-algae; second phase of the pyrolysis process as a raw material was used macro-algae and HDPE plastic waste. Pyrolysis processes were carried out at 3 t^o - 300, 350, 400^{o}C. Totally pyrolysis is carried out with 6 options.

Results and discussions

Figure shows the pyrolysis process tº variation since the beginning of the process pyrolysis pure *Cladophora* algae, from the reactor into the oven. The 3 curves show a change in tº per unit of time to different terminal pyrolysis tº - 300, 350 and 400˚ C.



The red line - is isolated moment in time when the first split in liquid drop. The time variation of different pyrolysis process tº was 300˚ C at 60 min and at 350 and 400˚ C 55 min.

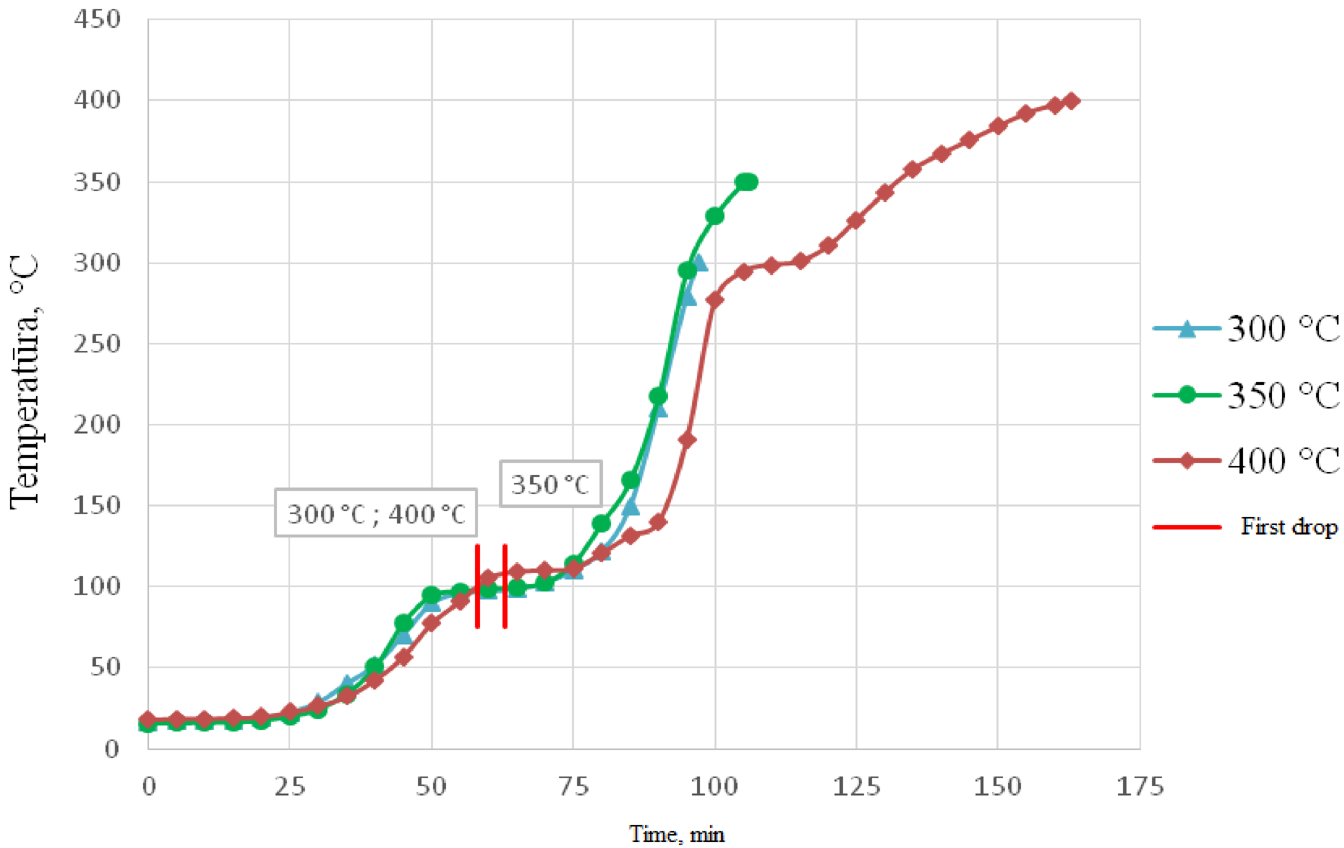
Product yields from macro-algae

the highest yield to any final pyrolysis t° of the 3 resulting products where solid - carbon. The following is a liquid product, and at least pyrolysis macro-algae formed gaseous product.

Pyrolysis Temperature °C	Liquid yields, %	Solid yield, %	Gas, %
300	33,40	46,53	20,07
350	34,54	44,78	20,68
400	34,52	41,85	23,63

Product yields from macro-algae

Due to low yield of the liquid product in the first stage of pyrolysis was carried out in the second stage of pyrolysis. In the second stage, different raw material was used for pyrolysis process *Cladophora* macro-algae and HDPE plastic waste. Macro-algae and plastic were blended in a ratio of 50:50.



Graph contains the mixture of inputs pyrolysis t° change over time under different pyrolysis t° (300, 350, 400° C).

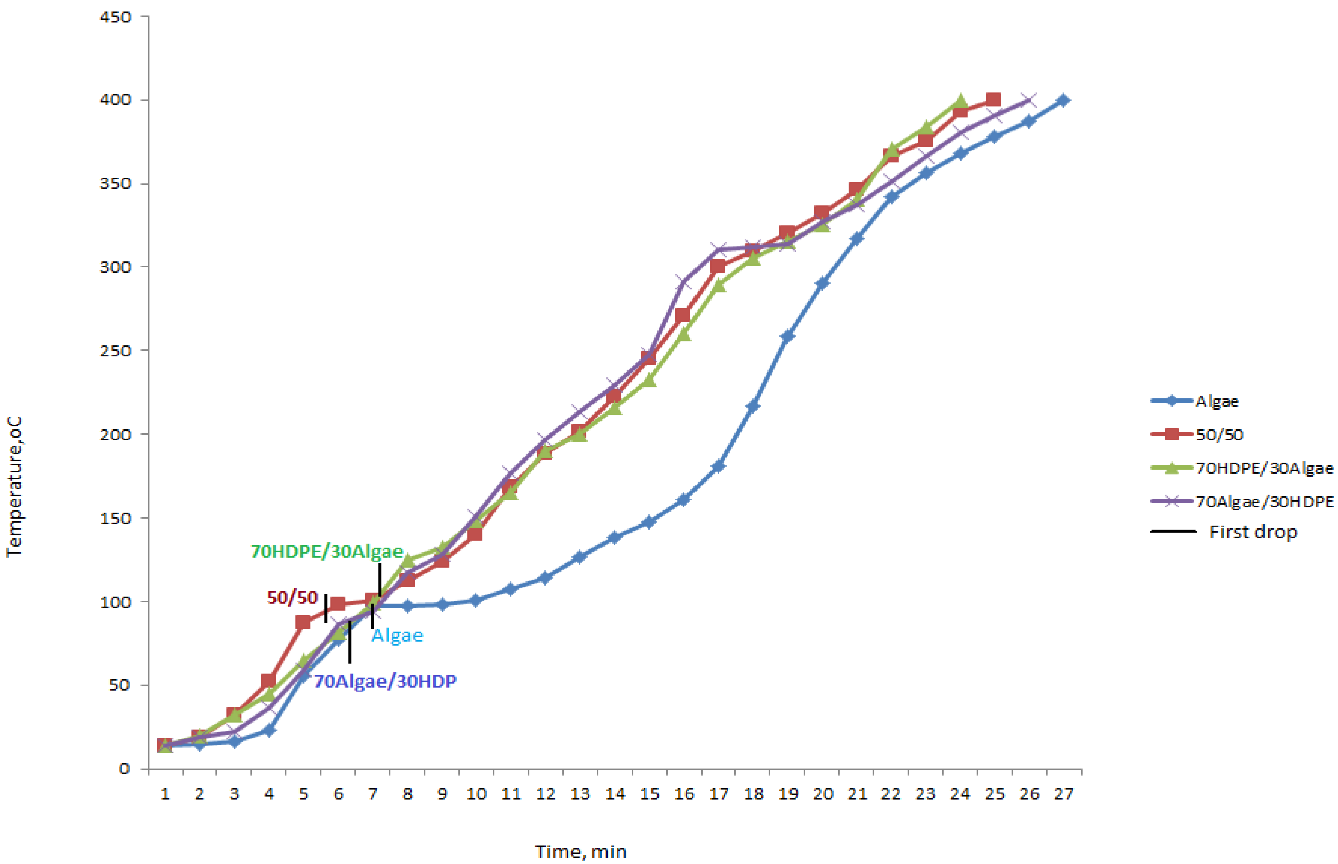
Product yields from macro-algae

As pyrolysis pure macro-algae, following a mixed raw pyrolysis was estimated average t° raising speed to different final pyrolysis process t°: 300 ° C – 2.83 ° C/min; 350 ° C – 3.04 ° C/min; 400 ° C – 2.55 ° C/min. The highest yield to any final pyrolysis t° of the 3 resulting products where solid - carbon. The following is a liquid product, and at least pyrolysis macro-algae and waste plastic formed gaseous product

Pyrolysis temperature, °C	**Liquid, %**	**Solid, %**	**Gas, %**
300	28,86	59,17	11,97
350	36,05	36,46	27,49
400	45,53	25,63	28,84

Product yields from macro-algae

Different ratio of raw material was fed into the reactor. The graph indicates the different proportions of raw materials give the pyrolysis oil. The pyrolysis process works under 400ºC. In this tº, the yield of bio-oil was very high compared to other two stages (34.52%, 45.53%). Pyrolysis process tº variation - The point in time when first drop of liquid drop (the graph shows in black line) at 400ºC of pyrolysis process reaches the tº



Third pyrolysis process at 400^{o}C

This research is more concentrated on 400^{o}C pyrolysis process. In the above given sample pyrolysis was only at 400^{o}C, in that each raw material mixtures have certain percentage of liquid, solid and gaseous state.

The gas is not essential, but it can be burned. The pure macro-algae yield oil is less because of more water content in that. In HDPE plastic waste there is no water content, mixing of HDPE and algae pyrolysis process the percentage oil yield in every proportion is high.

Sample Mixtures	**Liquid (%)**	**Solid Form (%)**	**Gas (%)**
100% Algae	35.12	42.38	22.50
50% Algae & 50% HDPE	47.84	32.82	19.34
70% HDPE & 30% Algae	61.12	18.18	20.70
70% Algae & 30% HDPE	38.64	36.88	24.48

Fuel characteristics of pyrolysis products

Pyrolysis of biomass produces useful products like ***gas***, ***oil*** and ***solid char*** which can be used as fuel or a feedstock for petrochemicals and other applications.

The difference in composition of chars from terrestrial biomass and seaweeds is linked to the differences in nature and structure of the biomass. Due to the higher content of ash, the char obtained from seaweeds had a lower heating value than those from grape seed and safflower oil cake. Due to the low sulphur and ash content, the chars obtained from terrestrial biomass can be considered as a solid fuel with high heating value. But pulverized fuel combustion systems that permit the use of low NOx burners should be chosen since they have high nitrogen content (Putun Ozbay, 2005)

Parameter	**Torrefaction** (%)(Prins, 2006)	**Slow pyrolysis** (%) (Williams, 1996)	**Fast pyrolysis in a fluidized bed reactor** (%) (Gerder, 2001)
t^{o} (^{o}C)	300	300	476
Liquid yield (wt%)	28	28	67.4
Char (wt%)	60.8	66.8	16
Gas (wt%)	11.2	5.2	16.6

Comparison between several pyrolysis processes (Ozbay, 2005)

Distillation of Pyrolysis oil

In this proposition vacuum refining is utilized to separate the water from the pyrolysis oil. In 30°C vacuum pressure of 1000 mbar can be used to isolate the water, it takes couple of minutes after to expand the t° of around 90°C hydrocarbon mixture will get. These can be utilized to determine the physical and chemical properties. The rate of water and hydrocarbon mixture is given below.

A large amount of water from the raw material is unavoidable in the bio-oil even if it is dry material. The existence of water in bio-oil will decrease the quality of the bio-oil, thus water should be removed from the bio-oil.

Distillation of Pyrolysis oil

Distillated oil percentage

Sample Mixtures	Liquid Product (%)	Residue (%)	Water (%)
100% Algae	30	10	60
50/50	25	45	30
70%HDPE/30%Algae	28	54	18
30%HDPE/70%Algae	25	33	42

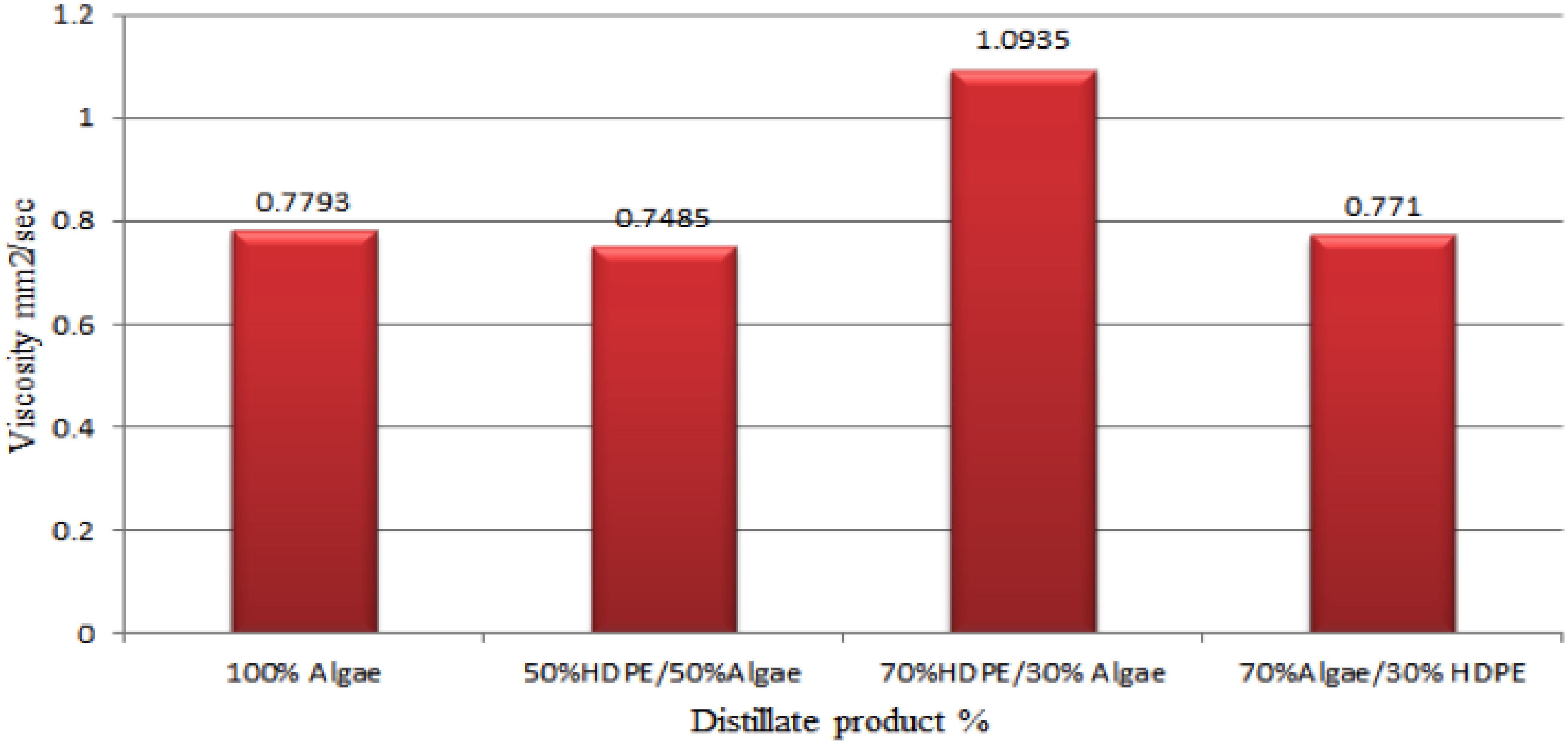
Analysis of Viscosity and Density Properties

Viscosity

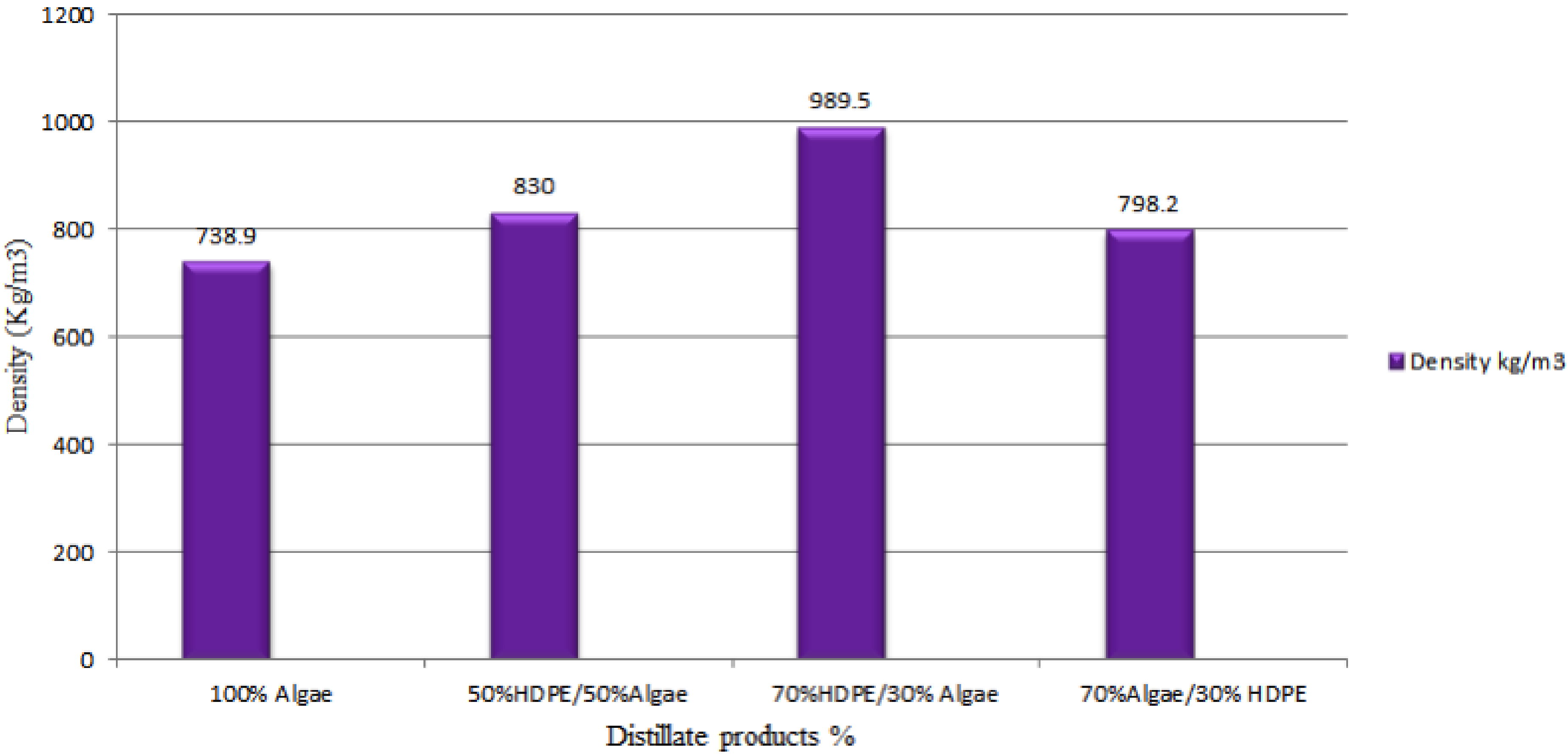
The viscosity of distilled oil of different mixtures was performed under the ASTM standard. ***Viscosity is a measure of the internal friction of fluid.*** The greater the friction, the greater the amount of force required to cause this movement, which is called shear. Shearing occurs whenever the fluid is physically moved or distributed, as in pouring, spreading, spraying, mixing, etc. High viscous fluids, therefore, require more force to move than less viscous material.

Distilled bio-oil viscosity range depends on the properties such as ***water content, oxygen content*** and ***the storage conditions***. Therefore, in ambient conditions or at higher t^{o}, the viscosity of bio-oil may increase. ***Viscosity is an indicator for the stability and age of bio-oil***. Additives like ethyl acetate, methyl isobutyl ketone and methanol, acetone, methanol, acetone and methanol, and ethanol will reduce the initial viscosity of bio-oil and aging rate (Diebold, J.P. and S. Czernik, 2004).

Viscosity of different samples



Density of different samples



Analysis of Chemical properties
Ash test

Ash is the residue of ***bio-oil*** after its combustion, and the ash is determined according to ASTM D 482. The ash of bio-oil is usually varied in 0.004-0.03 wt% (Oasmaa & Czernik, 1999), which is also relevant to the raw materials and reaction conditions. In general, the ash content is higher for the straw oil than for other oils due to their originally higher amounts in straw than in wood (Sipila, et al., 1998).

The ash content of the bio-oil is a measure of the amount of ***inorganic noncombustible*** material it contains. The distillated bio-oil was performed in the ash test with different ratios of raw materials. The table below shows the ash content of bio-oil.

Sample	**Ash content, %**
100% Algae	1.03
50% HDPE/50% Algae	1.43
70%HDPE/30%Algae	1.52
70%Algae/30%HDPE	1.24

Elemental Analysis

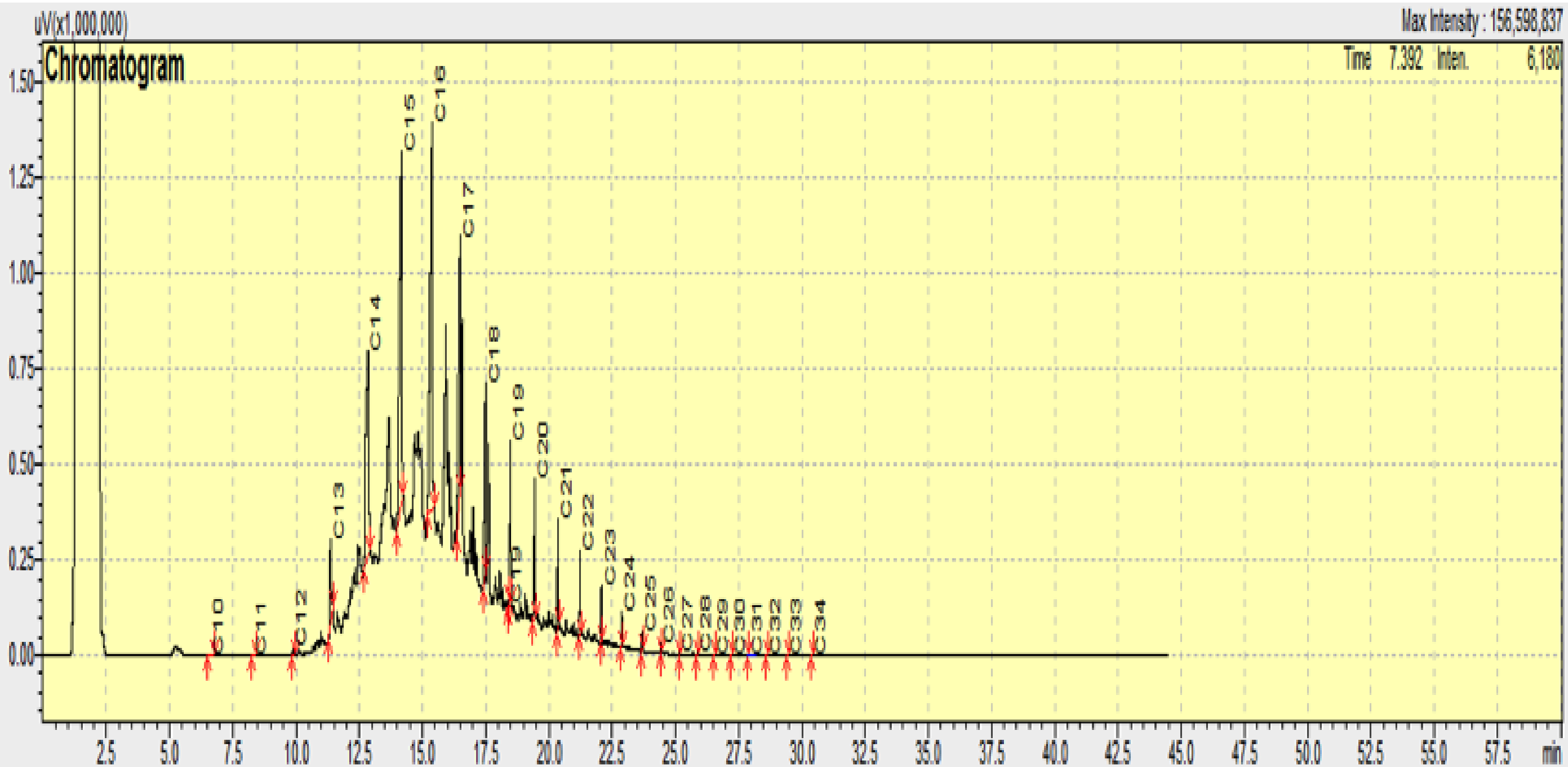
The aim of elemental organic analysis in general is the determination of the elemental composition of organic compounds. Major constituents of organic substances are C, H, N, S and O besides halogens, P and metals. The table presents the fuel properties of analysis of bio-oil from macro-algae and plastic waste

Samples	Nitrogen %	Carbon %	Sulfur %	Hydrogen %
100%	0.061	2.616	0.485	7.140
50%HDPE/50%Algae	0.315	4.242	0.239	8.255
70%HDPE/30%Algae	0.341	4.181	0.215	7.605
70%Algae/30%HDPE	0.204	2.191	0.211	6.769

Gas Chromatography of pure algae

The GC analyses were carried out in order to find out the hydrocarbons present in the fuel. The different sample fuels which were obtained by second step distillation were analyzed by GC. The samples of macro-algae fuel which obtained after 2nd step distillation were complex mixture and contain different class of hydrocarbons which are shown in the table below. After distillation was introduced to GC analysis, where GC had following peaks and results, as shown down in graph below.

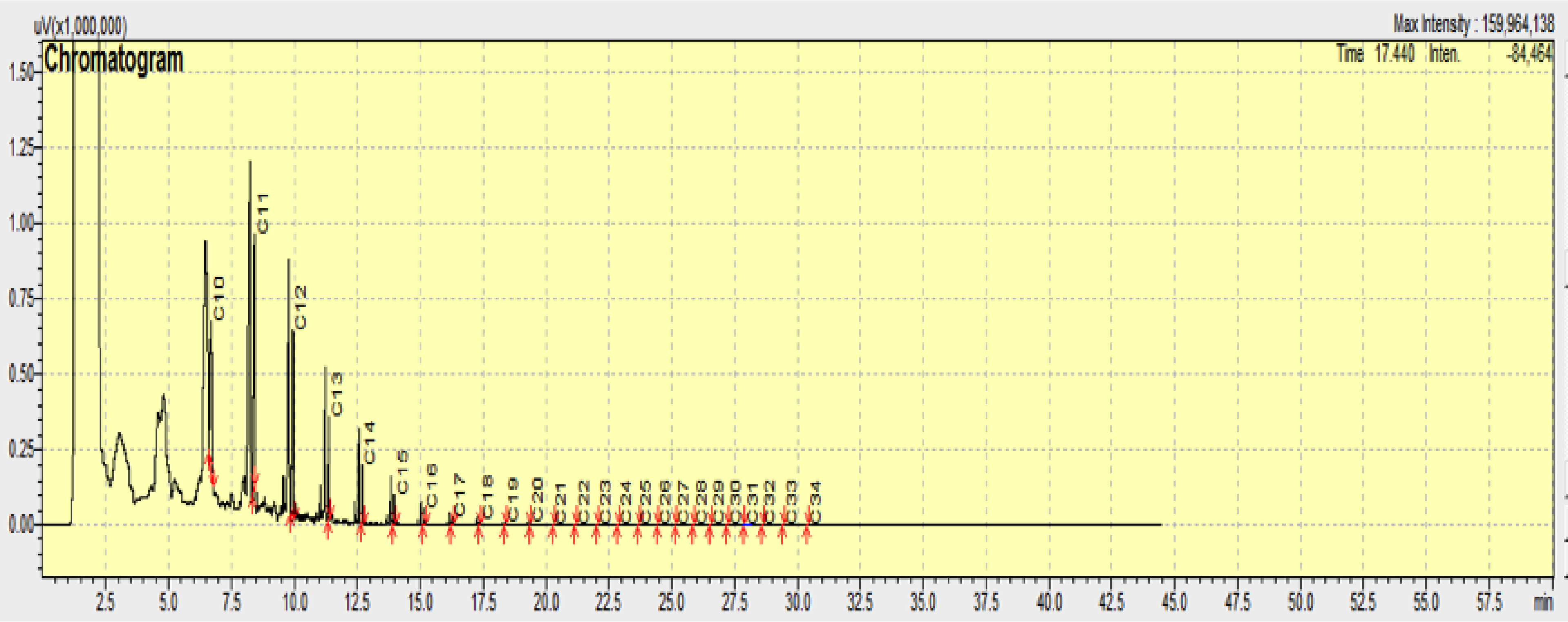
Gas Chromatography of pure algae



Carbon number	Concentration
C10	0.667
C11	0.29
C12	3.572
C13	45.877
C14	256
C15	374.42
C16	352.65
C17	187.7
C18	98.76
C19	0.1645
C19	72.25
C20	61.55
C21	37.70
C22	30.488
C23	15.30
C24	10.40
C25	4.433
C26	2.456
C27	0.85
C28	0.388
C29	0.326

The table shows the compounds were determined based on retention time and boiling point when the compound was detected in the fuel sample. From lower boiling point C_{10} to higher boiling point C_{34} were traced by GC, where the lower compound C_{10} (at retention time 6.595) and highest compound C_{34}(at retention time 30.389). The C_{15} has more concentration of 374.42

70 HDPE/ 30 ALGAE Chromatography analysis



Gas Chromatogram of Macro-algae and HDPE

Carbon numbers	Concentration
C10	141.4
C11	184.2
C12	111.24
C13	43.41
C14	23.516
C15	12.031
C16	5.23
C17	3.0315
C18	1.614
C19	0.9035
C20	0.7705
C21	0.618
C22	0.6135
C23	0.438
C24	0.401
C25	0.287
C26	0.311
C27	0.262
C28	0.2235
C29	0.1495
C30	0.1485

The compounds were determined based on retention time and boiling point when the compound was detected in the fuel sample. From lower boiling point C10 to higher boiling point C34 were traced by GC, where the lower compound C10 (at retention time 6.689) and highest compound C34(at retention time 30.387). The table 12 shows the GC of plastic waste and macro-algae.

Recommendations

The ***bio-oils have several undesired properties for fuel applications*** such as high ***oxygen/water*** contents, high ***viscosity***, and ***corrosiveness***. These undesired properties present many obstacles to use bio-oil as a substitute for petroleum based fuel.

Recommendation of upgrading bio-oil using various technologies gives better bio-oil qualities. ***Novel integrated refinery processes are needed to systematically upgrade bio-oils into transportation fuels*** that have desirable qualities, while producing other value-added co-products to make the economics work.

Conclusions 1

Pyrolysis of macro-algae and plastic waste was performed in batch reactor, to investigate the effects of pyrolysis t^o and product yields. The different ratio of raw material was carried out in the reactor. The proportion of 70% HDPE and 30% ALGAE has maximum bio-oil yield of 61.12% was obtained at final pyrolysis t^o of 400 ^{o}C.

This ***different raw material mixtures bio-oil was distillated under vacuum pressure of 1000mbar***. At 30^{o}C temperature water can be separated after increasing the t^o of about 90 ^{o}C hydrocarbon mixture has been separated.

The physical properties of hydrocarbon mixture from 70% HDPE and 30% Algae raw material ***have high viscosity and high density*** (1.0935 mm2/s, 989.5 kg/m3) property. The ash content of hydrocarbon mixtures from different ratios of raw material has less amount of ash compared to blue green algae bio-oil.

Conclusions 2

The elemental analysis of ***distillated bio-oil*** from 70% HDPE and 30% ALGAE ***has higher carbon*** (4.181 %) and ***hydrogen*** (7.605 %) content than ***pure macro- algae*** (Carbon 2.616% and hydrogen 7.140%) distillated bio-oil.

In gas chromatography the distillated bio-oil from macro-algae was composed of a very complex mixture of hydrocarbon compounds of 5-20 carbons. In 70% HDPE and 30% ALGAE have hydrocarbon ranges from C10 to C34. Compare to pure macro-algae concentration 70% HDPE and 30% ALGAE has more concentration of C15 - 374.42.

Conclusions 3

The result obtained from this study, possible to increase the liquid product yield at 400^{o}C temperature. The ***different proportions of raw material are used in this research***, but the pyrolysis bio-oil yield is high in 70% HDPE and 30% ALGAE as shown earlier. This pyrolysis bio-oil was distillated to separate the hydrocarbon mixtures. The physical and chemical property of hydrocarbon mixtures was determined.

The ***viscosity and density of 70% HDPE and 30% ALGAE*** is high compared to other proportions of raw material. The distillated bio-oil ***has less hydrocarbon concentration because of using plastic waste*** compared to pure macro-algae. The oil yield and property of 70% HDPE and 30% ALGAE gives better results.


Thank You for Attention