

CERTIFICATION OF APPROVAL

Effect of Biomass Pre-Treatment on Bio-Oil Yield

By

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Approved by,

.....

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not undertaken or done by unspecified sources or person.

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(ASYRIZULFITRI BIN CHE HASAN)

ABSTRACT

The alternative separation processes for biomass components, steam explosion is considered to be one of the most important. The attractive features of steam explosion in comparison to autohydrolysis, pulping and other methods include the potential for significantly reducing the environmental impact; the investment. The research on biomass conversion technology has attracted great attention of the world along with the shortage of fossil energy resources. But the effect and efficiency of the pretreatment technique now used in biomass conversion are not so perfect. Using new steam explosion technique as a pretreatment process of biomass conversion has been reported rarely. The mechanism of steam explosion and its application effect in biomass conversion and utilization were introduced and analyzed respectively.

ACKNOWLEDGEMENT

First of all, I would like to thank to Allah S.W.T to make my Final Year Project flows smoothly, silky and victorious along the two semesters of completion period.

I would ever be indebted to my supervisor; Prof Dr. Yoshimitsu Uemura, whose encouragement, guidance and support from initial to the final stage enabled to develop a strong understanding of this project, named Effect of Biomass Pre-Treatment on Bio-Oil Yield. Though his assistance needs him to sacrifice his precious times, he never once complain but continuously conveyed high positive spirits. Without his guidance and persistent help, this project would not have been possible.

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Not to forget all the lecturers who have taught me the knowledge of Chemical Engineering, my big gratitude goes to them for their sincere teaching has equipped me with strong fundamentals of engineering knowledge of which has ease the completion of this project.

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CHAPTER 1

INTRODUCTION

1.1 PROJECT WORK BACKGROUND

Steam explosion is developed by W.H. Mason in 1928, which use the saturated water vapor (0.69 – 4.83 MPa) 160-260 °C heated biomass and maintain a time of a few seconds to several minutes, and then decompress it to atmospheric pressure suddenly. Different materials need different steam explosion temperature and retention time, some scholars have put steam temperature and retention time of convergence as a parameter with the intensity of steam explosion, R_0 , each type of material has its own optimum temperature and time parameters in steam explosion pretreatment, so that different scholars made different conclusions, but they all have confirmed that the semi-cellulose, lignin and cellulose of biomass were effective separated by steam explosion, which greatly enhanced the subsequent hydrolysis and conversion rate of cellulose.

1.2 PROBLEM STATEMENT

Biomass is a clean and renewable energy resource, usually referred to biomass plants use of solar energy by photosynthesis and stored as its own energy. The energy stored by plants every year Biomass is a clean and renewable energy resource, usually referred to biomass plants use of solar energy by photosynthesis and stored as its own energy. The energy stored by plants every year was about 10 times of the world's main fuel consumption, but there was less than 1% of it was used by us till now. Since the beginning of the 1970's, with the impact of the global oil crisis and the improving of people's environmental awareness, the world began to pay more attention to developing and highly efficient conversion techniques of biomass. Because the energy density of biomass straw is lower than other fuels, the processing power consumption is so large, in addition, the special structure of cellulose, hemicelluloses and lignin of the biomass straw makes it difficult to digest and decomposition, these factors has seriously hindered the conversion and use of biomass. While scholars have carried out a lot of research on pre-processing of biomass and achieved some result, but have yet to find a more efficient way. Therefore, the pretreatment technique is the key problems needed to be solved to improve the efficiency of biomass conversion and utilization.

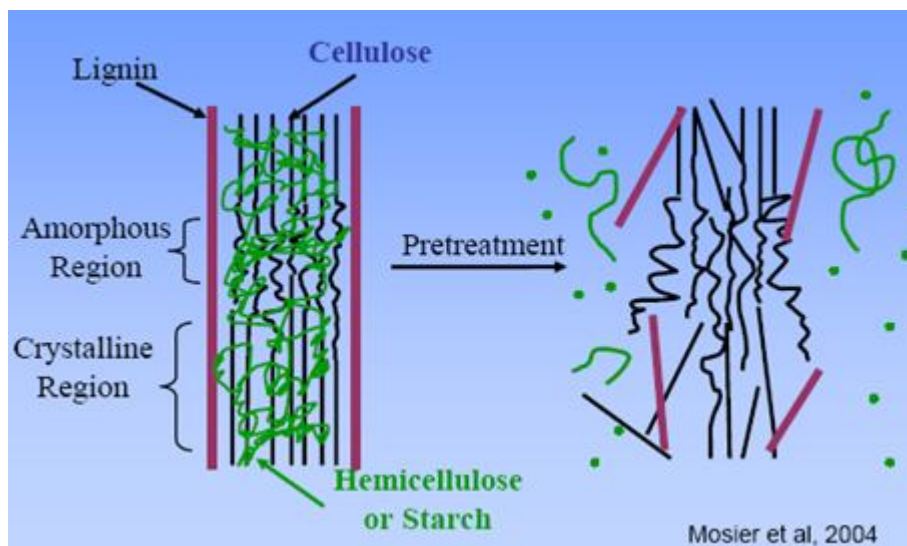


Figure 1.1: Fractionation of Biomass Structure

1.3 OBJECTIVE

To study the effect of pretreatment of biomass using steam explosion method on bio oil yield.

1.4 SCOPE OF STUDY

Plant biomass is an important resource for energy, food and useful chemicals due to its abundance in nature and its renewable character. The aim of economically feasible biomass processing is to achieve a complete utilization of various biomass components. For my project, there are four samples that have to be analyzed:

- i) Kernel shell before steam explosion
- ii) Kernel shell after steam explosion
- iii) Empty fruit bunches before steam explosion
- iv) Empty fruit bunches after steam explosion.



Figure 1.2: Kernel Shell before Steam Explosion



Figure 1.3: K. Shell after Steam Explosion



Figure 1.4: EFB before Steam Explosion



Figure 1.5: EFB after Steam Explosion

The samples have been prepared by my supervisor, Prof Dr. Yoshimitsu, and I use the samples to do analysis. Basically, there are four analyses have to be run:

- i) Ash content analysis
- ii) CHNS content analysis
- iii) Calorie content analysis
- iv) Moisture content analysis

1.5 RELEVANCY OF THE PROJECT

Percent composition is a process where a sample of some material is analyzed for its elemental and sometimes isotopic composition. Elemental analysis can be qualitative (determining what elements are present), and it can be quantitative (determining how much of each are present). Elemental analysis falls within the ambit of analytical chemistry, the set of instruments involved in deciphering the chemical nature of our world. For organic chemists, elemental analysis almost always refers to CHNS analysis—the determination of the mass fractions of carbon, hydrogen, nitrogen, and heteroatom of a sample. This information is important to help determine the structure of an unknown compound, as well as to help ascertain the structure and purity of a synthesized compound.

Moisture analysis covers a variety of methods for measuring moisture content in both high level and trace amounts in solids, liquids, or gases. Moisture in percentage amounts is monitored as a specification in biomass industry. There are many applications where trace moisture measurements are necessary for manufacturing and process quality assurance. Trace moisture in solids must be controlled for plastics, pharmaceuticals and heat treatment processes. Gas or liquid

measurement applications include dry air, hydrocarbon processing, pure semiconductor gases, bulk pure gases, dielectric gases such as those in transformers and power plants, and natural gas pipeline transport.

The energy needed to increase the temperature of a gram of water by 1 °C depends on the starting temperature and is difficult to measure precisely. Accordingly, there have been several definitions of the calorie. The two perhaps most popular definitions used in older literature are the 15 °C calorie and the thermo chemical calorie. The factors used to convert measurements in calories to their equivalents in joules are numerically equivalent to expressions of the specific heat capacity of water in joules per gram or kilojoules per kilogram.

Determination of the ash content of biomass is important to stabilize the processing. It is often important to know the mineral content of biomass during processing because this affects the physicochemical properties of the biomass.

Those four parameters are important to be analyzed to study the effectiveness of steam explosion as a pretreatment process.

1.6 FEASIBILITY STUDIES

Because the energy density of biomass is lower than other fuels, the processing power consumption is so large, in addition, the special structure of cellulose, hemicelluloses and lignin of the biomass straw makes it difficult to digest and decomposition, these factors has seriously hindered the conversion and use of biomass. While scholars have carried out a lot of research on pre-processing of biomass and achieved some result, but have yet to find a more efficient way. Therefore, the pretreatment technique is the key problems needed to be solved to improve the efficiency of biomass conversion and utilization. The project size is considered medium risk and the project time frame cannot exceed 5 months for researching on the article related. This project is still allowable to be conducted in the time frame considered.

CHAPTER 2

LITERATURE REVIEW

2.1 ASH CONTENT ANALYSIS

Ash is the inorganic residue remaining after the water and organic matter have been removed by heating in the presence of oxidizing agents, which provides a measure of the total amount of minerals within a food. Analytical techniques for providing information about the total mineral content are based on the fact that the minerals (the “analyte”) can be distinguished from all the other components (the “matrix”) within a food in some measurable way. The most widely used methods are based on the fact that minerals are not destroyed by heating, and that they have a low volatility compared to other food components. The three main types of analytical procedures used to determine the ash content of biomass are based on this principle: *dry* ashing, *wet* ashing and *low temperature plasma dry* ashing. The method chosen for a particular analysis depends on the reason for carrying out the analysis, the type of biomass analyzed and the equipment available. Ashing may also be used as the first step in preparing samples for analysis of specific minerals, by atomic spectroscopy or the various traditional methods described below.

Ash from woody biomass comes from the minerals present in the structure of trees and shrubs in addition to any soil contamination. Properties of wood ash depend on a variety of factors including type of tree or shrub, part of the tree or shrub (bark, wood, leaves), type of waste (wood, pulp, or paper residue), combination with other fuel sources, type of soil and climate and conditions of combustion. Ash management presents both a problem and an opportunity. Removal of ash from the furnace and disposal in landfill areas incurs economic, environmental, and social costs for energy firms/facilities as well as the forest products industry. However, if ash is recycled in forest or agricultural ecosystems or used to reclaim mine spoils, depletion of vegetation nutrients, other than nitrogen, and acidification associated with intensive biomass removal can be radically reduced.

Characterization of ash by elemental composition and fusion temperatures, an indicator of the softening and melting behavior of ash, is important when selecting biomass fuels because it

provides information on how much ash will be generated requiring disposal. Agricultural residues typically generate significantly more ash than woody biomass. Moreover, characterization by elemental composition and fusion temperatures indicates the potential for slagging and fouling of burners and boilers from ash deposition. When wood, alone, is combusted, ash deposition is not typically a problem because combustion temperatures are likely to be low.

However, when biomass is co-fired with coal combustion temperatures are considerably higher and may reach a level where slagging could occur. Ash from woody biomass, in general, stimulates microbial activities and mineralization in the soil by improving both the soil's physical and chemical properties. Improved soil quality from the nutrients found in wood ash can lead to better growing conditions for vegetation. Wood ash has a high alkalinity or neutralizing capacity

2.2 CALORIE CONTENT ANALYSIS

Biomass is the most important source to increase the production of energy based on renewable energy sources. Combustion is the main applied technology to produce heat and power from biomass and is generally economically feasible. The combustion of biomass as fuel has many environmental and economic advantages. It is because biomass is a cheap, clean and renewable source of energy.

Biomass types are composed of a number of constituents and they have complex structures. With respect to chemical and physical properties, biomass species have large differences.

Hemicelluloses, cellulose, lignin and extractive matter are the major constituents of biomass which are present in different ratios and structures in different biomass species.

The calorific value of biomass is an indication of the energy chemically bound in it and in the combustion process it is converted into heat energy. Calorific value is the most important property of a fuel which determines the energy value of it. The design and control of a biomass combustor depend strongly on the calorific value of the biomass fuel.

The calorific value of a biomass fuel can be determined experimentally or can be calculated from ultimate and/or proximate analyses results. The experimental determination of calorific values and ultimate analyses requires special and expensive instrumentation, whereas proximate analyses data can be obtained with relative ease using common laboratory equipment. This makes proximate analyses data very attractive for estimation of the calorific value. On the other hand, calculation may also be used as a general check on the accuracy of the observed data.

Fuel	Net Calorific Value (CV) by mass GJ/tonne	Net Calorific Value (CV) by mass kWh/kg	Bulk density kg/m ³	Energy density by volume MJ/m ³	Energy density by volume kWh/m ³
Wood chips (30% MC)	12.5	3.5	250	3,100	870
Log wood (stacked - air dry: 20% MC)	14.7	4.1	350-500	5,200-7,400	1,400-2,000
Wood (solid - oven dry)	19	5.3	400-600	7,600-11,400	2,100-3,200
Wood pellets	17	4.8	650	11,000	3,100
Miscanthus (bale - 25% MC)	13	3.6	140-180	1,800-2,300	500-650
House coal	27-31	7.5-8.6	850	23,000-26,000	6,400-7,300
Anthracite	33	9.2	1,100	36,300	10,100
Heating oil	42.5	11.8	845	36,000	10,000
Natural gas (NTP)	38.1	10.6	0.9	35.2	9.8
LPG	46.3	12.9	510	23,600	6,600

Table 1: Calorific Value for Several Fuels

2.3 CARBON, HYDROGEN, NITROGEN AND SULFUR (CHNS) ANALYSIS

CHNS Analysis is a form of Elemental Analysis concerned with determination of only Carbon (C), Hydrogen (H) and Nitrogen (N) in a sample. The most popular technology behind the CHN analysis is combustion analysis where the sample is first fully combusted and then the products of its combustion are analyzed. The full combustion is usually achieved by providing abundant oxygen supply during the combustion process. In this setup the analyzed products: Carbon, Hydrogen and Nitrogen oxidize and form carbon dioxide - CO₂, water - H₂O, and nitric oxide - NO, respectively. These product compounds are carefully collected and weighted. The weights are used to determine the elemental composition, or *empirical formula*, of the analyzed sample. Carbon analysis is performed by oxidizing a sample in oversupply of oxygen, trapping the resulting Carbon Dioxide CO₂, and then measuring it by a detector. To achieve accurate measurements the combustion of the sample should be complete. Depending on the material of the sample some accelerators could be used. The accelerators help to initiate and speed up the

combustion process and also ensuring that the combustion is complete. Accelerators should not skew the final results by introducing any additional Carbon into the analysis process.

Purity of oxygen used in the combustion process also affects the results. Oxygen might contain residual amounts of Carbon Dioxide (CO_2). Even when additional Oxygen purifying equipment is used traces of CO_2 might still influence the result. This issue is addressed by conducting calibration tests on the Oxygen itself before combusting the actual sample. Calibration tests will also help to account for any Carbon traces introduced by the equipment, like the furnace and the crucible. There are several methods to measure the concentration of Hydrogen in a specimen. For example, a method of determining the concentration of Hydrogen in a specimen consists of heating the specimen in a furnace at about 1500°C in a atmosphere of Helium. Then the byproducts of fusion are swept in an analyte stream from the furnace. The levels of carbon dioxide in the analyte stream are detected and calculated. After that the Hydrogen compounds in the analyte stream are also detected as a function of temperature to identify concentrations of specific hydrogen compounds by employing a heated CuO catalyst to convert hydrogen compounds in the analyte stream to H_2O and providing an H_2O infra-red detector immediately downstream of the catalyst to detect Hydrogen as a function of detected H_2O . The effect of detected CO_2 levels on the level of Hydrogen measured by the H_2O infra-red detector are computed and compensated the measured Hydrogen level based upon the previous step. As it was discovered in the 18th century, there was a fraction of air that did not support combustion. That fraction was indeed Nitrogen. Nitrogen is a non-reactive gas at normal temperatures and the combustion technology used to oxidize the Nitrogen sample is different from that of Carbon analysis. To analyze Nitrogen quite often the sample is heated to very high temperatures of 3000°C (5432°F) in the atmosphere of inert gas, like Helium (He). Nitrogen is released from the sample into the Helium atmosphere. This changes physical qualities of the atmosphere, primarily the rate of thermal conduction. The change in the rate is measured to derive the amount of Nitrogen released during the process. All elemental analysis techniques have to take into consideration impurities introduced by the equipment, such as furnace, crucible, detectors, as well as those of the inert gas, like Helium in our case. To compensate the effect of those impurities on the concentrations of detected Nitrogen compounds, a series of tests could be run with and without the sample.

Material	C	H	O	N	S	Ash
Cypress	55.0	6.5	38.1	—	—	0.4
Ash	49.7	6.9	43.0	—	—	0.3
Beech	51.6	6.3	41.4	—	—	—
Wood (average)	51.6	6.3	41.5	0	0.1	1
Miscanthus	48.1	5.4	42.2	0.5	< 0.1	2.8
Wheat straw	48.5	5.5	3.9	0.3	0.1	4
Barley straw	45.7	6.1	38.3	0.4	0.1	6
Rice straw	41.4	5	39.9	0.7	0.1	—
Bituminous coal	73.1	5.5	8.7	1.4	1.7	9
Lignite	56.4	4.2	18.4	1.6 ^a	—	5

Table 2.1: Ultimate Analyses for Typical Biomass Material (wt %)

2.4 MOISTURE CONTENT ANALYSIS

Moisture is simply water diffused in a relatively small quantity. Nearly all materials contain at least a diminutive volume of moisture as a component of the molecular makeup. Moisture is a given in the mass of materials, however the relative percentage is dynamic and therefore not constant. Materials from the perspective relation to moisture content, generally a sample of material will continually increase or decrease in weight because of hygroscopic action. Hygroscopic action is the amount of moisture a material will absorb relative to ambient temperature and humidity conditions. Temperature and humidity can be controlled in laboratory environments. However in processing, transportation and storage facilities they are impractical to control. If random sampling is correctly administered, the representation will closely reflect the properties of the whole batch. Moisture content can be thought of as the amount of water in a material or substance. Generally, H₂O content is difficult to measure because of the complex intermolecular bonding properties within the substance matrix. For measurable water content to be justifiably determined and proper levels sustainable in a processing environment, water content of a sample material is then referred to as moisture content in the testing and evaluation process of moisture analysis.

Biomass	Moisture ^a (%)	VM (%)	FC (%)	Ash (%)	LHV (MJ/kg)
Wood	20	82	17	1	18.6
Wheat straw	16	59	21	4	17.3
Barley straw	30	46	18	6	16.1
Lignite	34	29	31	6	26.8
Bituminous coal	11	35	45	9	34

Table 2.2: Proximate of some Biomass Feedstock (%)

2.5 KERNEL SHELL



Figure 2.1: Before Grinded Kernel Shell

Palm kernel shell that we are referring is palm kernel from oil palm fruit. As showed in the image, every oil palm fruit is consists of oil palm nut, and mesocarp (the meat). In palm oil industry, the crash shell without nut is referring to palm kernel shell.

At crude palm oil process, after, mesocarp fibre and oil palm nut will be separated. The oil palm nut will go through nut drying process and then later for nut cracking. Kernel will be separated for kernel oil process and the nut shell will become the palm kernel shell. Palm kernel shell will be pile up and store at open space.

Palm kernel shell can be considered as pellet form because of it nature form, due to it high grade renewable fuel for burning solid, low ash and low sulphur content, palm kernel shell has been used as a burner for power plant. One of the most favorable used of palm kernel shell is to process become charcoal. As received, both in co firing with steam coal or burned at biomass power plants, usually blended with other grades of biomass, like wood chips.

Furthermore, the burned palm kernel shell charcoal has other economy value too. Palm kernel shell charcoal has also been used as activated carbon for water purification; promote organic farming, and also an active agent for soil improvement.

2.6 EMPTY FRUIT BUNCHES

Currently, there are more than three million hectares of oil palm plantations. In total, about 90 million mt of renewable biomass (trunks, fronds, shells, palm press fiber and the empty fruit bunches) are produced each year. The empty fruit bunches (EFB) represent about 9% of this total. They are the residue left after the fruit bunches are pressed at oil mills, and the oil extracted. The oil mills are located near or in the plantation itself.

EFB is a suitable raw material for recycling because it is produced in large quantities in localized areas. In the past, it was often used as fuel to generate steam at the mills. The ash, with a potassium content of about 30%, was used as fertilizer. Burning is now prohibited by regulations to prevent air pollution. The EFB is now used mainly as mulch. Placed around young palms, EFB helps to control weeds, prevent erosion and maintain soil moisture. However, due to the current labor shortage, the transportation and distribution of EFB in the field is getting more expensive. There is a growing interest in composting EFB, in order to add value, and also to reduce the volume to make application easier.

The empty fruit bunch fiber (EFB) was identified as the first of the series of standards on oil palm fibers because of logistic reasons. The EFB has the highest fiber yield and is the only material commercially utilized for fiber extraction but there are good potentials for the exploitation of the other two materials (oil palm fronds and trunks).

The standard is unique in that it is an indigenous standard and is the first in the world that directly relates to the oil palm residues. Extensive study and research had been conducted both by FRIM and PORIM in collaboration with the manufacturers. After several meetings and discussions, the committee had identified critical parameters affecting the quality of the end product. The critical characteristics of oil palm fiber include the fibre length, moisture content, oil content and impurities. Details on the acceptable limits and methods of determination are given in the standard, MS 1408 :1997 (P) - Specification for oil palm empty fruit bunch fibre. For the purpose of commercialization, the standard recommends ONE grade of empty fruit bunch fibre (EFB).

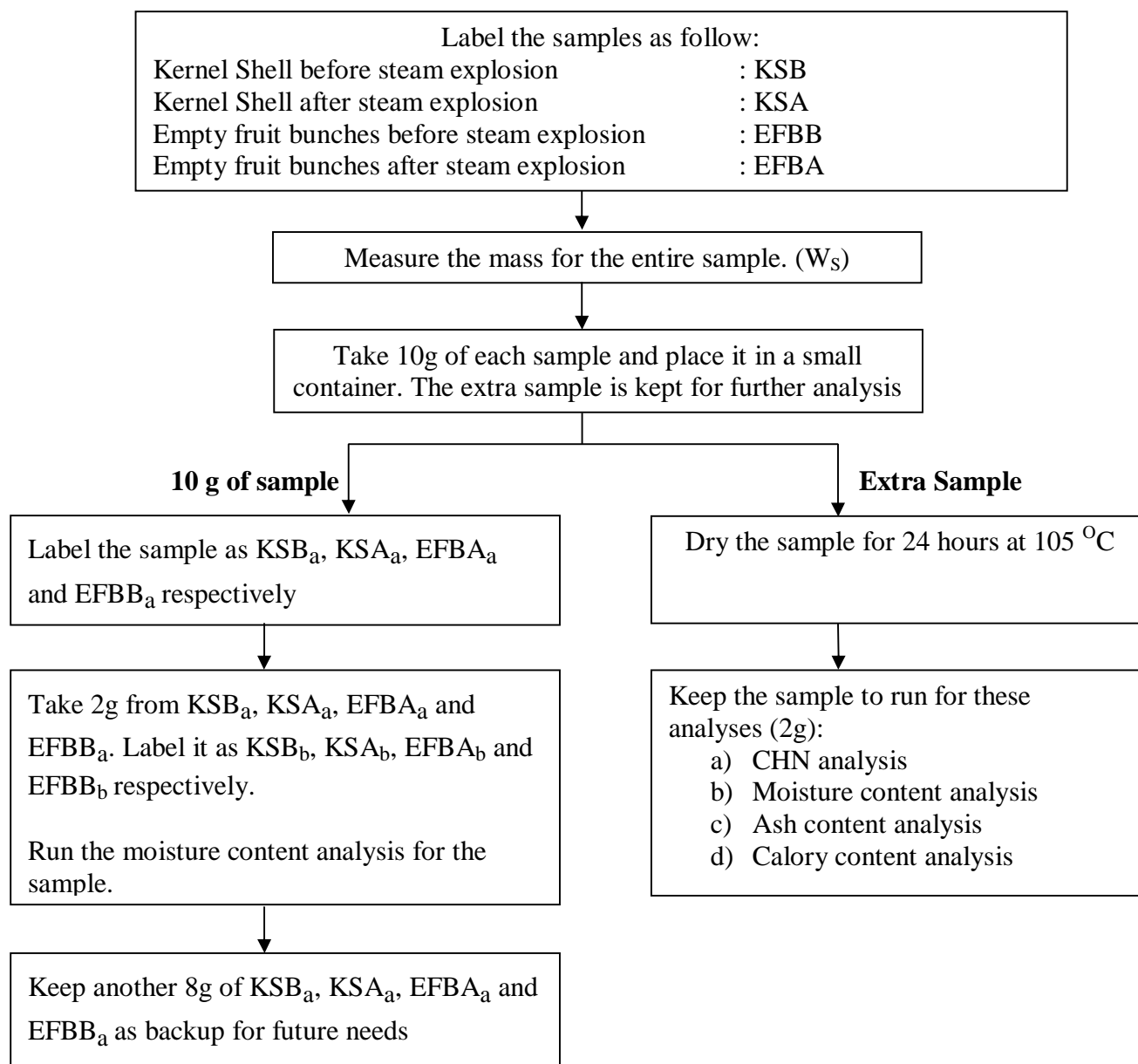
Characteristically EFB fibres are clean, biodegradable and compatible than many other fibres from other wood species. EFB fibres are suitable for the manufacture of mattress, car seat, insulation, and composite panel product and particle board. The choice and selection of fibre length is very much dependent on the nature of the manufactured product. For example, long fibre length is suitable for mattress and short fibre makes excellent particle board.

CHAPTER 3

METHODOLOGY

3.1 PROJECT METHODOLOGY

Methodology of Samples Preparation to Run Analyses

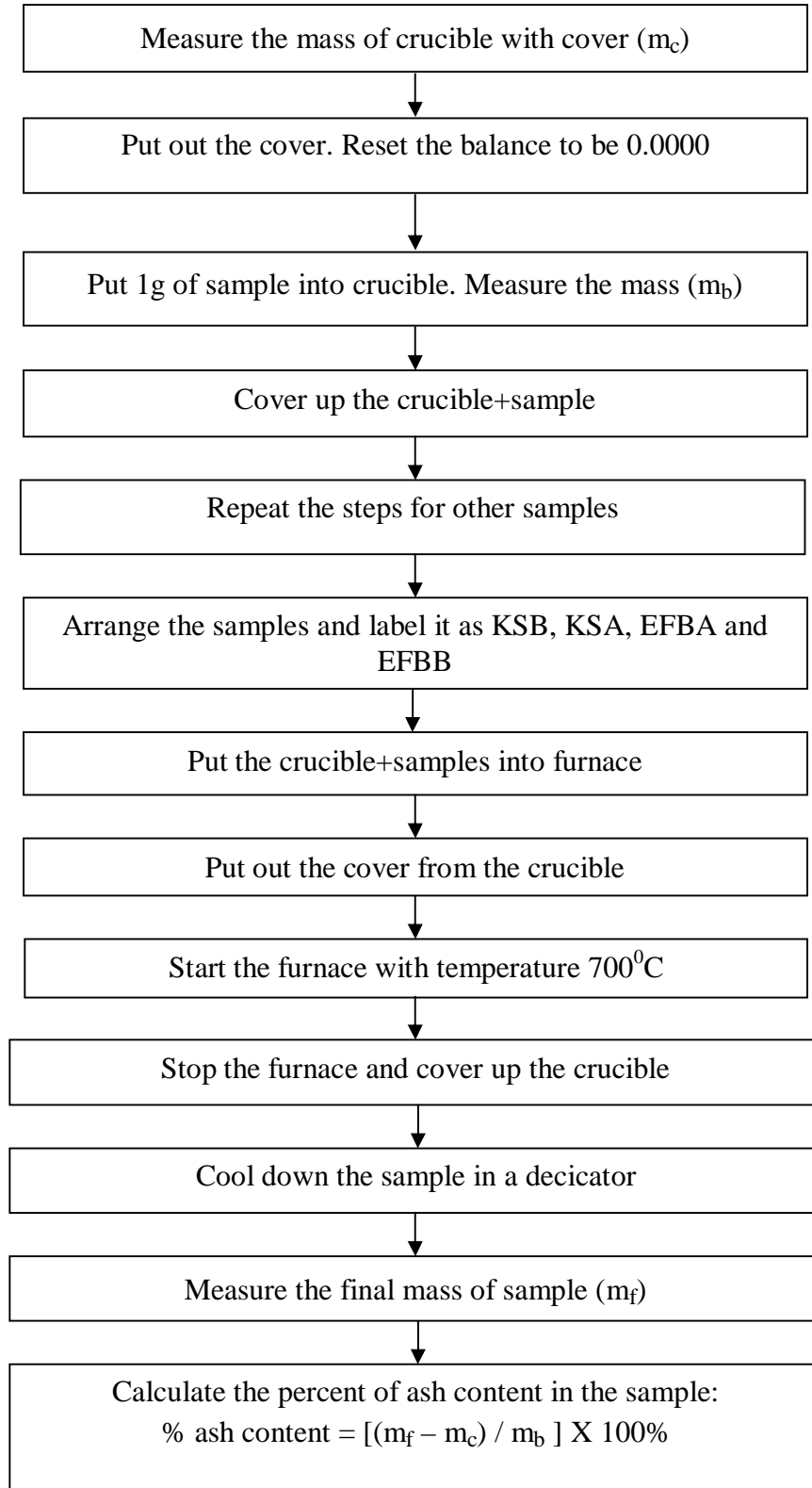


From the chart, there are five analyses must be run:

- Moisture content analysis for non-dried sample
- Moisture content analysis for dried sample

- iii) Ash content analysis
- iv) CHNS Analysis
- v) Calories content analysis

Methodology for Ash Content Analysis



Methodology for Calorie Content Analysis

- 1) Tie thread to the sample holder
- 2) Measure and record the mass of the sample
- 3) Place sample crucible into holder
- 4) Submerge thread into sample
- 5) Close bomb tightly
- 6) Place bomb into calorimeter
- 7) Key in sample weight and thread's calorie value
- 8) Start the equipment



Figure 3.1: Preparation of Samples before Calorie Content Analysis

Methodology for CHN Analysis

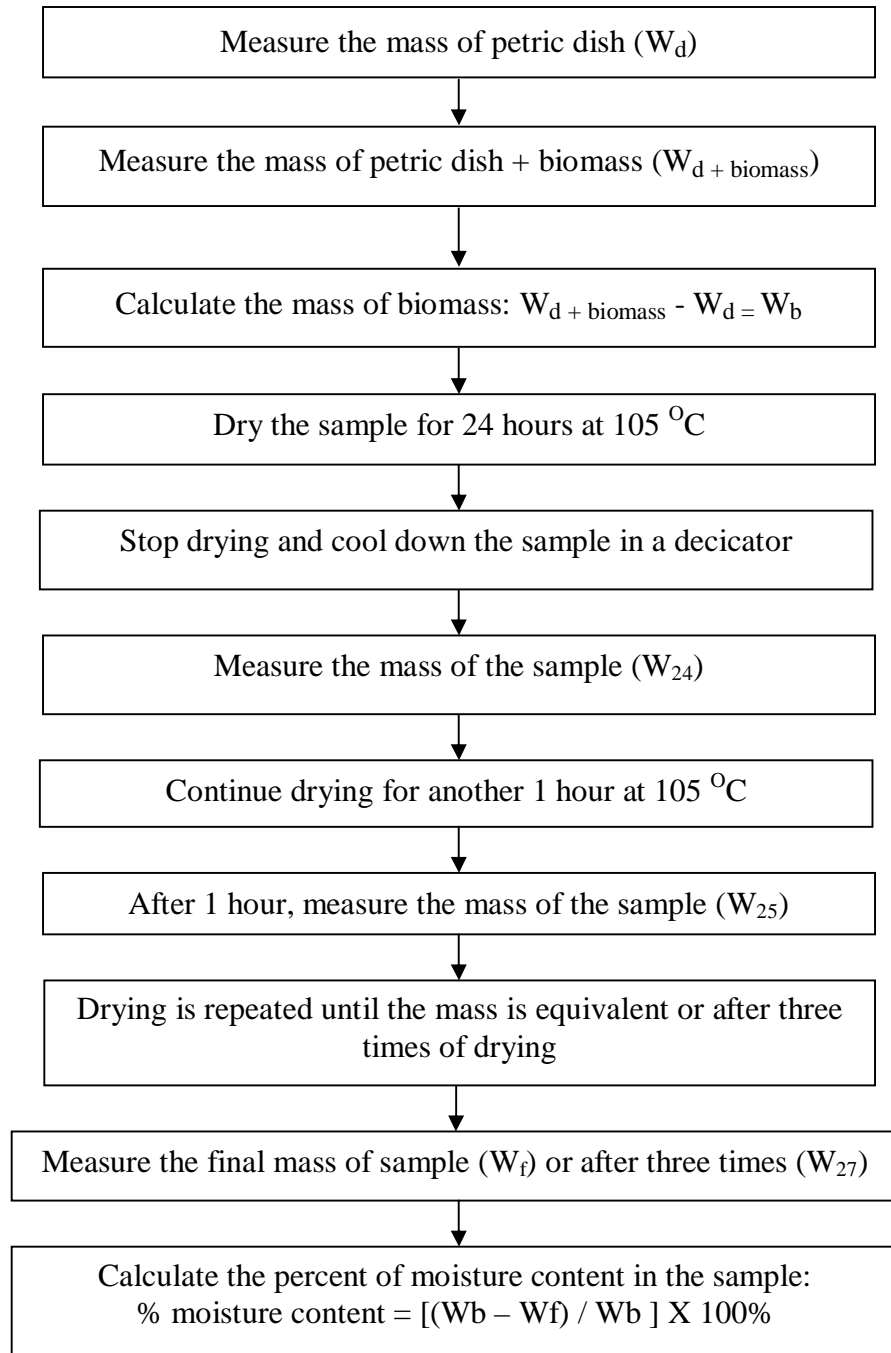
- 1) The pan arrests are raised.
- 2) The sample container is placed on the sample pan
- 3) Place a weight on the reference pan to counter the weight of the sample container. This weight should be approximately equal to the weight of the container.
- 4) The pan arrests are lowered and “AUTOTARE” button is pressed. Wait until the “Int” is complete.
- 5) “Range” button is pressed until “Auto” or the required range appears on the left display.
- 6) The pan arrests are raised and the container is removed from the sample pan. Place the sample in the container.
- 7) The container and sample is placed on the sample pan. The door is closed.

- 8) The pan arrests are lowered. The right display shows the weight of the sample in milligrams (about 2 mg).
- 9) After all mass of samples have been measured, put the samples into calibration. The result of CHN of the samples will appear.



Figure 3.2: Preparation of Samples before CHN Analysis

Methodology for Moisture Content Analysis



3.2 TOOLS REQUIRED

- 3.3.1 CHNS analyser – is a scientific instrument which can determine the elemental composition of a sample. The name derives from the three primary elements measured by the device: carbon (C), hydrogen (H) and nitrogen (N). Sulfur (S) and oxygen (O) can also be measured. The analyzer uses a combustion process to break down substances into simple compounds which are then measured. By separating out inorganic carbon using a solvent, organic carbon in a sample can be measured using this device as well.
- 3.3.2 Bomb calorimeter – A type of constant-volume calorimeter used in measuring the heat of combustion of a particular reaction. Bomb calorimeters have to withstand the large pressure within the calorimeter as the reaction is being measured. Electrical energy is used to ignite the fuel; as the fuel is burning, it will heat up the surrounding air, which expands and escapes through a tube that leads the air out of the calorimeter. When the air is escaping through the copper tube it will also heat up the water outside the tube. The temperature of the water allows for calculating calorie content of the fuel.
- 3.3.3 200 mL beaker – A simple container for stirring, mixing and heating liquids commonly used in many laboratories.
- 3.3.4 Organic mask – A device designed to protect the wearer from inhaling harmful dusts, fumes, vapors, and/or gases. Respirators come in a wide range of types and sizes used by the military, private industry, and the public. Respirators range from cheaper, single-use, disposable masks to reusable models with replaceable cartridges.
- 3.3.5 Petric dish – a shallow glass or plastic cylindrical lidded dish that biologists use to culture cells or small moss plants.
- 3.3.6 100 mL weighing bottle – Glass laboratory equipment used for precise weighing of solids.
- 3.3.7 Organic cartridge – A device to allocate the organic mask safely.

3.3 Gantt Chart Key Milestone

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Figure 3.3: Gantt chart for the Project

CHAPTER 4

RESULTS AND DISCUSSION

4.1 PREPARATION OF THE SAMPLES

Sample	Entire Sample (g)			10 g of Sample (g)			2g of 10g Sample (g)		
	Wb	Wb+s	Ws	Wc	Wc+s	Ws	Wc	Wc+s	Ws
KSB	13.9368	131.2062	117.3234	4.3595	14.3565	10.0	58.7576	60.7753	2.0177
KSA	13.9434	66.7050	52.7616	4.3136	14.3178	10.0	56.9130	58.9430	2.0300
EFBB	13.9095	192.5508	178.6413	4.3365	14.3352	10.0	57.1932	59.1959	2.0027
EFBA	13.9422	68.2495	54.3073	4.3503	14.3552	10.0	47.0309	49.0377	2.0068

Table 4.1: Preparation of the Samples

KSB : Kernel shell before steam explosion

KSA : Kernel shell after steam explosion

EFBB : Empty fruit bunches before steam explosion

EFBA : Empty fruit bunches after steam explosion

Wc : Mass of petric dish

Wb : Mass of beaker

Ws : Mass of sample

4.2 ASH CONTENT ANALYSIS

Sample	Mc	Mc Ave	Mb	Mb Ave	Mf	Mf Ave
A	20.9403	20.9355	1.015	1.0198	20.9968	20.9911
	20.9306		1.0246		20.9854	
B	19.3965	19.4009	1.0115	1.0111	19.4503	19.4508
	19.4053		1.0107		19.4512	
C	20.3049	20.2986	1.0512	1.0618	20.3679	20.3696
	20.2923		1.0724		20.3712	
D	19.1738	19.1743	1.0197	1.0192	19.2129	19.2162
	19.1749		1.0186		19.2195	

Table 4.2: Result of Ash Content Analysis

A = EFB before steam explosion

B = EFB after steam explosion

C = KS before steam explosion

D = KS after steam explosion

Mc = Mass of crucible

Mb = Mass of biomass

Mf = Final mass

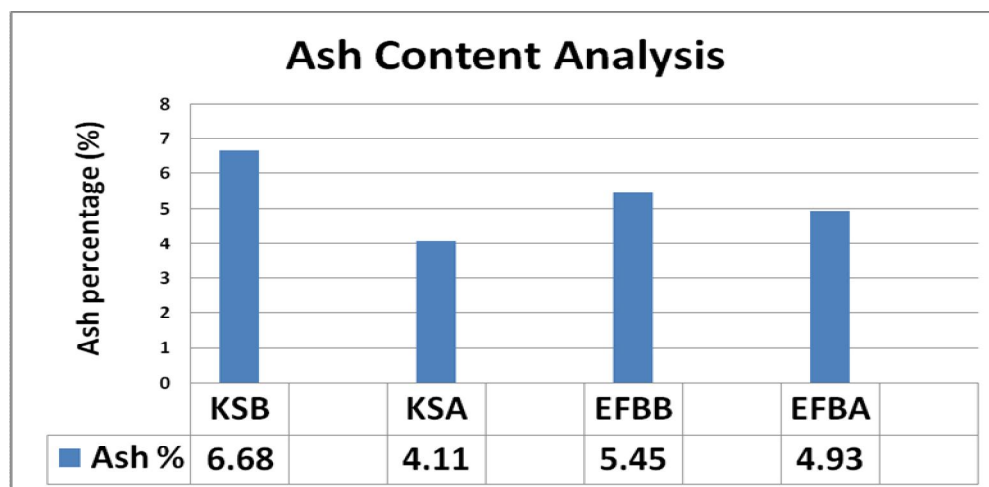


Figure 4.1: Graph of Result of Ash Content Analysis

Percentage of Ash Content in Samples;

$$\text{Ash \%} = (\text{Mf} - \text{Mc}) / \text{Mb} \times 100\%$$

For Sample A;

$$\begin{aligned}\text{Ash \%} &= (20.9911 - 20.9355) / 1.0198 \times 100\% \\ &= 5.4520\%\end{aligned}$$

For Sample B;

$$\begin{aligned}\text{Ash \%} &= (19.4508 - 19.4009) / 1.0111 \times 100\% \\ &= 4.9352\%\end{aligned}$$

For Sample C;

$$\begin{aligned}\text{Ash\%} &= (20.3696 - 20.2986) / 1.0618 \times 100\% \\ &= 6.6868 \%\end{aligned}$$

For Sample D;

$$\begin{aligned}\text{Ash \%} &= (19.2162 - 19.1743) / 1.0192 \times 100\% \\ &= 4.1111 \%\end{aligned}$$

Discussion on Ash Content Analysis

The chemical breakdown of a biomass fuel, by either thermo-chemical or bio-chemical processes, produces a solid residue. When produced by combustion in air, this solid residue is called 'ash' and forms a standard measurement parameter for solid and liquid fuels. The ash content of biomass affects both the handling and processing costs of the overall, biomass energy conversion cost.

During biochemical conversion, the percentage of solid residue will be greater than the ash content formed during combustion of the same material.

For a biochemical conversion process, the solid residue represents the quantity of non-biodegradable carbon present in the biomass. This residue will be greater than the ash content

because it represents the recalcitrant carbon which cannot be degraded further biologically but which could be burnt during thermo-chemical conversion.

Dependent on the magnitude of the ash content, the available energy of the fuel is reduced proportionately. In a thermo-chemical conversion process, the chemical composition of the ash can present significant operational problems. This is especially true for combustion processes, where the ash can react to form a 'slag', a liquid phase formed at elevated temperatures, which can reduce plant throughput and result in increased operating costs.

Slagging and fouling are problems that occur when the ash begins to melt, causing deposits inside the combustion equipment. Ash ideally remains in a powdery form at all times. However, under some conditions, the combustion ash can partially melt, forming deposits on the combustor surfaces (fouling) or hard chunks of material in the base of the combustion chamber (slagging/clinkering). Certain mineral components in biomass fuels, primarily silica, potassium, and chlorine, can cause these problems to occur at lower temperatures than might be expected.

Many studies have observed that the high mineral content in grasses and field crops can contribute to fouling and clinkering—a potentially expensive problem for a combustion system. The timing of harvest can affect this property, with late harvested crops having noticeably lower ash content. Dirt in the fuel also adds to the mineral content and associated clinkering and fouling problems; therefore, fuel should be kept free of soil and other contaminants. Slagging and fouling can be minimized by keeping the combustion temperature low enough to prevent the ash from fusing. Alternately, some biomass combustion equipment uses an opposite approach—it is designed to encourage the formation of clinkers but is able to dispose of the hardened ash in an effective manner.

From data gathered, we can see that the ash content for both kernel shell and empty fruit branches is decreases after steam explosion has been performed. For kernel shell, the ash content decreases from 6.68% to 4.11%. It decreases with 2.57%. Meanwhile for empty fruit branches, the ash content decreases from 5.45% to 4.93. It means that reduces 0.52% of ash content has occurred. This proves that steam explosion is an efficient way to reduce the ash content in biomass.

4.3 CALORIE CONTENT ANALYSIS

Sample	Wc	Wc Ave	Wb	Wb Ave	(Wc X Cv)	(Wc X Cv) Ave	H (J/g)	H Ave (kJ/kg)
KSB	0.2679	0.2647	0.5145	0.5171	5339.247	5274.4745	18555	18.578
	0.2614		0.5197		5209.702		18601	
KSA	0.2551	0.2451	0.5107	0.5112	5084.143	4884.843	19124	19.235
	0.2351		0.5117		4685.543		19346	
EFBB	0.2666	0.2652	0.5087	0.5127	5313.338	5285.436	19251	19.133
	0.2638		0.5167		5257.534		19015	
EFBA	0.2675	0.2664	0.5177	0.5145	5331.275	5308.3375	19231	19.213
	0.2652		0.5113		5285.4		19195	

Table 4.3: Result of Calorie Content Analysis

KSB : Kernel shell before steam explosion

KSA : Kernel shell after steam explosion

EFBB : Empty fruit bunches before steam explosion

EFBA : Empty fruit bunches after steam explosion

Wc : Mass of crucible

Wb : Mass of biomass

Cv : Calory value

H : Energy

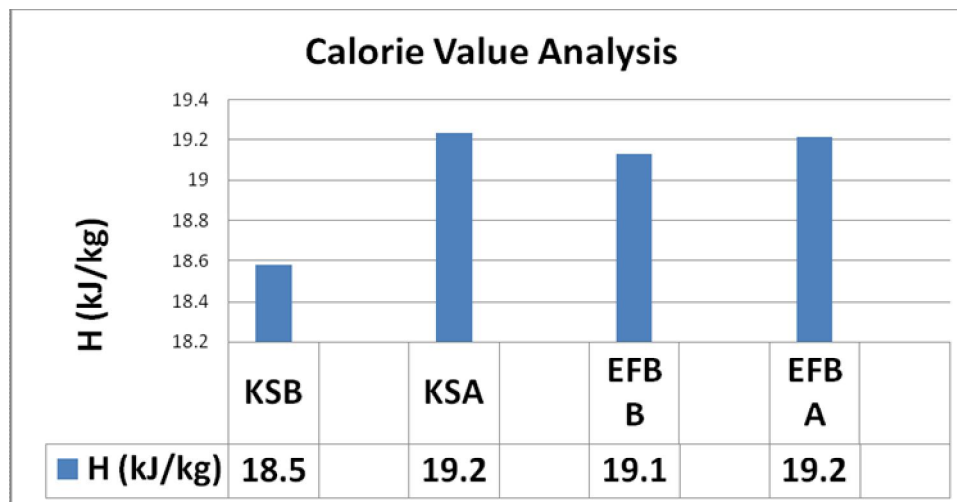


Figure 4.2: Graph of Result of Calorific Value Analysis

Percentage of Differences

Differences of calorific value $= (H_1 - H_0)/H_0 \times 100\%$

For kernel shell;

Increment of calorific value $= (19.2 - 18.5)/18.5 \times 100\%$
 $= 3.8\%$

For empty fruit bunches;

Increment of calorific value $= (19.2 - 19.1)/19.1 \times 100\%$
 $= 0.52\%$

Discussion on Calorie Content Analysis

The calorific value (CV) of a material is an expression of the energy content, or heat value, released when burnt in air. The CV is usually measured in terms of the energy content per unit mass, or volume; hence MJ/kg for solids, MJ/l for liquids, or MJ/Nm³ for gases. The CV of a fuel can be expressed in two forms, the gross CV (GCV), or higher heating value (HHV) and the net CV (NCV), or lower heating value (LHV).

The HHV is the total energy content released when the fuel is burnt in air, including the latent heat contained in the water vapor and therefore represents the maximum amount of energy potentially recoverable from a given biomass source. The actual amount of energy recovered will vary with the conversion technology, as will the form of that energy i.e. combustible gas, oil, steam, etc. In practical terms, the latent heat contained in the water vapor cannot be used effectively and therefore, the LHV is the appropriate value to use for the energy available for subsequent use.

When quoting a CV, the moisture content needs to be stated, as this reduces the available energy from the biomass. It appears normal practice to quote both the CV and crop yield on the basis of dry matter tonnes (dmt), which assumes zero percent moisture content. If any moisture is present, this reduces the CV proportional to the moisture content.

From the result achieved, the calorific value of both kernel shell and empty fruit branches increases after steam explosion has been performed. For kernel shell, the calorific value increases from 18.5kJ/kg to 19.2 kJ/kg; increases 0.7 kJ/kg or 3.8%. Meanwhile for empty fruit branches, the calorific value increases from 19.1kJ/kg to 19.2kJ/kg; increases 0.1kJ/kg or 0.52%. The calorific value for kernel shell is higher than empty fruit branches after steam explosion has been performed.

4.4 CHNS ANALYSIS

Sample	Carbon (%)	Carbon Ave	Hydrogen (%)	Hydrogen Ave	Nitrogen (%)	Nitrogen Ave
KSB	44.5	44.03	5.95	5.635	1.67	1.225
	43.56		5.32		0.78	
KSA	46.07	45.93	5.7	5.745	1.4	1.52
	45.79		5.79		1.64	
EFBB	46.26	46.16	6.31	6.365	1.46	1.595
	46.06		6.42		1.73	
EFBA	45.73	45.9	6.09	6.09	1.53	1.845
	46.07		6.09		2.16	

Table 4.4: Result of CHN Analysis

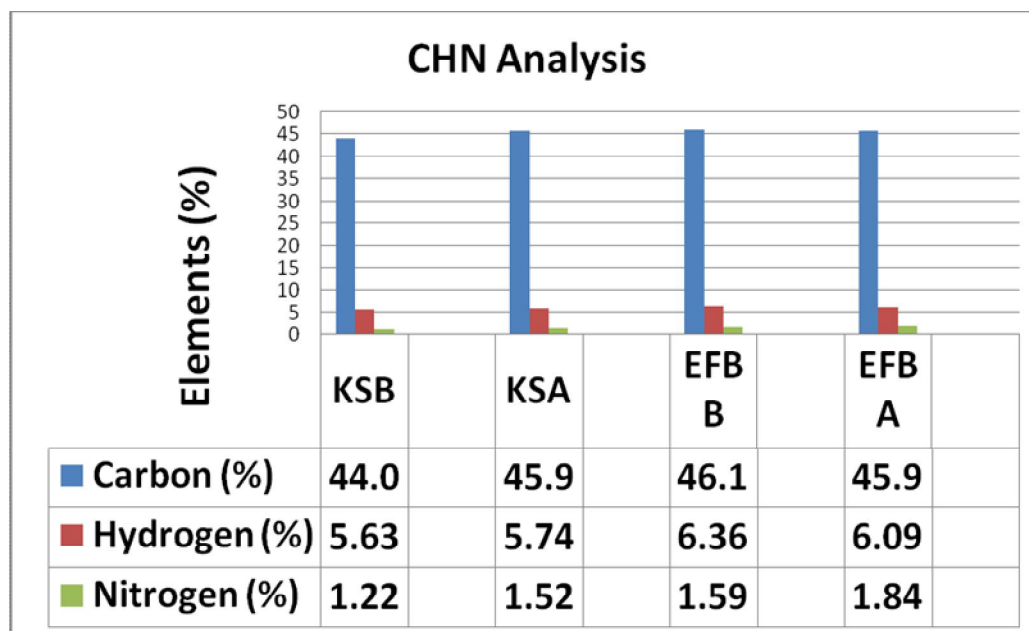


Figure 4.2: Graph of Result of CHN Analysis

Fuel analysis has been developed based on solid fuels, such as coal, which consists of chemical energy stored in two forms, fixed carbon and volatiles:

- The volatiles content, or volatile matter (VM) of a solid fuel, is that portion driven-off as a gas (including moisture) by heating (to 950 °C for 7 min)

- The fixed carbon content (FC), is the mass remaining after the releases of volatiles, excluding the ash and moisture contents.

From results obtained, we can see the carbon value of kernel shell increase from 44.0% to 45.9%. Meanwhile, for empty fruit branches, the carbon percentage decreases from 46.1% to 45.9% after steam explosion performed.

CHN analysis is used to determine the VM and FC contents of the biomass fuel. Fuel analysis based upon the VM content, ash and moisture, with the FC determined by difference, is termed the proximate analysis of a fuel. Elemental analysis of a fuel, presented as C, N, H, O and S together with the ash content, is termed the ultimate analysis of a fuel. The significance of the VM and FC contents is that they provide a measure of the ease with which the biomass can be ignited and subsequently gasified, or oxidized, depending on how the biomass is to be utilized as an energy source. This type of fuel analysis is of value for biological conversion processes only once the fuel is produced, enabling a comparison of different fuels to be undertaken. The significance of the O: C and H: C ratios on the CV of solid fuels can be illustrated using a Van Krevelen diagram. Comparison of bio fuels with fossil fuels, such as coal, shows clearly that the higher proportion of oxygen and hydrogen, compared with carbon, reduces the energy value of a fuel, due to the lower energy contained in carbon–oxygen and carbon–hydrogen bonds, than in carbon–carbon bonds

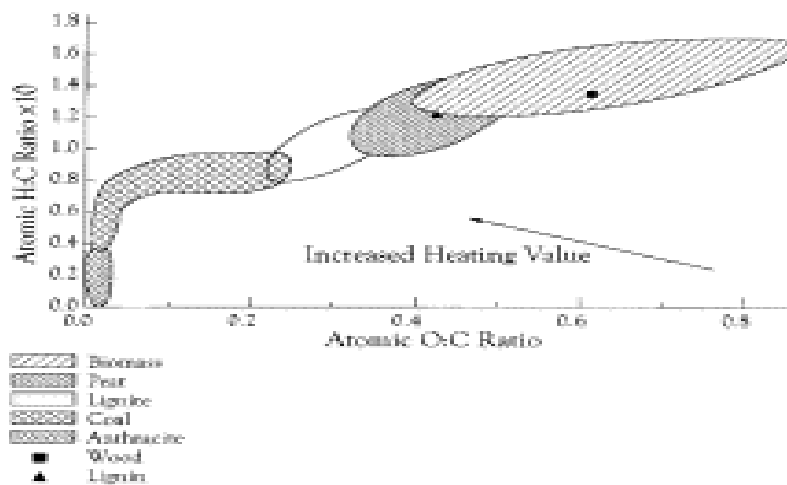


Figure 4.3: Van Krevelen Diagram

4.5 MOISTURE CONTENT ANALYSIS

Non Dried Samples

	After 24h (g)			After 25h (g)			After 26h (g)			After 27h (g)		
	Before	After	ΔT	Before	After	ΔT	Before	After	ΔT	Before	After	ΔT
KSB	60.7753	60.6770	0.0983	60.6770	60.6428	0.0342	60.6428	60.6126	0.0302	60.6126	60.6070	0.0056
KSA	58.9430	58.8891	0.0539	58.8891	58.8860	0.0031	58.8860	58.8791	0.0069	58.8791	58.8743	0.0048
EFBB	59.1959	59.0652	0.1307	59.0652	59.0622	0.0030	59.0622	59.0606	0.0016	59.0606	59.0595	0.0011
EFBA	49.0377	48.9677	0.0700	48.9677	48.9663	0.0014	48.9663	48.9643	0.0020	48.9643	48.9614	0.0029

Table 4.5: Result of Analysis for Non-dried Sample with Crucible

	After 24h (g)			After 25h (g)			After 26h (g)			After 27h (g)		
	Before	After	ΔT	Before	After	ΔT	Before	After	ΔT	Before	After	ΔT
KSB	2.0177	1.9194	0.0983	1.9194	1.8852	0.0342	1.9194	1.8892	0.0302	1.8892	1.8836	0.0056
KSA	2.0300	1.9761	0.0539	1.9761	1.9730	0.0031	1.9761	1.9692	0.0069	1.9692	1.9644	0.0048
EFBB	2.0027	1.8720	0.1307	1.8720	1.8690	0.0030	1.8720	1.8704	0.0016	1.8704	1.8693	0.0011
EFBA	2.0068	1.9368	0.0700	1.9368	1.9354	0.0014	1.9368	1.9348	0.0020	1.9348	1.9319	0.0029

Table 4.6: Result of Analysis for Non-dried Sample without Crucible

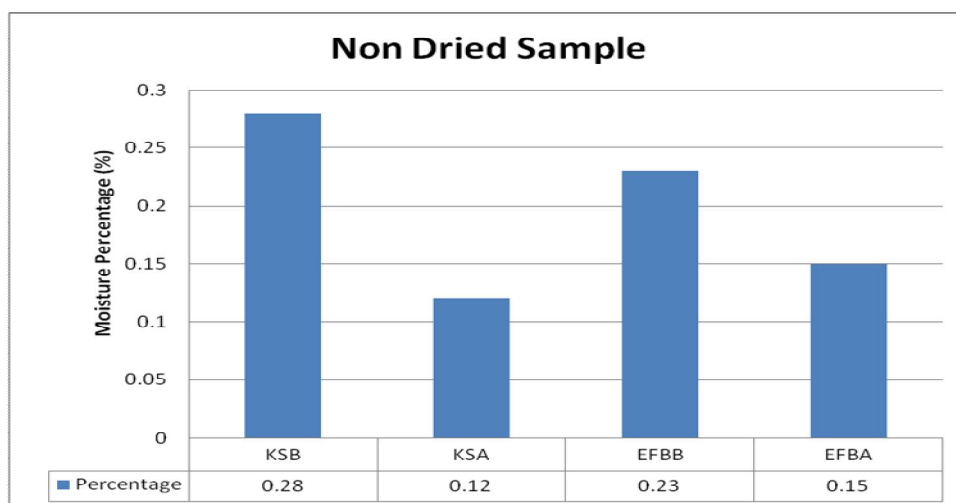


Figure 4.4: Graph of Result of Analysis for Non-dried Sample

Percentage of moisture content in the non-dried samples:

$$\text{Moisture \%} = (M_0 - M_{27})/M_0 \times 100\%$$

$$\begin{aligned} \text{For KSB} &= [(2.0177 - 1.8836)/2.0177] \times 100\% \\ &= 0.28\% \end{aligned}$$

$$\begin{aligned} \text{For KSA} &= [(2.0300 - 1.9644)/2.0300] \times 100\% \\ &= 0.12\% \end{aligned}$$

$$\begin{aligned} \text{For EFBB} &= [(2.0027 - 1.8693)/2.0027] \times 100\% \\ &= 0.23\% \end{aligned}$$

$$\begin{aligned} \text{For EFBA} &= [(2.0068 - 1.9319)/2.0068] \times 100\% \\ &= 0.15\% \end{aligned}$$

Dried Samples

	2g of 10g Sample (g)		
	W _c	W _{c+s}	W _s
KSB	58.7571	60.7576	2.0005
KSA	56.9125	58.9138	2.0013
EFBB	57.1927	59.1931	2.0004
EFBA	47.0296	49.0317	2.0021

Table 4.7: Preparation of Dried Sample

	24h			25h			26h			27h		
	Before	After	ΔT	Before	After	ΔT	Before	After	ΔT	Before	After	ΔT
KSB	60.7576	60.7464	0.0112	60.7464	60.7421	0.0043	60.7421	60.7388	0.0033	60.7388	60.7381	0.0007
KSA	58.9138	58.9104	0.0034	58.9104	58.9074	0.0030	58.9074	58.8915	0.0159	58.8915	58.8912	0.0003
EFBB	59.1931	59.1619	0.0312	59.1619	59.1587	0.0032	59.1587	59.1570	0.0017	59.1570	59.1554	0.0016
EFBA	49.0330	49.0186	0.0144	49.0186	49.0153	0.0033	49.0153	49.0096	0.0057	49.0096	49.0083	0.0013

Table 4.8: Result of Analysis for Dried Sample with crucible

	24h			25h			26h			27h		
	Before	After	ΔT	Before	After	ΔT	Before	After	ΔT	Before	After	ΔT
KSB	2.0005	1.8885	0.0112	1.8885	1.8842	0.0043	1.8842	1.8809	0.0033	1.8809	1.8802	0.0007
KSA	2.0013	1.9979	0.0034	1.9979	1.9949	0.0030	1.9949	1.9790	0.0159	1.9790	1.9787	0.0003
EFBB	2.0004	1.9692	0.0312	1.9692	1.9660	0.0032	1.9660	1.9643	0.0017	1.9643	1.9627	0.0016
EFBA	2.0021	1.9877	0.0144	1.9877	1.9844	0.0033	1.9844	1.9787	0.0057	1.9787	1.9774	0.0013

Table 4.9: Result of Analysis for Dried Sample without crucible

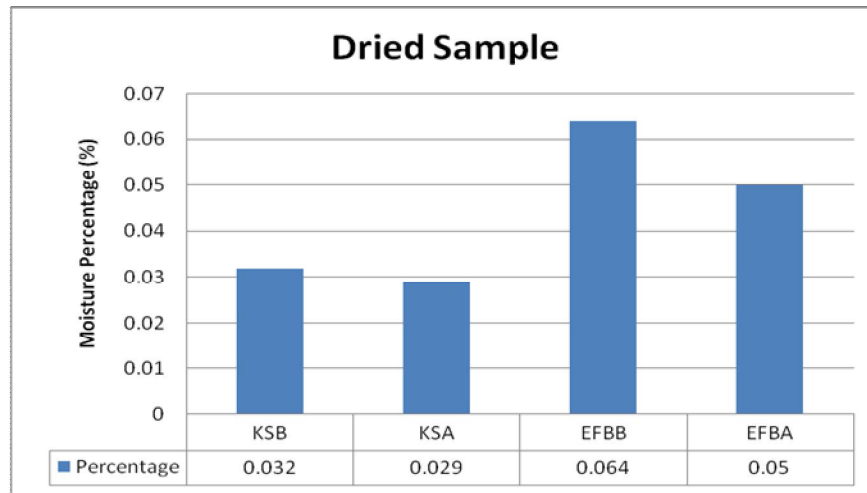


Figure 4.5: Graph of Result of Analysis for Dried Sample

Percentage of moisture content in the sample:

$$\begin{aligned} \text{KSB} &= [(2.0005 - 1.8802)/2.0005] \times 100\% \\ &= 0.032\% \end{aligned}$$

$$\begin{aligned} \text{KSA} &= [(2.0013 - 1.9787)/2.0013] \times 100\% \\ &= 0.038\% \end{aligned}$$

$$\begin{aligned} \text{EFBB} &= [(2.0004 - 1.9627)/2.0004] \times 100\% \\ &= 0.064\% \end{aligned}$$

$$\begin{aligned} \text{EFBA} &= [(2.0021 - 1.9774)/2.0021] \times 100\% \\ &= 0.050\% \end{aligned}$$

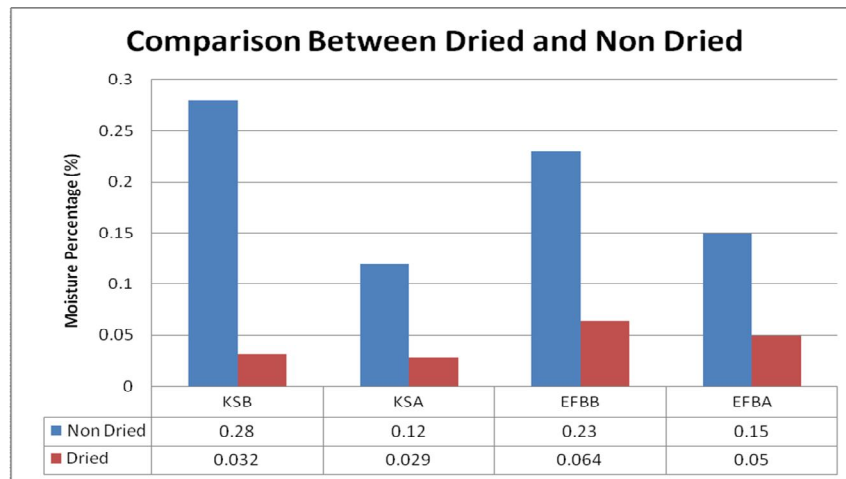


Figure 4.6: Graph of Comparison between Dried and Non Dried Samples

Discussion on Moisture Content Analysis

Two forms of moisture content are of interest in biomass:

- Intrinsic moisture: the moisture content of the material without the influence of weather effects
- Extrinsic moisture: the influence of prevailing weather conditions during harvesting on the overall biomass moisture content.

In practical terms, it is the extrinsic moisture content that is of concern, as the intrinsic moisture content is usually only achieved, or applicable, under laboratory conditions. Also of importance in respect of the prevailing weather conditions at the time of harvesting, is the potential contamination of the harvested biomass by soil and other detritus, which can in turn have a significant deleterious impact on other 'material' properties during subsequent treatment or processing. The parameters of interest that are affected by such contamination are the ash and alkali metal content of the material.

Other factors aside, such as conversion to alcohol or gas/oil, the relationship between biomass moisture content and appropriate bio-conversion technology is essentially straight forward, in that thermal conversion requires low moisture content feedstock (typically <50%), while bio-conversion can utilize high moisture content feedstock. Thermal conversion technologies can also use feedstock with high moisture content but the overall energy balance for the conversion process is adversely impacted.

From the results obtained, we can see that the moisture content of both kernel shell and empty fruit branches decreases after steam explosion has been performed. For non dried kernel shell, the moisture content decreases from 0.28% to 0.12%, decreases about 57%.

$$\begin{aligned}\% \text{ differences} &= (0.28 - 0.12) / 0.28 \times 100\% \\ &= 57\%\end{aligned}$$

For dried kernel shell, the moisture content decreases from 0.032% to 0.029%, decreases about 9.38%.

$$\begin{aligned}\% \text{ differences} &= (0.032 - 0.029) / 0.032 \times 100\% \\ &= 9.38\%\end{aligned}$$

For non dried empty fruit branches, the moisture content decreases from 0.23% to 0.15%, decreases about 34.78%.

$$\begin{aligned}\% \text{ differences} &= (0.23 - 0.15) / 0.23 \times 100\% \\ &= 34.78\%\end{aligned}$$

For dried empty fruit branches, the moisture content decreases from 0.064% to 0.050%, decreases about 21.8%.

$$\begin{aligned}\% \text{ differences} &= (0.064 - 0.050) / 0.064 \times 100\% \\ &= 21.8\%\end{aligned}$$

A low moisture level in the fuel is usually preferable because high-moisture fuels burn less readily and provide less useful heat per unit mass (much of the energy in wet fuel is used to heat and vaporize the water). Extremely dry fuel, however, can cause problems such as dust that fouls equipment or can even be an explosion hazard. The moisture content in a fuel can be calculated by one of two methods: wet basis or dry basis. In the case of wet-basis calculations, the moisture content is equal to the mass of water in the fuel divided by the total mass of the fuel. In the case of dry-basis calculations, the moisture content is equal to the mass of water in the fuel divided by the mass of the dry portion of the fuel. It is important to know which type of calculation is being used, as the two values can be quite different in magnitude. For example, a 50 percent wet-basis moisture level is the same as a 100 percent dry-basis moisture level. The practical maximum moisture level for combusting fuel is about 60 percent (wet basis), although most commercial equipment operates tolerably well with fuels that only have up to about 40 percent moisture. The HHV and LHV of wood fuel are shown in Figure 2 as a function of fuel moisture content.

We can see that after steam explosion, the moisture content of all samples decrease. Besides that, the dried samples have lower percentage of decreases, since the moisture have been eliminated by drying process. These prove that steam explosion is an efficient way to increase the yield of bio oil from biomass.

CONCLUSION

Steam explosion is an effective pretreatment for converting biomass into its major components.

Those analyses are important to examine the effectiveness of steam explosion.

- 1) The moisture content is lower. Then, it decreases the time for drying process for biomass before further process is taken.
- 2) The efficiency can be increases by re-drying the biomass.
- 3) The ash content decreases. It will decrease the unnecessary elements in biomass, then increases the efficiency
- 4) The calorie value is higher. It proves that the energy contained in the biomass is higher
- 5) The carbon value is higher after steam explosion. Carbon is the main element in bio oil (hydrocarbon). Increasing of carbon value means increasing in bio-oil yield.

The key for successful pretreatment determination, efficient bio fuel, and superior biomass quality is fast test determination without lengthy pauses in production processes.

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