A Study of Energy Recovery Potential from Poultry Industry Waste Sludge

By

Ahmad Ariff Bin Jamaludin

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A Project Dissertation Submitted in Partial Fulfillment of
The requirement for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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Approved by,

(Ir. Dr. Mohd Shiraz Bin Aris)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
MAY 2011

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 been undertaken or done by unspecified sources or persons.

(AHMAD ARIFF BIN JAMALUDIN)

ABSTRACT

This report discusses the research and experimental works that had been done based on this chosen topic, which is **A Study of Energy Recovery Potential from Poultry Industry Waste Sludge.** Waste sludge originates from the process of waste water treatment plant. The main objectives of this project are to determine the actual quantity of potential energy that can be recovered and the Carbon, Hydrogen, Nitrogen and Sulfur (CHNS) content from the poultry industry waste sludge. The energy content from the waste sludge will be determined by using the Bomb Calorimeter and the CHNS content will be determined by using the CHNS Analyzer. The result obtained is then used to estimate the power generation. This project is carried out by using the waste sludge sample from Ayamas Food Corporation (Ayamas Klang), Integrated Poultry Industry (Ayamas Penang), Dinding Poultry Processing Plant (Dinding Perak) and Farm's Best Food Industies (Farm's Best Melaka). The results from this project can be used as the parameters to build an energy recovery system plant. The energy recovery system plant will benefit both the industries and environment whereby the industries can have a saving in disposing the waste sludge while the usage of land for land filling can be decreased.

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CHAPTER 1
INTRODUCTION

1.1 Project Background

The basic idea of this project is to study on the energy recovery potential from poultry industry waste sludge. Typically, the waste sludge from the industries is disposed to the landfill. To dispose the waste sludge to the landfill is costly. Through research, the waste sludge may have potential energy that can be recovered from it. The potential energy recovered can be used to generate power. This power can be used to be supplied back to the industries. Indirectly, this will benefit the industries in term of financial. Such industries will have a saving at the cost of disposing the waste and paying for power supply. Other than that, this will also benefit the environment when the rate of land scarceness can be reduced.

1.2 Problem Statement

EarthTrends stated that the major energy consumption by sources in Malaysia consist of fossil fuels (47.21%), crude oil and natural gas liquids (25.36%) and natural gas (19.80%) [1]. Majority of industries continues to use gasoline and diesel since they are easy to be obtained and have high efficiency. However, combustion of such conventional fuels gives bad effects to the environment because of the sulfuric, carbonic and nitric acids generated. In related to that fact, most experts agree that the oil reserves will be depleted. Searching for alternative and clean energy sources is the answer to this problem.

Other than that, industries dispose their waste sludge to the landfill. This gives a bad impact both to the industries and the environment whereby the industries have to pay to dispose the waste sludge which is costly while the scarcity of land is increasing. In Malaysia, approximately 98% of the total waste is disposed to the landfill and this is including the waste sludge from the industries [2]. The method of land filling needs an improvement as this also will benefit both the industries and the environment.

1.3 Objectives

Objectives play as an important role in any project. They are as a guideline and a target in completing such project. The main objectives of this project are to:

1) Determine the moisture content of the poultry industry waste sludge.
2) Determine the actual quantity of potential energy that can be recovered from the poultry industry waste sludge.
3) Determine the Carbon, Hydrogen, Nitrogen and Sulfur (CHNS) content from the poultry industry waste sludge.
4) Estimating the power that can be generated from the poultry industry waste sludge.

1.4 Scope of Study

This project is primarily to determine the actual quantity of energy recovery potential that can be recovered from poultry industry waste sludge in Malaysia. After researches are done on the waste characteristics, samples of waste sludge are collected from identified poultry industries. The samples of waste sludge had been experimented through three types of analyses and they are Moisture Content Analysis, Calorimetric Analysis and Carbon, Hydrogen, Nitrogen and Sulphur Analysis (CHNS analysis). The analyses conducted are to determine the moisture content, quantity of energy that can be recovered and the Carbon, Hydrogen, Nitrogen and Sulphur content of the waste sludge. The results gathered from the Moisture Content and Calorimetric Analysis is then used to estimate the power that can be generated. The findings of this project can be used as parameters and references to develop an energy recovery system plant.

1.5 Case Study

In this project, samples of waste sludge from 4 poultry industries are taken to be studied on and they are Ayamas Food Corporation (Ayamas Klang), Integrated Poultry Industry (Ayamas Penang), Dinding Poultry Processing Plant (Dinding Perak) and Farm's Best Food Industries (Farm's Best Melaka). These industries are the commercial poultry processing plant whereby they process large quantity of chickens per day thus produce large amount of waste every day. Three of the factories which are Ayamas Klang, Dinding Sitiawan and Farm's Best Melaka do more than just slaughtering the chickens. They also process food like nuggets and sausages that are made from chicken meat while Ayamas Penang slaughters chickens only and do not process food. The details of the 4 industries are listed in the table 1.

Table 1: The poultry industries details

Factory	Input (chicken process per day)	Output (amount of waste sludge produced per day, kg)	Location
Ayamas Food Corporation	85000 - 92000	400 - 500	Klang (Selangor)
Integrated Poultry Industry	20000 - 22000	2700 - 2800	Bukit Mertajam (Pulau Pinang)
Dinding Poultry Processing Plant	45000 - 48000	900 - 1000	Sitiawan (Perak)
Farm's Best Food Industries	33000 - 35000	500 - 600	Masjid Tanah (Melaka)

Though they treat their own waste with their waste water treatment plant, they still dispose their waste sludge to the landfill. Samples of waste sludge from these industries were taken to do the experimental works on them. This is to investigate the moisture content, energy recovery potential and CHNS content from the waste sludge itself.

CHAPTER 2
LITERATURE REVIEW

This chapter discusses the researches done to understand more about the industrial waste and the equipments those are used in this project in order to make success of this project.

2.1 Industrial Waste

Industrial waste can be defined as the waste produced by industrial activity such as that of factories, mills and mines [3]. Toxic waste, chemical waste, industrial solid waste and municipal are the other names of industrial waste. The waste from the industrial activity can be divided into two categories which are hazardous and non-hazardous.

2.1.1 Hazardous Waste

Hazardous waste can be defined as the waste that contains harmful chemical to the humans or the environment. Hazardous waste pose a substantial hazard to human health or the environment when improperly treated, stored, transported, disposed or managed [4]. This type of waste can be found in the form of gaseous, liquids or solids.

There are four characteristics of hazardous wastes and such wastes will be classified as hazardous wastes if the wastes exhibit at least one of the four characteristics. The four characteristics are [3]:

i. Ignitable

   Ignitable wastes are the wastes those can create fires under certain conditions, spontaneously combustible or have a flash point less than 60°C (140°F). Examples of the ignitability wastes are waste from paints and used solvent.

ii. Corrosive

Corrosive wastes are the wastes those are acids or bases. In this case, the pH for the acids wastes is defined as less than or equal to 2 while the pH for the base wastes is defined as greater than or equal to 12.5. The corrosive wastes are capable of corroding metal containers such as storage tanks, drums and barrels.
Example of the corrosive wastes is battery acid.

iii. Reactive

Reactive wastes are the wastes those are unstable under normal conditions. Reactive wastes can cause explosions, toxic fumes, gases or vapors when heated, compressed or mixed with water.
Examples of the reactive wastes are lithium-sulfur batteries and cyanide plating.

iv. Toxic

Toxic wastes are the wastes those containing concentrations of certain substances in excess of regulatory threshold which are expected to cause injury or illness to human health or the environment.
Examples of toxic wastes are wastes form fertilizers and chlorinated solvent.

The hazardous waste can be found in different physical states such as gaseous, liquids and solids. Hazardous waste cannot be disposed of by common means like other waste. Hazardous waste needs to undergo different treatment in order to be stabilized and to be disposed [3]:

i. Recycling

One of the ways to treat or dispose hazardous is through recycling. Some of the hazardous waste can be recycled into new products. As an example, the heavy metals from lead-acid batteries or electronic circuit boards can be recovered and used in new products.

ii. Portland Cement

Portland Cement is a cement based solidification and stabilization. This treatment is basically turning the sludge into cement. Cement is used because it can treat a range of hazardous wastes by improving physical characteristics and decreasing the toxicity and transmission of contaminants.

iii. Neutralization

Through this treatment, the corrosive acid is neutralized with a basic substance so that it is no longer corrosive. Another way to neutralize the waste is pH adjustment. The pH is an important factor on the leaching activity of the hazardous waste. By adjusting the pH of the toxic materials, the leaching ability of the waste is reduced.

iv. Incineration

Incineration is the process of burning the waste at a high temperature. Energy can be recovered from the waste throughout the gases released in the process.

v. Hazardous waste landfill

Hazardous waste can also be disposed to the landfill or permanent disposal facility. In term of hazardous waste, landfill is defined as a disposal facility where hazardous waste is placed as a waste management unit.

vi. Pyrolisis

In this process, waste will be eliminated by using pyrolisis in an ultra high temperature electrical arc, in inert conditions to avoid combustion. This treatment method may be preferable to high temperature incineration in some circumstances such as in the destruction of concentrated organic waste types, including PCBs, pesticides and other persistent organic pollutants.

2.1.2 Non-Hazardous Waste

Non-hazardous waste can be defined as the waste that is not toxic, presents no hazard and thus requires no special treatment. Basically, non-hazardous waste or ordinary industrial waste is generated by the industrial but is similar by its nature and composition to household waste [6].

Particularly, it includes ordinary waste by companies, shopkeepers and trades people such as paper, cardboard, wood and textiles. Due to its non-hazardous characteristic, this waste is often sorted and treated in the same facilities as household waste. In Malaysia, other than to be recycled, the non-hazardous waste is disposed to the landfill [2].

2.2 Poultry Industry Waste Sludge

Waste sludge is a product that produced from waste water treatment plant. It is in the form of semi-solid material. Meat processing and animal slaughtering can produced significant amounts of meat tissues that are still rich in fats and proteins but they cannot be used for human. This is because in some cases, these materials contains pathogenic organism which can gives bad effects on human [7]. However, all the waste sludge from the four industries had been tested in the laboratory and found out to be safe. Though, sludge is however rich in nutrients and contains valuable organic matter. These two elements make the spreading of this kind of waste on land as a fertilizer or an organic soil improver suitable [8].

2.3 Equipments

The main equipments that will be used in this project will be the Oven, Bomb Calorimeter and Carbon, Hydrogen, Nitrogen and Sulfur (CHNS) Analyzer. Below is the description of the instruments.

2.3.1 Oven

Oven is used in this project to dry the waste sludge samples taken from the industries. This is to eliminate the water content in the waste sludge as well as to determine the approximate moisture content of the samples. Through researches, the average moisture content of poultry industry waste is found to be 75% [9]. It is important to find out the moisture content because it will determine the efficiency of a sample to be as a fuel.

2.3.2 Bomb Calorimeter

Calorimetric analysis is one of the analyses that will be used in the project to determine the potential energy recovery content in the waste sludge. In a calorimeter, combustion processes take place under precisely defined conditions [10]. For this purpose, the decomposition vessel is charged with a weighed in fuel (dried waste sludge) sample, the fuel sample is ignited, and the increase in temperature in the calorimeter system is measured. The specific gross calorific value of the sample is calculated from [10]:

- The weight of the fuel sample.
- The heat capacity (C value) of the calorimeter system.
- The increase in temperature of the water in the inner vessel of the measurement cell.

To optimize the combustion process, the decomposition vessel is filled with pure oxygen (99.95%). The pressure of the oxygen atmosphere in the decomposition vessel is 30bar. The exact determination of the gross calorific value of a substance is based on the requirement that the combustion proceeds under precisely defined conditions. The applicable standards are based on the following assumptions [10]:

- The temperature of the substance to undergo combustion is 22°C before combustion.
- The water contained in substance and the water formed during combustion of compounds in the substance containing hydrogen is present after combustion in liquid state.
- No oxidation of atmospheric nitrogen takes place.
- The gaseous products of combustion consist of oxygen, nitrogen, carbon dioxide and sulfur dioxide.
- Solid ash is formed.

Through researches, it is found to be that the average heating value for poultry industry waste is 12300 Joules per gram [9]. This value shows the potential energy that can be recovered from poultry industry waste sludge.

2.3.3 CHNS Analyzer

The CHNS Analyzer find utility in determining the percentages of Carbon, Hydrogen, Nitrogen, Sulphur and Oxygen of organic compounds, based on the principle of "Dumas method" which involves the complete and instantaneous oxidation of the sample by "flash combustion". The combustion products are separated by a chromatographic column and detected by the thermal conductivity detector (T.C.D.), which gives an output signal proportional to the concentration of the individual components of the mixture [11].

There are different techniques for the determination of CHN \ CHNS \O. It brings a new level of precision, accuracy, speed of analysis and ease of operation. The built in chromatographic column converts the compound and elutes it in the form of NO_2, CO_2, SO_2, H_2O which are then detected with the help of Thermal Conductivity Detector [11] .

2.4 Rankine Cycle

In this project, the application of Rankine cycle for steam turbine generator is used to estimate the power that can be generated by the poultry industry waste sludge. Rankine cycle is a thermodynamic cycle used to generate electricity in many power stations [13]. The poultry industry waste sludge is taken as the fuel to generate the steam. The superheated steam is generated in a boiler and then expanded in a steam turbine. The turbine will drive a generator to convert the work into electricity [13].

CHAPTER 3
METHODOLOGY

This chapter discusses the methods or project works that had been done in order to complete the project. In the next sub-chapter shows work flow or step of this project.

3.1 Procedure Identification

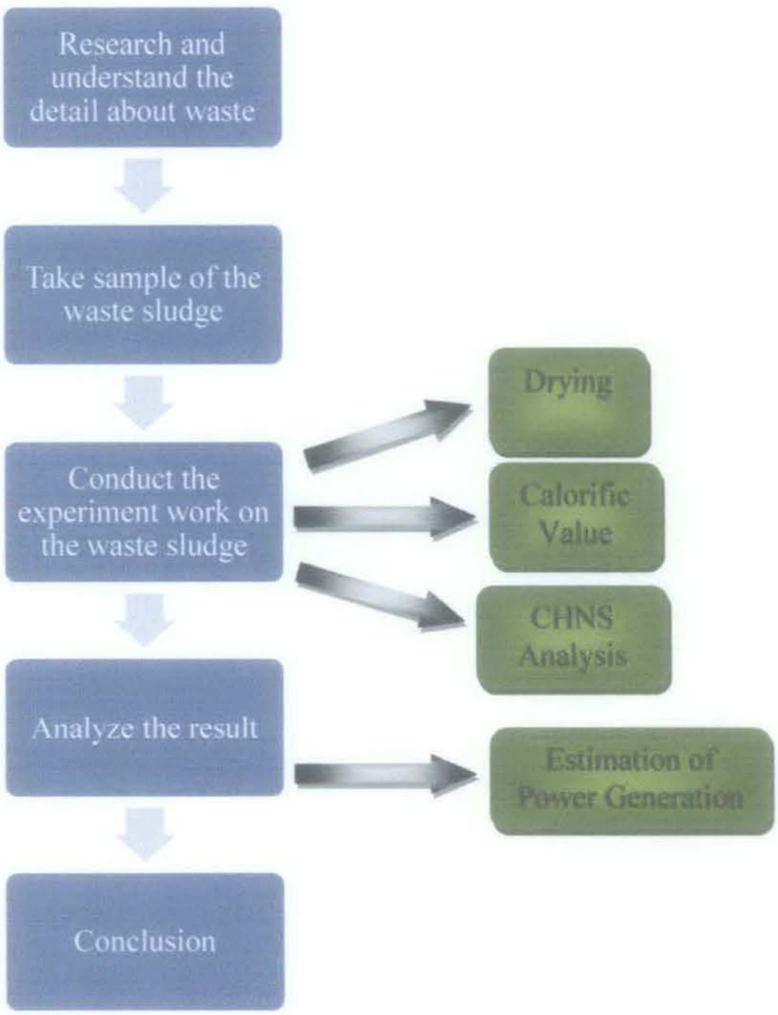


Figure 1: Process flow chart

For the first step of this project, it will be focused more on understanding the type of wastes that are produced by the industrial. Research will be done in order to understand more on what is waste, the types of waste and the way to treat or dispose the waste.

For the second step, the sample of the waste sludge will be taken from the industry that was determined to be focus on. In this project, the industry that will be focused on is poultry industry.

For the third step, the sample of the waste sludge will be experimented through the three types of experiments. They are Moisture Content Analysis, Calorimetric Analysis and Carbon, Hydrogen, Nitrogen and Sulphur (CHNS) Analysis. This is to identify the moisture content, quantity of energy that can be recovered and the CHNS content of the poultry industry waste sludge.

For the fourth step, the result from the experimental works will be analyzed. The results gathered from the third step will be used to estimate the power that can be generated from the poultry industry waste sludge.

The last step is to make a conclusion and recommendation based on the result gathered. A development of energy recovery system plant can be based on the result gathered. The result gathered can be the parameters and references for such development.

3.2 Analyses

Experiments are carried out in order to determine the efficiency and capability of poultry industry waste sludge to become as the source of biomass energy. All the samples from the four poultry industries had undergoes the same experiment to get the information needed.

3.2.1 Moisture Content Analysis

Moisture content is determined by drying the waste sludge sample by using the oven at 105°C. The weight of the samples is measured every 40 minutes to see the differences. The samples are dried until the weight reading became constant. The moisture content percentage is then determined by subtracting the final weight from the initial weight of the samples.

3.2.2 Calorimetric Analysis

To do the Calorimetric Analysis, the Bomb Calorimeter is used. The objective of conducting this analysis is to determine the calorific value of the waste sludge. In other word, the energy content in the waste sludge can be determined. The details of the Bomb Calorimeter are as below:

- Brand: IKA
- Model : C5000

The apparatus that will be used in this experiment are as below:

- Spatula
- Weight measurement device
- Tweezers
- Cutter

The experiment procedures conducted are as below:

Pre-experiment:

1. Bomb Calorimeter is ensured to be in a good condition.
2. Adequate compressed Oxygen is ensured to be supplied to the machine. For this machine, it requires 420Psi to run the experiment.
3. The machine is switched on. The machine is left until it stable. Usually, it takes about 10-15minutes to become stable.

Experiment:

1. The crucible is placed in the weight measurement device. The weight is set as 0.
2. Sample is poured into the crucible by using spatula.
3. The weight is measured and the reading is recorded.
4. The cotton thread is attached to the ignition wire.

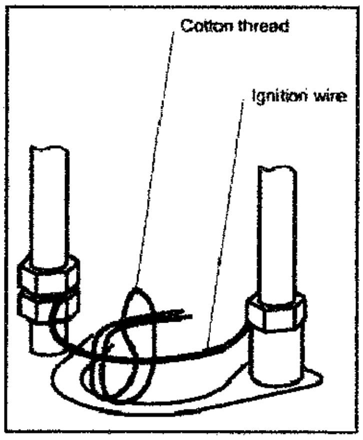


Figure 2: Cotton thread is attached to ignition wire

5. The cotton thread is aligned by using the tweezers so that it is suspended into the crucible and touches the sample. This will ensure that the burning thread will ignite the sample during the ignition process. The cotton thread is ensured to properly immerse into the sample.
6. The crucible is placed into the crucible holder.
7. The cover is put into the decomposition vessel.
8. The decomposition vessel is closed and locked by using the cap screw.

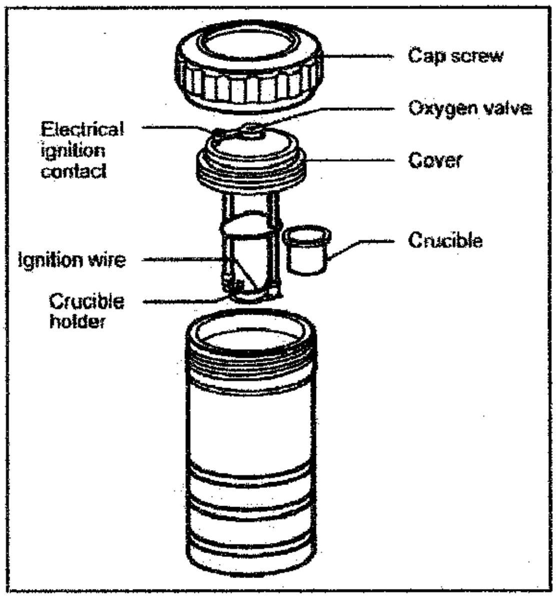


Figure 3: The decomposition vessel assembly

9. The decomposition vessel is put into the filling head of the measurement cell cover.

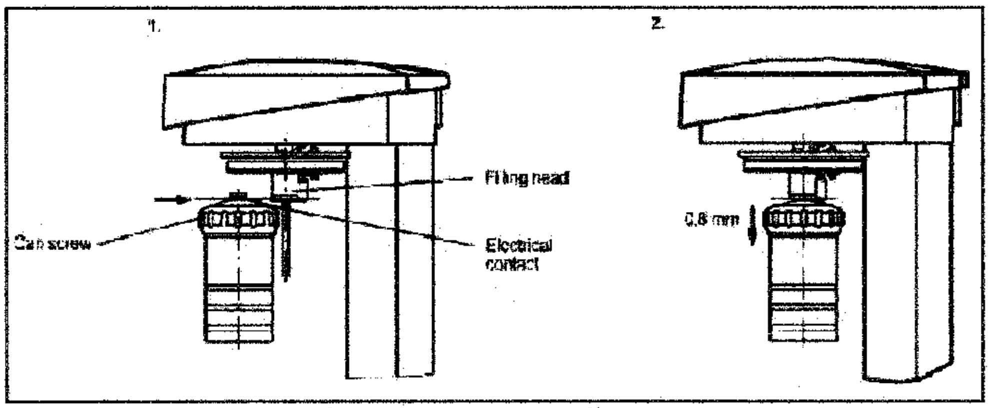


Figure 4: Measurement cell cover

10. The weight of the sample is keyed in into the Bomb Calorimeter.
11. As soon the message *Start* button appeared, the button is clicked and the decomposition vessel will be brought into the machine automatically. The decomposition vessel is then filled with oxygen. Next, the inner vessel is filled with water.
12. It takes about 15-20 minutes to complete. When the measurement is complete, the measurement cell cover opens and pressure is released from the decomposition vessel. The inner vessel is emptied. After that, the cover opens up completely. As soon the message *Bomb*↑, the button is clicked and

the decomposition vessel will be raised up automatically. The decomposition vessel can be retrieved.

13. The decomposition vessel is opened and the crucible is checked for any signs of incomplete combustion. If combustion was not complete, the result of the experiment is not valid. The experiment must be repeated.
14. The crucible is washed thoroughly and dry. The procedures were repeated with different samples.

Post-experiment:

1. All the equipments and tools especially the crucible, spatula and decomposition vessel is washed and cleaned thoroughly.
2. All the equipments and tools are kept dried.
3. The workspace cleaned.

3.2.3 CHNS Analysis

In the combustion process (furnace at ca. $1000^{0}C$), carbon is converted to carbon dioxide, hydrogen to water, nitrogen to nitrogen gas or oxides of nitrogen and sulfur to sulfur dioxide. If other elements such as chlorine are present, they will also be converted to combustion products, such as hydrogen chloride. A variety of absorbents are used to remove these additional combustion products as well as some of the principal elements, sulfur for example, if no determination of these additional elements is required.

The combustion products are swept out of the combustion chamber by inert carrier gas such as helium and passed over heated (about 600^{0} C) high purity copper. This copper can be situated at the base of the combustion chamber or in a separate furnace. The function of this copper is to remove any oxygen not consumed in the initial combustion and to convert any oxides of nitrogen to nitrogen gas. The gases are then passed through the absorbent traps in order to leave only carbon dioxide, water, nitrogen and sulphur dioxide.

Detection of the gases can be carried out in a variety of ways including:

i. A GC separation followed by quantification using thermal conductivity detection.
ii. A partial separation by GC ('frontal chromatography') followed by thermal conductivity detection (CHN but not S).
iii. A series of separate infra-red and thermal conductivity cells for detection of individual compounds.

Quantification of the elements requires calibration for each element by using high purity 'micro-analytical standard' compounds such as acetanilide and benzoic acid.

3.2.4 Uncertainty

In order to make sure all the data gathered is analyzed precisely, uncertainty range is calculated for all the results gather collected. The bias error for all the data is calculated by using the equation below:
The standard deviation is calculated by using the equation below:

Standard deviation = $\sqrt{\frac{1}{n}\sum(x-\bar{x})^2}$
n = number of sample
x = actual reading of every samples
$\bar{x}$ = average reading of samples

Bias error = $t_{\frac{\alpha}{2}}\, x\, \frac{s}{\sqrt{n}}$
$t_{\frac{\alpha}{2}}$ = student t value
α = confidence level
s = standard deviation
n = number of sample

Precision error = precision of equipment = ±0.01

$$\text{Calibration error} = \frac{\text{standard sample reading} - \text{standard sample actual reading}}{\text{standard sample reading}} \times 100\%$$

$$\text{Uncertainty (RSS)} = \sqrt{(bias\ error)^2 + (precision\ error)^2 + (calibration\ error)^2}$$

3.2.5 Power Estimation Analysis

The result gathered from the Moisture Content Analysis and Calorimetric Analysis is used to estimate the power generation. In this project, the power generation is estimated based on the Rankine cycle application for steam turbine generator. In the analysis of power generation estimation, steam turbine with an output of 2Megawatts is set to calculate the mass fuel burning rate for the poultry industry waste sludge. The efficiency of the boiler is set to be 85% as taken from the reference [13] due to proper equipment to calculate the efficiency is not available yet.

3.3 Gantt Chart for Final Year Project I

Table 2: Gantt chart for Final Year Project I

No	Details	Week														
		1	2	3	4	5	6		7	8	9	10	11	12	13	14
1	Selection of Project Topic	■						MID SEMESTER BREAK								
2	First meeting with my supervisor		■													
3	Preliminary Research work															
	a) Research the detail about waste			■	■											
	b) Determine the area to be focused on				■	■	■									
4	Preliminary Report preparation			■												
5	Submission of Preliminary Report (20 August 2010)				●											
6	Get the waste sludge sample						■		■							
7	Progress report preparation								■							
8	Submission of Progress Report									●						
9	Seminar (compulsory)									●						
10	Get familiar with the tool that will be use								■	■	■	■				
11	Conduct experiment on the waste sludge								■	■	■	■				
12	Analyze the result											■	■	■		
13	Submission of Interim Report Final Draft															●
14	Oral Presentation preparation													■	■	
15	Oral Presentation															●

● Suggestion milestone ■ Process

3.3 Gantt Chart for Final Year Project II

Table 3: Gantt chart for Final Year Project II

No	Details	Week															
		1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
1	Conduct Moisture Content Analysis	■	■	■	■				MID SEMESTER BREAK								
2	Conduct Calorimetric Analysis					■	■	■									
3	Submission of Progress Report									●							
4	Conduct CHNS Analysis									■	■	■	■				
5	Estimate the Power Generation													■			
6	Pre-EDX												●				
7	Submission of Draft Report													●			
8	Submission of Dissertation (soft bound)														●		
9	Submission of Technical Paper														●		
10	Oral Presentation Preparation														■		
11	Oral presentation															●	
12	Submission of Project Dissertation (hard bound)																●

● Suggestion milestone ■ Process

CHAPTER 4
RESULTS AND DISCUSSION

This chapter shows the results and discusses the experimental works that have been done on the samples taken from each factory. Each sample from the 4 factories was divided into 30 samples to be studied on by using different equipments.

4.1 Moisture Content

The moisture content from the waste sludge is determined by drying them. All of the samples from the poultry industries were dried by using the oven at 105°C. The weight of the samples is measured every 40 minutes to see the differences. The samples are dried until the weight reading became constant. The moisture content is then determined by subtracting the final weight from the initial weight of the samples. The percentage of moisture content from every sample and their range of uncertainty are shown in the table 4 and figure 5.

Table 4: Average moisture content for all samples

Sample	Moisture Content (%)	Uncertainty
Ayamas Klang	71.82	±1.74
Ayamas Penang	90.78	±0.21
Dinding Perak	68.52	±1.55
Farm's Best Melaka	74.39	±0.95

The result shows that samples from Ayamas Penang have the highest moisture content which is 90.78% and the samples from Dinding Perak have the lowest moisture content. High moisture content is not a good property for such material to be taken as fuel. This is because it will lower the boiler efficiency and this will cause the power output is less [12]. In order to make sure the samples give the maximum output, they must be dried first thus give higher efficiency as fuel. The calculation to find the uncertainty for this experiment is shown in Appendix 9.

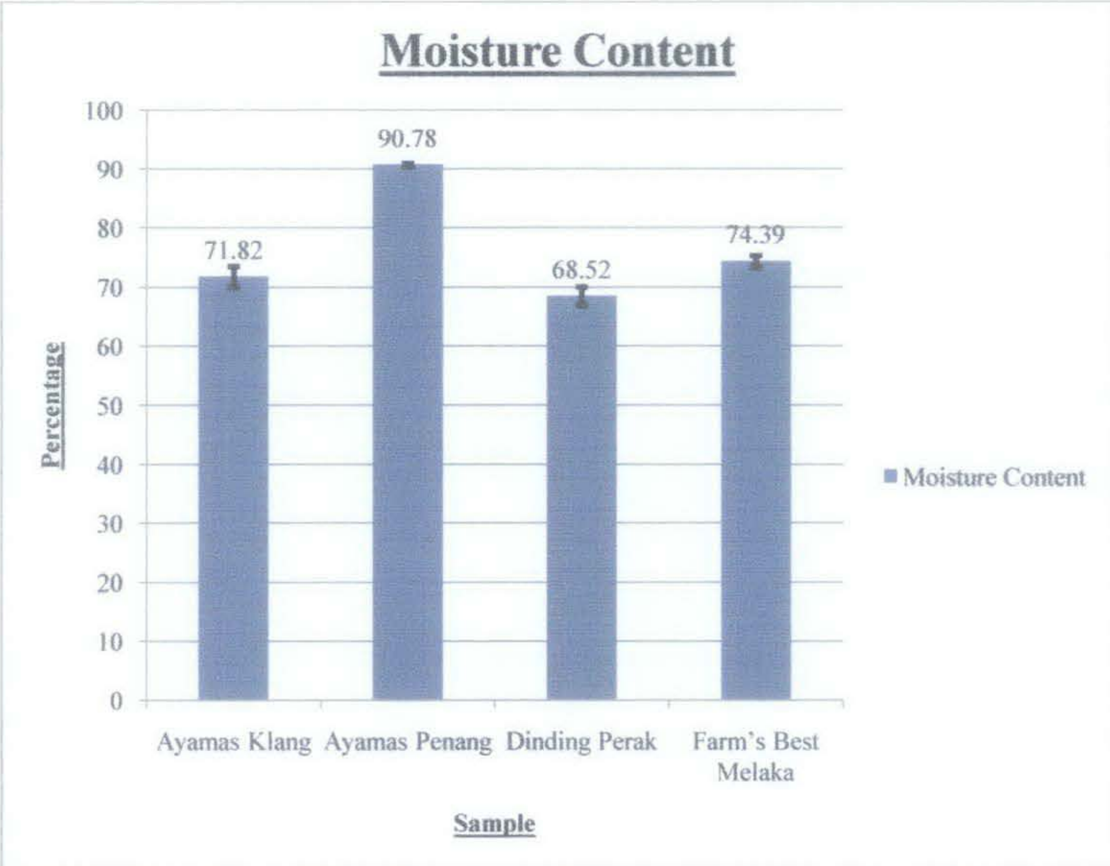


Figure 5: Average moisture content with error bar

4.2 Energy Content

By using the Bomb Calorimeter, the energy content or the calorific value of the waste sludge is determined. After the waste sludge is dried, the waste sludge is then being experimented by using the Bomb Calorimeter. The energy content for every sample and their range of uncertainty are shown in the table 5 and figure 6.

Table 5: Energy content data for all samples

Sample	Ayamas Klang (J/g)	Ayamas Penang (J/g)	Dinding Perak (J/g)	Farm's Best Melaka (J/g)
1	28548	21448	33873	27243
2	28149	21228	34632	27785
3	27138	21439	34091	27400
4	28628	21205	33542	26996
5	27972	21279	32571	27194
6	27770	21799	32949	27083
7	28571	21561	31194	27243
8	28607	21045	34506	27528
9	28758	21533	33876	27602
10	28697	21360	34657	27175
11	29001	21577	34535	27028
12	28637	21553	34326	27462
13	29162	21639	34477	27740
14	28271	21867	34228	27447
15	28236	21733	34445	27414
16	28666	21221	34509	27690
17	28621	21764	33795	27804
18	29441	21994	34451	27963
19	28517	21669	34469	27915
20	28732	21343	33887	27353
21	29498	20994	34140	27180
22	28531	21173	33720	27020
23	29510	21460	33920	27170
24	29406	20837	34130	26840
25	28865	21539	33980	27100
26	29227	21338	33780	27030
27	29439	21488	33880	26950
28	29164	21697	34490	26830
29	29405	21546	34180	26890
30	29418	21859	33810	26660
Average	28752.83	21472.93	33968.10	27291.17
Uncertainty	±2882.80	±2149.14	±3406.66	±2732.07

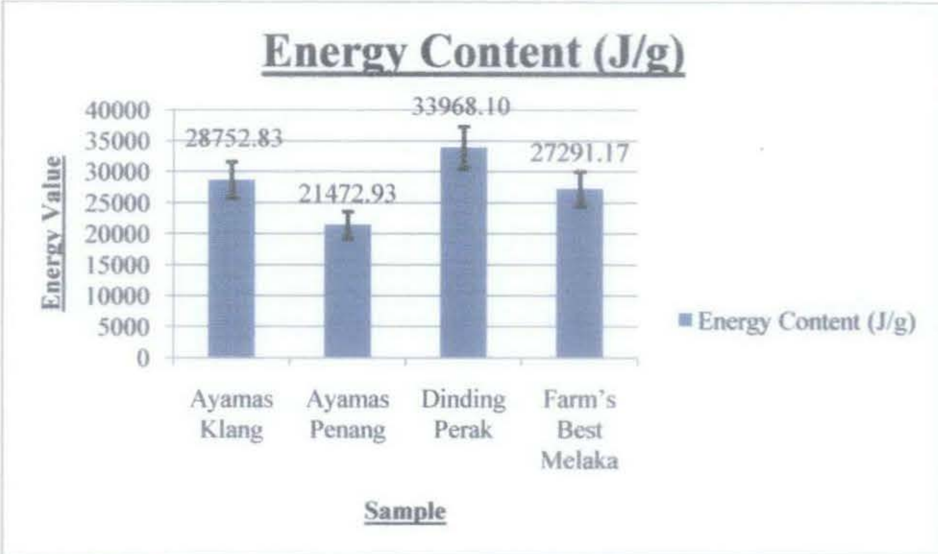


Figure 6: Average energy content value with error bar

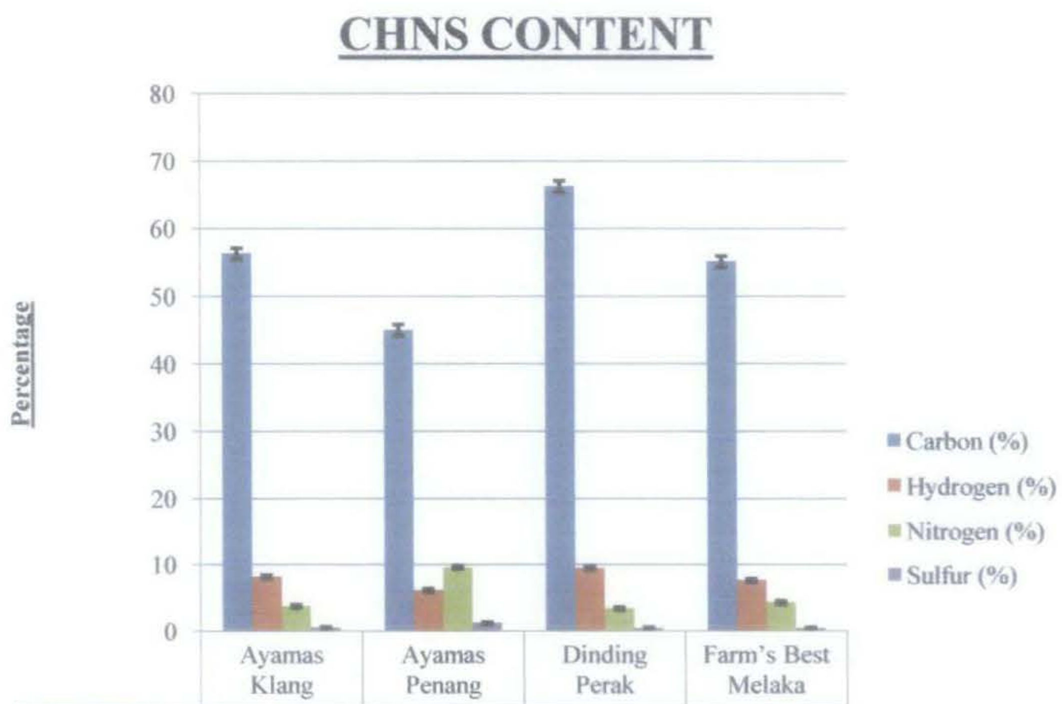
From the result, it shows that the energy content of all samples is relatively high. The samples from Dinding's Perak have the highest average energy content which is 33968.10 Joules per gram while the samples from the Ayamas Penang have the lowest average energy content which is 21472.93 Joules per gram. The samples from the Ayamas Klang and Farm's Best Melaka have the results in between the two factories which are 28752.83 and 27291.17 Joules per gram. All the samples show high amount of energy that can be recovered. All the data gathered from this experiment can be used to determine the parameter in designing the energy recovery potential system plant. The calculation to find the uncertainty for this experiment is shown in Appendix 10.

4.3 Carbon, Hydrogen, Nitrogen and Sulfur Content

After the energy content of the samples is identified, CHNS content of the samples is then determined. The CHNS content of the waste sludge is determined by using the CHNS Analyzer. The percentage of average CHNS content for every sample and their range of uncertainty are shown in the table 6 and figure 7.

Table 6: Average CHNS content value for all samples

Sample	Carbon (%)	Hydrogen (%)	Nitrogen (%)	Sulfur (%)
Ayamas Klang	56.349	8.254	3.816	0.587
Uncertainty	±0.76	±0.27	±0.10	±0.14
Ayamas Penang	45.100	6.217	9.645	1.288
Uncertainty	±0.75	±0.16	±0.16	±0.11
Dinding Perak	66.318	9.538	3.447	0.477
Uncertainty	±0.94	±0.27	±0.15	±0.10
Farm's Best Melaka	55.171	7.668	4.399	0.493
Uncertainty	±0.86	±0.08	±0.12	±0.05



	Ayamas Klang	Ayamas Penang	Dinding Perak	Farm's Best Melaka
Carbon (%)	56.35	45.09	66.32	55.17
Hydrogen (%)	8.254	6.217	9.538	7.668
Nitrogen (%)	3.816	9.645	3.447	4.399
Sulfur (%)	0.587	1.288	0.477	0.493

Figure 7: Average CHNS content with error bar

From the result, it shows that samples from Dinding Perak have the highest average content of carbon (66.32%) while samples from Ayamas Penang have the lowest average content of carbon (45.09%). This can conclude that the higher content of carbon in such sample gives higher energy content. Other than that, all the samples have a low level of Sulfur. This is good because this element can give bad effect on the equipment because it is corrosive. This behavior may cause the equipments in the energy recovery system plant damage. The data gathered from this analysis can be used as parameters and references to design an energy recovery system plant. The calculation to find the uncertainty for this experiment is shown in Appendix 15.

4.4 Estimation of Power Generation

The result from the moisture content and energy content analysis is used to determine the power generation estimation. In the analysis of power generation estimation, steam turbine with an output of 2Megawatts is set to calculate the mass fuel burning rate for the poultry industry waste sludge. The efficiency of the boiler is set to be 85% as taken from the reference [13] due to proper equipment to calculate the efficiency is not available yet. For boiler efficiency calculation, proper boiler needs to be fabricated to burn the poultry industry waste sludge and the product from the combustion need to be analyzed by using gas analyzer. The T-s diagram of the Rankine cycle for the steam turbine and the calculations involved is showed in the next page.

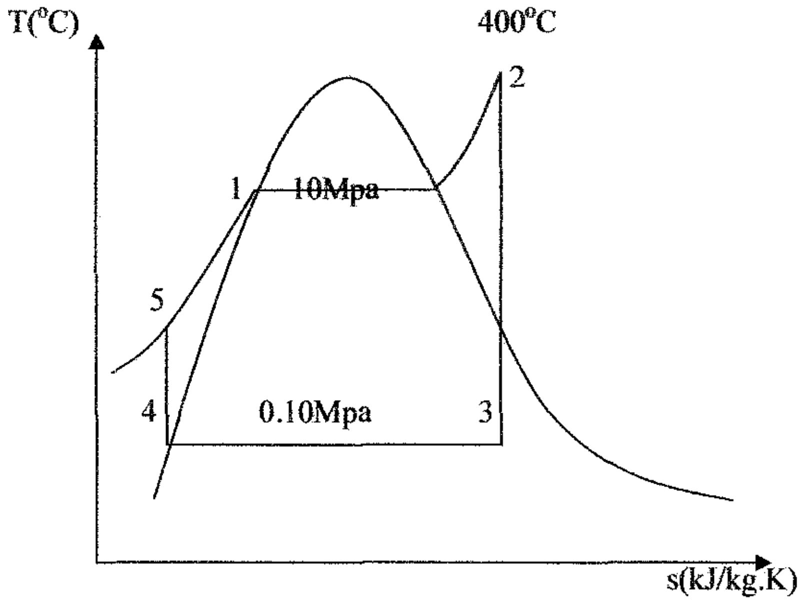


Figure 8: T-s diagram for the Rankine cycle

Mass flow rate for steam, $\dot{m}_s$

$\dot{m}_s\,(h_2-h_3)$ = Power Output = 2Megawatts (MW)

From superheated steam table at T = 400°C, P = 10MPa,

The enthalpy is, h_2 = 3096.50kJ/kg

h_3 is a mixture and can be calculated by using this equation, $h_3 = h_f + x_3 h_{fg}$.

Before that, x_3 must be determined first and it can be calculated from $s_3 = s_f + x_3 s_{fg}$

s_2 = 6.2120kJ/kg.K

$s_2 = s_3$

$s_3 = s_f + x_3 s_{fg}$

At T=100°C, P=0.1013Mpa

s_f= 1.3071kJ/kg.K

s_{fg}= 6.0486kJ/kg.K

so, $x_3 = \frac{(s_3 - s_f)}{s_{fg}}$

$$x_3 = \frac{(6.2120\text{kJ/kg.K} - 1.3071\text{kJ/kg.K})}{6.0486\text{kJ/kg.K}} = 0.8109$$

Calculating for enthalpy, h

$h_3 = h_f + x_3 h_{fg}$

$h_f = 419.00$kJ/kg, $h_{fg} = 2257.00$kJ/kg

$h_3 = 419.00$kJ/kg + 0.8109(2257.00kJ/kg)

$h_3 = 2249.20$kJ/kg

The mass flow rate then,

$\dot{m}_s (h_2 - h_3)$ = Power Output = 2MW

$\dot{m}_s = 2\text{x}10^3$ kW / (3096.50kJ/kg - 2249.20kJ/kg)

$\dot{m}_s = 2.3599$kg/s

<u>Boiler</u>

Fuel burning rate, $\dot{m}_f$

Energy lost by the boiler = Energy gained by the steam

$\dot{m}_f c_v \eta_{boiler} = \dot{m}_s (h_2 - h_5)$

h_5 is compressed liquid. It can be approximated using saturated water table at T=160°C,

$h_5 = 675.5$kJ/kg

from $\dot{m}_f c_v \eta_{boiler} = \dot{m}_s (h_2 - h_5)$

$$\dot{m}_f = \frac{2.3599\text{kg/s}\ (3096.50\text{kJ/kg} - 675.50\text{kJ/kg})}{(33968.10\ \text{kJ/kg})(0.85)}$$

$\dot{m}_f = 0.1979$kg/s

$\dot{m}_f = 0.1970$kg/s x 3600s/h

$\dot{m}_f = 709.20$kg/h

Daily sludge disposal amount 1000kg

About 31% only from total 1000kg of sludge is solid and 69% is water, so

Dried sludge = 0.31(1000kg)

Dried sludge = 310kg

Time = 310kg / 709.20kg/h = 0.44hours

Total power generated = 2MW (0.44h) = 0.88MWh

Therefore, the daily total sludge weight to be disposed which is about 1000kg can be used to generate 2MW electric for about 0.44 hours with the mass fuel burning rate 709.20kg/h.

The calculation above is done for the sample from Ayamas Penang. Below are the details for mass fuel burning rate and total power generated for other poultry factory based on the calculation above.

Table 7: Estimation of power generation data

Sample	**Mass fuel burning rate (kg/h)**	**Time (h)**	**Total power generated (MWh)**
Ayamas Klang	841.572	0.17	0.34
Ayamas Penang	1126.890	0.22	0.44
Dinding Perak	709.200	0.44	0.88
Farm's Best Melaka	886.650	0.18	0.36

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Samples of waste sludge were taken from four poultry industries to be studied on the potential energy that can be recovered. Thirty samples from each industry were experimented and the result is analyzed. From the researches and experiments done, the poultry industry waste sludge have high potential of becoming as a source of biomass energy.

Although the moisture content of the waste sludge is relatively high, they can be dried easily at constant temperature. The time taken to dry the waste sludge also is not very long.

The energy content of the poultry industry waste sludge is considerably high. This shows that poultry industry waste sludge have high potential to become as a biomass energy source.

The CHNS analysis of the samples also shows good indication for the poultry industry waste sludge to become as a biomass energy source. The average carbon content in the samples is significantly high while the average sulfur content is low.

In terms of safety, the sludge from all the four industries is proven to be safe clinically. But, the use of adequate Personal Protective Equipment is advisable to all personnel who are involved avoiding possibilities of any infections.

As a conclusion, there is a relatively high level of energy that can be recovered from poultry industry waste sludge and they have a potential to become as biomass energy source.

5.2 Recommendation

It is recommended that samples from poultry industries other than the four industries should be taken to get a bigger database for the study of energy recovery potential from poultry industry waste sludge that existed in Malaysia. From this larger database, an average of annual amount of waste sludge produced in Malaysia can be determined. This can conclude the actual amount energy that can be recovered from poultry industry waste sludge annually.

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Appendix 1: Weight of samples over times for Ayamas Klang

Sample	Mass, m (g)														Mass loss $\Delta m=m_i-m_f$	Moisture Percentage
	0 min	40 min	80 min	120 min	160 min	200 min	240 min	280 min	320 min	360 min	400 min	440 min	480 min	520 min		
1	21.71	16.53	13.81	11.61	10.28	9.16	8.50	8.11	7.92	7.89	7.85	7.83	7.83	7.83	13.88	63.93
2	22.56	17.18	14.28	11.84	10.54	9.27	8.78	8.59	8.54	8.52	8.45	8.43	8.42	8.39	14.17	62.81
3	20.29	15.20	12.52	10.50	9.52	7.72	7.24	7.13	7.09	7.08	7.04	7.04	7.01	7.01	13.28	65.45
4	17.53	13.33	10.86	9.51	8.02	6.88	6.22	5.71	5.43	5.34	5.33	5.31	5.28	5.28	12.25	69.88
5	20.16	14.66	11.63	9.34	7.70	6.27	5.67	5.49	5.44	5.43	5.39	5.38	5.36	5.36	14.80	73.41
6	19.64	15.51	13.15	11.05	9.66	8.31	7.28	6.62	6.25	6.18	6.13	6.12	6.09	6.09	13.55	68.99
7	20.35	15.29	12.08	9.73	8.08	6.60	5.68	5.09	4.93	4.90	4.85	4.83	4.80	4.80	15.55	76.41
8	21.95	17.49	14.75	12.77	10.88	9.54	8.48	7.45	6.50	5.79	5.48	5.35	5.27	5.27	16.68	75.99
9	20.10	15.66	12.52	10.22	8.71	7.41	6.38	5.62	5.11	5.01	4.97	4.92	4.90	4.90	15.20	75.62
10	20.82	15.92	12.69	10.86	8.99	7.57	6.52	5.69	5.22	4.92	4.86	4.81	4.78	4.78	16.04	77.04
11	23.18	17.91	13.97	11.37	9.40	7.95	6.51	5.68	5.35	5.28	5.24	5.20	5.18	5.18	18.00	77.65
12	21.94	17.03	14.77	12.72	11.38	10.18	9.01	8.28	7.71	7.34	7.16	7.08	7.05	7.05	14.89	67.87
13	16.62	12.94	11.14	9.10	7.69	6.67	5.91	5.54	5.38	5.35	5.31	5.28	5.26	5.26	11.36	68.35
14	18.91	13.22	10.33	8.12	6.54	5.34	4.78	4.64	4.60	4.58	4.54	4.54	4.53	4.53	14.38	76.04
15	20.79	16.33	13.42	10.74	8.95	7.66	6.78	6.24	6.02	5.98	5.96	5.92	5.89	5.89	14.90	71.67
															Average	71.41%

Appendix 2: Weight of samples over times for Ayamas Klang (continue)

Sample	Mass, m (g)														Mass loss $\Delta m = m_i - m_f$	Moisture Percentage
	0 min	40 min	80 min	120 min	160 min	200 min	240 min	280 min	320 min	360 min	400 min	440 min	480 min	520 min		
16	21.13	15.91	13.79	11.16	9.43	8.29	7.51	7.17	7.02	7.01	6.98	6.96	6.96	6.92	14.21	67.25
17	19.37	15.28	12.83	10.25	8.72	7.58	6.63	6.04	5.85	5.82	5.78	5.75	5.75	5.75	13.62	70.31
18	20.02	15.55	12.64	10.25	8.81	7.65	6.65	5.90	5.29	5.09	5.02	4.98	4.94	4.94	15.08	75.32
19	21.71	17.76	15.40	13.32	11.76	10.54	9.45	8.45	7.57	7.08	6.91	6.84	6.82	6.82	14.89	68.59
20	21.19	17.92	14.83	13.15	11.36	10.22	9.36	8.55	7.93	7.38	7.13	6.88	6.77	6.77	14.42	68.05
21	19.47	14.55	12.14	9.82	8.45	7.29	6.11	5.38	4.89	4.83	4.79	4.74	4.72	4.72	14.75	75.76
22	21.83	18.44	14.81	12.76	10.86	9.42	8.41	7.67	7.04	6.69	6.60	6.55	6.51	6.51	15.32	70.18
23	19.44	15.07	11.42	9.04	7.19	6.02	5.43	5.28	5.24	5.20	5.20	5.19	5.16	5.16	14.28	73.46
24	16.46	12.85	9.86	9.53	8.51	7.67	6.89	6.30	5.76	5.49	5.39	5.35	5.32	5.32	11.14	67.68
25	19.93	16.86	13.72	12.07	10.56	9.42	8.64	8.14	7.64	7.27	7.07	6.93	6.87	6.87	13.06	65.53
26	19.47	14.74	12.66	10.96	9.26	8.03	7.32	6.77	6.23	5.86	5.77	5.72	5.68	5.68	13.79	70.83
27	19.54	14.29	11.00	8.71	7.18	5.67	4.80	4.36	4.25	4.22	4.19	4.17	4.16	4.16	15.38	78.71
28	17.37	13.36	10.76	10.27	7.54	6.59	6.00	5.48	5.01	4.73	4.63	4.58	4.54	4.54	12.83	73.86
29	18.93	13.99	10.33	7.39	5.68	4.73	4.15	4.07	4.02	4.01	3.98	3.96	3.96	3.96	14.97	79.08
30	20.10	15.11	10.68	7.79	6.07	5.00	4.45	4.35	4.30	4.28	4.27	4.25	4.25	4.25	15.85	78.86
															Average	72.23%

Appendix 3: Weight of samples over times Ayamas Penang

Sample	Mass, m (g)														Mass loss Δm=m$_i$-m$_f$	Moisture Percentage
	0 min	40 min	80 min	120 min	160 min	200 min	240 min	280 min	320 min	360 min	400 min	440 min	480 min	520 min		
1	20.96	12.3	7.16	4.31	2.67	2.03	1.98	1.98	1.96	1.95	1.95	1.94	1.94	1.94	19.02	90.74
2	21.49	14.31	9.62	6.60	4.41	2.81	2.18	2.07	2.03	2.02	2.01	2.00	2.00	2.00	19.49	90.69
3	19.25	12.24	8.04	5.18	3.14	2.13	1.91	1.89	1.85	1.85	1.85	1.84	1.84	1.84	17.41	90.44
4	21.15	14.14	9.77	6.74	4.42	2.95	2.27	2.14	2.08	2.07	2.06	2.05	2.05	2.05	19.10	90.31
5	17.54	9.70	5.31	3.11	2.01	1.7	1.68	1.68	1.67	1.67	1.67	1.66	1.66	1.66	15.88	90.54
6	20.94	12.78	7.66	4.66	2.88	2.09	2.01	2.01	1.98	1.97	1.97	1.96	1.96	1.96	18.98	90.64
7	20.86	13.36	8.69	5.59	3.50	2.45	2.08	2.01	1.98	1.97	1.96	1.95	1.95	1.95	18.91	90.65
8	20.61	14.14	9.89	6.83	4.48	3.09	2.39	2.06	1.96	1.94	1.93	1.92	1.92	1.92	18.69	90.68
9	19.31	10.97	6.35	3.76	2.57	1.96	1.88	1.88	1.86	1.86	1.85	1.84	1.84	1.84	17.47	90.47
10	24.49	15.55	9.80	6.09	3.72	2.57	2.39	2.38	2.35	2.35	2.34	2.33	2.33	2.33	22.16	90.49
11	23.28	16.24	11.14	7.36	4.83	3.09	2.37	2.23	2.19	2.18	2.17	2.16	2.16	2.16	21.12	90.72
12	20.22	13.29	8.26	5.12	3.22	2.19	1.94	1.93	1.90	1.90	1.89	1.79	1.79	1.79	18.43	91.15
13	19.56	9.47	4.49	2.21	1.84	1.82	1.81	1.81	1.80	1.80	1.29	1.29	1.29	1.29	18.27	93.40
14	20.26	12.13	7.16	4.31	2.52	1.92	2493.7	1.87	1.85	1.85	1.85	1.84	1.84	1.84	18.42	90.92
15	18.57	10.68	5.61	3.27	2.23	1.76	1.73	1.73	1.71	1.70	1.70	1.60	1.60	1.60	16.97	91.38
															Average	90.88%

Appendix 4: Weight of samples over times Ayamas Penang (continue)

Sample	Mass, m (g)														Mass loss $\Delta m = m_i - m_f$	Moisture Percentage
	0 min	40 min	80 min	120 min	160 min	200 min	240 min	280 min	320 min	360 min	400 min	440 min	480 min	520 min		
16	17.94	10.05	5.51	3.27	2.06	1.75	1.70	1.73	1.71	1.71	1.71	1.70	1.70	1.70	16.24	90.52
17	19.62	12.95	7.92	4.98	3.00	1.96	1.83	1.82	1.81	1.80	1.8	1.79	1.79	1.79	17.83	90.88
18	18.93	10.3	4.95	2.61	1.8	1.69	1.67	1.66	1.66	1.66	1.65	1.64	1.64	1.64	17.29	91.34
19	20.24	11.8	6.43	3.62	2.15	1.85	1.83	1.83	1.82	1.81	1.81	1.80	1.80	1.80	18.44	91.11
20	18.78	12.51	7.51	4.48	2.6	1.83	1.73	1.73	1.72	1.71	1.71	1.70	1.70	1.70	17.08	90.95
21	21.85	16.7	11.00	8.13	5.41	3.72	2.69	2.28	2.09	2.06	2.06	2.05	2.05	2.05	19.80	90.62
22	20.15	15.72	11.83	7.52	5.48	3.54	2.64	2.21	1.98	1.93	1.91	1.91	1.91	1.91	18.24	90.52
23	21.57	17.09	13.05	9.09	6.48	4.65	3.35	2.48	2.22	2.17	2.15	2.15	2.15	2.15	19.42	90.03
24	19.79	14.85	11.71	8.02	5.53	3.79	2.69	2.22	1.98	1.92	1.90	1.90	1.90	1.90	17.89	90.40
25	21.77	17.39	12.20	9.19	6.69	4.83	3.94	3.32	2.78	2.37	2.13	2.05	2.02	2.02	19.75	90.72
26	22.10	16.98	11.36	8.44	5.43	3.65	2.77	2.24	2.11	2.08	2.07	2.07	2.07	2.07	20.03	90.63
27	21.59	15.16	11.10	8.47	6.11	3.79	2.72	2.20	2.04	2.01	1.99	1.99	1.99	1.99	19.60	90.78
28	23.65	20.21	17.38	14.61	11.51	8.15	5.96	4.81	3.62	2.83	2.41	2.28	2.27	2.27	21.38	90.40
29	22.72	17.77	13.87	8.79	5.13	3.25	2.41	2.20	2.16	2.14	2.13	2.12	2.12	2.12	20.60	90.67
30	22.53	18.57	12.35	9.99	6.46	4.38	3.33	2.70	2.31	2.13	2.11	2.10	2.10	2.10	20.43	90.68
															Average	90.68%

Appendix 5: Weight of samples over times for Dinding Perak

Sample	Mass, m (g)														Mass loss $\Delta m = m_i - m_f$	Moisture Percentage
	0 min	40 min	80 min	120 min	160 min	200 min	240 min	280 min	320 min	360 min	400 min	440 min	480 min	520 min		
1	19.42	16.04	13.19	11.29	9.66	8.66	7.63	6.77	6.27	5.88	5.69	5.60	5.57	5.57	13.85	71.32
2	19.79	16.40	13.57	11.69	10.05	9.05	8.01	7.14	6.64	6.26	6.05	5.96	5.90	5.90	13.89	70.19
3	19.01	16.36	12.58	10.54	8.85	7.88	6.98	6.34	5.83	5.52	5.37	5.30	5.26	5.26	13.75	72.33
4	18.37	15.10	12.97	12.26	10.44	9.10	8.37	7.55	6.65	6.22	5.78	5.51	5.32	5.32	13.05	71.04
5	19.66	16.51	13.75	11.99	10.49	9.74	8.83	7.94	7.29	6.80	6.44	6.21	6.03	6.03	13.63	69.33
6	21.18	18.40	16.11	14.29	12.82	11.11	10.27	9.55	8.46	7.87	7.24	6.75	6.34	6.34	14.84	70.07
7	16.86	13.36	10.09	8.40	7.05	6.36	5.65	5.29	5.12	5.02	5.00	5.00	4.99	4.99	11.87	70.40
8	19.29	14.28	12.10	10.19	8.60	7.71	6.76	6.13	5.87	5.70	5.67	5.65	5.62	5.62	13.67	70.87
9	19.67	14.98	12.49	10.96	9.98	8.64	7.74	7.11	6.43	6.15	6.00	5.93	5.85	5.85	13.82	70.26
10	19.81	15.02	12.39	11.08	9.68	8.23	7.36	6.68	6.06	5.88	5.78	5.75	5.71	5.71	14.10	71.18
11	20.81	16.22	13.71	12.03	11.08	9.90	9.02	8.16	7.22	6.79	5.86	5.83	5.80	5.80	15.01	72.13
12	20.63	16.04	13.53	11.85	10.90	9.72	8.84	7.98	7.04	6.61	6.27	6.12	6.03	6.03	14.60	70.77
13	18.16	13.49	10.96	9.59	8.59	7.55	6.97	6.29	5.88	5.64	5.36	5.24	5.14	5.14	13.02	71.70
14	17.15	12.79	10.61	9.60	8.90	7.92	7.21	6.69	6.00	5.64	5.31	5.14	5.03	5.03	12.12	70.67
15	22.08	16.30	13.17	11.51	9.76	8.81	7.79	7.21	6.83	6.64	6.59	6.57	6.56	6.56	15.52	70.29
															Average	70.84%

Appendix 6: Weight of samples over times for Dinding Perak (continue)

Sample	Mass, m (g)														Mass loss $\Delta m = m_i - m_f$	Moisture Percentage
	0 min	40 min	80 min	120 min	160 min	200 min	240 min	280 min	320 min	360 min	400 min	440 min	480 min	520 min		
16	19.36	13.96	11.53	10.00	8.97	8.26	7.52	6.77	6.12	5.72	5.49	5.36	5.30	5.30	14.06	72.62
17	19.35	14.83	12.44	10.88	9.90	9.22	8.26	7.38	6.60	6.15	5.82	5.64	5.54	5.54	13.81	71.37
18	21.66	15.62	12.98	11.38	10.30	9.55	8.70	7.89	7.14	6.68	6.31	6.10	5.97	5.97	15.69	72.44
19	18.91	13.34	11.39	10.34	9.47	8.85	7.96	7.15	6.44	6.02	5.63	5.44	5.29	5.29	13.62	72.03
20	22.22	18.28	14.46	13.03	12.06	11.36	10.43	9.56	8.65	8.12	7.50	7.04	6.69	6.69	15.53	69.89
21	31.67	27.44	24.59	22.54	20.85	19.25	17.62	16.14	14.82	13.47	12.55	11.96	11.45	11.45	20.21	63.83
22	34.62	30.48	27.83	25.73	24.12	22.52	20.96	19.58	18.31	16.92	15.82	14.96	13.57	13.57	21.05	60.81
23	39.57	35.82	33.16	31.17	29.59	28.06	26.66	25.53	24.22	22.72	21.25	20.03	17.85	17.85	21.72	54.90
24	24.85	20.98	18.99	17.25	15.67	14.34	13.12	11.96	11.06	10.16	9.45	8.95	8.50	8.50	16.35	65.81
25	26.10	22.64	20.46	18.76	17.12	15.83	14.49	13.46	12.43	11.43	10.60	10.02	9.44	9.44	16.66	63.82
26	37.20	31.07	27.57	25.01	22.72	20.64	18.89	17.26	15.93	14.75	13.68	13.00	12.27	12.27	24.93	67.02
27	29.33	24.50	21.61	19.41	17.76	15.94	14.41	13.16	11.99	11.23	10.60	10.48	10.39	10.39	18.94	64.57
28	29.57	25.81	23.53	21.87	20.31	18.97	17.50	16.23	14.98	13.72	12.60	11.68	10.58	10.58	18.99	64.23
29	23.26	19.44	16.97	15.17	13.60	12.21	11.00	9.97	9.11	8.44	7.96	7.75	7.60	7.60	15.66	67.32
30	32.10	27.72	25.49	23.66	31.07	20.49	18.92	17.55	16.50	15.16	14.08	13.18	12.11	12.11	19.99	62.29
															Average	66.20%

Appendix 7: Weight of samples over times for Farm's Best Melaka

Sample	Mass, m (g)														Mass loss $\Delta m = m_i - m_f$	Moisture Percentage
	0 min	40 min	80 min	120 min	160 min	200 min	240 min	280 min	320 min	360 min	400 min	440 min	480 min	520 min		
1	20.34	14.91	12.23	9.92	7.43	6.06	5.22	4.67	4.47	4.31	4.22	4.16	4.11	4.11	16.23	79.79
2	22.39	15.57	12.38	10.46	7.92	6.74	6.10	5.70	5.45	5.28	5.16	5.10	5.03	5.03	17.36	77.53
3	22.29	15.22	12.20	10.47	8.50	7.51	6.93	6.45	6.23	6.02	5.87	5.81	5.14	5.14	17.15	76.94
4	23.40	19.33	16.92	14.41	11.34	9.07	7.77	6.82	6.18	5.85	5.60	5.49	5.36	5.36	18.04	77.09
5	20.53	7.59	12.64	10.93	8.40	7.07	6.04	5.32	4.79	4.50	4.29	4.17	4.03	4.03	16.50	80.37
6	19.30	11.67	8.94	7.19	5.69	5.04	4.65	4.47	4.35	4.26	4.21	4.20	4.15	4.15	15.15	78.50
7	19.97	14.96	12.80	10.57	8.65	7.38	6.62	6.05	5.58	5.19	4.98	4.85	4.75	4.75	15.22	76.21
8	20.84	15.34	13.00	11.12	9.38	8.23	7.44	6.78	6.30	5.93	5.65	5.53	5.45	5.45	15.39	73.85
9	23.27	15.76	12.21	10.16	8.45	7.63	7.10	6.86	6.73	6.60	6.56	6.52	6.46	6.46	16.81	72.24
10	19.67	13.56	10.22	8.31	7.05	6.10	5.56	5.14	4.80	4.65	4.59	4.53	4.50	4.50	15.17	77.12
11	19.07	13.42	10.79	9.00	7.61	6.49	5.88	5.37	5.01	4.89	4.86	4.82	4.74	4.74	14.33	75.14
12	22.24	17.81	15.62	13.55	11.84	10.54	9.43	8.46	7.58	7.00	6.61	6.35	6.20	6.20	16.04	72.12
13	23.06	16.97	13.12	10.50	8.51	7.52	6.93	6.59	6.33	6.24	6.20	6.17	6.11	6.11	16.95	73.50
14	17.85	14.65	11.94	10.17	8.42	7.28	6.48	5.64	5.14	4.95	4.86	4.81	4.74	4.74	13.11	73.45
15	21.31	14.85	11.73	9.63	8.10	7.03	6.45	5.96	5.77	5.66	5.61	5.58	5.52	5.52	15.79	74.10
															Average	75.86%

Appendix 8: Weight of samples over times for Farm's Best Melaka (continue)

Sample	Mass, m (g)														Mass loss $\Delta m = m_i - m_f$	Moisture Percentage
	0 min	40 min	80 min	120 min	160 min	200 min	240 min	280 min	320 min	360 min	400 min	440 min	480 min	520 min		
16	20.98	13.03	10.47	8.61	8.89	6.68	5.83	5.23	5.10	5.02	4.98	4.95	4.92	4.92	16.06	76.55
17	20.54	14.11	11.55	9.72	7.81	6.73	6.12	5.84	6.66	5.55	5.46	5.41	5.25	5.25	15.29	74.44
18	19.07	12.81	11.93	10.88	7.40	6.41	5.97	5.57	5.32	5.25	5.22	5.20	5.15	5.15	13.92	72.99
19	22.23	17.31	12.88	10.84	9.12	8.00	7.24	6.66	6.32	6.23	6.15	6.11	6.05	6.05	16.18	72.78
20	24.51	19.32	16.85	14.25	11.40	9.86	8.79	8.07	7.46	7.21	7.04	6.95	6.85	6.85	17.66	72.05
21	20.98	14.89	12.39	10.56	8.71	7.66	6.74	5.99	5.75	5.68	5.58	5.54	5.49	5.49	15.49	73.81
22	21.28	13.98	10.64	8.41	7.12	6.46	5.87	5.60	5.55	5.52	5.44	5.42	5.39	5.39	15.89	74.67
23	20.43	13.46	10.70	8.46	7.01	6.33	5.84	5.57	5.50	5.47	5.40	5.36	5.33	5.33	15.10	73.90
24	16.01	9.82	7.70	6.26	5.17	4.89	4.75	4.63	4.58	4.58	4.53	4.50	4.49	4.49	11.52	71.95
25	17.16	11.64	8.94	7.06	5.99	5.33	5.03	4.87	4.83	4.83	4.75	4.72	4.72	4.72	12.45	72.52
26	15.36	10.42	8.65	7.36	6.26	5.63	4.99	4.68	4.59	4.56	4.46	4.43	4.41	4.41	10.95	71.27
27	16.13	11.67	9.54	7.97	6.63	5.87	5.26	4.83	4.74	4.73	4.67	4.62	4.59	4.59	11.53	71.51
28	11.83	8.40	6.23	4.93	4.20	3.86	3.64	3.51	3.47	3.46	3.41	3.31	3.30	3.30	8.53	72.10
29	14.82	11.39	8.69	6.68	5.53	4.96	4.53	4.29	4.24	4.22	4.15	4.14	4.12	4.12	10.71	72.23
30	14.85	11.69	9.06	7.67	6.43	5.78	5.19	4.58	4.51	4.46	4.39	4.36	4.32	4.32	10.53	70.90
															Average	72.91%

Appendix 9: Calculation detail for moisture content

Component	Ayamas Klang	Ayamas Penang	Dinding Perak	Farm's Best Melaka
Standard deviation	4.6567	0.5643	4.1516	2.5400
Bias error	1.74	0.21	1.55	0.95
Uncertainty	±1.74	±0.21	±1.55	±0.95

The standard deviation is calculated by using the equation below:

Standard deviation = $\sqrt{\frac{1}{n}\sum(x-\bar{x})^2}$

n = number of sample

x = actual reading of every samples

$\bar{x}$ = average reading of samples

Bias error = $t_{\frac{\alpha}{2}}\ x\ \frac{s}{\sqrt{n}}$

$t_{\frac{\alpha}{2}}$ = student t value

α = confidence level

s = standard deviation

n = number of sample

Uncertainty (RSS) = $\sqrt{(bias\ error)^2}$

*Precision error = non-applicable for this equipment

*Calibration error = non-applicable for this equipment

Appendix 10: Uncertainty calculation for energy content

Component	Ayamas Klang	Ayamas Penang	Dinding Perak	Farm's Best Melaka
Standard deviation	557.0369	238.5252	693.4644	340.0680
Bias error	207.97	89.057	258.915	126.969
Precision error	2875.283	2147.293	3396.810	2729.117
Calibration error	1.328	1.328	1.328	1.328
Uncertainty	±2882.80	±2149.14	±3406.66	±2732.07

The standard deviation is calculated by using the equation below:

Standard deviation = $\sqrt{\frac{1}{n}\sum(x-\bar{x})^2}$

n = number of sample

x = actual reading of every samples

$\bar{x}$ = average reading of samples

Bias error = $t_{\frac{\alpha}{2}}\, x\, \frac{s}{\sqrt{n}}$

$t_{\frac{\alpha}{2}}$ = student t value

α = confidence level

s = standard deviation

n = number of sample

Precision error = precision of equipment = ±0.01

Calibration error = $\frac{\text{standard sample reading} - \text{standard sample actual reading}}{\text{standard sample reading}}$ x 100%

Uncertainty (RSS) = $\sqrt{(bias\ error)^2 + (precision\ error)^2 + (calibration\ error)^2}$

Appendix 11: CHNS data for Ayamas Klang

Sample from Ayamas Klang				
Sample	Carbon (%)	Hydrogen (%)	Nitrogen (%)	Sulfur (%)
1	52.61	9.096	4.122	1.348
2	54.49	8.693	3.857	1.347
3	56.03	8.486	4.381	1.235
4	54.31	7.273	3.728	0.262
5	56.25	9.234	3.794	1.166
6	55.55	8.491	4.307	0.946
7	55.81	8.247	3.776	0.760
8	55.85	8.027	3.456	0.555
9	56.60	7.941	4.247	0.456
10	57.30	7.855	3.767	0.306
11	57.64	8.081	3.718	0.396
12	57.56	8.050	3.416	0.309
13	56.93	7.869	3.442	0.258
14	64.43	9.105	3.802	0.375
15	58.15	8.018	3.750	0.143
16	56.31	7.763	3.802	0.234
17	56.62	7.690	3.999	0.476
18	59.66	8.438	3.468	0.277
19	54.39	7.352	4.376	0.237
20	54.08	7.392	3.699	0.235
21	56.25	10.60	3.578	1.044
22	56.04	9.469	3.768	1.054
23	57.00	9.061	3.583	0.924
24	55.60	8.340	3.791	0.673
25	54.18	7.852	3.983	0.567
26	56.46	7.998	4.039	0.481
27	56.46	7.954	3.550	0.403
28	55.16	7.588	3.779	0.337
29	56.32	7.911	3.565	0.422
30	56.43	7.757	3.931	0.385
Average	56.35	8.25	3.82	0.59

Appendix 12: CHNS data for Ayamas Penang

Sample from Ayamas Klang				
Sample	Carbon (%)	Hydrogen (%)	Nitrogen (%)	Sulfur (%)
1	52.61	9.096	4.122	1.348
2	38.71	7.074	8.200	1.064
3	45.30	7.476	9.594	0.511
4	45.38	7.04	9.625	0.728
5	45.06	6.813	9.710	1.775
6	45.67	6.567	9.736	2.074
7	41.54	5.833	8.909	1.125
8	49.06	6.793	10.460	1.804
9	44.52	6.182	9.888	1.028
10	45.11	6.003	9.686	1.357
11	45.16	6.054	9.767	1.308
12	45.42	6.015	9.744	1.443
13	45.19	6.080	9.808	1.476
14	46.09	5.993	9.928	1.364
15	47.75	6.084	9.762	1.539
16	45.78	6.116	9.772	1.478
17	44.04	5.847	9.517	1.442
18	43.071	5.807	9.332	1.357
19	45.89	6.082	9.630	1.278
20	45.22	6.039	9.728	1.281
21	45.15	6.027	9.744	1.005
22	50.33	6.653	10.640	1.558
23	46.55	6.184	9.893	1.264
24	43.51	5.862	8.876	1.160
25	44.86	6.038	9.852	1.090
26	45.30	6.153	9.781	1.244
27	45.65	6.123	9.554	1.312
28	44.52	5.899	9.559	0.999
29	43.12	5.866	9.670	1.245
30	45.40	6.060	9.728	1.322
Average	45.10	6.22	9.65	1.29

Appendix 13: CHNS data for Dinding Perak

Sample from Ayamas Klang				
Sample	Carbon (%)	Hydrogen (%)	Nitrogen (%)	Sulfur (%)
1	62.38	8.979	3.571	0.288
2	64.61	9.499	2.922	0.476
3	65.04	10.96	3.029	0.986
4	58.99	9.539	4.690	0.714
5	64.65	10.21	3.348	0.640
6	64.21	9.733	3.043	0.441
7	67.51	10.07	3.020	0.407
8	65.43	9.618	2.903	0.235
9	66.33	9.425	3.125	0.152
10	66.35	9.559	2.644	0.239
11	68.94	11.80	3.565	1.136
12	68.30	10.87	3.574	1.040
13	68.27	10.25	3.979	0.723
14	65.85	9.505	4.188	0.691
15	67.14	9.482	3.193	0.417
16	66.72	8.996	3.378	0.239
17	70.19	9.660	3.242	0.385
18	68.50	9.147	3.300	0.240
19	68.17	9.266	3.122	0.300
20	74.14	10.02	3.308	0.275
21	65.86	9.303	3.647	0.841
22	65.34	9.119	3.703	0.451
23	65.69	8.992	3.706	0.442
24	66.29	9.006	3.766	0.285
25	66.29	9.105	3.487	0.673
26	66.53	9.119	3.473	0.458
27	65.14	8.474	3.781	0.198
28	65.24	8.821	3.553	0.471
29	65.54	8.822	3.506	0.249
30	65.90	8.793	3.645	0.239
Average	66.32	9.54	3.45	0.48

Appendix 14: CHNS data for Farm's Best Melaka

Sample from Ayamas Klang				
Sample	Carbon (%)	Hydrogen (%)	Nitrogen (%)	Sulfur (%)
1	52.09	7.630	4.387	0.440
2	53.30	7.828	4.002	0.668
3	53.23	7.470	4.039	0.137
4	51.06	7.482	4.668	0.400
5	51.77	7.503	4.467	0.369
6	52.59	7.496	4.255	0.553
7	52.62	7.684	4.259	0.576
8	52.34	7.362	3.940	0.323
9	53.32	7.580	3.634	0.626
10	51.27	7.317	4.550	0.331
11	55.46	7.595	4.504	0.584
12	55.36	7.357	4.787	0.259
13	56.20	7.437	4.335	0.463
14	55.55	7.578	4.607	0.675
15	56.39	7.823	4.500	0.510
16	56.14	7.804	4.494	0.485
17	59.84	7.924	5.010	0.439
18	57.44	7.845	4.512	0.645
19	56.56	7.553	4.164	0.554
20	54.12	7.685	5.053	0.448
21	55.29	7.638	4.667	0.347
22	56.67	8.087	4.444	0.429
23	57.95	7.847	4.571	0.739
24	56.41	7.755	4.237	0.482
25	57.81	7.503	4.103	0.403
26	57.85	8.125	4.363	0.638
27	54.69	7.694	4.937	0.435
28	56.64	7.891	4.039	0.417
29	58.62	7.899	4.096	0.820
30	56.56	7.651	4.331	0.604
Average	55.17	7.67	4.40	0.49

Appendix 15: Uncertainty calculation for CHNS Analysis

Ayamas Klang				
Component	**Carbon**	**Hydrogen**	**Nitrogen**	**Sulfur**
Standard deviation	2.0259	0.7108	0.2658	0.36244
Bias error	0.7564	0.2654	0.0992	0.1353
Uncertainty	±0.7564	±0.2654	±0.0992	±0.1353

Ayamas Penang				
Component	**Carbon**	**Hydrogen**	**Nitrogen**	**Sulfur**
Standard deviation	2.0114	0.4234	0.4296	0.3036
Bias error	0.75	0.16	0.16	0.11
Uncertainty	±0.75	±0.16	±0.16	±0.11

Dinding Perak				
Component	**Carbon**	**Hydrogen**	**Nitrogen**	**Sulfur**
Standard deviation	2.5045	0.7115	0.4071	0.26177
Bias error	0.94	0.27	0.15	±0.1
Uncertainty	±0.94	±0.27	±0.15	±0.1

Farm's Best Melaka				
Component	**Carbon**	**Hydrogen**	**Nitrogen**	**Sulfur**
Standard deviation	2.3142	0.2045	0.3191	0.1461
Bias error	0.86	0.08	0.12	0.05
Uncertainty	±0.86	±0.08	±0.12	±0.05

The standard deviation is calculated by using the equation below:

Standard deviation = $\sqrt{\frac{1}{n}\sum(x-\bar{x})^2}$

n = number of sample

x = actual reading of every samples

$\bar{x}$ = average reading of samples

Bias error = $t_{\frac{\alpha}{2}}\, x\, \frac{s}{\sqrt{n}}$

$t_{\frac{\alpha}{2}}$ = student t value

α = confidence level

s = standard deviation

n = number of sample

Uncertainty (RSS) = $\sqrt{(bias\ error)^2}$

*Precision error = non-applicable for this equipment

*Calibration error = non-applicable for this equipment