OPTIMIZE THE PRODUCTION OF CHARCOAL FROM LOCAL BIO-MATERIAL

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OPTIMIZE THE PRODUCTION OF CHARCOAL FROM LOCAL BIO-MATERIAL

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Thesis submitted in fulfillment of the requirements
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UNIVERSITI MALAYSIA PAHANG
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We certify that the thesis entitled "Optimize The production of Charcoal from Local Bio-Material" is written by Umi Najwa Maulad Mohd Noor. We have examined the final copy of this thesis and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Chemical Engineering. We herewith recommend that it be accepted in fulfillment of the requirements for the degree of Bachelor of Chemical Engineering.

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ABSTRACT

Charcoal is the dark grey residue produced by slow pyrolysis consists of carbon and ash. It is usually used for art, medicine, filter and fuel. The charcoal can be produced from any agricultural waste like wood, coconut shells and others. Coconut charcoal, however, is widely used for the high quality activated carbon. This research aims to optimize the production of charcoal by carbonization process. The objectives of this research are to find the optimum condition in producing the coconut based charcoal and to analyze the weight loss and the functional group of the charcoal. The production of charcoal was carried out at different carbonization temperature and different time range. The product was analyzed using FTIR. The results shown that the weight of the product decreased with increase in time and temperature. It was found that the optimum condition for producing charcoal is 450^{o}C and 10 min. It was also found that the functional groups appeared are alkanes, alkenes and alkynes based on FTIR analysis.

ABSTRAK

Arang adalah bahan baki kelabu gelap yang dihasilkan oleh pirolisis perlahan yang terdiri daripada karbon dan abu. Ia biasanya digunakan untuk alatan seni, perubatan, penapisan dan bahan api. Arang boleh dihasilkan daripada bahan buangan pertanian seperti kayu, tempurung kelapa dan lain-lain. Arang kelapa, bagaimanapun, digunakan secara meluas untuk menghasilkan karbon aktif yang berkualiti tinggi. Kajian ini bertujuan untuk mengoptimumkan penghasilan arang berdasarkan proses karbonisasi. Objektif kajian ini adalah untuk mencari keadaan optimum dalam menghasilkan arang berasaskan kelapa dan menganalisis kehilangan berat serta kumpulan berfungsi arang. Penghasilan arang ini dijalankan pada suhu karbonisasi dan jarak masa yang berbeza. Produk yang terhasil dianalisis menggunakan FTIR. Hasil kajian menunjukkan bahawa berat produk menurun dengan peningkatan dalam masa dan suhu. Ia didapati bahawa keadaan optimum untuk menghasilkan arang ialah pada suhu $450^{o}C$ dan 10 minit. Kumpulan berfungsi yang wujud adalah alkana, alkena dan alkina berdasarkan analisis daripada FTIR.

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LIST OF ABBREVIATIONS

^{o}C - degree Celsius
-
% - Percentage
g - gram
cm^{-1} - Wavenumber
mm - millimetre
cm - centimeter
min - minute
I - iodine
Br - bromine
Cl - chlorine
H - hydrogen
F - fluorine
EFB - Empty fruit bunch
PAC - powder activated carbon
GAC - granular activated carbon
ZDDP - zinc dialkyl dithiophosphate
IR - Infrared
SEM - scanning electron microscope
FTIR - Fourier Transform Infrared Spectrometer
TPD - temperature programmed desorption
XPS - X-ray photoelectron spectroscopy
NMR - nuclear magnetic resonance

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF RESEARCH

Charcoal is the dark grey residue consisting of carbon and any remaining ash obtained by removing water and other volatile constituents from animal and vegetation substances. Charcoal can be produced from any agricultural waste and was encourage the use of biomass resources that has no other value (unsuitable for animal or human consumption or composting) such as wood, sawdust, bagasse (dried sugar cane), corn cobs, palm fronds and coconut shells [Manpreet Singh et. al., 2010]. It is usually produced by slow pyrolysis by heating of wood or other substances in the absence of oxygen. Some of the widely used raw materials are bagasse, sawdust, coconut husk, coconut shell and oil palm shell [Neil Noble, 2002]. Charcoal has been used since earliest times for a range of purposes including art, medicine, filter and fuel. Charcoal also has been an important domestic product for many years. Its greatest use is for home and outdoor recreational cooking. Besides, it is also used in the manufacture of carbon disulfide, carbon tetrachloride, sodium cyanide and other industrial chemicals. Other than that, charcoal also can be converted to activated carbons and other industrial uses [Arlie W. Toole et. al., 1961].

The charcoal can be classified into three common types such as briquette, lump and extruded based on its size and shape, its process and each type has its specific application. The choices of raw materials to produce the charcoal are depending on their price and stability of supply and potential extent of activation.

Coconut shells are the abundant waste-product from the coconut oil and desiccated coconut industry and in most tropical countries after taking its water for drinking and fiber for fatty oil. It is said that charcoal manufactures from coconut shell and converted into activated carbon is considered superior to those obtained from other sources. It is because of small macropores structure which renders it more effective for the adsorption of gas and vapor and for the removal of color, oxidants, impurities and odor of compounds. It has been the most popular feed stock for the activated carbon production.

In this study, the optimal condition in producing the charcoal is determine through experiment using any kind of local bio-material products. The variables include the temperature and holding time. The analysis for the charcoal is using Fourier Transform Infrared Spectrometer (FTIR) which is to know the functional groups appeared in the samples.

1.2 PROBLEM STATEMENT

The optimal operating condition in producing charcoal is not well known in production processes. According to the paper written by Gratuito et al., 2008, basically, the production of the product is only for the requirement of the users not for the manufacturers' side like the cost of process utilities. So, this research is to study about the optimum operating condition of the production of the charcoal. Besides, as said in paper written by Tan et al., 2008, about 151,000ha of land in Malaysia was being used for coconut plantation in 2001. In 2009, the production of coconuts in Malaysia is about 555,120 tonnes per year. So, the wastes from this plantation are too much. This study is also necessary to overcome the waste problems.

1.3 OBJECTIVE

The objectives of this study are:

i) To find the optimum condition in producing the charcoal by considering the temperature and time.

ii) To analyze the weight loss of the charcoal and also the functional groups appeared.

1.4 RESEARCH SCOPE

In general, the scopes of this research are as following:

i) The preparation of the charcoal using local bio-material such as coconut shell by experimental process.
ii) The variables for this experiment are holding time and temperature.
iii) The method used to produce the charcoal is using carbonization process.
iv) The optimal condition in producing charcoal and the comparison of the functional groups appeared for each samples.

1.5 RATIONAL AND SIGNIFICANCE

Charcoal has many usages by itself but when it is being activate and become activated carbon, it has lots more usage. Activated carbon is one of the important adsorbent in many applications. This research is necessary for the charcoal and activated carbon’s industry because knowing the optimum operating conditions of the production gives lots of advantages such as reducing the utilities cost and time of production but increasing in the properties of the production of the charcoal. Besides, the production of the waste from bio-material such as coconut shell, coconut husk, palm oil sludge and empty fruit bunch (EFB) also being one of the problems in this country. So, this study also will be one of the ways to manage the waste from being abundant and to convert them to become useful.

CHAPTER 2

LITERATURE REVIEW

2.1 CHARCOAL

Charcoal is an impure carbon as it contains ash. It is obtained by heating wood until its complete pyrolysis (carbonization) occurs, leaving only carbon and inorganic ash. In many parts of the world, charcoal is still produced semi-industrially, by burning a pile of wood that has been mostly covered with mud or bricks. The limited supply of oxygen prevents the charcoal from burning. A more modern alternative is to heat the wood in an airtight metal vessel, which is much less polluting and allows the volatile products to be condensed.

Pyrolysis is a thermochemical decomposition of organic material at elevated temperature without the participation of oxygen. It involves the simultaneous change of chemical composition and physical phase and is irreversible. It is a special case of thermolysis and is the most commonly used for organic materials. In general, pyrolysis of organic substances produces gas and liquid products and leaves a solid residue richer in carbon content, char. Extreme pyrolysis, which leaves mostly carbon as the residue is called carbonization. The process is used heavily in the chemical industry to produce charcoal, activated carbon, methanol, and other chemicals. It also used to convert waste into safely disposable substances. Besides, it can be called in various names such as dry distillation, destructive distillation or cracking. Pyrolysis is different from other high-temperature processes like combustion and hydrolysis because it does not involve reactions with oxygen, water or any other reagents.

Charcoal produced under well-controlled carbonization conditions may be hard and brittle, or comparatively soft and crumbly, when rubbed and handled. In weight, it may be rather heavy to quite light. This physical property is related to the weight of the dry wood of the various species, which in a given volume may be heavy (sugar maple, beech, oaks and longleaf pine; average specific gravity of 0.63), medium (elm, alder, ash, soft maple and jack pine; average specific gravity of 0.48) and light (cottonwood and most softwoods; average specific gravity of 0.39). Well-prepared charcoal weighs about one-third as much as wood and is reduces to roughly one-half of the volume of wood. The apparent specific gravity of charcoal ranges from about 0.2 to 0.5, depending on the specific gravity of wood from which it was made.

Charcoal has been used since the earliest times for a range of purposes including art and medicine, but by far its most important use has been a metallurgical fuel. Charcoal is the traditional fuel of a blacksmith’s forge and other applications where an intense heat is wanted. It was also used historically as a source of carbon black by grinding it up. In this form, charcoal was important to early chemist and was a constituent of formulas for mixtures such as gunpowder. Due to its high surface area, charcoal can be used as a filter, as a catalyst or as an absorbent.

2.1.1 Characteristic Of Charcoal

There are some characteristic of the charcoal that can be analyze such as moisture content, volatile matter, fixed carbon content and ash content.

Charcoal fresh from an opened kiln contains very little moisture, usually less than 1 %. Absorption of moisture from the humidity of the air itself is rapid and there is, with time, a gain of moisture which even without any rain wetting can bring the moisture content to about 5-10 %, even in well-burned charcoal. When the charcoal is not properly burned or where pyroligneous acids and soluble tars have been washed back onto the charcoal by rain, as can happen in pit and mound burning, the hygroscopitity of the charcoal is increased and the natural or equilibrium moisture content of the charcoal can rise to 15 % or even more. Moisture is an adulterant which lowers the calorific or heating value of the charcoal, where charcoal is sold by weight, keeping the moisture content high by wetting with water is often practiced by dishonest dealers. The volume and appearance of charcoal is hardly changed by addition of water. For this reason bulk buyers of charcoal prefer to buy either by gross volume, e.g. in cubic meters, or to buy by weight and determine by laboratory test the moisture content and adjust the price to compensate. In small markets sale is often by the piece. It is virtually impossible to prevent some accidental rain wetting of charcoal during transport to the market but good practice is to store charcoal under cover even if it has been bought on a volume basis, since the water it contains must be evaporated on burning and represents a direct loss of heating power. This occurs because the evaporated water passes off into the flue and is rarely condensed to give up the heat it contains on the object being heated in the stove. Quality specifications for charcoal usually limit the moisture content to around 5-15 % of the gross weight of the charcoal. Moisture content is determined by oven drying a weighted sample of the charcoal. It is expressed as a percentage of the initial wet weight. There is evidence that charcoal with high moisture content (10 % or more) tends to shatter and produce fines when heated in the blast furnace, making it undesirable in the production of pig iron.

The volatile matter other than water in charcoal comprises all those liquid and tarry residues not fully driven-off in the process of carbonization. When the carbonization temperature is low and time in the retort is short, then the volatile matter content increases. These effects are reflected in the yield of charcoal produced from a given weight of wood. At low temperatures (300 ^{o}C) a charcoal yield of nearly 50 % is possible. At carbonization temperatures of 500-600 ^{o}C volatiles are lower and retort yields of 30 % are typical. At very high temperatures (around 1,000 ^{o}C) the volatile content is almost zero and yields fall to near 25 %. As stated earlier, charcoal can reabsorb tars and pyroligneous acids from rain wash in pit burning and similar processes. Thus the charcoal might be well burned but have high volatile matter content due to this factor. The volatile matter in charcoal can vary from a high of 40 % or more down to 5 % or less. It is measured by heating away from air, a weighed sample of dry charcoal at 900 °C to constant weight. The weight loss is the volatile matter. Volatile matter is usually specified free of the moisture content. High volatile charcoal is easy to ignite but may burn with a smoky flame. Low volatile charcoal is difficult to light and burns very cleanly. A good commercial charcoal can have a net volatile matter content -

(moisture free) of about 30 %. High volatile matter charcoal is less friable than ordinary hard burned low volatile charcoal and so produces fewer fines during transport and handling. It is also more hygroscopic and thus has higher natural moisture content.

The fixed carbon content of charcoal ranges from a low of about 50 % to a high of around 95 %. Thus charcoal consists mainly of carbon. The carbon content is usually estimated as a "difference", that is to say, all the other constituents are deducted from 100 as percentages and the remainder is assumed to be the per cent of "pure" or "fixed" carbon. The fixed carbon content is the most important constituent in metallurgy since it is the fixed carbon which is responsible for reducing the iron oxides of the iron ore to produce metal. But the industrial user must strike a balance between the friable nature of high fixed carbon charcoal and the greater strength of charcoal with a lower fixed carbon and higher volatile matter content to obtain optimum blast furnace operation.

Ash is determined by heating a weighed sample to red heat with access of air to burn away all combustible matter. This residue is the ash. It is mineral matter, such as clay, silica and calcium and magnesium oxides, etc., both present in the original wood and picked up as contamination from the earth during processing. The ash content of charcoal varies from about 0.5 % to more than 5 % depending on the species of wood, the amount of bark included with the wood in the kiln and the amount of earth and sand contamination. Good quality lump charcoal typically has an ash content of about 3 %. Fine charcoal may have very high ash content but if material less than 4 mm is screened out the plus 4 mm residue may have an ash content of about 5-10 %.

2.1.2 Activated Carbon

The word activated in the name due to its high degree of micro porosity which is 1 gram of activated carbon has a surface area in excess of 500 m^2 which is about one tenth the size of an American football field. Activated carbon has been used since the early part of the 20th century for water and wastewater treatment [Kalderis et al., 2008], water purification, volatile organic chemicals and pesticide residual removal. It is also called activated charcoal or activated coal which is a form of carbon that has been processed to make it extremely porous and thus to have a very large surface area for adsorption or chemical reactions. It removes pollutants by capturing chemical compounds on the porous surfaces. A carbon with large holes would be best at picking up heavy organic chemicals, while smaller pores would catch the lighter pollutants [Engber, 2005]. Carbon has a natural affinity for organic pollutants like benzene through adsorption which bind to its surface. If the carbon is "activate", at higher temperature, it will form pores that increase its surface area. The shape of the activated carbon looks like beehive which absorbs the pollutant fast. This activated carbon is increasingly used as an economic and stable mass separation agent for the removal of surfactants to raise the final product quality in many industrial processes. Besides, it also plays an important role in many areas of modern science and technology such as purification of liquids and gases, separation of mixtures and catalysis [Kang et al., 2006].

The activated carbons are high porosity, high surface area materials, manufactures by carbonization and activation of carbonaceous materials. It can be design for adsorption of specific adsorbate using appropriate precursor and by optimizing the activation process conditions [Srinivasakannan and Zailani, 2004]. Though relatively expensive, activated carbon has been widely used for the removal of impurities in food products and its production has been significantly increased ever since it has been used in the production of municipal tap water [Kim, 2010].

Activated carbon presents a group of well-established, universal and versatile adsorbents. The characteristic in choosing the types include pore structure, particle size, and total surface area and void space between particles [Steve and Erika, 1998]. The activated carbons are complex products which are difficult to classify on the basis of their behavior, surface characteristics and preparation methods. Mostly, it has been classified based on the physical characteristics such as powder activated carbon (PAC), granular activated carbon (GAC), impregnated carbon, and others. The GAC version is mostly used in water treatment which can adsorb soluble substances such as adsorption of organic, non-polar substances (mineral oil, BTEX, Poly aromatic hydrocarbons (PACs) and (Chloride) Phenol), adsorption of halogenated substances (I, Br, Cl, H and F), odor, taste, yeasts, various fermentation products and non-polar substances.

Figure 2.1: Activated Carbon

Under scanning electron microscope (SEM), the high surface area structures of activated carbon are revealed. These micro pores provide superb conditions for adsorption to occur since adsorbing material can interact with many surfaces simultaneously. Physically, activated carbon binds materials by van der Waals force or London dispersion force but it does not bind well to certain chemicals including alcohols, glycols, strong acids and bases, metals and most inorganics.

There are several properties of activated carbon that usually be analyzed:

a) ***Iodine number***

Iodine number is the most fundamental parameter used to characterize activated carbon performance. It is a measure of activity level which is the higher number indicates higher degree of activation, often reported in mg/g in range of 500-1200 mg/g. it is a measure of the micro pore content of the activated carbon by adsorption of iodine from solution. It is equivalent to surface area of carbon between 900 m^2/g and 1100 m^2/g which is the standard measure for liquid phase applications.

Basically, iodine number is a measure of the iodine adsorbed in the pores. In water treatment carbons have iodine number ranging from 600 to 1100. Naturally, this parameter is used to determine the degree of exhaustion of a carbon in use. However, this practice should be viewed with caution as chemical interaction with the adsorbate may affect the iodine uptake giving false results. It is recommended if it has been shown to be free of chemical interactions with adsorbates and if an experimental correlation between iodine number and the degree of exhaustion has been determined for the particular application.

b) ***Molasses***

Molasses number is a measure of the mesopore content of the activated carbon by adsorption of molasses from solution. A high molasses number indicates a high adsorption of big molecules in range of 95-600. It is also a measure of the degree of decolorization of a standard molasses solution that has been diluted and standardized against standardized activated carbon. Due to the size of color bodies, the molasses number represents the potential pore volume available for larger adsorbing species. As all of the pore volume may not be available for adsorption in a particular wastewater application, and some of the adsorbate may enter smaller pores, it is not a good measure of the worth of a particular activated carbon for a specific application. Frequently, this parameter is useful in evaluating a series of active carbons for their rates of adsorption.

c) ***Methylene blue (MB)***

Some carbons have a mesopore structure which adsorbs medium size molecules such as the dye methylene blue. The adsorption is reported in g/100g which is in range of 11-28g/100g.

d) ***Hardness***

It is a measure of the activated carbon’s resistance to attrition. It is important indicator of activated carbon to maintain its physical integrity and withstand frictional forces imposed by backwashing, etc. there are large differences in the hardness of activated carbons, depending on the raw material and activity level.

e) ***Ash content***

It reduces the overall activity of activated carbon and efficiency of reactivation. The metal oxides (Fe_2O_3) can leach out of activated carbon resulting in discoloration. Acid/water soluble ash content is more significant than total ash content. Soluble ash content can be very important for aquarists as ferric oxide can promote algal growths. A carbon with low soluble ash content should be used for marine, freshwater fish and reef tanks to avoid heavy metal poisoning and excess plant/algal growth.

f) ***Particle size distribution***

The finer the particles size of an activated carbon, the better the access to the surface area and the faster the rate of adsorption kinetics. In vapor phase systems this needs to be considered against pressure drop which will affect energy cost. Careful consideration of particle size distribution can provide significant operating benefits.

2.2 MAJOR PROCESSES

The carbonization process is the major process in producing the charcoal. It is includes drying and heating to separate by-products, including tars and other hydrocarbons from raw materials, as well as to drive off any gases generated. The process completed by heating the material over 400 ^{o}C in an oxygen-free atmosphere that cannot support combustion. The carbonization step is also a process where the carbon material is pyrolyzed at temperature in range of 600-900 ^{o}C under inert atmosphere.

According to Neil Noble, 2002, the process is divided into four stages which are combustion, dehydration, exothermic reaction and cooling. The oxygen is supply in combustion process and the temperature rises from ambient to over 500 ^{o}C. When the fire is established, the oxygen supply is reduced after the firing point is closed and temperature drops to about 120 ^{o}C. Free water is driven out at a reduced temperature of about 100 ^{o}C and the kiln gives out thick, white and moist steam. When the wood has dried, temperature rise to about 280 ^{o}C and the wood begin to break down into charcoal, water vapor and other chemicals. The smoke at this stage is yellow, hot and oily and the temperature is maintained by controlling the air flow through holes and vents to help burn more wood. After the carbonization is complete, the kiln cools to below 100 ^{o}C and charcoal can be removes for further cooling. It is also said that the process of carbonization is greatly dependent on the carbonization temperature, the moisture content of the wood (the drier the better), the skill of the producer and the condition of the wood (lignin content).

2.2.1 Raw Material

There are lots of raw materials that can be used to produce charcoal and the most research interest is in agricultural by-products such as rubber seed coat, pecan shell, corncob, bamboo and oil palm fiber [Tan et al., 2008]. The selection of the raw material is depends on the design specifications since different raw material will produce the different properties of charcoal. The annual global production of 800 million tonnes of sugarcane results in 240 million tonnes of bagasse while the estimates annual world rice production is about 571 million tonnes resulting in approximately 140 million tonnes of rice husk available annually for utilization [Kalderis et al., 2008].

In most literature, it said that, in the recent years, the interest in the production of charcoal from agricultural by-products and residual wastes such as coconut shells are increasing because of their availability to be acquired. The coconut shells are the waste product of most of the tropical countries and the production from this material is more financially viable [Gratuito et al., 2008]. In 2009, it is reported that the coconut palms are grown in more than 80 countries of the world with total production of 61 million tonnes per year. For example, a number of chemical and physical processes such as flocculation, chemical coagulation, precipitation, ozonation and adsorption have been widely used to treat dye bearing wastewaters. However, the adsorption onto activated carbon (from charcoal) has been found to be superior compared to other techniques for wastewater treatment in terms of its capability for efficiently adsorbing a broad range of adsorbates and its simplicity of design. The commercially activated carbon is still considered expensive due to the used of non-renewable and relatively expensive starting material such as coal. Therefore, this has prompted a growing research interest in the production of activated carbons from renewable and cheaper precursors which is from industrial and agricultural by-products.

Figure 2.2: Raw Coconut Shells

Coconut shells are the abundant waste-product from the coconut oil and desiccated coconut industry and in most tropical countries after taking its water for drinking and fiber for fatty oil. According to Gratuito et al., 2008, the production of activated carbon from these material more financially viable since using grain or coal as raw materials, required extra amount of money for procurement. Coconut shell activated carbons have more advantages over other carbons materials besides of being a form of carbon that can absorb many gases, vapors and solid. It is because of its high density, high purity, virtually dust-free nature, harder and more resistant to attrition. It has been the most popular feed stock for the activated carbon. Activated carbon made of coconut shells has generally been proven to have superior adsorptive capability in liquid and gaseous phase application due to its properties such as high micro porosity, hardness, and high density, low ash content, more resistant to attrition and longer service life.

According to the most reliable names of international activated carbons supplier, Effigen Sdn. Bhd., based on their procedure, an average of 3.3 tons raw material is used to produce 1 ton of charcoal and 3 tons of charcoal will produce about 1 ton of activated carbon. Coconut shell is the only raw material used to produce activated carbon from this company.

2.2.2 Equipment for Making Charcoal

Charcoal has been made ever since the first metallurgic processes were discovered and provided the heat needed for working and smelting Bronze, Copper, Iron, Silver and to manufacture of glass. It was produced in the woods on leveled ground the charcoal clamps being protected from the wind in the woods. A charcoal stack was built around a chimney and covered with straw or bracken covered with earth and then lit at the top of the stack, allowed to burn and controlled by covering air holes with earth. The process took days and had to be watched day and night. When the carbonization was complete, the charcoal was quenched with steam (Arlie W. Toole et. al., 1961). Then, the methods of charcoal burning improved. It is using large metal retort (refer Figure A in appendix), a greater quantity of charcoal could be produced.

Kilns are one of the traditional charcoal productions which acquired skill. The most critical factor in the efficient conversion of wood to charcoal is the careful operation of the kiln. Wood must be dried and carefully stacked to allow an even flow of air through the kiln and sufficient time for reactions to take place. If kilns not operated correctly, yields can be half the optimum level. There are four types of kilns which are traditional kilns, brick and concrete kilns, portable steel kilns and mini-charcoal kilns (Neil Noble, 2002). Refer to Figure B to Figure E in appendix.

2.2.3 Parameters

There are about two variables in production of charcoal which are holding time and carbonization temperature.

a) Time

The duration of the carbonization has a significant effect on the development of the carbon’s porous networks. The time should be enough to eliminate all the moisture and most of the volatile components in the precursor to cause pores to develop. Longer durations cause enlargement of pores at the expense of the surface area and also the control of the carbonization time is of economic interest since shorter times are generally desired as it equates to reduction in the energy consumption [Gratuito et al., 2008].

b) Carbonization Temperature

The application of heat to an impregnation material further accelerates the thermal degradation and the volatilization process which leads to development of pores, increase of surface area and the subsequent mass loss. The selection of the carbonization temperature is based on several factors which include the type of raw materials. For the different biomass precursors, it in range of 400 to 800 ^{o}C [Diao et al., 2002] while for coal-based materials can go as high as 900 ^{o}C [Karacan et al., 2007]. The optimum carbonization temperature for higher surface area was found to be 500 ^{o}C for rubber wood sawdust [Srinivasakannan and Zailani, 2004]. Temperature lower than 500 ^{o}C for grain sorghums produces micro porous carbons but with small surface areas while temperature higher than 600 ^{o}C yielded mesoporous carbons with high surface areas [Diao et al., 2002].

2.3 TYPES OF CHARCOAL

Charcoal is used as a type of fuel, most commonly to fuel grills for cooking. There are several different types of charcoal can choose from, with the most common types being briquette, lump, and extruded.

Among the briquette variety, there are several different types of charcoal. Generally, the briquette is made from a combination of charcoal, mineral carbon, brown coal, borax, sodium nitrate, sawdust, limestone, and starch. Each of these ingredients has its own special properties to contribute to the charcoal briquette. The charcoal, along with the mineral carbon and the brown coal, serves as a heat source. The borax is a press release agent, while the starch is a binder. The sodium nitrate and the sawdust both assist with ignition and the starch is a binder. Other different types of charcoal briquettes may be marketed as “natural.” In this case, they may only contain charcoal and starch. Still other different types of charcoal briquettes contain additional ingredients, such as lighter fluid or paraffin, in order to make them easier to light. The addition of these ingredients does not create a health hazard in these different types of charcoal, because the fuel is burned off before it can contaminate the food.

Figure 2.3: Briquette charcoal

Lump charcoal is one of the other different types of charcoal. This charcoal is created solely from hardwood and, as a result, burns hotter than other types. Since lump charcoal burns at such a high temperature, it creates less ash than briquette charcoal.

Figure 2.4: Lump charcoal

Extruded charcoal is created through a process called extrusion, which is a highly pressurized process that pushes materials through a preset mold. The heat and pressure of the extruding process hold the charcoal together. In this case, the material is either carbonized wood or raw ground wood. Through the extrusion process, these different types of charcoal are made into log shapes.

Figure 2.5: Extruded charcoal

The characteristics of the charcoal products (briquette, lump and extruded forms) vary widely from product to product. There are also other different types of charcoal that contain ingredients meant to help add flavor to the food, such as mesquite. These ingredients are part of the charcoal and, therefore, do not burn off like the lighter fluid. The smoke that results from burning these different types of charcoal contains the flavor, which is added to the food during cooking.

2.4 APPLICATION

The charcoal is used in purification and filtration, medicine, art, sewage treatment, air filters in gas masks and respirators, filter in compressed air and many other applications. It is the most widely used absorbent since most of its chemical (surface group) and physical properties (pore size distribution and surface area) can be tuned according to what is needed. Charcoal has been an important domestic product for many years and regardless of how it produced, it has wide market acceptance (Arlie W. Toole et. al., 1961).

2.4.1 Environmental Applications

Carbon adsorption has numerous applications in removing pollutants from air or water streams both in the field and in industrial processes such as spill cleanup, groundwater remediation, drinking water filtration, air purification and volatile organic compounds capture from painting, dry cleaning, gasoline dispensing operations and other processes. Activated charcoal is also used for the measurement of radon concentration in air.

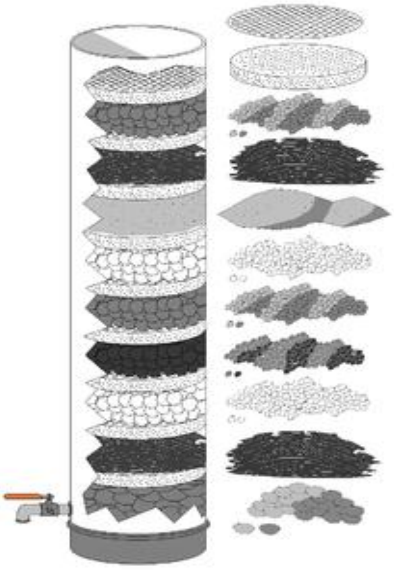


Figure 2.6 : Activated carbon is usually used in water filtration systems. The activated carbon is in the fourth level counted from bottom in the picture.

2.4.2 Medical Applications

Charcoal was consumes in the past as dietary supplement for gastric problems in the form of charcoal biscuits. Now, it can be consumed in tablet, capsule or powder form for digestive effects. Red colobus monkeys in Africa have been observed eating charcoal for the purposes of self-medication. Their leafy diets contain high levels of cyanide, which may lead to indigestion. So they learned to consume charcoal, which absorbs the cyanide and relieves indigestion. This knowledge about supplementing their diet is transmitted from mother to infant

In medical applications, the activated carbon is used to treat poisonings and overdoses following oral ingestion. It is thought to bind to poison and prevent its absorption by the gastrointestinal tract. Dosing is usually empirical at 1 g/kg of body mass (adolescents or adults around 50-100 g) which basically given only once but depending on the drug taken. It is rare situation which the activated carbon is used to filter out harmful drugs from the blood stream of poisoned patients. The activated charcoal has become the treatment of choice for many poisonings, and other decontamination methods such as ipecac-induced emesis or stomach pumping are now used rarely.

Incorrect application such as into the lung will results in pulmonary aspiration which can sometimes be fatal if immediate medical treatment is not initiated. The activated charcoal has been shown to not be effective in long term accumulation of toxins like with the use of toxic herbicides. It will bind the toxin to prevent stomach and intestinal absorption. The binding is reversible so a cathartic such as sorbitol may be added as well. It interrupts the enterohepatic and enteroenteric circulation of some drugs/toxins and their metabolites.

Tablets or capsules of activated charcoal are used in many countries as an over-the-counter drug to treat diarrhea, indigestion and flatulence [Stearn, 2007]. The activated charcoal is also used for bowel preparation by reducing intestinal gas content before abdominal radiography to visualize bile and pancreatic renal stones.

2.4.3 Gas and Chemical purification

Charcoal may be activated to increase its effectiveness as a filter. Filters with activated carbon are usually used in compressed air and gas purification to remove oil vapors, odors and other hydrocarbons from the air. The most common designs use a first stage and second stage filtration principle in which activated carbon is embedded inside the filter media. Activated charcoal filters are used to retain radioactive gases from a nuclear boiling water reactor turbine condenser. The air vacuumed from the condenser contains traces of radioactive gases. The large charcoal beds adsorb these gases and retain them while the filtered air passes through.

Besides, activated carbon is commonly used to purify solutions containing unwanted colored impurities such as during a recrystallization procedure in Organic Chemistry.

2.5 FOURIER TRANSFORM INFRARED SPECTROMETER (FTIR)

FTIR is one of the most widely used tools in the oil analysis laboratory. Its value lies principally in the fact that it is a purely instrument-based test (meaning it does not need extensive sample preparation or wet chemistry), it is relatively quick to perform and is capable of simultaneously detecting multiple parameters, including water, fuel, glycol, oil oxidation, soot and certain additives. In fact, at face value, it would appear to be the ideal solution to providing quick, inexpensive oil analysis.

FTIR can be used to identify chemicals from spills, paints, polymers, coatings, drugs, and contaminants. FTIR is perhaps the most powerful tool for identifying types of chemical bonds (functional groups). The wavelength of light absorbed is characteristic of the chemical bond as can be seen in this annotated spectrum.

Figure 2.7: Fourier Transform Infrared Spectrometer (FTIR)

By interpreting the infrared absorption spectrum, the chemical bonds in a molecule can be determined. FTIR spectra of pure compounds are generally so unique that they are like a molecular "fingerprint". While organic compounds have very rich, detailed spectra, inorganic compounds are usually much simpler. For most common materials, the spectrum of an unknown can be identified by comparison to a library of known compounds. We have several infrared spectral libraries including on-line computer libraries. To identify less common materials, IR will need to be combined with nuclear magnetic resonance, mass spectrometry, emission spectroscopy, X-ray diffraction, and/or other techniques.

Besides, it is based on the fundamental principles of molecular spectroscopy. This broad-ranging area of physics and chemistry covers a multitude of experimental techniques, some of which are found in other oil analysis tests, and others that are so sophisticated that they are of importance only in research laboratories. The basic principle behind molecular spectroscopy is that specific molecules absorb light energy at specific wavelengths, known as their resonance frequencies. For example, the water molecule resonates around the 3450 wavenumber (given the symbol cm^{-1}), in the infrared region of the electromagnetic spectrum.

An FTIR spectrometer works by taking a small quantity of sample and introducing it to the infrared cell, where it is subjected to an infrared light source, which is scanned from 4000 cm^{-1} to around 600 cm^{-1}. The intensity of light transmitted through the sample is measured at each wavenumber allowing the amount of light absorbed by the sample to be determined as the difference between the intensity of light before and after the sample cell. This is known is the infrared spectrum of the sample.

In the infrared region of the spectrum, the resonance frequencies of a molecule are due to the presence of molecular functional groups specific to the molecule. A functional group is simply a group of two or more atoms, bonded together in a specific way. In the water molecule (H_2O), it is the O-H functional group that contributes to the resonance frequency around 3450 cm^{-1}. To the oil analyst, functional groups are both a benefit and a hindrance to FTIR analysis. The benefit is that different types of molecules, such as the additive ZDDP (zinc dialkyl dithiophosphate) and water, or fuel and glycol that have different functional groups absorb infrared light at different wavelengths. Therefore, it is possible to determine the presence of different molecules in the sample with FTIR, simply by measuring the absorption at different wavelengths, or wavenumber [Noria, 2002].

The similarity of functional groups creates a problem with FTIR. For example, if a sample is analyzed and the infrared absorption recorded in the 3600 to 3400 cm^{-1} region, one may not be able to differentiate between absorption due to water, glycol contamination or antioxidant additives, because their absorptions peaks are usually fairly broad and may overlap. Fortunately, the glycol molecule also absorbs light in other regions of the infrared spectrum, specifically 880, 1040 and 1080 cm^{-1}, which provides confirmation. However, in this region of the spectrum, absorption due to the oil molecules themselves can, and does, occur.

For some parameters such as soot, water and glycol, their concentrations can be determined using a simple calibration procedure, which relates the amount of absorbed light to a known concentration of each contaminant, using a calibration curve supplied with the FTIR spectrometer. For soot specifically, FTIR data is sometimes also reported as the amount of light transmitted rather than absorbed, typically around 2000 cm^{-1}. In this instance, a higher degree of soot loading results in a reduction in the amount of light transmitted, which is reflected in the FTIR data reported.

Manufacturers of FTIR instruments are aware of this limitation and many have introduced the concept of auto referencing to attempt to resolve this issue. Auto referencing allows the lab to run a single new oil reference for each type of oil in use, and store the FTIR spectrum as a new oil reference for future use, whenever used oil samples are submitted to the lab for FTIR analysis. While auto referencing helps to minimize problems associated with not having a new oil sample for each used oil sample, variations between oil batches, changes in oil formulation and the fact that multiple resonance absorption features can occur at the same wavenumber serve to limit the sensitivity and accuracy of FTIR data. For this reason, most oil analysis labs treat FTIR as a screening tool and back-up this method with confirming tests such as Karl Fischer if water is indicated, or the flash point test if fuel is suspected.

Table 2.1: Characteristic of IR Absorptions

Frequency, cm^{-1}	**Bond**	**Functional Group**
3640–3610 (s, sh)	O–H stretch, free hydroxyl	alcohols, phenols
3500–3200 (s,b)	O–H stretch, H–bonded	alcohols, phenols
3400–3250 (m)	N–H stretch	1°, 2° amines, amides
3300–2500 (m)	O–H stretch	carboxylic acids
3330–3270 (n, s)	–C≡C–H: C–H stretch	alkynes (terminal)
3100-3000 (s)	C-H stretch	aromatics
3100-3000 (m)	=C-H stretch	alkenes
3000-2850 (m)	C-H stretch	alkanes
2830-2695 (m)	H-C=O: C-H stretch	aldehydes
2260-2210 (v)	C≡N stretch	nitriles
2260-2100 (w)	-C≡C- stretch	alkynes
1760-1665 (s)	C=O stretch	carbonyls (general)
1760-1690 (s)	C=O stretch	carboxylic acids
1750-1735 (s)	C=O stretch	esters, saturated aliphatic
1740-1720 (s)	C=O stretch	aldehydes, saturated aliphatic
1730-1715 (s)	C=O stretch	α, β–unsaturated esters
1715 (s)	C=O stretch	ketones, saturated aliphatic
1710–1665 (s)	C=O stretch	α,β–unsaturated aldehydes, ketones
1680–1640 (m)	–C=C– stretch	alkenes
1650–1580 (m)	N–H bend	1° amines
1600–1585 (m)	C–C stretch (in–ring)	aromatics
1550–1475 (s)	N–O asymmetric stretch	nitro compounds
1500–1400 (m)	C–C stretch (in–ring)	aromatics
1470–1450 (m)	C–H bend	alkanes
1370–1350 (m)	C–H rock	alkanes
1360–1290 (m)	N–O symmetric stretch	nitro compounds

1335–1250 (s)	C–N stretch	aromatic amines
1320–1000 (s)	C–O stretch	alcohols, carboxylic acids, esters, ethers
1300–1150 (m)	C–H wag (–CH_2X)	alkyl halides
1250–1020 (m)	C–N stretch	aliphatic amines
1000–650 (s)	=C–H bend	alkenes
950–910 (m)	O–H bend	carboxylic acids
910–665 (s, b)	N–H wag	1°, 2° amines
900–675 (s)	C–H “oop”	aromatics
850–550 (m)	C–Cl stretch	alkyl halides
725–720 (m)	C–H rock	alkanes
700–610 (b, s)	–C≡C–H: C–H bend	alkynes
690–515 (m)	C–Br stretch	alkyl halides

m=medium, w=weak, s=strong, n=narrow, b=broad, sh=sharp

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In general, the methods used are the preparation of raw material, preparation of charcoal and the analysis using Fourier Transform Infrared Spectroscopy (FTIR).

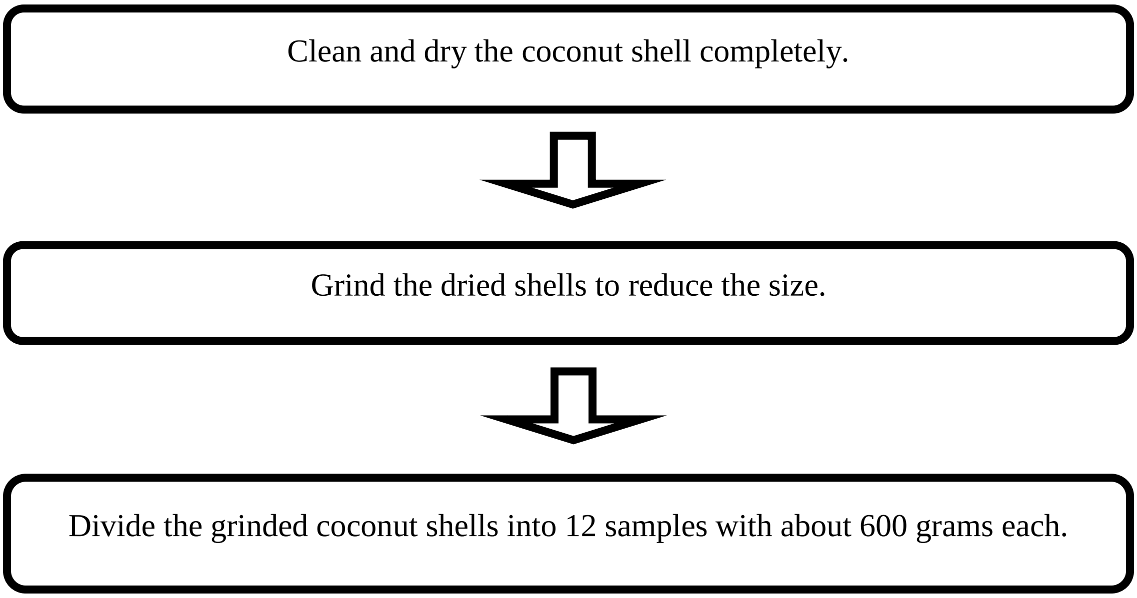
3.2 EQUIPMENT AND APPARATUS

The equipment and apparatus involved in the experiment are as listed in the Table 3.1 and can refers Figure F to Figure K in appendix for some of the pictures.

Table 3.1: Equipment and apparatus

EQUIPMENT & APPARATUS
Glass Furnace
Fourier Transform Infrared Spectrometer (FTIR)
Weighing scale
Gloves
Spatula
Hammer
Aluminium foil
Containers

3.3 PREPARATION OF RAW MATERIAL (COCONUT SHELLS)



Clean and dry the coconut shell completely.

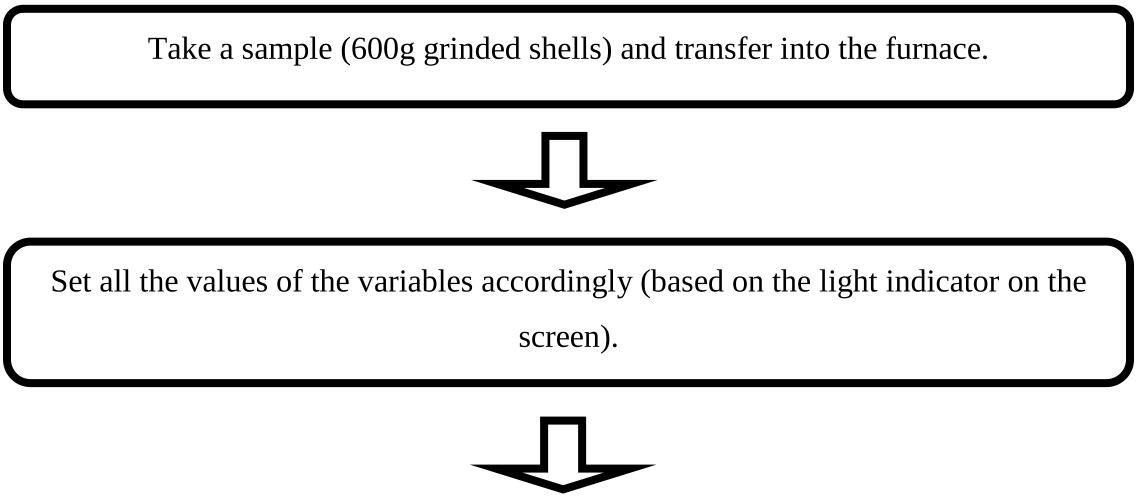
Grind the dried shells to reduce the size.

Divide the grinded coconut shells into 12 samples with about 600 grams each.

Figure 3.1: Flow diagram of preparation of raw material (coconut shells)

The coconut shells were clean from any dirt on its surface and were dried under sun light in two days’ time. The shells must be completely clean and dried on the inside and outside of the shells. Then, the dried shells were grinded to reduce the size around 1 cm to 4 cm diameter. After that, the grinded coconut shells were divided into 12 samples with about 600 g in each sample. Refer to Figure L in appendix.

3.4 PRODUCTION OF CHARCOAL



Take a sample (600g grinded shells) and transfer into the furnace.

Set all the values of the variables accordingly (based on the light indicator on the screen).

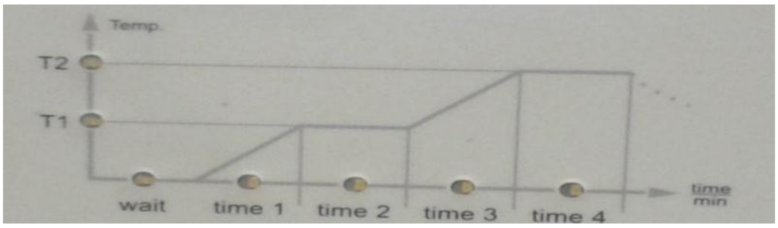


Figure 3.2 : Graph for Glass Furnace

Wait = 5 min

Time 1 = 10 min

Time 2 = 10 min

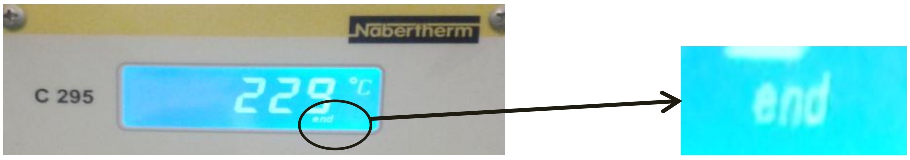
Time 3 = 15 min

Time 4 = holding time (10, 20,30 min)

T1 = 200 °C

T2 = manipulated temperature (400, 450, 500, 600, 800 °C)

Press the start button. The process is done when the screen shows ‘end’. Wait until the temperature drop below 200 °C and then, collect the sample (charcoal).

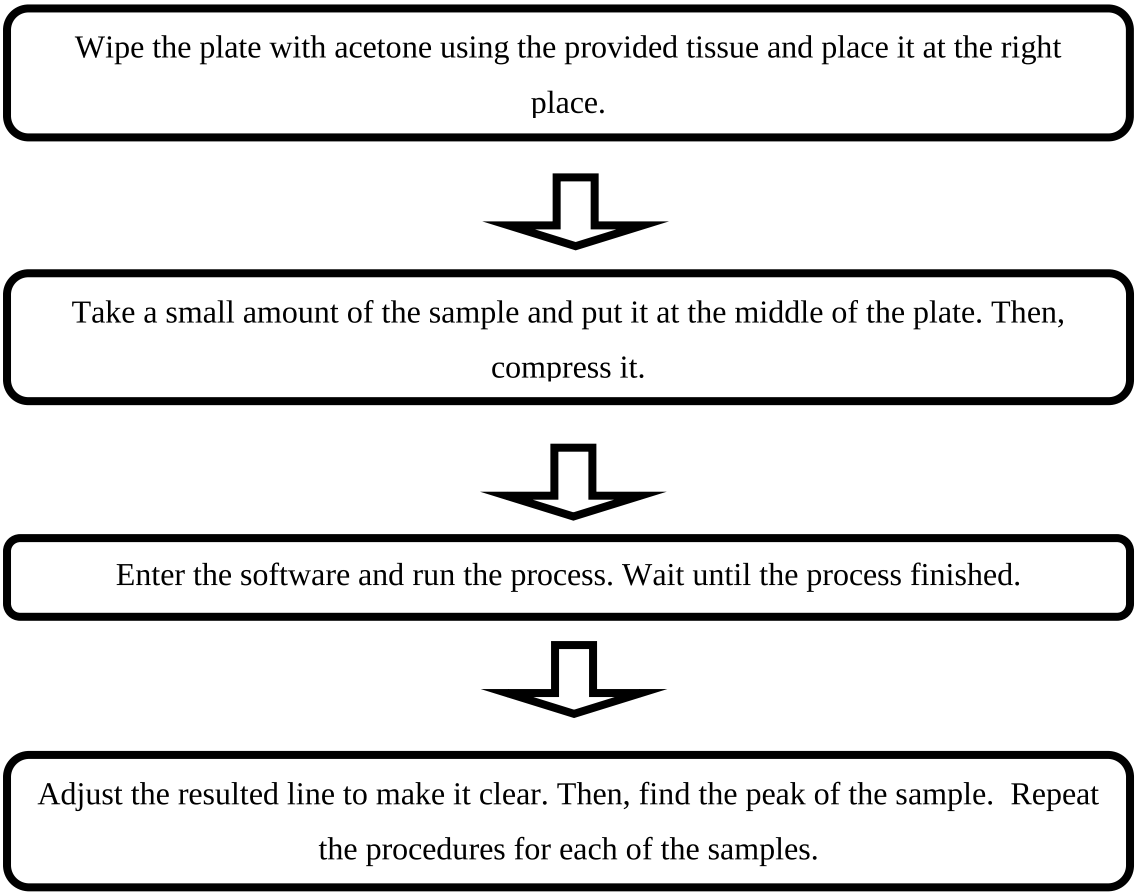


Repeat all the procedures for each of the samples with different in time 4 and T2.

Figure 3.3: Flow diagram of production of charcoal

The sample of 600 g of grinded shells was transferred into the glass furnace for carbonization process. All the values needed for the process were set according to the guideline provided by the lab owner of the furnace. [There are four phases (A, B, C and D) but for this experiment only used phase A]. The values are: wait = 5 min; time 1 = 10 min; time 2 = 10 min; time 3 = 15 min; time 4 = (10, 20, 30 min); T1 = 200 ^{o}C and T2 = (400, 450, 500, 600, 800 ^{o}C). Make sure the value for other phases were set zero. After that, the start button was press and the process was done when the screen showed ‘end’. The sample (charcoal) was collected after the temperature drop below 200 ^{o}C. [It is because the starting temperature for the furnace is set at 200 ^{o}C. So, it must be below that temperature before proceeding with other samples]. All the procedures were repeated for each of the sample with different in time 4 value and T2 value.

3.5 ANALYSIS OF CHARCOAL



Wipe the plate with acetone using the provided tissue and place it at the right place.

Take a small amount of the sample and put it at the middle of the plate. Then, compress it.

Enter the software and run the process. Wait until the process finished.

Adjust the resulted line to make it clear. Then, find the peak of the sample. Repeat the procedures for each of the samples.

Figure 3.4: Flow diagram of analysis of charcoal

Before start the analysis, the standard procedures when handling the FTIR must be done. Firstly, the round-shape plate has to be wiping with acetone solution using the provided tissue. Make sure to wipe without scratch. Then, place the plate at the right position. There is the label “Ge” at the plate and it must be face outside to prevent error in analysis. A small amount of the sample was taken using spatula and put it in the middle of the plate. Then, the sample is compress. After that, the analysis can be run and wait until the process finished. The resulted line will be obtained and it can be adjusted to make it clear. So, the peak can be easily detected. Then, save the file. All the procedures have to be repeated for each of the samples.

CHAPTER 4

RESULT AND DISCUSSIONS

4.1 INTRODUCTION

Experiments were done to find the optimum condition in producing the charcoal by considering the carbonization temperature and holding time. The charcoal’s weight produced and the functional groups appeared are determined through the experimental procedures.

4.2 WEIGHT OF CHARCOAL

There are 12 samples were prepared for the experiment. The starting weight of raw material (coconut shells) is 600 grams for each sample. After they undergo the carbonization process in different carbonization temperature and different holding time, there are huge differences in weights lost. Table 4.1 showed the weight of each sample after the experiment done.

Table 4.1: The weight of samples after Carbonization Process

Temperature, °C	Holding Time, min	Weight after, g
400	**10**	169.5
	20	190.88
	30	81.80
450	**10**	134.8
	20	47.93
	30	31.10
500	**10**	45.30
	20	32.70
	30	26.93
600	**10**	15.20
	20	0.00
800	**10**	0.00
	30	0.00

The weight of the samples decreasing over temperature and time. When the temperature increase, the weight loss of the sample also increased because the moisture content and volatile content in the sample are drive out during the process.

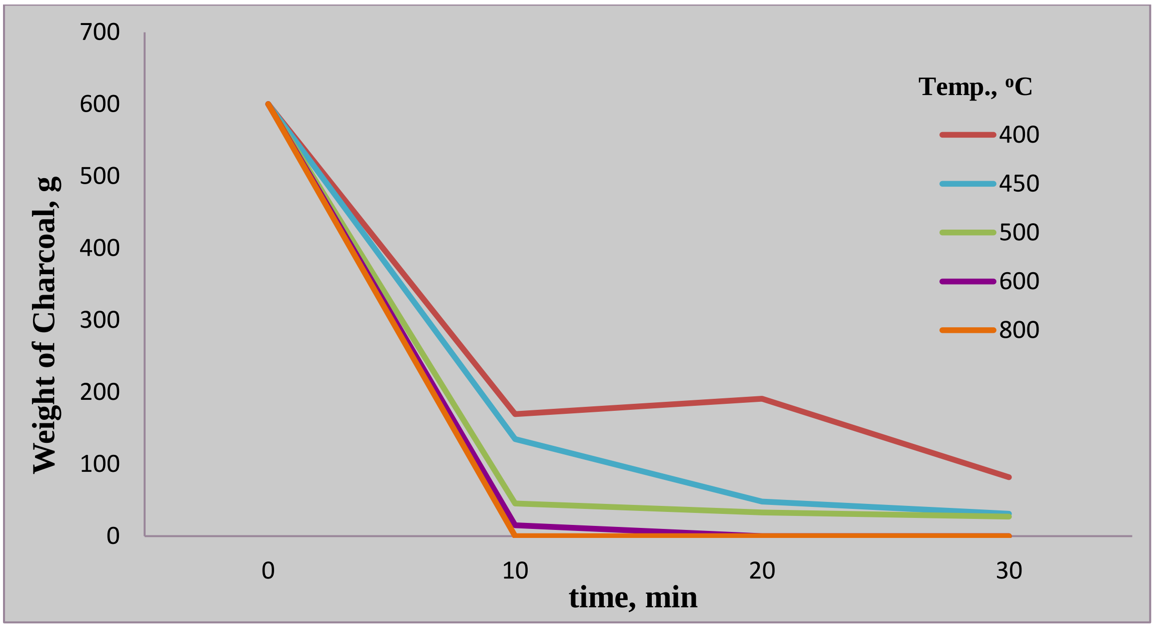


Figure 4.1: Graph of Weight of Charcoal, g vs. Holding Time, min

Based on Figure 4.1, the weight of the sample started at 600 g and then decrease sharply to below 200 g for all the temperatures. At 400 °C, the weight of the charcoal is the highest while at 800 °C is the lowest. It continued decreased by time. As we can see on the graph, for the line 400 °C, the graph is slightly increase at 20 minutes and decrease again at 30 minutes. For the other lines, the weights are always decreased.

The higher value at temperature, 400 °C and time, 20 minutes, may be due to human error when handling the product. As all know, charcoal is one of the good absorbent. So, it can absorb humidity of the air rapidly if it exposed to the environment. Within time, it will gain some weight because of the moisture content increased. Moisture is an adulterant which lowers the calorific value of the charcoal. Charcoal is sold by weight so, keeping the moisture content high often practiced by dishonest dealers. At 800 °C, the raw material turned into ash and no charcoal produced.

According to the book title “Industrial Charcoal Making” published in 1985, at temperature 400 °C to 500 °C, the transformation of charcoal is practically complete but need further heating to drive off more remaining tar and raise the fixed carbon content about 75 %. It also said that the normal percentage for good quality commercial charcoal must be above 70 % of fixed carbon and moisture content below 10 %.

So, based on literatures and the results, we can predict that the optimum condition for producing charcoal is at temperature 450 °C and 10 min time.

4.3 ANALYSIS USING FTIR

The analysis using FTIR is to check the functional groups in each of the samples. Charcoal is black in color, so it will absorb almost all of the radiation in visible spectrum and the peak obtained usually a sum of the interaction of different types of groups [Shen et. al., 2008]. The FTIR plots for different carbonization temperature and different holding time range were shown in Figure 4.2 to Figure 4.10.

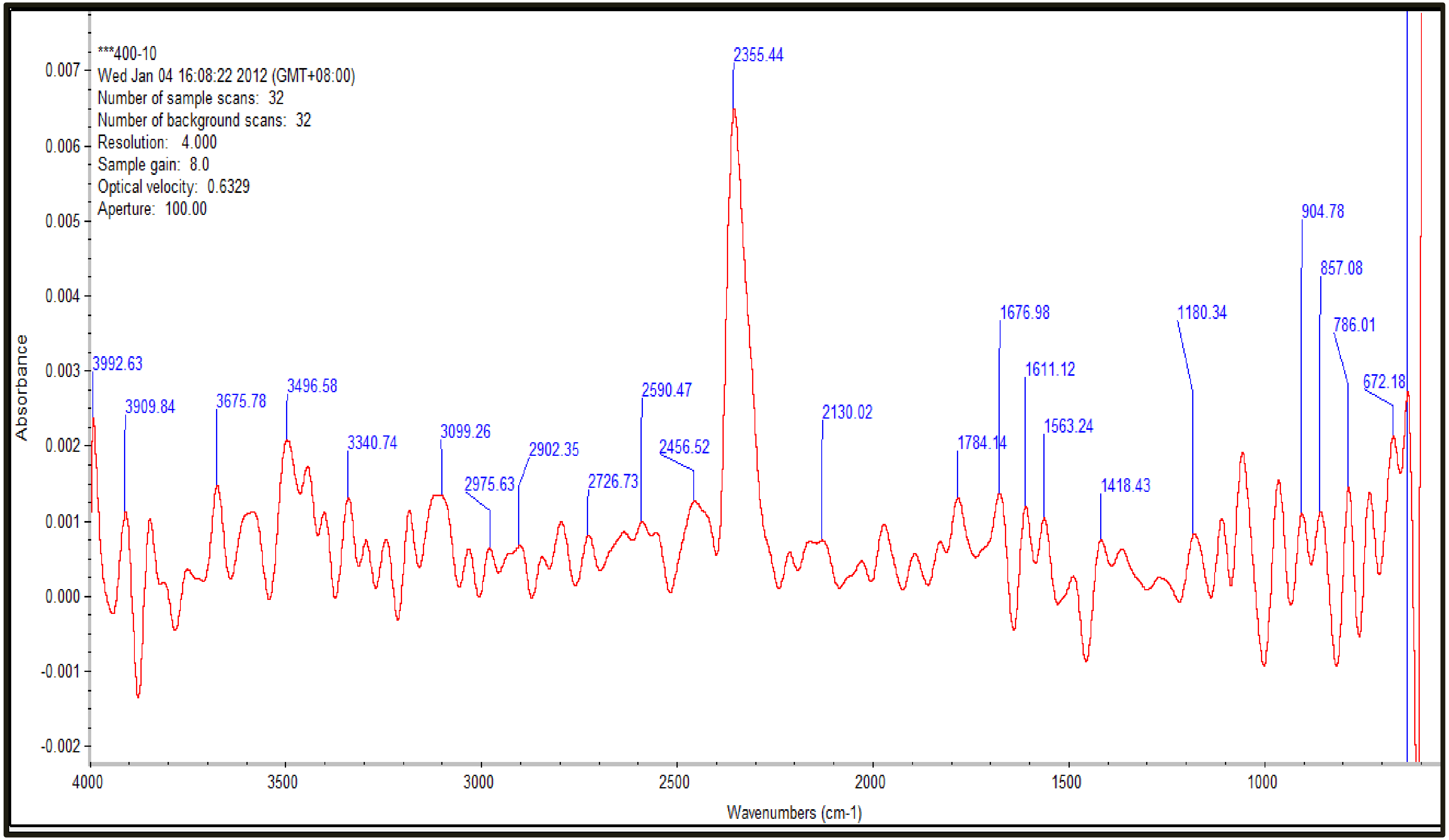


Figure 4.2: Graph for temperature = 400 ^{o}C and time = 10 min

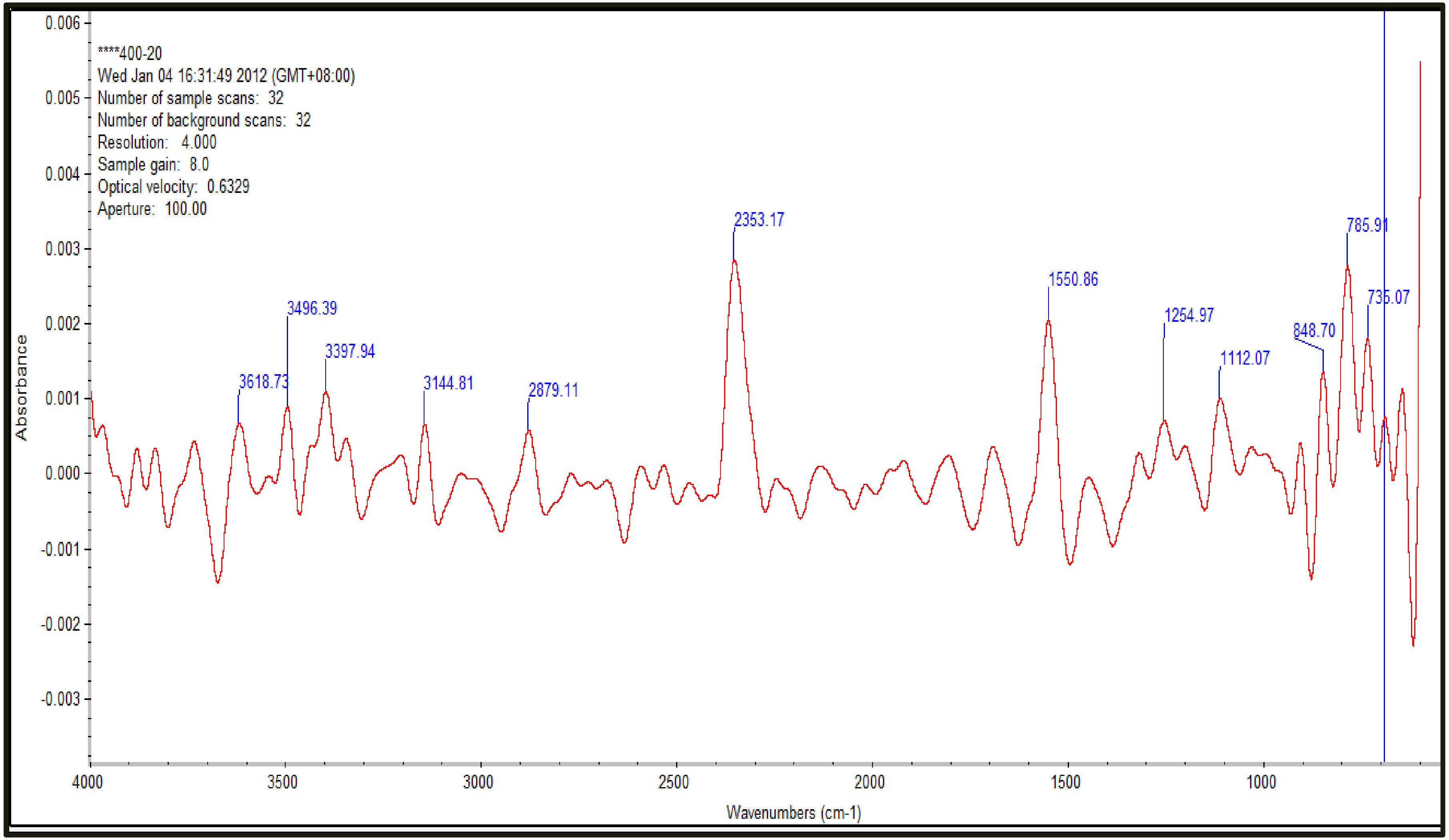


Figure 4.3: Graph for temperature = 400 ^{o}C and time = 20 min

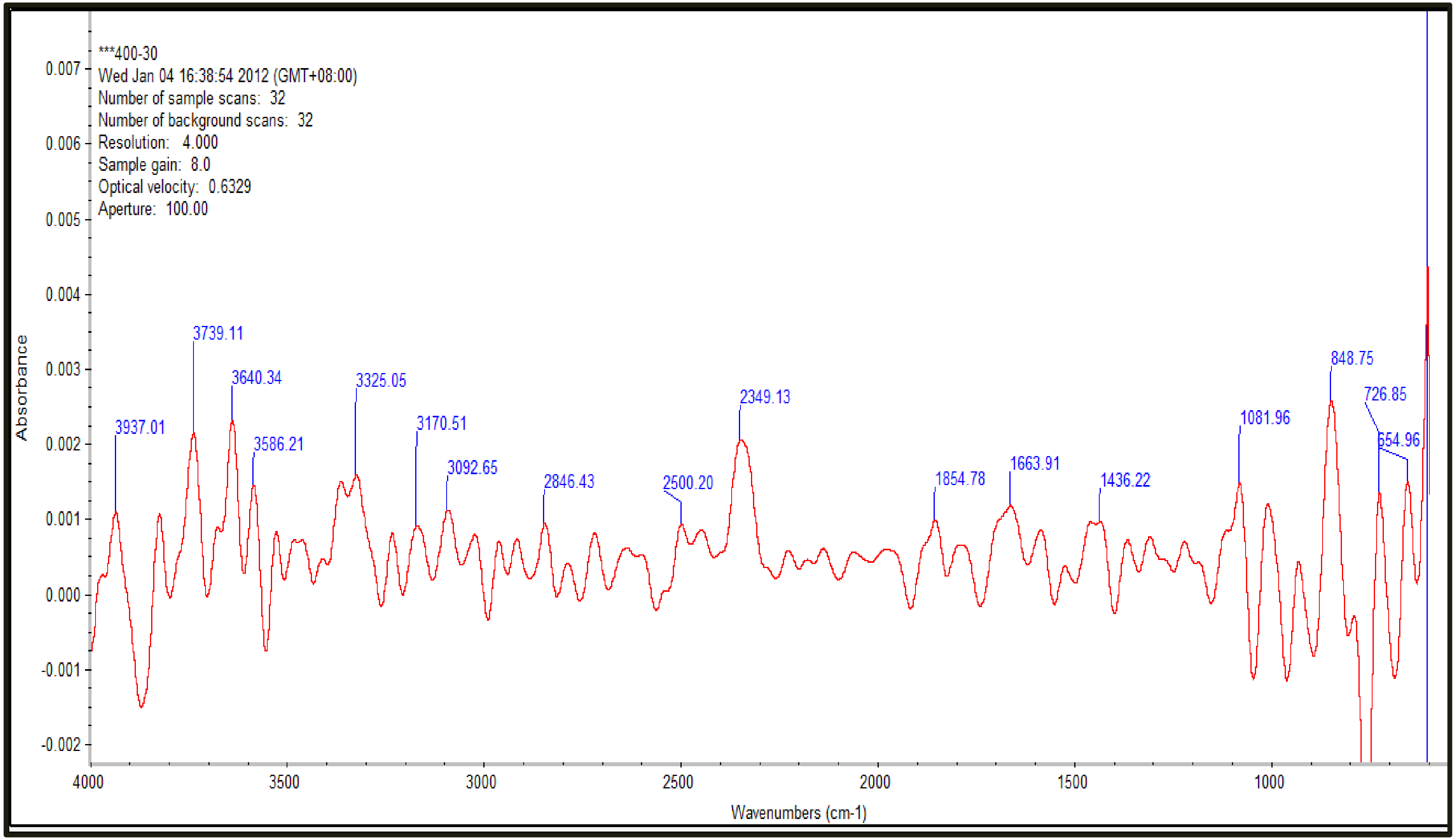


Figure 4.4: Graph for temperature = 400 ^{o}C and time = 30 min

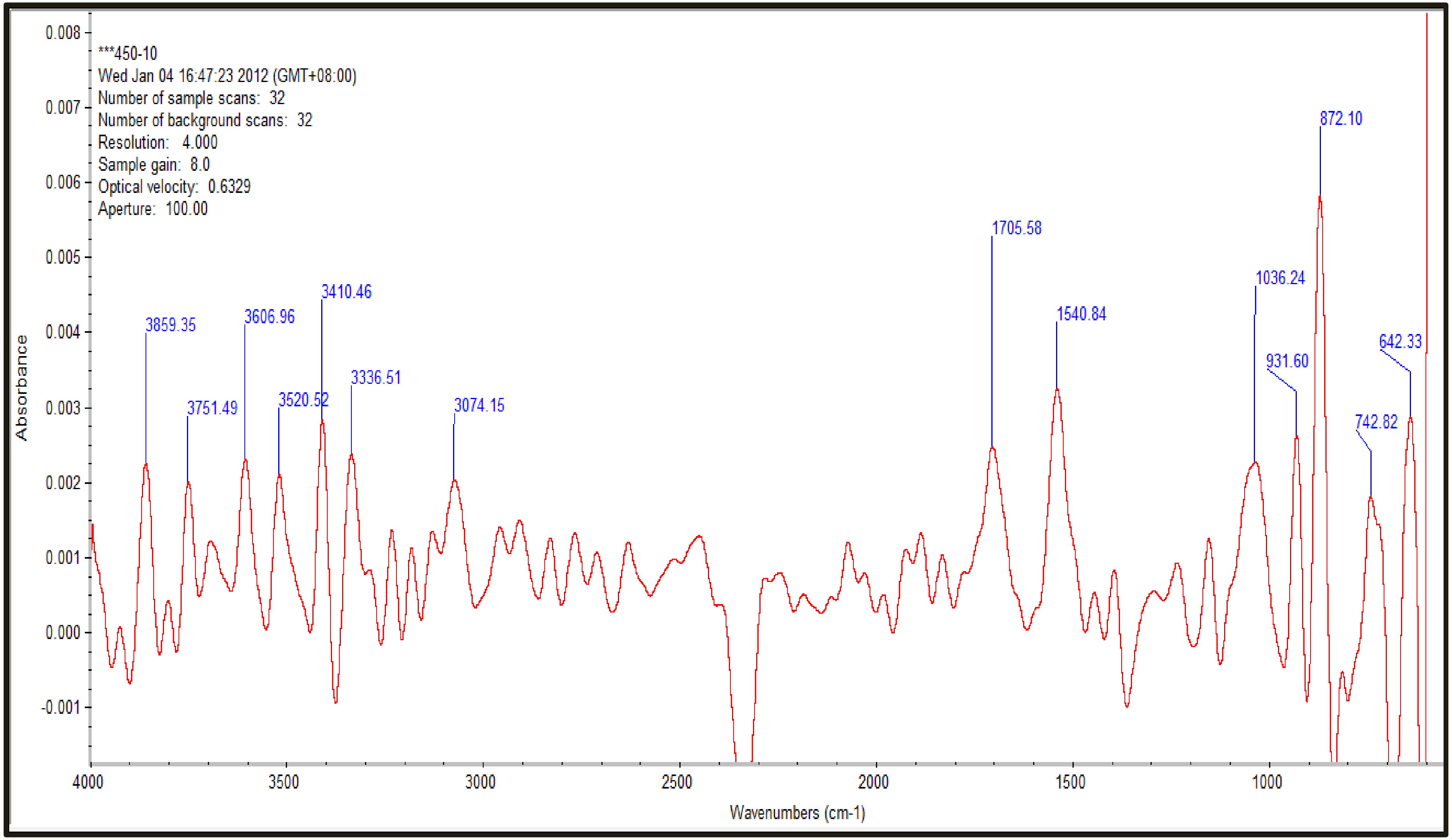


Figure 4.5: Graph for temperature = 450 ^{o}C and time = 10 min

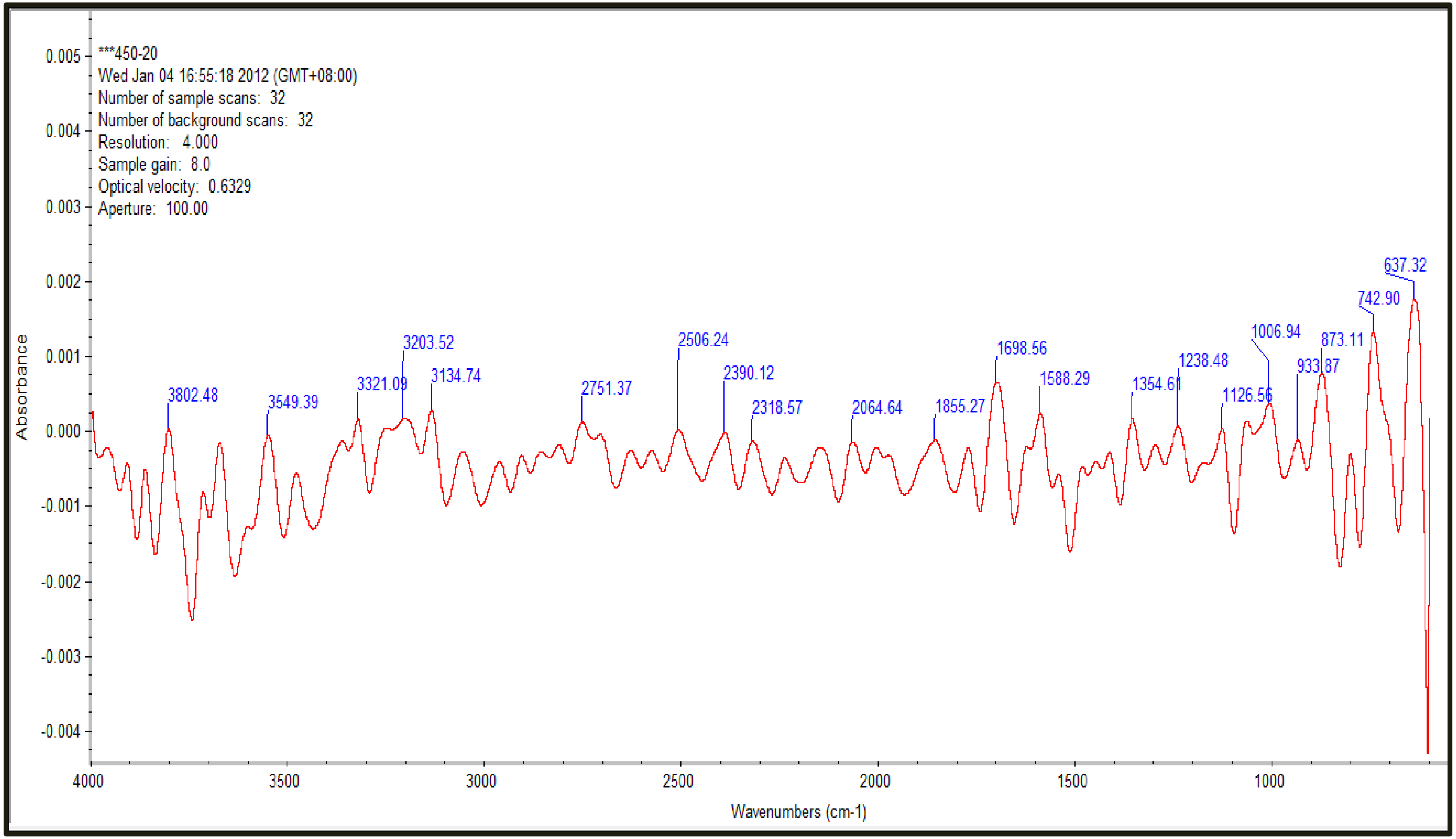


Figure 4.6: Graph for temperature = 450 ^{o}C and time = 20 min

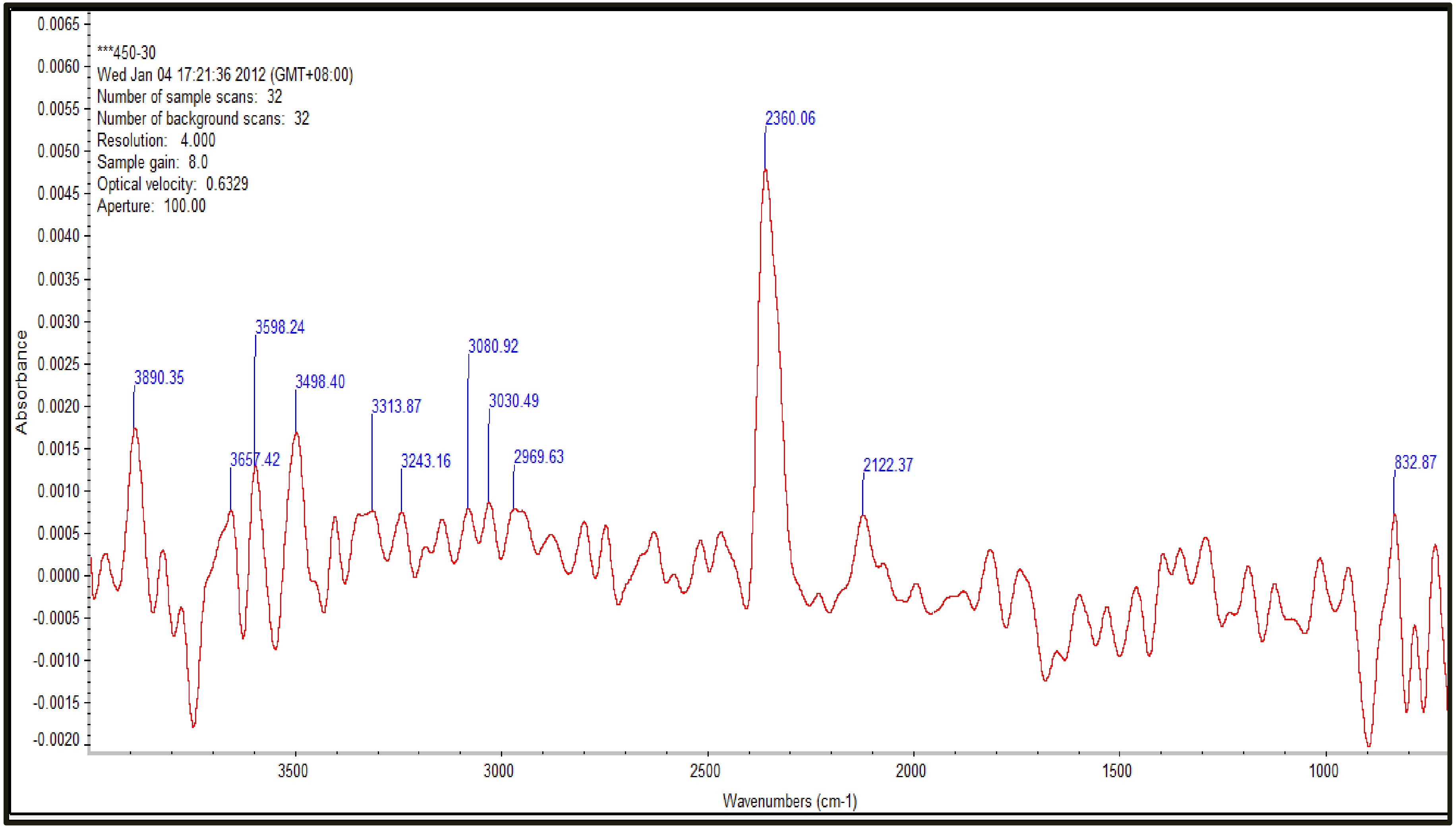


Figure 4.7: Graph for temperature = 450 ^{o}C and time = 30 min

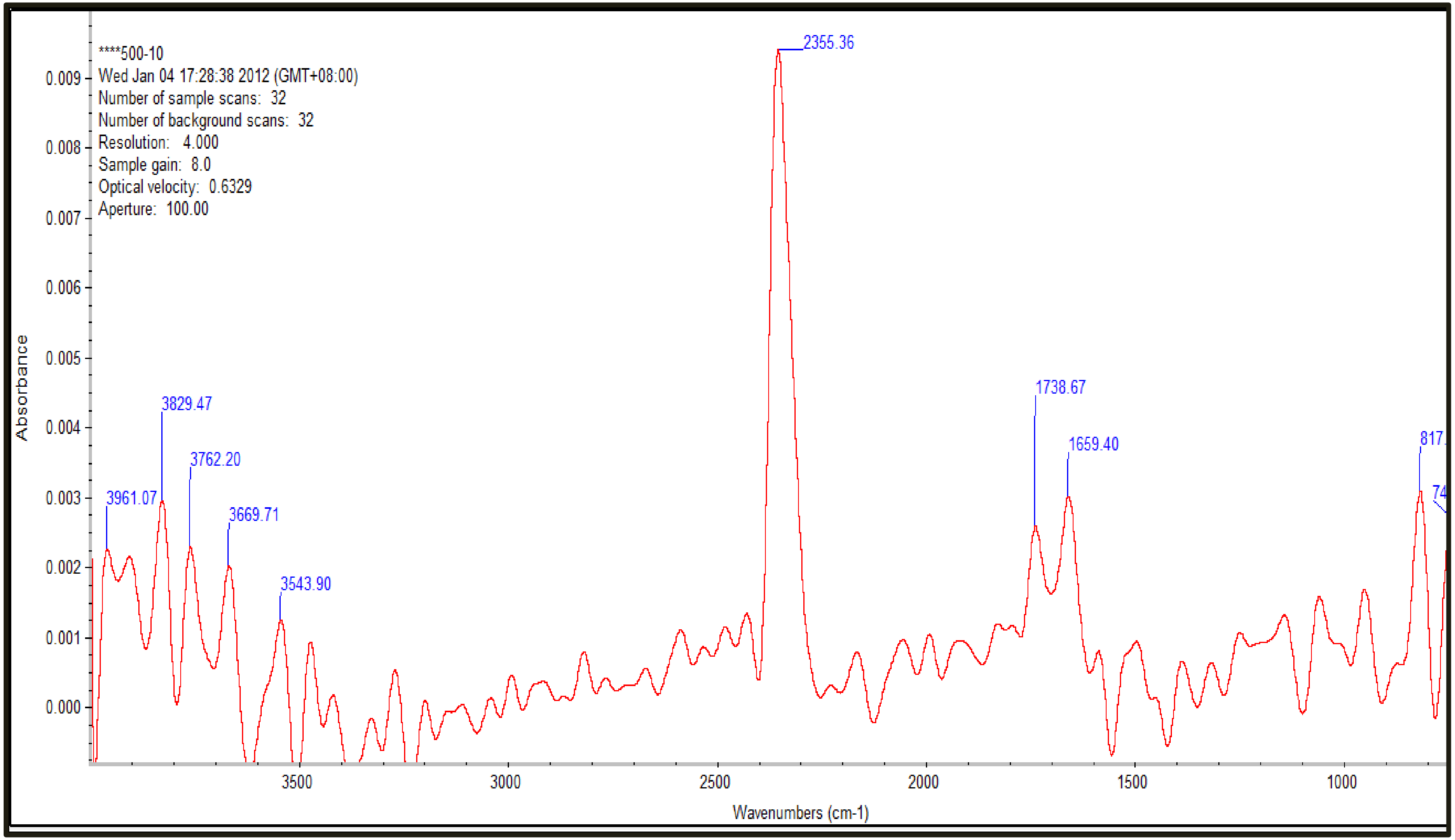


Figure 4.8: Graph for temperature = 500 ^{o}C and time = 10 min

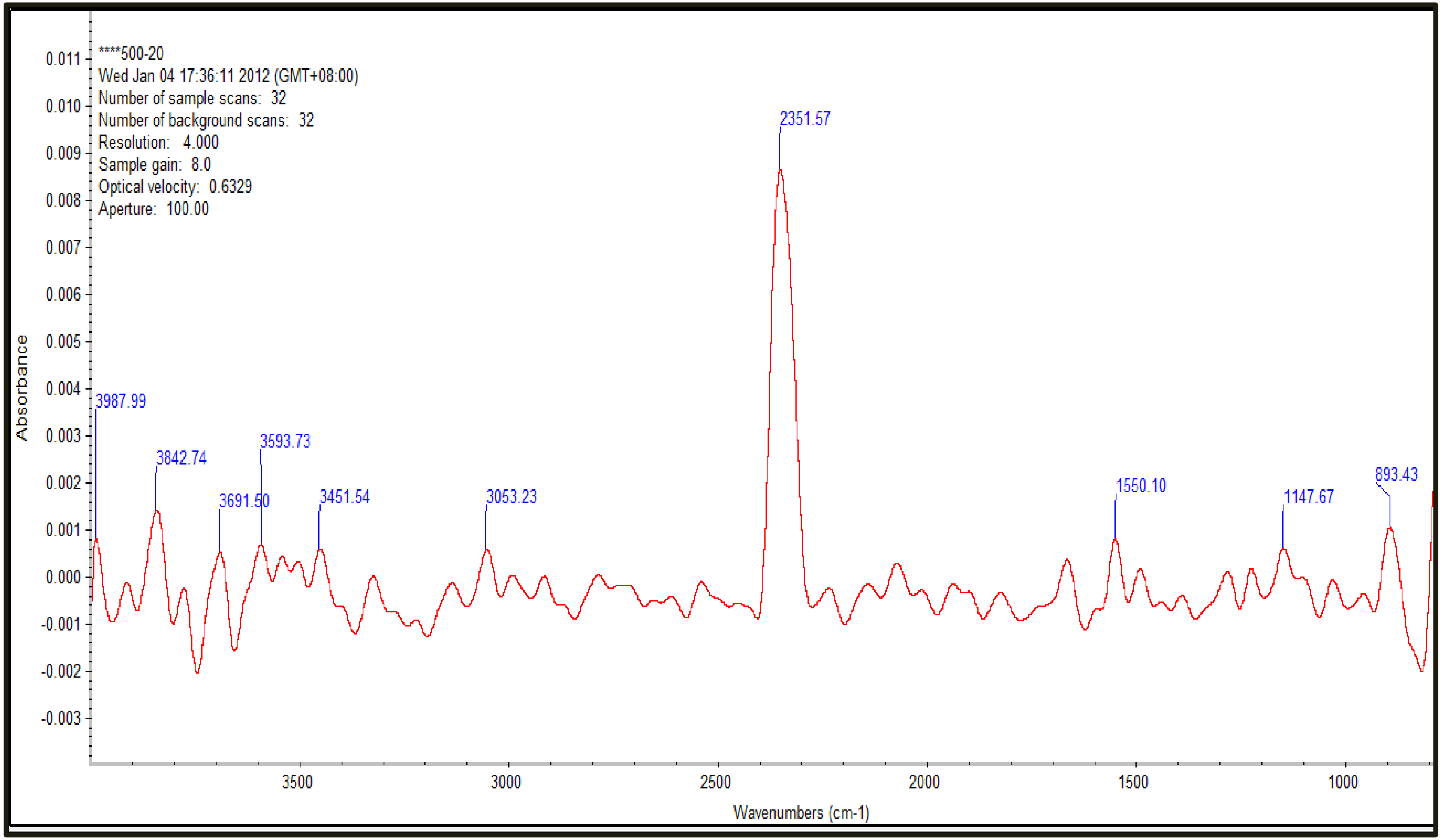


Figure 4.9: Graph for temperature = 500 ^{o}C and time = 20 min

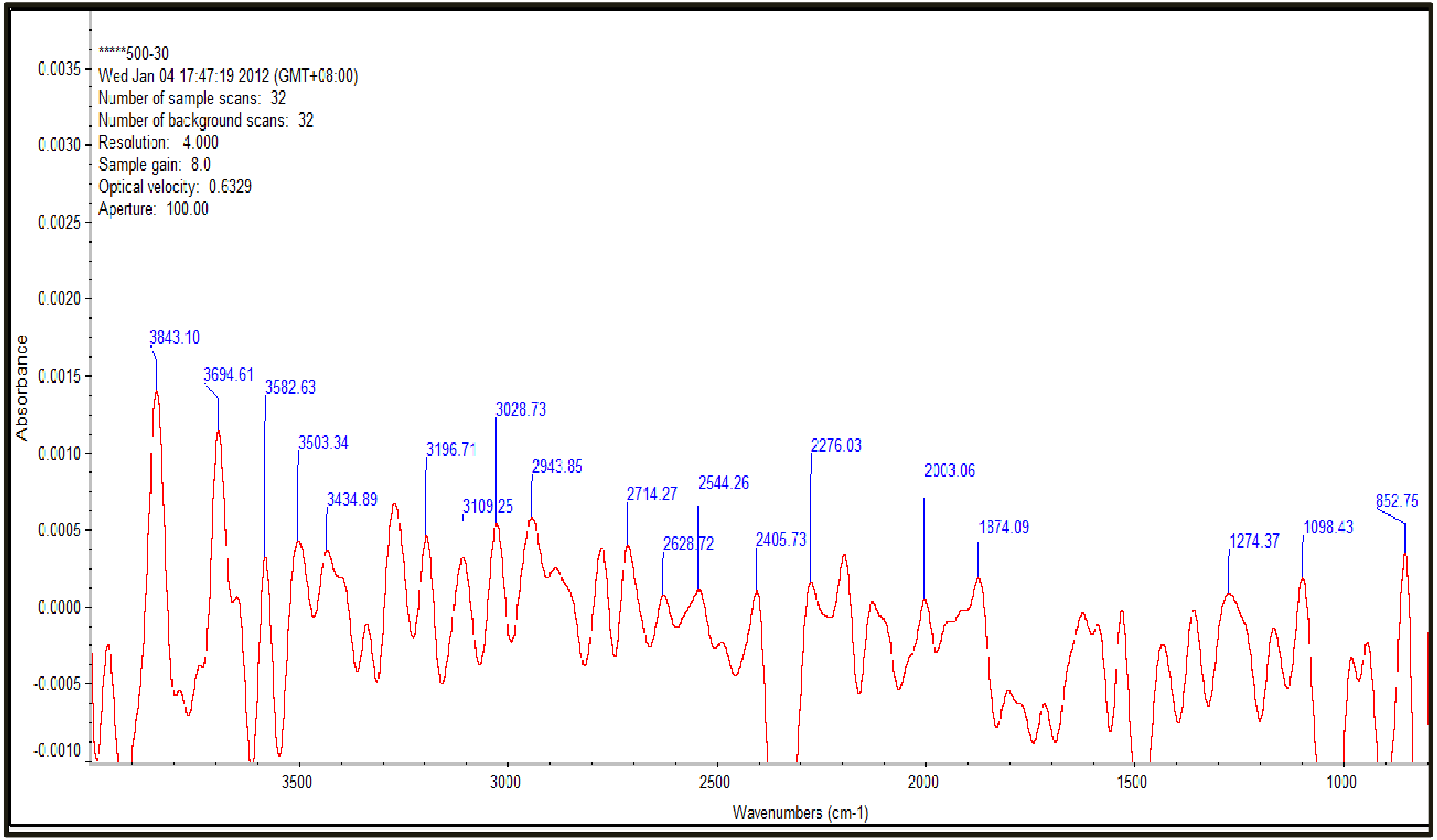


Figure 4.10: Graph for temperature = 500 °C and time = 30 min

Based on the graphs analysis, Figure 4.2 to Figure 4.10, the peak shows the functional groups appeared in the sample. The common functional groups appeared in most of the samples are in the range as following:

1) 3000 – 2800 = alkanes (C-H stretch)
2) 3100 – 3010 = alkenes (=CH stretch)
3) 2260 – 2100 = alkynes (C,C triple bond stretch)
4) 3500 – 3200 = alcohols (O-H stretch)
5) 3400 – 2500 = carboxylic acids (O-H stretch)

Based on the IR Tutorial by "*Organic Chemistry Undergraduate Courses, Spectroscopy*" website, the region (3000-2800cm^{-1}) is the strong bands due to C-H stretch. In simple alkanes, there are a few bands can be assigned such as C-H stretch (3000-2800cm^{-1}), C-H bend/scissoring (1470-1450 cm^{-1}), C-H rock, methyl (1370-1350 cm^{-1}) and C-H rock, methyl, seen only in long chain alkanes (725-720 cm^{-1}). Most of the organic compounds have these features.

Stretching vibrations of the =C-H bond are of higher wavenumber than those of the C-H bond in alkanes which is greater than 3000cm^{-1}. Only alkenes and aromatics show a C-H stretch slightly higher than 3000 cm^{-1}. Compounds that do not have C=C bond show C-H stretch only below 3000 cm^{-1}. The regions for this group are C=C stretch (1680-1640 cm^{-1}), =C-H stretch (3100-3000 cm^{-1}) and =C-H bend (1000-650 cm^{-1}).

For the –C≡C– stretch, it is appeared as a weak band (2260-2100cm$^{-1)}$. This region only appeared in very few organic compounds. The strong band for this functional group is C-H stretch range 3330-3270cm^{-1} but it is indistinguishable because of other functional groups on the same molecule absorb in this region such as O-H stretch. The regions are –C≡C– stretch (2260-2100 cm^{-1}), –C≡C–: C-H stretch (3330-3270 cm^{-1}) and –C≡C–: C-H bend (700-610 cm^{-1}).

Alcohols have characteristic IR absorptions associated with both the O-H and the C-O stretching vibrations. The O-H stretch of alcohols appears in the region 3500-

3200 cm^{-1} and is a very intense, broad band. The C-O stretch shows up in the region 1260-1050 cm^{-1}.

Carboxylic acids show a strong, wide band for the O-H stretch. Unlike the O-H stretch band observed in alcohols, the carboxylic acid O-H stretch appears as a very broad band in the region 3300-2500 cm^{-1}, centered at about 300 cm^{-1}. This is the same region as the C-H stretching bands of both alkyl and aromatic groups. So, a carboxylic acid shows a ‘messy” absorption pattern in the region 3300-2500 cm^{-1}, with the broad O-H band superimposed on the sharp C-H stretching bands. It is so broad because carboxylic acids usually exist as hydrogen-bonded dimers. The other regions for this group are C=O stretch (1760-1690 cm^{-1}), C-O stretch (1320-1210 cm^{-1}) and O-H bend (1440-1395 cm^{-1} and 950-910 cm^{-1}).

Carbon is the most compound consist in charcoal. So, the functional groups appeared should be alkanes, alkenes and alkynes.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

As the conclusion, the weight loss increased when the temperature and time increasing. At this condition, the moisture and other volatile component were eliminated from the samples. But if the charcoal exposed too long in the environment, it will increase the weight by increasing the moisture content. This is always been practicing by some of the dishonest charcoal dealers. The properties of the charcoal (fixed carbon content, moisture content, ash content, calorific value and volatile matter) are also very important to know in producing the best charcoal.

Charcoal contain mostly of carbon. So, the functional groups that should appeared most must contain carbon bonding. From the analysis, it showed that alkanes and alkenes groups appeared but there are also functional group of alcohols and carboxylic acids in the samples.

5.2 RECOMMENDATION

There are some recommendations for this research:

1) This research only focuses on production of charcoal. Charcoal has many usages but charcoal with activation process has lots more applications. This research should continue for activation process to make activated charcoal. The activated carbons produced by coconut shell charcoal are the superior to those produced from other sources because of its small macropores structure.

2) This research does not have any testing for the charcoal. The laboratory test for its absorption strength can be done to prove that the charcoal can be commercialized.

3) The functional group analysis can be done with other types of techniques such as chemical titration methods, temperature programmed desorption (TPD), X-ray photoelectron spectroscopy (XPS) and nuclear magnetic resonance (NMR). The result obtained from each technique can be compared.

4) Besides of only analyze the functional groups in the charcoal, other analysis should be done as well such as the analysis of the characteristics of the charcoal for more accurate result. The analysis that can be done like elemental analysis (moisture content, fixed carbon content, calorific value and so on), the analysis of the surface area or other related analysis.

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APPENDIX

Figure A1: Metal retort

Figure A2: Making charcoal from retort

Figure B: Traditional kiln

Figure C: Brick and concrete kiln

Figure D: Portable steel kiln

Figure E: Mini-charcoal kiln

Figure F: Glass furnace

Figure G: Fourier Transform Infrared Spectrometer (FTIR)

Figure H: Analytical scale (weighing)

Figure I: Glove

Figure J: Spatula

Figure K: Aluminium foil

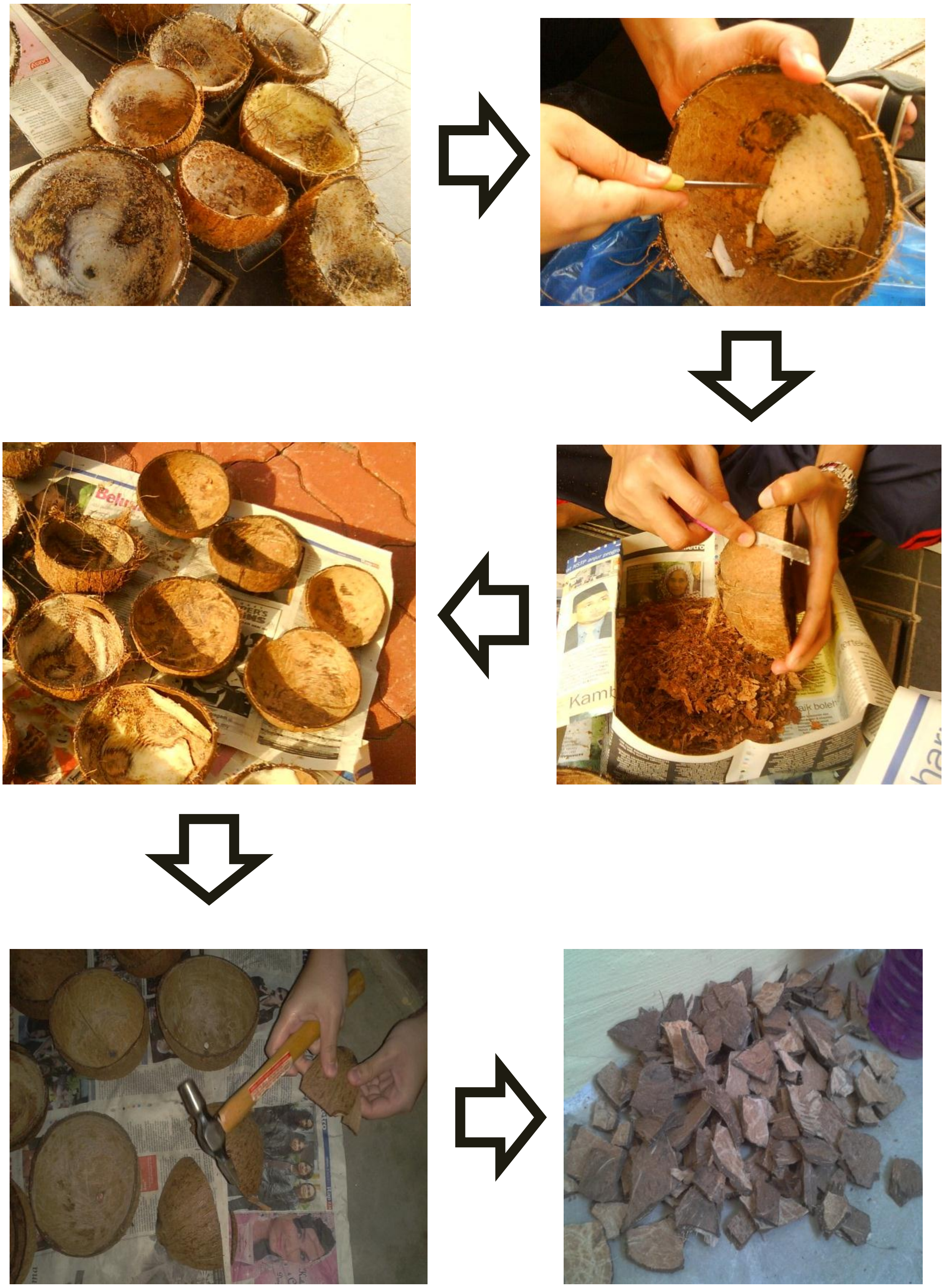

Figure L: Procedures of preparation of coconut shells