VOT 75186

COMBUSTION BEHAVIOUR OF POULTRY AND PLASTICS WASTE IN AS BENCH SCALE COMBUSTOR

(SIFAT PEMBAKARAN SISA BUANGAN AYAM DAN PLASTIK DALAM PEMBAKAR SKALA MEJA)

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UNIVERSITI TEKNOLOGI MALAYSIA

2006

ACKNOWLEDGEMENT

I would like to take this opportunity to extend my sincere thanks and appreciation to the following persons who have directly or indirectly given me contribution towards the success of this research.

First to my research team, Associate Profesor Hanizam Sulaiman and Dr. Abdul Razak Rahmat without them this research project cannot be completed successfully. The author wish to thank the staff of Pihak Berkuasa Pasir Gudang (PBT), because of their permission of collecting MSW sample at Pasir Gudang Landfill especially En. Mohd Yusuf Wahab, En. Ali and En Razman. I would also like to thank the Research Management Center, Universiti Teknologi Malaysia for financial support under Fundemental Research Grant VOT75186.

Last but not least, I would like to thank all those people around me including my family, my research team and friends who had been very supportive and thoughtful.

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(Keywords: Poultry Waste, Plastic Waste, Energy Recovery, Combustion Behaviour)

Nowadays, combustion municipal solid waste (MSW) with energy recovery is the most popular method to decrease the usage of landfill. It is another alternative to overcome landfill site scarcity beside material reuse and recycling. Recently, combustion poultry for the purpose of energy recovery was the best method to dispose of animal by product such as poultry. To substitute coal as fuel, MSW and poultry were compacted into pellet to identify fuel characteristics from this fuel. The purpose of this study is to study the effect of poultry on fuel characteristics of MSW. In this study, poultry and MSW will be mixed with five types of mixtures on a weight basis (0 %, 25 %, 35 %, 50%, 70% of poultry). Both the poultry and MSW were crushed to a uniform powder. Poultry were mixed with MSW and made into pellets using hand held pelletizer. These pellets size were 27 mm in diameter and 15 mm in length. The pellet weighed was roughly 5 g. All the mixtures were pelleted to a compaction ratio 1:5. The pellet was sent to the furnace to determine ash content and volatile matter. Calorific value was determined using bomb calorimeter. Volatile matter, residual moisture content and calorific value increased with increasing percentage of poultry in pellet fuel. Ash content decreased with increasing percentage of poultry in pellet fuel. Therefore, inclusion poultry to MSW pellet fuel enhanced properties of fuel. 35 wt % is the minimum percentage of poultry to MSW pellet fuel produced fuel with good properties.

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Pembakaran bahan buangan perbandaran bagi tujuan pemulihan tenaga adalah cara yang sangat popular pada masa kini. Ini merupakan salah satu cara untuk mengurangkan penggunaan tempat bagi bahan buangan selain penggunaan semula barangan dan kitar semula. Selain itu, pembakaran adalah cara yang terbaik untuk melupuskan bahan sisa dan sampingan daripada haiwan seperti ayam. Tujuan ujikaji ini adalah untuk mengkaji kesan daging ayam ke atas bahan bakar daripada bahan buangan perbandaran untuk menghasilkan bahan bakar yang mempunyai ciri-ciri yang baik. Dalam ujikaji ini, bahan bakar daripada bahan buangan perbandaran yang mengandungi 0%, 25 %, 35 %, 50%, 70% daging dihasilkan. Ayam dan bahan buangan perbandaran dikisar menjadi serbuk dan dimampatkan dengan nisbah mampatan 1:5 untuk membentuk peluru kecil. Peluru kecil bahan bakar ini mempunyai diameter 27mm dan panjangnya 15mm dan mempunyai berat 5 g. Bahan bakar ini dibakar di dalam relau untuk menentukan jumlah bahan yang meruap dan kandungan abu. Jumlah tenaga ditentukan menggunakan kalorimeter bom. Didapati, jumlah bahan yang meruap, baki kandungan lembapan dan jumlah tenaga meningkat dengan meningkatnya peratus pertambahan daging ayam ke dalam bahan bakar daripada bahan buangan perbandaran. Kandungan abu menurun dengan pertambahan peratus daging ke dalam bahan bakar daripada bahan buangan perbandaran. Maka, pertambahan daging ayam dapat menghasilkan bahan bakar yang mempunyai ciri-ciri yang baik. 35 % daging ayam adalah nilai minimum untuk menambahkan daging ke dalam bahan bakar dari bahan buangan perbandaran untuk menghasilkan bahan bakar yang baik.

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LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLE

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

Municipal Solid Waste (MSW) is defined as all waste under the control of local authorities or agents on their behalf. It includes all household waste, street litter, waste delivered to council recycling points, municipal parks and garden waste, council office waste, civic amenity waste and some commercial waste from shops and small traders (Charles A. Ambrose, 2002).

Daniel Hoornweg *et al.* (1999) defined waste as any unwanted material intentionally thrown away for disposal. However, certain wastes may eventually become resources valuable to others once they are removed from the waste stream. MSW includes wastes generated from residential, commercial, industrial, institutional, construction and demolition, process and municipal services.

Waste composition is also influenced by external factors, such as geographical location, the population's standard of living, energy source, and weather. Waste composition indicates the components of the waste stream given as a percentage of the total mass or volume. The component categories used are compostables (includes food, yard, and wood wastes), paper, plastic, glass, metal, and the others includes ceramics, textiles, leather, rubber, bones, inerts, ashes, coconut husks, bulky wastes, household goods (Hani *et al.,* 1992).

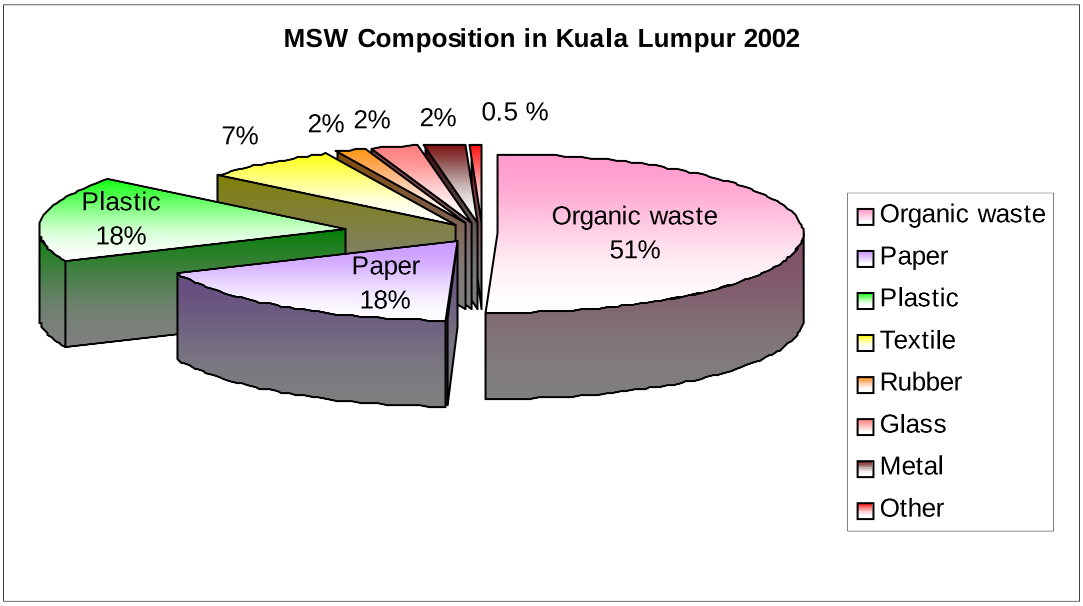

Figure 1.1: MSW composition in Kuala Lumpur 2002 (Cheah, C. W., 2003)

MSW composition in Kuala Lumpur are divided into 8 categories and they are organic waste, paper product, plastic, textile, rubber, glass, metal, and the others. Other category is defined as miscellaneous or beside the other major components.

According to Figure 1.1, 18 % from the total composition of MSW in Kuala Lumpur is plastic. Organic waste is the major composition in MSW. While rubber, glass and metal have similar percentage, 2% for each category.

Table 1.2 indicates that MSW in Malaysia is high in plastic content compared to other countries. In year 2002, 18% of MSW in Malaysia was plastics. Thailand contributed 11 wt % plastic waste in MSW composition (Somtip and Cherdchan, 1998). Plastic waste in India is around 7 wt% from total amount of MSW in this country. China only produced low plastic waste content 4.5 wt % from total composition. It can be proved with increasing efficiencies of the new incinerators in China. The incinerators in China were impressed by their ability to remove particulates and harmful gases.

Table 1.1: Comparison of MSW composition between Kuala Lumpur with other cities.

Composition of MSW	**Kuala Lumpur 2002 (Cheah, C.W.)**	**Hat Yai 1996 (Somtip and Cherdchan, 1998)**	**India 1999 (Pieter, 1999)**	**China 1998 (Henderson, et. al, 2000)**
Organic Waste (wt %)	50.54	51.36	42.60	60.00
Paper (wt %)	17.67	18.48	16.50	3.10
Plastic (wt %)	17.57	10.86	6.70	4.50
Textile (wt %)	7.18	1.34	0.00	1.30
Rubber (wt %)	1.86	1.07	9.90	0.00
Glass (wt %)	2.34	5.04	2.90	0.80
Metal (wt %)	2.38	2.43	1.50	0.30
Other (wt %)	0.46	9.42	19.90	30.00

The increasing amount of MSW generated in our society causes landfill site scarcity. Increasing of population and urbanization process are significant factors contributed to MSW generation rapid increase. Material reuse, recycling and combustion with energy recovery are some of the methods used to reduced MSW.

Combustion of MSW with energy recovery is known as waste to energy system (WTE). However, the large variety in MSW composition and differences in thermal degradation behaviour of MSW components makes waste to energy system a challenge.

Recently, Avian influenza virus mostly found in birds especially chicken, also can infect humans is spreading around the world. Avian influenza virus usually refers to influenza A viruses found chiefly in birds, but infections can occur in humans. It is known as bird flu disease. Due to this problem, the disposal of the infected poultry is currently being addressed. One such disposal option is the combustion poultry for the purpose of energy recovery. One of the main objectives in combustion of poultry is to ensure that any living organism is totally destroyed during the process. Poultry waste has good fuel properties compared with conventional fuels such as wood that has an average calorific value of 6000 btu/lb (13.9 MJ/kg). Poultry has high ash content, averaging between 13.8 and 33.1 %.

1.1 Objectives

The objectives of this study as follows;

i. To study the effect of poultry on the fuel characteristics of MSW with high plastic content.

ii. To determine the minimum inclusion rate of poultry to MSW pellets to produce fuel with good properties.

1.2 Scope

Poultry was obtained from a wet market while MSW was collected from Pasir Gudang Landfill site. Both the poultry and MSW were crushed to a uniform powder with maximum particle size of 0.5 mm^2. In this study, five types of mixtures of poultry and MSW on a weight basis were made (0 %, 25 %, 35 %, 50%, 70% of poultry). Poultry were mixed with MSW and made into pellets using hand held pelletizer. These pellets size were 27 mm in diameter and 15 mm in length. The pellet weighed was roughly 5 g. All the mixtures were pelleted to a compaction ratio 1:5. The pellet was sent to the furnace to determine ash content and volatile matter. Calorific value was determined using bomb calorimeter.

CHAPTER 2

LITERATURE REVIEW

The generation of excessive amounts of waste per capita is a main problem to all developed countries. As increasing of population, the amount of waste material generated has increased to a level that is unsustainable. In many cases, this has led to the closure of landfills and the introduction of strategies that incorporate several waste handling steps such as waste separation, waste recycling and energy recovery. The stages that have to be considered when handling wastes are prevention of the generation of waste, reuse of waste materials for new products, incineration waste with energy recovery and land filling or disposal.

2.1 MSW With High Plastic Content

Waste composition is also influenced by external factors, such as geographical location, the population's standard of living, energy source, and weather. Composition of waste as described by Thailand Pollution Control Department (1998) is divided onto compostables, paper, plastics, glass, metal and others.

Plastics contribute to an increasing volume in the solid waste stream. A study in 2002 by Cheah (2002) shows that, average plastic in MSW is about 17.57 % by weight. Table 2.1 shows the amount of plastics in MSW in Malaysia. From the table, it can conclude that amount of plastic waste in MSW range from 16 – 19 wt % from July 2001 until Jun 2002.

Table 2.1: Composition of plastics in MSW in Malaysia 2002 (Cheah, C. W., 2002)

Year	**Plastics in MSW (%)**
July 2001	18.59
August 2001	16.09
September 2001	15.90
October 2001	17.97
November 2001	18.34
December 2001	18.05
January 2002	16.95
February 2002	18.47
March2 002	16.63
April 2002	17.80
May 2002	18.03
Jun 2002	18.03

2.2 Incineration of MSW

Destroying waste through incineration has been practiced for many years. In the mid-1800s, waste incinerators were in common use in England and as early as 1896 the streets of Oldham were lit by electricity generated from waste. Today, waste disposal by incineration is common in many developed countries.

Table 2.2 shows percentage incineration of MSW in 1993 in many developed countries. 79 % municipal waste was incinerated in Switzerland. Incineration MSW was obviously applied to Japan and Denmark as 72 % and 65 % respectively from total weight of waste was incinerated in these countries. (M. Morris and L. Waldheim, 1998).

Table 2.2: Percentage of Municipal Waste Incinerated (1993)

Countries	**Percentage of municipal waste incinerated (1993) %**
Switzerland	79
Japan	72
Denmark	65
Sweden	59
The Netherlands	39
Germany	22
Italy	17
USA	16
Spain	6
United Kingdom	5

Incineration of MSW has many advantages such as significant volume reduction (about 90%) and mass reduction (about 70%), complete disinfections and energy recovery (Elliott P., and Booth R., 1996).

Thus, incineration meets the requirements of detoxification, decrement and resource recovery. In addition, these methods have been technically proven as an effective waste treatment approach. Therefore, most cities in China have constructed MSW incineration plants. For instance, Shenzhen, Beijing and Shanghai have constructed mass burning incinerators and pyrolytic incinerators, while Wuhan, Guangzhou and Shenyang plan to construct incineration devices. Japanese built the first MSW incineration plant in Shenzhen, China (Barducci G., 1991).

However, incineration of MSW produces significant pollutant flue gases and gives rise to considerable amount of solid residues. However, the hazardous fractions in MSW are concentrated in the solid residues. Indeed, pollutant elements such as As, Cd, Cu, Cr, Hg, Ni, Pb and Zn have been described in such residues (Barducci G. *et. al*., 1995). If such elements released during storage, it gaves a potentially negative impact on environmental quality, human health and groundwater as well as surface-water resources (Barducci G. *et. al*., 1995).

Another important way to manage solid waste is to recover the energy value of products after their useful life. One such method involves combustion of MSW or garbage in waste to energy facilities. Modern energy recovery facilities burn solid waste in special combustion chambers, and use the resulting heat energy to generate steam and electricity.

The gasification process has been developed to produce electricity. Waste gasification is an economical and environmentally thermal processing alternative to the well established process of waste incineration with energy recovery (Niessen, W.R., and Marks, C.H., 1996). This process generated steam from fuel such as biomass and solid wastes (M. Morris and L. Waldheim, 1998).

These energy recovery facilities are designed to achieve high combustion temperatures that help MSW burn cleaner and create less ash for disposal. Modern air pollution control devices are used to control and reduce potentially harmful particulates and gases from incinerator emissions.

2.3 Plastic waste as fuel substitute

Plastic waste has high calorific value. However, high calorific value, leads to decreased incineration capacity if the incinerator is ‘heat limited’. Plastics are also generally considered a benefit in MSW incineration as a fuel that is low in ash and moisture (Mark, F.E., 1994). Table 2.3 is the conclusion adapted from Mark, F. E. (1994) about the role of plastics in MSW combustion.

Based on Table 2.3, plastics provide high energy content, low ash and moisture content in MSW incineration. It shows that we can burn MSW with high plastics contents use its heat energy to produce steam. Plastic combustion produces volatiles, which ignite quite easily. Also the low moisture levels in plastics means that the heat requirements to raise the material temperature is low.

Table 2.3: Combustion data for components of Municipal Solid Waste. (Mark, F.E., 1994)

Material	Heat Energy (MJ/kg)	Ash (wt%)	Moisture (wt%)
Paper/cardboard	11-17	8-9	6-15
Compostibles	4-6.3	15-30	60-70
Fines	3-4	15-30	40
Textiles	13-16	2-5	22.5
Plastics	33-39	2-4.3	10

According to Cheah, C. W. (2002) study, he observed that combustion of MSW resulted 8.76 % ash content, 8.60 % fixed carbon and 82.65 % volatile matter. Calorific value of MSW in Kuala Lumpur for 2002 was 21.027 MJ/kg. Table 2.4 indicates Malaysia generated MSW with high calorific value, low ash content and fixed carbon but MSW has high volatile matter. Plastic contributed to high calorific value of MSW as plastic waste content in MSW is 18 wt % from total composition.

Fisher M. M. (1996) can prove it as he found that plastics represented only 9.5 by weight of the municipal waste steam but provide almost 30 % of the energy content of MSW.

Table 2.4: Physical Properties of MSW in Kuala Lumpur in year 2002 (Cheah, C. W., 2002)

Analysis	Kuala Lumpur 2002
Ash (dry basis) wt %	8.76
Fixed Carbon	8.60
Volatile Matter wt %	82.65
Calorific value MJ/kg	21.027

According to Table 2.5, L. Sorum *et al.* (2001) found that plastics wastes such as Polystyrene (PS), Polypropylene (PP), Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE) had no ash and higher heating value (HHV) ranging from 42 to 47 MJ/kg.

Table 2.5: Proximate Analysis and Calorific Value of Plastics (L. Sorum *et al.* (2001)

Plastics	**Volatile Matter (wt %)**	**Fixed Carbon (wt %)**	**Ash Content (wt %)**	**Calorific Value (MJ/kg)**
HDPE	100.0	0.0	0.0	46.4
LDPE	100.0	0.0	0.0	46.6
PP	100.0	0.0	0.0	46.4
PS	99.8	0.2	0.0	42.1
PVC	94.8	4.8	0.4	22.8

Boettcher (1992) has pointed out that as plastics are generally derived from petroleum or natural gas, they have stored energy values higher than any other material commonly found in the waste stream. Polyolefins commonly used in packaging can generate more energy than coal and almost as much energy as fuel oil. When plastics are processed in modern waste to energy facilities (WTE), they can help other wastes combust more completely, leaving less ash for disposal.

A study on co-combustion of mixed plastic packaging waste with MSW was carried out at a municipal solid waste combustor plant in Würzburg, Germany in 1993-94 (Mark, F. E., 1994). The trial compared typical MSW containing 8.5 – 12 wt.% of plastics, with MSW samples to which higher contents of plastic waste were deliberately added. The two enriched MSW samples contained 16 – 19.5 wt % and 23.5-27 wt. % of plastics waste respectively. The presence of an increased proportion of plastic waste gave increased fuel volatility and also more homogeneous combustion behaviour. As a result, it was found that the addition of plastics waste at levels up to 15 wt% led to lower residual unburned carbon in the ash residues. This characteristic broadens the scope for secondary applications for the ash as a useful raw material.

Frankenhaeuser *et al.* (1996) studied co-combustion of mixed plastic waste and coal in a bubbling fluidized bed low-pressure steam boiler. Mixed plastic waste was defined as the plastic fraction that is collected and separated from household waste; it is commingled, dirty and comprised mainly of packaging. The co-combustion of mixtures of plastic waste with coal was found to be comparable in efficiency to that of coal alone, for a range of coal-plastic ratios. The waste plastics were found to be a cleaner fuel than coal.

2.4 Poultry and Meat in Energy Production

Meat and bone meal (MBM) and poultry bone meal (PBM) are produced in rendering plants where animal offal and bones are mixed, crushed and cooked together. During the cooking process, tallow is extracted and the remaining material, which is dried and crushed (R. Bradley, 1991).

Recently, Avian influenza virus mostly found in birds especially chicken, also can infect humans is spreading around the world. It is known as bird flu disease. Due to this problem, the disposal of the infected poultry is currently being addressed. One such disposal option is the combustion poultry for the purpose of energy recovery. One of the main objectives in combustion of poultry is to ensure that any living organism is totally destroyed during the process. Poultry waste has good fuel properties compared with conventional fuels such as wood that has an average calorific value of 6000 Btu/lb (13.9 MJ/kg). Juan et.al (2002) found that the massic energy of combustion of the poultry litter “dry samples” was 14 447 kJ/kg and for “wet samples” decreased linearly with increasing water content. Poultry includes litter and peat has high ash content, averaging between 15.7 and 33.1 %.

Beside the fuel properties of poultry, MBM also has good fuel properties compared with conventional fuels, which has an average calorific value of 16.18 MJ/kg (Power Gen Power Technology, 1997). Hourtai, J. and Flykatman, M. (1992) found that peat has a value in the range 8 –14 MJ/kg as a conventional fuel. Compared to MBM, peat has low heat value. However, MBM has high ash content, averaging between 12.8 – 30.7 %.

Zhu and Lee (2005) have studied the co-combustion of poultry wastes (litter, manure and sawdust) with natural gas in the advanced Swirling Fluidized Bed Combustor. They found that the carbon combustion efficiencies for the three wastes could reach as high as 95%, 89% and 83% for co-combustion of sawdust, poultry litter and poultry manure, respectively at the optimal operations conditions. Another study had been done by Abelha et.al (2003) on combustion of poultry litter in a fluidized bed combustor. They found that the combustion efficiency was improved when introducing part of the air as secondary to the freeboard in stages and with some turbulence. However, the combustion and feeding to combustor will be unstable when the moisture content in poultry litter above 25%

K. McDonnell, *et al.* (1999) studied combustion of fuel made from a mixture of MBM and milled peat, at MBM inclusion rates of 0%, 30%, 50%, 70% and 100%. From Table 2.6, it was observed that MBM material with high peat inclusion ratios showed low ash content compared with compounds with low or no peat included in the pellet. MBM has high ash content. The main reason was MBM consist of Ca in bonemeal remained in combustor. Peat pellets displayed the longest char combustion period. Therefore, pure peat pellets have low ash content. The low char combustion for MBM may be as a result of its high ash content.

Table 2.6: Analysis of Pellets Fuel Consist in Meat and Bonemeal (MBM) and Peat (K. McDonnell, *et al.*, 1999)

	100 % peat	**25 % MBM 75 % peat**	**35 % MBM 65 % peat**	**50 % MBm 50% peat**	**100 % MBM**
Ash	3.5	12.5	14.8	17.5	30.4
Moisture	23.0	20.10	23.2	15.0	6.9

2.5 Fuel Characteristics

Proximate analysis is important to analyze fuel characteristics. Proximate analysis for the combustible components of MSW includes the following tests , volatile matter, moisture content, ash content and fixed carbon (Singer, 1981; Tchobanglous, *et al*., 1993).

2.5.1 Ash Content in Fuel

Ash is the non-combustible matter and high ash content would result in severe pollution (Wang, *et al*., 2000).

Stuart, B.J., et al. (1994) defined ash as the residue remaining after ignition of a substance in furnace with certain temperature. When pellet was combusted, less volatile elements are retained in the bottom ashes and grate siftings, while volatile elements of low boiling temperature are easy to volatilize at high temperature, and come into the gas phase.

Chandler A.J. (1997) defined ash is a hazard to human health or the environment as ash consist of pollutant elements such as Cd, Cu, Cr, Hg, Ni, Pb and Zn .

Flykatman, M. (1992) found that MBM has high ash content, averaging between 12.8 – 30.7 %. From Cheah, C. W. (2002) study, he observed that MSW with high plastic content consist of 8.76 wt % ash content. L. Sorum *et al.* (2001) found that paper and cardboard has 20.2 % and 8.4 % ash content respectively. Plastics haven't ash content excluded PVC that consist of 0.4 wt % ash content. Coal has 5.7 % ash content.

2.5.2 Moisture Content in Pellet Fuel

In this research, 3 types of moisture content were determined. Determined moisture content is moisture of the sample after drying process in an oven for 100^0C to vaporize water in the sample. Residual moisture is moisture after drying and packing process to determine moisture in ambient temperature after sample was drying. Total moisture content is total moisture in the sample before it was dried. It is includes residual and moisture content of sample.

Moisture content in sample means the water contained in the sample. Moisture content determines the quality of MSW as a fuel. High moisture content decreases the heating value thus reducing the conversion efficiency and performance, as large amount of energy would be used for vaporization. This would also discourage the sustainability of combustion (Wang, *et al*., 2000).

K. McDonnell, *et al.* (1999) found that MBM has 6.9 wt % moisture content. Peat has moisture content range between 40 % to 50 %.

2.5.3 Volatile Matter in Pellet Fuel

Volatile matter content in sample means those products that will volatile when drying in a controlled condition of temperature, time and airflow. Volatile matter is exclusive of moisture and form in gas or vapour. It determines pyrolisis capability of the MSW. High volatile content means that most of the caloric value would be released as volatile combustion at the free board (Wang, *et al*., 2000).

Cheah, C. W. (2002) observed that MSW has 82.65 wt % volatile matter. L. Sorum *et al.* (2001) found that paper and cardboard have 88.5 wt% and 73.6 wt % volatile matter respectively. Peat has 50.3 % volatile matter while plastics volatilized completely in combustor except PVC which has 94.8 wt % volatile matter.

2.6 Calorific Value

To develop the facility for recovery energy from MSW, the knowledge of energy content in MSW is necessary. Calorific value (CV) is defined as the number of heat units evolved when unit mass of material is completely burned and is measured in joules per gram (J/g) or British thermal units per pound (Btu/lb) (Abu Qudais and Abu Qdais, 1999). Energy content can be determined by carrying out experiment through the use of calorimeter, but it is also quite time consuming (Ali Khan and Abu Ghararah, 1991).

Moreover, municipal solid waste characteristics could be changed as a result of changing of population and living culture of the city. Therefore running out experiment from year to year to determine the calorific value would also increase the budget of research. Abu Qudais and Abu Qdais (1999) also proved that the energy content of MSW is directly related to the plastic/ paper ratio.

L. Sorum *et al.* (2001) observed that plastics have energy value range between 40 – 50 MJ/kg. Coal has 27 GJ/ton heat value. Paper and cardboard have 19.3 MJ/kg and 16.9 MJ/kg energy value respectively.

CHAPTER 3

METHODOLOGY

This chapter covers methodology and procedure undertake in this research. It discusses equipments used, sample preparation, proximate analysis and determination of calorific value. Proximate analysis is the determination of volatile matter, ash content and moisture content. Fixed carbon is determined from equation according to ASTM D 5681-98.

3.1 Equipments

3.1.1 Grinder
3.1.2 Shredder
3.1.3 Hand held pelletizer
3.1.4 Furnace
3.1.5 Bomb Calorimeter

3.2 Sample Preparation

3.2.1 Municipal Solid Waste (MSW) Preparation

i. Samples of municipal solid waste (MSW) are collected from the landfill site in Tanjung Langsat, Pasir Gudang which is under management of Pihak Berkuasa Tempatan Pasir Gudang (PBT).

ii. Sample was left to dry under the sun for 3 days.

iii. MSW was sorted manually to determine its composition.

iv. Sample of MSW was packed in a sealable bag and transported to laboratory for analysis.

v. Samples were cut using scissors to 5 cm^2 in size.

vi. Sizes of samples were further reduced to less then 0.5 cm^2 using grinder.

vii. Shredded samples were grinded to form homogenous powder.

viii. The powder samples were packed and labeled into sealable polyethylene bags, and were stored to prevent physical and chemical properties change as recommended in ASTM E 954-94.

3.2.2 Poultry Meat Sample Preparation

i. A 2 kg of poultry meat was obtained from supermarket.

ii. The poultry was cooked and dried in an oven at 100^0C until its weight changes within 0.5 wt %.

iii. Poultry was shredded to form powder with average particle size less than 0.5 mm^2 by using shredder in accordance to ASTM E 829-94.

3.3 Pellet Fuel Preparation

i. MSW and poultry were mixed according to the following composition on a weight basis. Compositions of poultry are 0%, 25 %, 35 %, 50%, and 70% for each sample on a weight basis.

ii. 5 g of samples were compressed into a 30 mm diameter die at compaction ratio 1: 5 to form pellet fuel.

iii. The final weight and sizes of each pellet was recorded.

3.4 Sample Analysis

3.4.1 Determination of Residual Moisture (ASTM E 190-87, E 949-88)

i. An empty container was preheated for about 15 to 20 minutes under the conditions at which the sample would be dried.

ii. 1 g of analysis sample was dipped out with a spoon and quicklyplaced into the container.

iii. The sample was left in an n oven at temperature 107 ± 3° C for 1 hour.

iv. The weight of sample after dried for 1 hour was recorded after it was cooled to room temperature.

v. Residual moisture and total moisture content in the sample was calculated using equations below -:

$$R = \frac{S - B}{S} \times 100\% \qquad [3.1]$$

Where;

R = residual moisture, %

S = weight of sample used, g

B = weight of sample after heating, g

$$M = \frac{R\,(100 - A)}{100} + A \qquad [3.2]$$

Where;

M = total moisture content, %

R = residual moisture, %

A = determine moisture during preparation of the sample, %

3.4.2 Determination of Volatile Matter (ASTM E 897-88)

i. Volatile matter was determined by using furnace that able to reach temperature up to 1000^{o}C.

ii. 1 g of sample was weighed and recorded.

iii. It was then placed into a weighed crucible.

iv. The crucible was sealed with its cover and placed into the furnace chamber, with temperature maintained at 950 ± 20^{0}C.

v. After 7 minutes, the crucible was removed from the furnace. The crucible was cooled to room temperature.

vi. The crucible weight was recorded without disturbing the cover.

vii. Volatile matter calculation was determined using equation 3.3.

$$V = \left[\frac{A - B}{A} \times 100\right] - M \qquad [3.3]$$

Where;

V = volatile matter, %

A = weight of sampled used,g

B = weight of sample after heating,g

M = moisture (determine from [3.2])

3.4.3 Determination of Ash Content (ASTM E 830-87)

i. 1 g of analysis sample was placed into a weighed uncovered crucible.

ii. The uncovered container with sample in it was then placed into the furnace at low temperature and gradually heat to 725 ± 25^0C. temperature of furnace was kept constant for 1 hour.

iii. Weight was recorded after the crucible was cooled to room temperature.

iv. Ash content was determined using equation 3.4.

$$As = \frac{A - B}{C} \times 100 \qquad [3.4]$$

Where;

As = ash content, %

A = weight of container and ash residue, g

B = weight of empty container

C = weight of sample used, g (including residual moisture)

3.4.4 Determination of Fixed Carbon (ASTM D 5681-98 a)

i. Fixed carbon content was calculated using equation 3.5 below.

$$Fc = 100 – (M+ V + A) \qquad [3.5]$$

Where;

Fc = fixed carbon,%
M = total moisture,%
V = volatile matter, %
A = ash content, %

3.5 Determination of Calorific Value

The experiment to determine calorific value of MSW was conducted by Malaysian Cocoa Board using adiabatic bomb calorimeter. This technique was based upon the principles of calorimetric. This experiment was carried in accordance to standard procedures outlined in ASTM D 240-02.

i. For this calorimetric technique, a reaction vessel containing the sample and excess pure oxygen mixture was immersed in a water bath at ambient conditions, usually at room temperature, 25^{o}C.

ii. Current passed through an ignition wire, and accomplished ignition of the pre-measured sample and excess pure oxygen.

iii. The energy released by the complete combustion of the reactants within vessel was absorbed by water bath, and caused the water jacket temperature to rise.

iv. A pure compound of a known heating value like benzoic acid in this present study was burned in order to obtain a thermal response, or water equivalence, of the apparatus to a particular heat release.

v. In this experiment, the water equivalence (W) was determined using the tablet of benzoic acid.

vi. The combustion procedure was carried out in the presence of pure oxygen and the value W was determined from the equation below.

$$W = \frac{(H_{OB} \times m_B) + Q_N + Q_Z}{\Delta T} \quad (kJ/^{o}C) \qquad [3.6]$$

Where,

H_{OB} = caloric value of reference substance (26,456 Jgm^{-1})

M_B = weight of the reference substance

Q_N = correction of formation of sulphuric acid

Q_z = the sum of all the extraneous quantities of heat

Using a constant-volume oxygen bomb calorimeter, the heating value of solid sample was calculated using equation 3.7 below.

$$HV = \frac{W \Delta T - E_1 - E_2 - E_3 - E_4}{m} \qquad [3.7]$$

Where,

W = water equivalent, kJ/°C

ΔT = temperature rise, °C

E_1 = correction heat of formation of nitric acid

E_2 = correction heat of formation of sulfuric acid

E_3 = correction for combustion of gelatin capsule used with liquid testing

E_4 = correction for heat combustion of firing wire

m = weight of sample, g

HV = heating value of fuel, kJ/kg

CHAPTER 4

RESULT AND DISCUSSION

To produce good properties fuel, one must considers properties of sample either it is combustible matter or not. The fuel characteristics were analyzed. They includes ash content, volatile matter, moisture content, fixed carbon and energy value.

Table 4.1 shows that volatile matter increased with increasing percentage of poultry in MSW pellet fuel. Volatile matter increased slightly with increasing inclusion of poultry to MSW pellet fuel. Ash content decreased with increasing percentage of poultry in MSW pellet fuel. Residual moisture content increased with increasing inclusion of poultry to MSW pellet fuel.

Table 4.1: Fuel Characteristics of MSW in Pasir Gudang Landfill, Tanjung Langsat

Sample	Volatile Matter (wt %)	Ash Content (wt %)	Fixed Carbon (wt %)
0 %	89.60	10.21	0.19
25 %	92.13	6.97	0.90
35 %	92.66	6.56	0.78
50 %	94.07	5.15	0.78
70 %	95.16	3.39	1.45

4.1 Volatile Matter in Pellet Fuel

Volatile matter analysis determines pyrolisis capability of the MSW. High volatile content means that most of the calorific value would be released as volatile combustion at the free board (Wang, *et al*., 2000).

According to Figure 4.1, it was observed that volatile matter increased as percentage of poultry in MSW pellet fuel increased. MSW pellet has less volatile matter compared to pellet with 70% inclusion of poultry. MSW pellet has volatile matter in range 89 - 90 wt %. Pellet with 70 wt % of poultry, has volatile matter in range 95 – 96 wt %.

This result agrees with previous study. As reported earlier by previous works, the inclusion of poultry to MSW has resulted an increased in volatile matter content of the fuel developed. Fuel with high volatile matter was not good. It is because as fuel combusted in boiler with high temperature, most of the energy released and cannot be converted into steam.

From figure 4.2, it can be seen that poultry has a high volatile matter compared to MSW .It may be influenced by composition of MSW that consist of non-combustible matter such as plastic, glass and metals Thus, inclusion of poultry will increase volatile matter and it is not suitable to produce fuel with high volatile matter, which there is more energy need for volatilization.

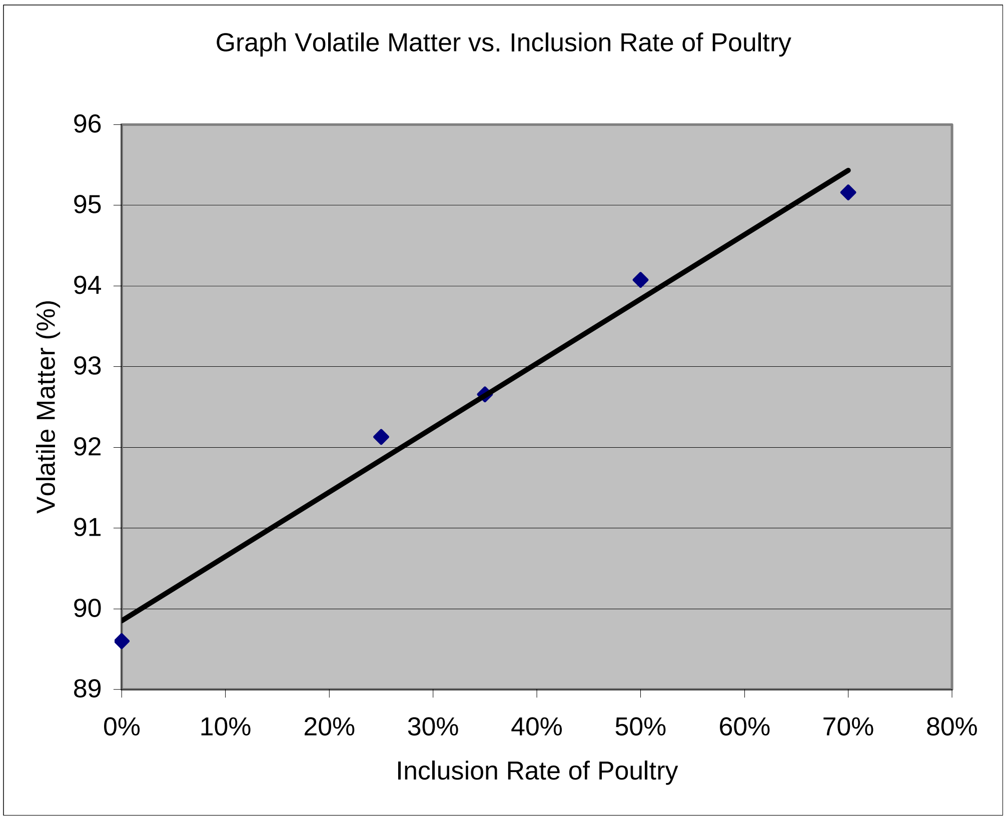

Figure 4.1: Graph Volatile Matter of Combusted Pellet Fuel

4.2 Ash Content in Pellet Fuel

Ash is related to volatile matter which volatile matter is volatile while ash is residue remaining after combustion of pellet fuel. Figure 4.2 shows that MSW has high ash content in a range 10 - 12 wt%. However, poultry has a low ash content compared to MSW. Pellet fuel with 70 wt % of poultry produced 2 – 4 wt % of ash content when the pellet was combusted.

According to Cheah, C. W. (2002), MSW consist in 8.76 wt % of ash content. A study by Power Gen Power Technology (1997) reported that ash content of poultry is 30.4 wt %. Ash content of poultry increased with increasing percentage of poultry to the fuel. From Figure 4.2, however, ash content decreased with increasing percentage of poultry in pellet fuel. This result opposes earlier study. The main reason is that in the current study, bonemeal was excluded. The poultry samples were pure poultry meat, while Power Gen Power Technology (1997) used both meat and bonemeal.

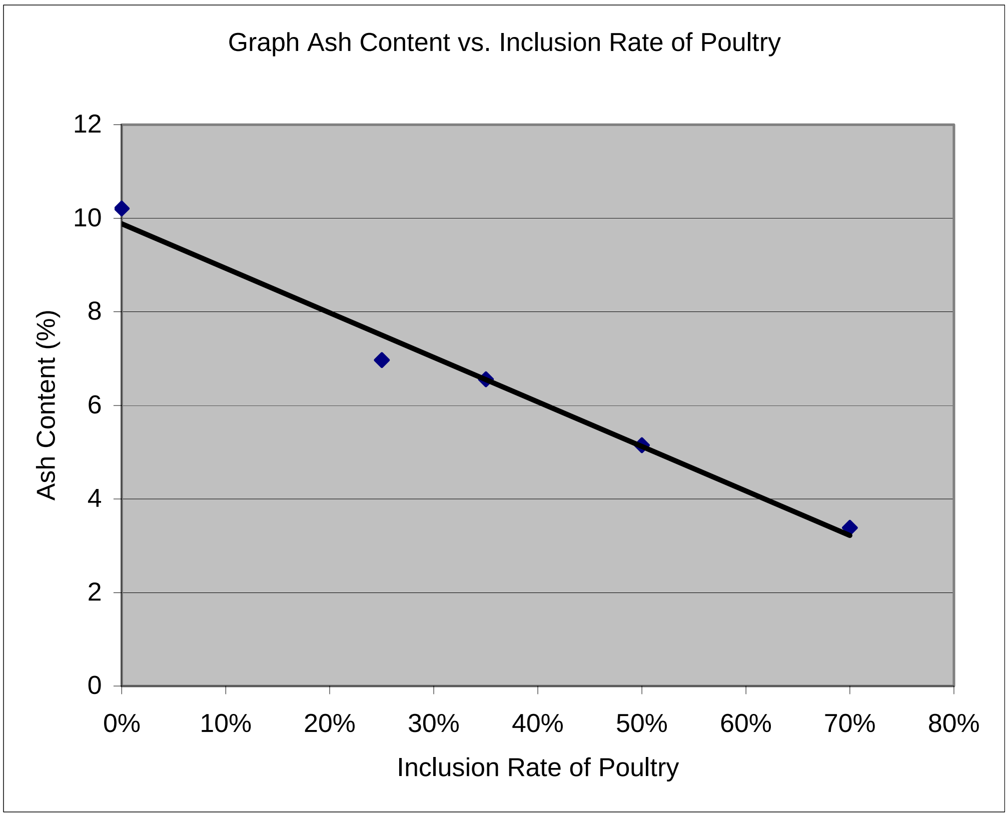

Figure 4.2: Graph Ash Content of Combusted Pellet Fuel

4.3 Calorific Value

Meat has high calorific value. According to Power Gen Power Technology (1997) and Cheah, C. W. (2002), calorific value of meat and MSW are 16.18 MJ/kg and 21.027 MJ/kg respectively. However, poultry litter has a combustion about 14.4 MJ/Kg at dry conditions and decrease linearly with the increasing water content (Davalos et.al., 2002)

Figure 4.3 indicates that poultry has high energy value compared to MSW. MSW pellet fuel consists of 16 MJ/kg energy value while poultry has 20 MJ/kg energy value. 25 % inclusion rate of poultry to pellet fuel released about

17 MJ/kg calorific value. 35 % inclusion rate of poultry to MSW pellet fuel released 17.5 MJ/kg calorific value. However, 50% inclusion rate of poultry released about 16.8 MJ/kg energy value. It was 0.2 MJ/kg less than energy value released from fuel with 35 % percentage of poultry. 70 % inclusion rate of poultry released 18.5 MJ/kg energy value. From these results, it can conclude that, calorific value increased with increasing percentage of poultry to MSW pellet fuel.

From previous study, inclusion rate of poultry increased calorific value of pellet fuel. This result agrees with result obtained from previous study.

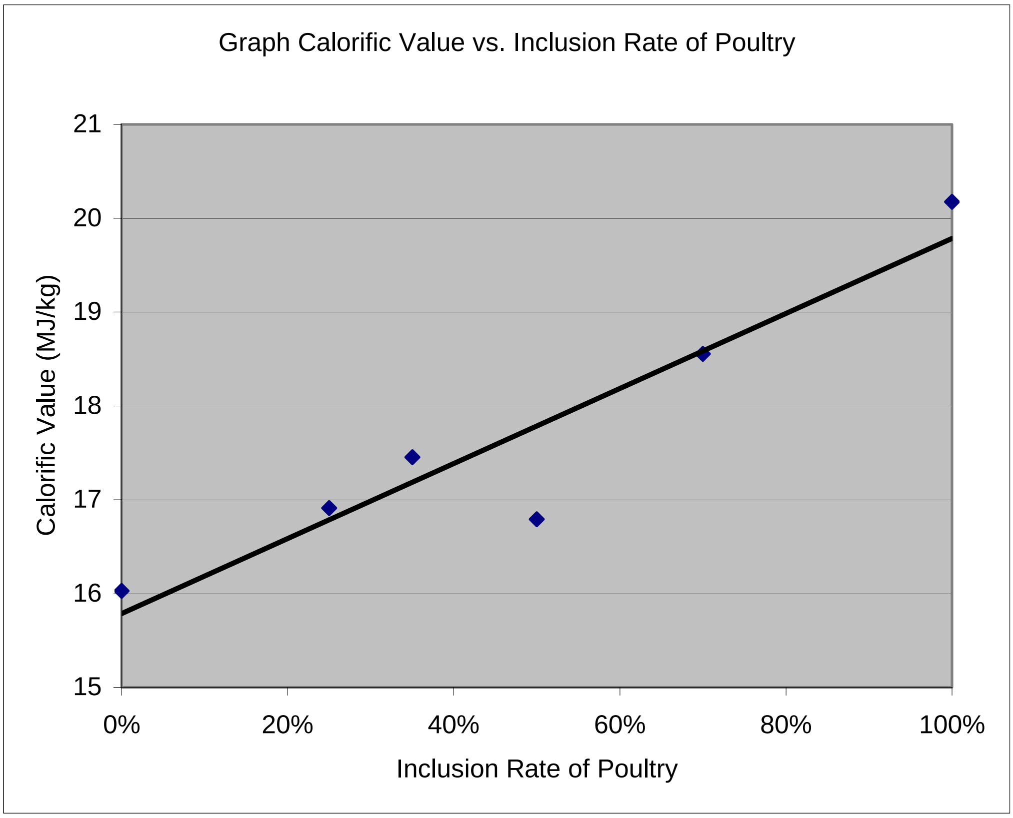

Figure 4.3: Graph Calorific Value of Pellet Fuel

4.4 Residual Moisture Content

Moisture content in sample means the water contained in the sample. Moisture content determines the quality of MSW as a fuel. High moisture content decreases the heating value thus reducing the conversion efficiency and performance, as large amount of energy would be used for vaporization. This would also discourage the sustainability of combustion (Wang, *et al*., 2000).

Figure 4.4 show that poultry has high moisture content. The reason is, poultry absorbed water. MSW has low moisture content. It is because, composition of MSW. MSW consist of plastic, glass and paper which not absorbed water and can be dried under the sun. however, residual moisture obtained from dry basis fuel. From Figure 4.4, 0.3 – 0.75 wt % of residual moisture obtained from various compositions was smaller amount of moisture content and did not affect other fuel characteristics. Therefore, to produce fuel with good properties and to ensure the sustainability of combustion, the pellet fuel must be dried in oven to vaporized water in sample.

From Figure 4.4, it was observed that, residual moisture increased with increasing percentage of poultry in pellet fuel. This result agrees with previous study result as residual moisture increased with increasing percentage of inclusion of poultry to the pellet fuel.

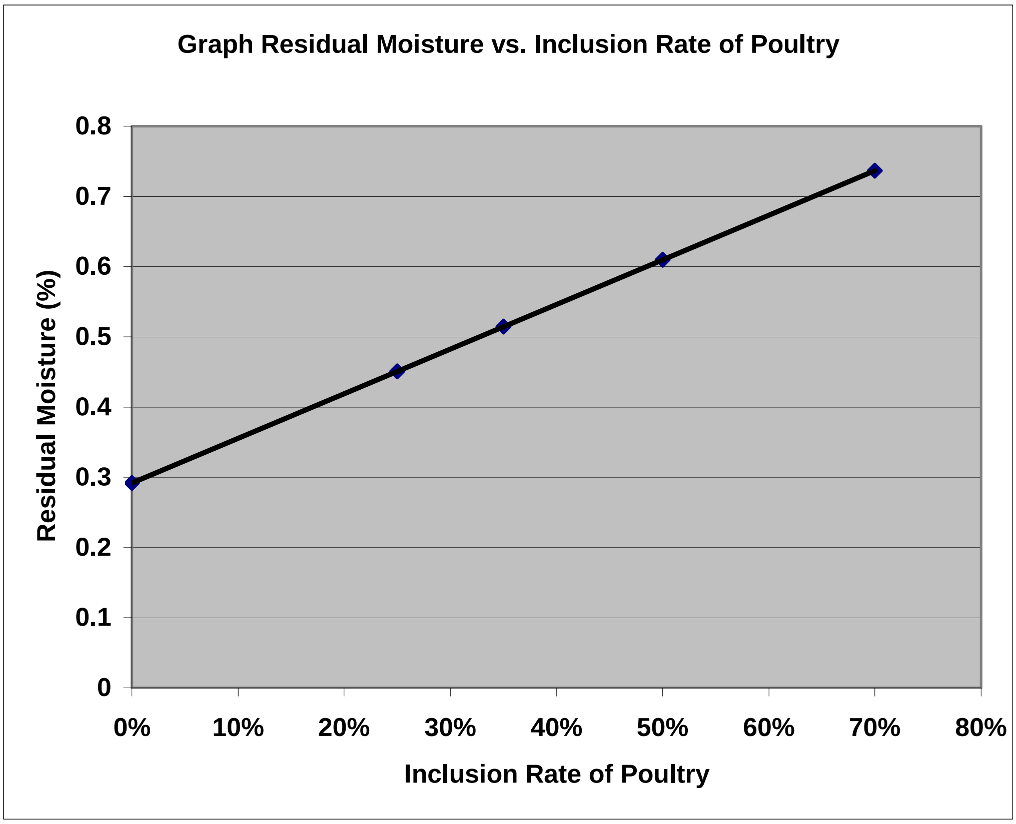

Figure 4.4: Graph Residual Moisture Content in Sample

4.5 Determination of Minimum Percentage of Poultry To Pellet Fuel

Figure 4.5 shows comparison between ash content and calorific value in pellet fuel. To produce good fuel, it must consider calorific value and also a significant factor is consideration of hazardous material produced. Ash content consists of heavy metal such as Cd, Cu, Cr, Hg, Ni, Pb and Zn. Therefore, ash residue remaining after combustion fuel must be less. Calorific value for pellet fuel must high value to convert heat energy released during combustion to make steam in waste to energy facilities. MSW is a suitable substance to substitute conventional fuel such as coal because MSW has high calorific value. MSW consist in plastic which has high energy value.

According to Figure 4.5, it was observed , 35 wt % is the minimum percentage of poultry to MSW pellet fuel to produce fuel with good properties especially for low ash content and high energy value. 35 wt % inclusion rate of poultry produced 7 wt % ash content and 17.5 MJ/kg energy value. Above 35 % percentage of poultry to pellet fuel is suitable composition of poultry to pellet fuel because it produced fuel with low ash content and high energy value.

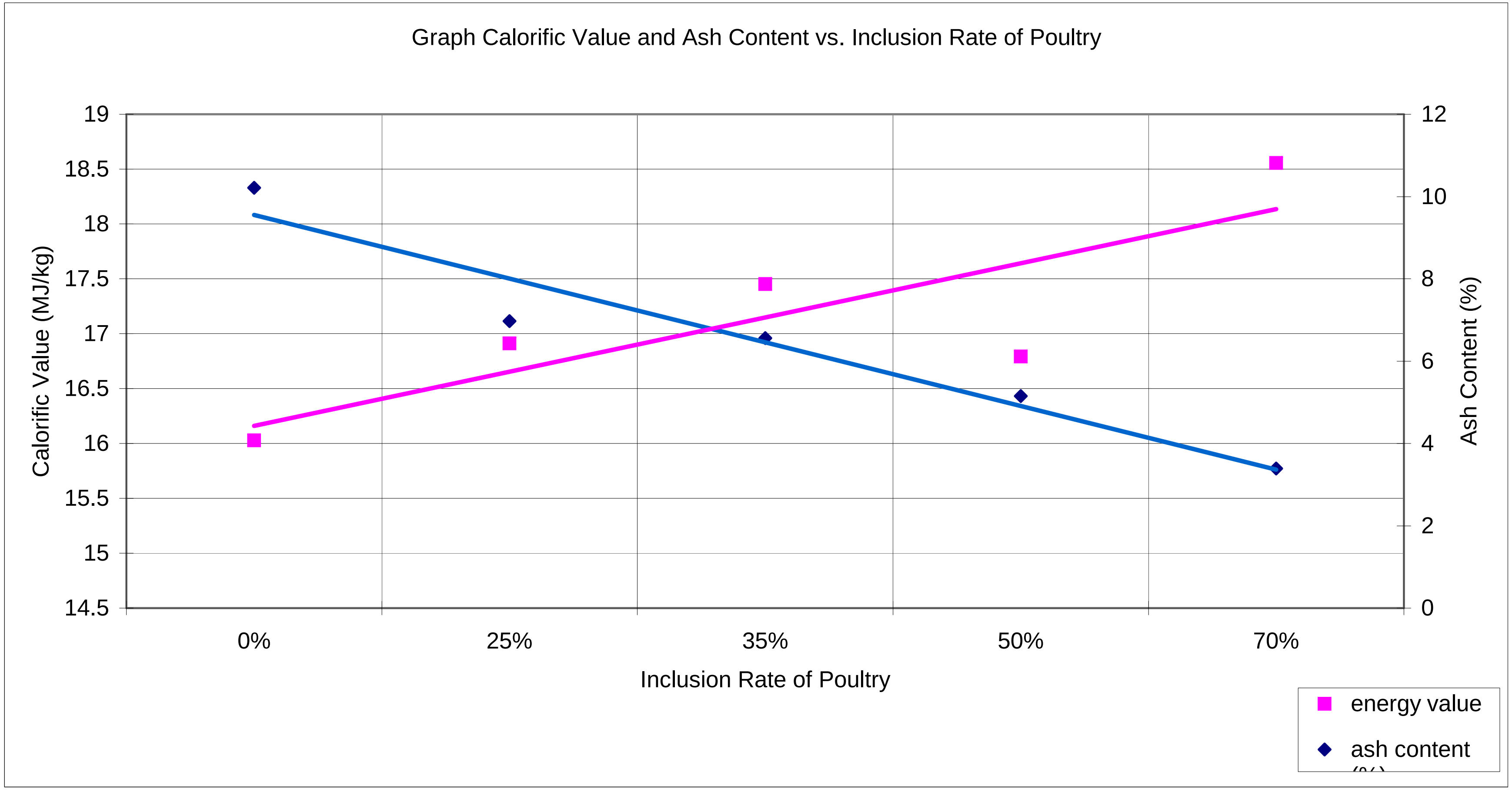

Figure 4.5: Graph Calorific Value and Ash Content in Pellet Fuel

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusions

i. Inclusion of poultry to MSW pellet fuel enhanced properties of fuel. Volatile matter, residual moisture content and calorific value increased with increasing percentage of poultry in pellet fuel. Ash content decreased with increasing percentage of poultry in pellet fuel.

ii. 35 wt % is minimum inclusion of poultry to MSW pellet fuel produced fuel with good properties.

5.2 Recommendations

i. To prevent the moisture lost during transportation, it is suggested to put the sample into container with close and tight cover.

ii. To obtain highly precision of result, it is recommended minimum number of sample is 30 for each composition.

iii. To analyze volatile matter and ash content of pellet fuel, it can improve the result if pressure in the furnace can be measured.

iv. To obtain accurate result, it is suggested to use furnace that can achieve temperature up to 1000°C. Temperature used to determine volatile matter and ash content in this study is 800°C, which is not correlated to real combustor.

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APPENDIX A

Volatile Matter

Sample	Weight Before (g)	Weight After (g)
0 %	5.0228	0.5525
25 %	4.9162	0.3870
35 %	4.9344	0.3624
50 %	5.7447	0.3405
70 %	4.8283	0.2336

Sample	Percentage of Volatile (%)
0 %	89.60
25 %	92.13
35 %	92.66
50 %	94.07
70 %	95.16

APPENDIX B

Ash Content

Sample	Weight of container + ash (g)	Weight of empty container (g)	Weight of sample (g)	Weight of container + ash (g)
0 %	76.3865	75.8666	5.0941	10.21
25 %	79.2013	78.8005	5.7505	6.97
35 %	79.7285	79.3530	5.7241	6.56
50 %	79.7747	79.4802	5.7161	5.15
70 %	83.9381	83.7608	5.2374	3.39

APPENDIX C

Moisture Content

Sample	Residual Moisture (%)	Determine Moisture (%)	Total Moisture (%)
Poultry Meat	0.927	35.004	35.607
MSW	0.292	7.189	7.4600

Sample	Residual Moisture (%)
0 %	0.2920
25 %	0.4508
35 %	0.5143
50 %	0.6095
70 %	0.7365

APPENDIX D

Grinder

Combustor

APPENDIX E

MSW Sample Before Collecting

MSW Sample After Collecting

APPENDIX F

(A)

(B)

(C)

A, B and C - Collecting and sorting MSW at Pasir Gudang Landfill Site