Combustion Processes of Rice Husks for Energy

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ABSTRACT

A very comprehensive study of the Rice Husk (RH) combustion conditions has been carried out at the Combustion Laboratory of the International Islamic University Malaysia using Thermogravimetric Analyzer (TGA). The main objective of this paper is to describe the first phase of a project to use RH as a fuel for the fluidized bed combustor at Universiti Kebangsaan Malaysia. Systematic investigation of the effect of process conditions on the combustion processes was carried out. This paper presents the experimental setup used in the study and the effect of combustion heating rate and oxygen composition on RH combustion processes. The effect of process conditions, such as combustion heating rate and combustion atmosphere, on rice husks combustion was quantified. The results showedthat the combustion profile can be divided into three stages: the evaporation of moisture content, rapid combustion, and slower combustion with ignition.

1. INTRODUCTION

During the past 50 years, research and experiments conducted on rice husk (RH) have demonstrated that it can be successfully used as a fuel. It has a high potential to supply electricity for small plants especially in rice husk industry. Reserve of fossil fuel and coal are decreasing, while the demand for energy is continuously increasing due to technological advancement of the world. Some of energy resources have to be exploited to offset the future shortage of fossil fuel. One of those options is the possible utilization of rice husk [1].

Paddy is a major crop in Malaysia and approximately half million hectares of land are cultivated with the crop. Annual production is about 2 million tons, resulting in the creation of about 0.4 million tons of RH. The bulk of husk was disposed of by burning in the open yard and this burning yields approximately 70,000 tons of rice husk ash. Rice husk consists mainly of carbon as cellulose and lignin, and ash as silica. Analysis was carried out on RH at National Electricity Board in Malaysia in 1986. It was found that the specific energy is equivalent to about 33% of the specific energy value of (heating) fuel oil that was used in the thermal power generating plant as shown in Table 1 [2]. The applications of the fluidized bed combustion technology in ASEAN region have been conducted on the application of the technology for rice husk, sawdust, municipal solid waste, oil palm solid waste, lignite and cob.

Table 1. Analysis result of rice husk.

Gross calorific value	14150 KJ/Kg
Moisture Content	5.72%
Ash Content	17.14%
Silica as SiO_2	15.91%
CHN as received excluding it from H_2O :	
C	37.0%
H	4.71%
N	0.36%

In Malaysia, the fluidized bed combustor (FBC) unit installed in Standard and Industrial Research Institute of Malaysia (SIRIM) was transferred to the National Rice and Paddy Board rice mill as the industrial collaborator. The combustor was used to burn rice husk from milling process. In the ASEAN region the research and development in this area are illustrated in Table 2 [3]. The biggest challenge in using FBC system for the rice husk combustion is the very light weight of the rice husk that requires longer time to have a good mixing for complete combustion. Another problem is the high content of the ash that will settle at the bottom of the combustor. FBC system should be designed carefully to use rice husk combustion for energy.

Table 2. Summary of FBC research and development (1989-1994).

Location	Fuel	Combustor Type	Dimension (cm)
Bandung, Indonesia (*Susanto, 1992*)	Sawdust, RH	SFBC (6 nozzles)	80 (dia)
Kuala Selangor, Malaysia (*Ahmad Hazri, 1992*)	RH	SFBC (1 nozzle)	108 (dia)
Bangi, Malaysia (*Abd. Halim & Kamaruzzaman, 1994*)	Coal, Lignite, Palm Oil, Solid Wastes	FBC	60 x 90
Laguna, Philippines (*Unciano et al., 1994*)	Sawdust, RH, Lignite	FBC	43 x 66
Chiang Rai, Thailand (*Suwanayuen et al., 1994*)	Lignite, RH, Corn Cob	FBC	125 x 260

Better understanding of the fundamental mechanisms of RH combustion is needed to achieve greater and more efficient utilization of RH. Furthermore, this knowledge also contributes to the development of more accurate models [5, 6] that describe the transient processes involved in the combustion. Properties of rice husks have been studied by various investigators [7, 8]. Some researchers have attempted to study the thermodynamic property [9] and the reactivity of rice husks [10].

2. EXPERIMENTAL PROCEDURES

Experiments were carried out in the thermogravimetric reactor (TGA-Perkin Elmer). The reactor system was interfaced to a microcomputer that performed the data acquisition and control tasks. The weight and the combustion temperature were continuously recorded during the experiments. Reactor operation was fully automatic since the computer controlled the furnace heater to achieve the desired furnace temperature at different heating rates and final heating temperatures. The reactor consisted of a Pt sample pan that was suspended from the weighing mechanism with a Pt wire. The balance accuracy was 0.1% and the sensitivity was 0.1 μg. The sample pan was placed inside a cylindrical ceramic furnace that was designed to provide high heating rates. The furnace can withstand temperatures up to 1150 °C and the reactor temperature was measured by a chromel-alumel thermocouple (type K, range: 0-1000 °C) located exactly below the sample pan. The experimental conditions were as listed in Table 3.

Table 3. Experimental conditions for rice husk combustion.

Heating Rate :	50, 100, 150 and 200.0 °C/min.
Final Temperature :	900 °C
Combustion atmosphere:	0%, 5%, 15%, 22%, and 35% Oxygen

The software used for the above purpose included multi-ramp program for gathering and analyzing multiple step data experiments with multiple heating. For each run, 7 to 10 pieces of RH were placed in the sample pan. Each experiment was repeated at least once to ensure consistancy in the data.

3. RESULTS AND DISCUSSIONS

A typical profile of combustion plots is shown in Figs. 1-4 for various combustion heating rates values of 50 °C/min., 100 °C/min., 150 °C/min., and 200 °C/min., at 0%, 5%, 15%, 22%, 28%, and 35% oxygen percentage. The profile can be divided into three stages as shown in Fig. 1:
(i) the evaporation of moisture content (between 50 °C - 150 °C), (ii) rapid combustion (between 300 °C - 380 °C), and (iii) slower combustion but with ignition (above 400 °C).

Thegraphs in Figs. 1-4 reveal the effect of combustion heating rates as follows:

- Complete evaporation happens at the early stages of the combustion (lower temperatures) for the lower heating rate values between 50 °C/min. to 100 °C/min.. For instantce, evaporation occurred at 110 °C, 140 °C, and 170 °C for heating rates of 50 °C/min., 150 °C/min, and 200 °C/min., respectively. Our results show that the moisture content is approximately 6% to 8% for most of the samples (see Fig. 3).
- The slope of solid weight loss during the second stage appears to be the same for most of the heating rates as given in Fig. 4. However, the increase of the combustion heating rates tends to increase the starting temperature of the second stage (ii). Also the increase of the heating rate means increasing the weight loss at the end of the second stage. Fig. 2 shows that the ignition temperature (final temperature of the second stage) tends to be higher under high heating rate values.
- At the third stage, the results show that the ignition temperatures increased with the increase of the heating rates values. The samples were observed to ignite between 400 °C - 450 °C and this is shown on the graph as a sudden loss of weight. For instance the ignition temperature of RH at 15% O_2 and 200 °C/min. was 410 °C.

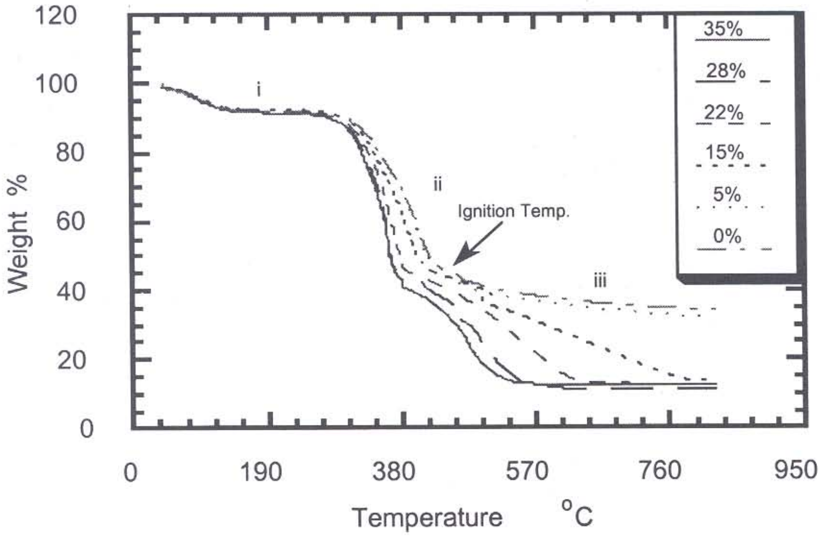

Fig. 1. Weight ratio vs. temperature at constant heating rate (50 °C/min).

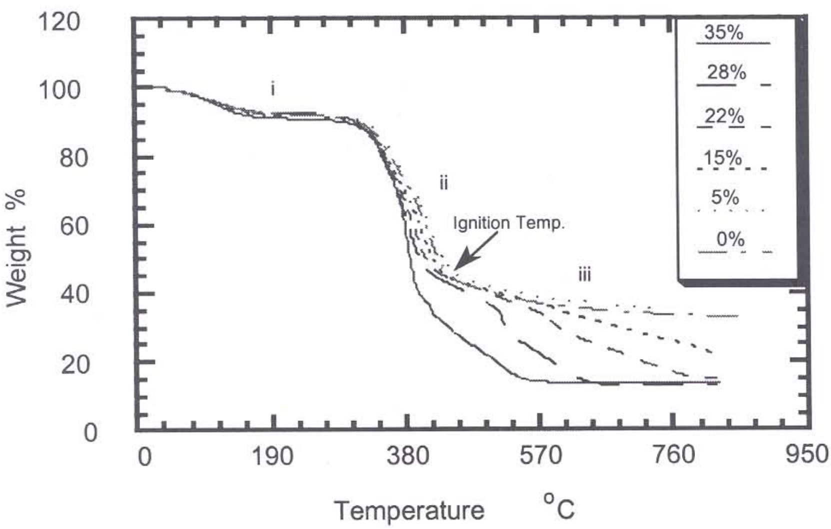

Fig. 2. Weight ratio vs. temperature at constant heating rate (100 °C/min).

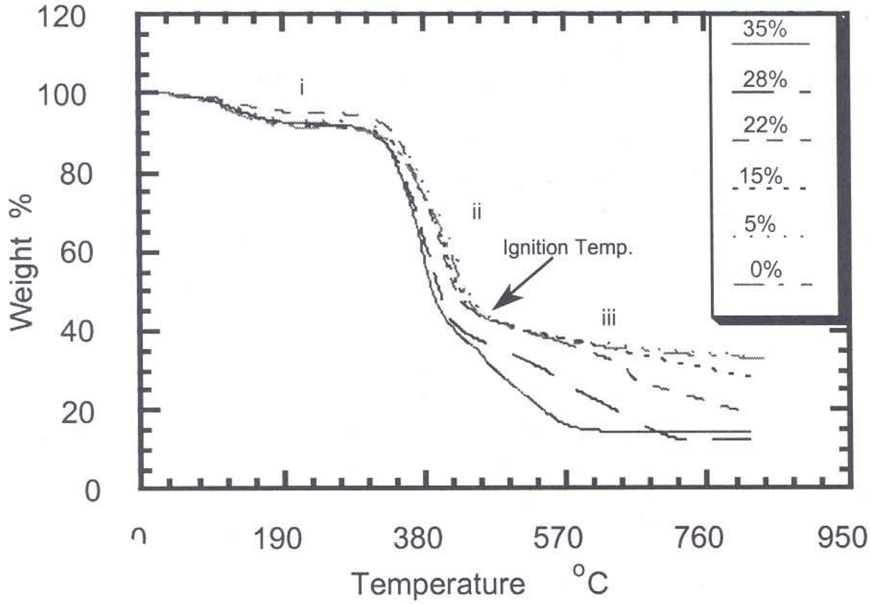

Fig. 3. Weight ratio vs. temperature at constant heating rate (150 °C/min).

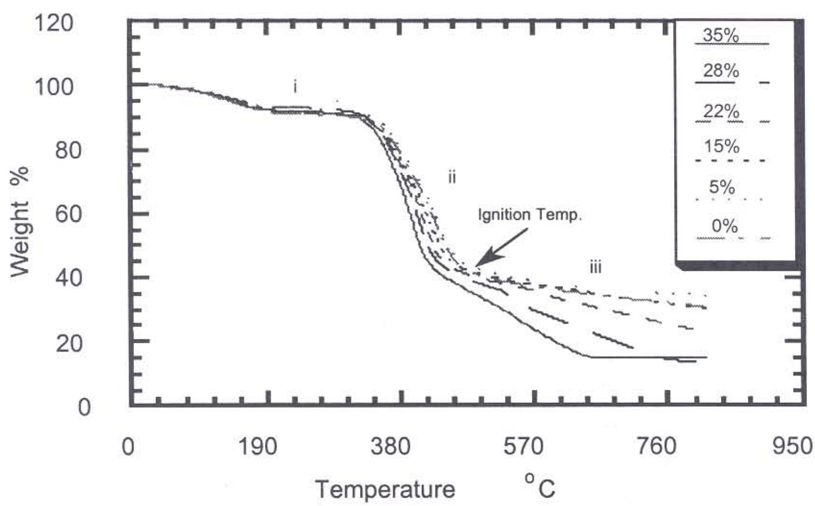

Fig. 4. Weight ratio vs. temperature at constant heating rate (200 °C/min).

- Finally, temperature for complete combustion increases with increasing heating rates. However in this test we set the maximum temperature to be 900 °C. After completing the combustion, the mass left is considered to be the weight of the rice husk ash. The average ash content measured in the lab was approximately between 12% to 35% of the total mass.

Fig. 5 shows the effect of the oxygen composition ratio on the combustion processes. Greater oxygen values will result in lower ash weight values, which means combustion is completed. On the other hand, lower oxygen values mean high ash weight percentage, e.g., incomplete combustion. Under 200 °C/min. heating rate and zero oxygen ratio the ash weight was 32% of the total weight of the sample, while at same heating rate and high O_2% it gives less amount of ash (incomplete combustion).

The effect of the oxygen percentage values (0%, 5%, 15%, 22%, 28%, and 35%) on the rice husk combustion is presented in Figs. 5-10. The investigation was done for different combustion heating rate values 50 °C/min., 100 °C/min., 150°C/min, and 200 °C/min. As clearly depicted in the plots, the oxygen composition does not affect the first and second stages (i and ii) of the combustion processes. In the third stage, the ignition temperature decreases with increasing the oxygen ratio. The graphs in Fig. 4 (for example) show that the ignition occurs by sudden change of weight at combustion temperatures of 460 °C and 425°C for zero and 35% oxygen ratio respectively.

The results of the tests shown in Figs. 5-10 are illustrated in Tables 4 and 5. Table 4 gives the starting temperature of the second stage (ii), the final temperature of the second stage (ignition temperature (ii)), weight loss ratio and ash weight ratio (%) for different heating rate values (50°C/min., 100°C/min., 150°C/min. and 200 °C/min.) at zero oxygen value and 100% nitrogen. From Table 4, it can be seen that the ignition temperature of 50 °C/min. is 420 °C which is greater than the ignition temperature at 200 °C/min. (460 °C). The difference is almost 40 °C. The oxygen composition values started with 5%, 15%, 22%, 28% and 35%. The ignition temperature of 50 °C/min. is 450 °C at 5% O_2 which is greater than the ignition temperature at 200 °C /min. (490 °C), the difference is almost 40 °C. The weight loss of the sample decrease from 68% (50 °C/min.) to 65% (200 °C/min.), which means the ash weight ratio increase from 32% at 50 °C/min. to become 35% at 200 °C/ min.

Table 4. Combustion processes of rice husks at zero oxygen with different heating rate value (refer to Fig. 5).

No.	Heating Rate °C/min.	Starting Temp. °C	Ignition Temp. °C	Weight Loss %	AshWeight %
1	50	300	420	68	32
2	100	320	450	68	32
3	150	330	455	68	32
4	200	350	460	67	33

Table 5 also describes the effect of the oxygen composition ratio on the starting temperature, ignition temperature, weight loss and the ash weight. From the data given in Table 6, it can be concluded that the increase of the oxygen ratio means decreasing of the ignition temperature and ash weight ratio. For instance, the ignition temperature of the rice husk at 100 °C/min. and 5% O_2 was 470°C, while the ignition temperature was 420 °C at higher oxygen ratio (15%). The ash weight ratio is 34% at 5% O_2 and 100 °C/min., while the weight of the ash was 20% at the same heating ratewith higher amount of oxygen (15%).

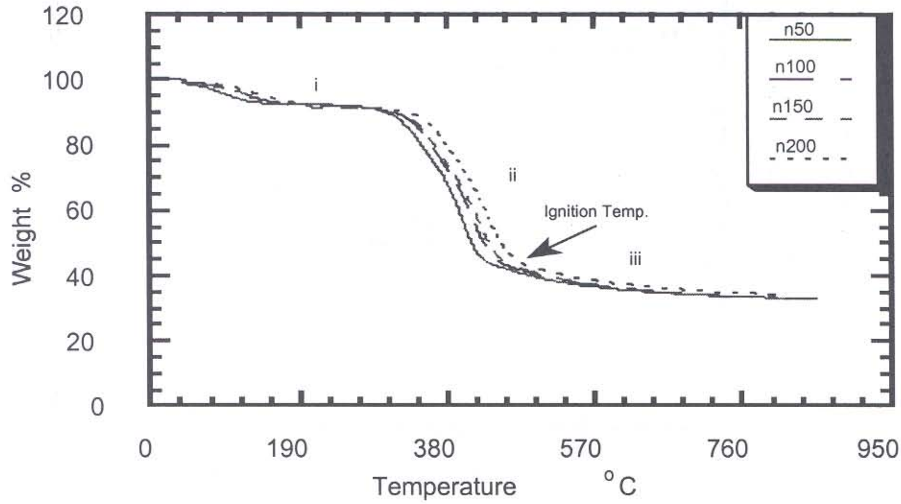

Fig. 5. Weight vs. temperature for different heating rate values (50°C/min, 100°C/min, 150 °C/min and 200 °C/min) at zero oxygen ratio (n).

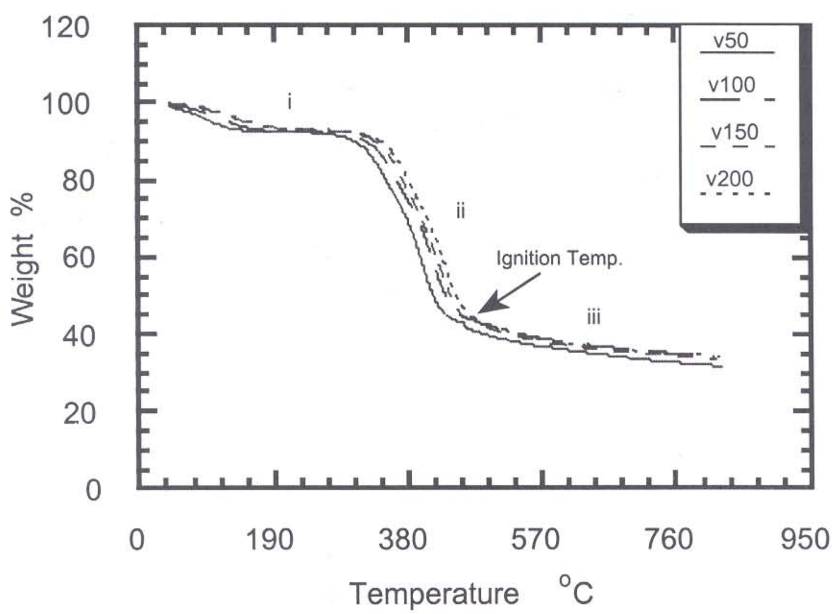

Fig. 6. Weight vs. temperature for different heating rate values (50°C/min, 100°C/min, 150 °C/min and 200 °C/min) at 5 % oxygen ratio (v).

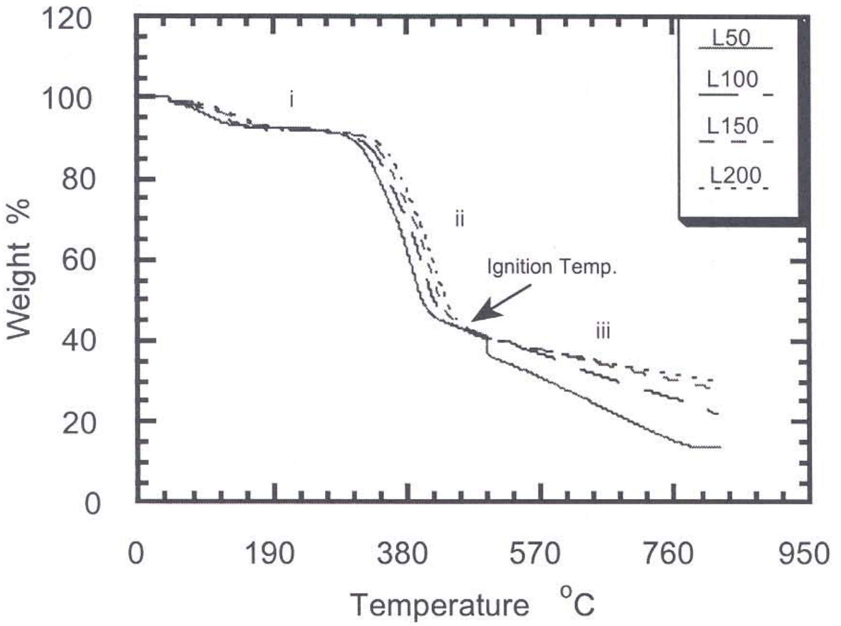

Fig. 7. Weight vs. temperature for different heating rate values(50°C/min, 100°C/min, 150 °C/min and 200 °C/min)) at 15 % oxygen ratio (L).

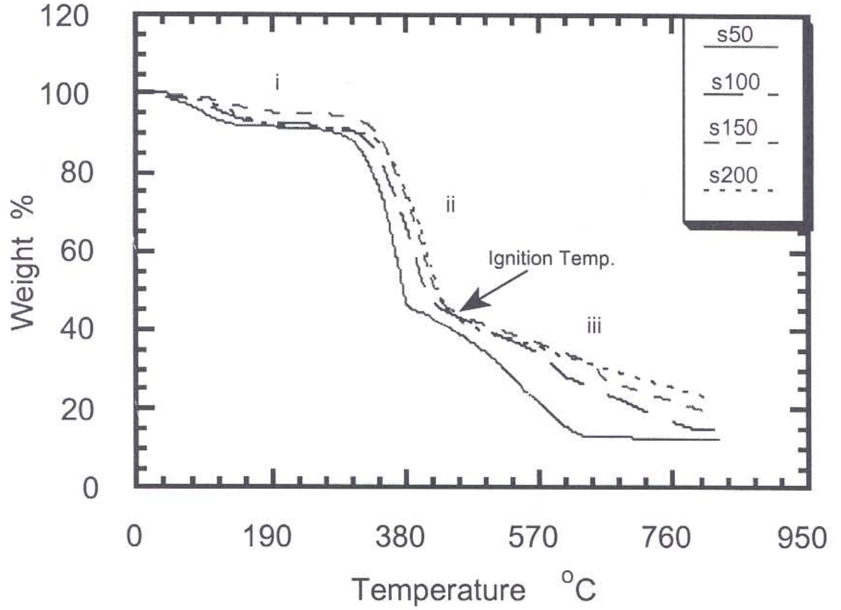

Fig. 8. Weight vs. temperature for different heating rate values (50°C/min, 100°C/min, 150 °C/min and 200 °C/min) at 22 % oxygen ratio (s).

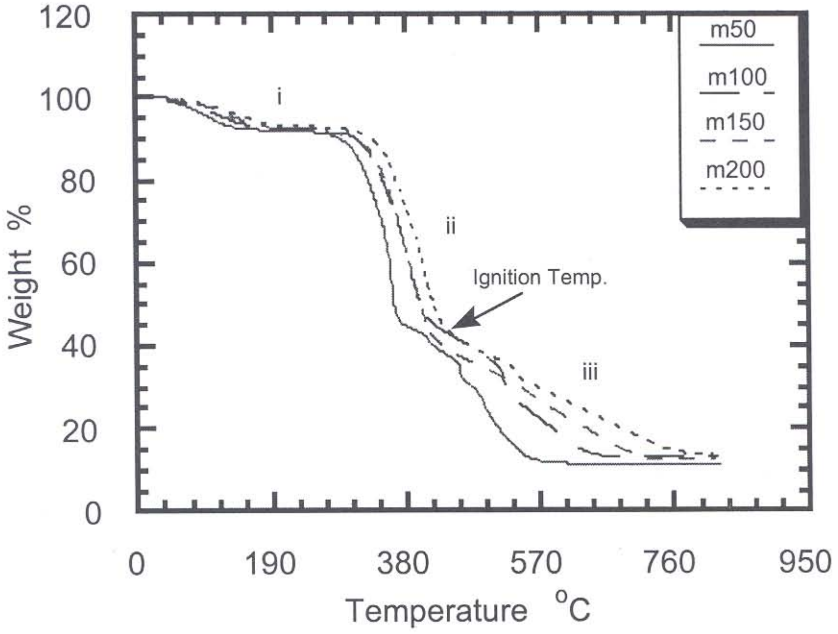

Fig. 9. Weight vs. temperature for different heating rate values (50°C/min, 100°C/min, 150 °C/min and 200 °C/min) at 28 % oxygen ratio (m).

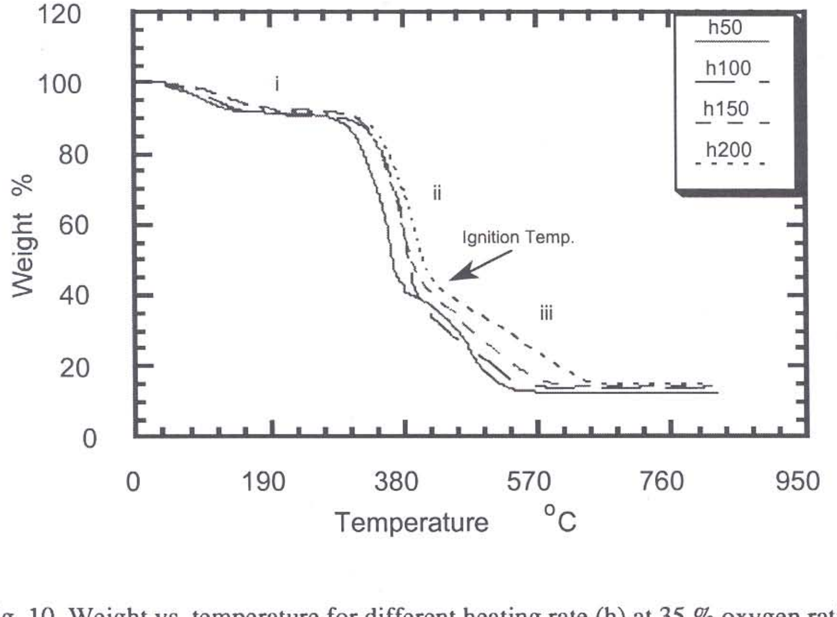

Fig. 10. Weight vs. temperature for different heating rate (h) at 35 % oxygen ratio.

Table 5. Combustion processes of rice husks at different oxygen percentages values with different heating rate values.

	Heating Rate °C/min.	Starting Temp. °C	Ignition Temp. °C	Weight loss %	Ash weight ratio %
	At 5% O_2 (refer to Fig. 6)				
1	50	300	450	68	32
2	100	320	470	66	34
3	150	330	480	65	35
4	200	340	490	65	35
	At 15% O_2 (refer to Fig. 7)				
1	50	300	400	85	15
2	100	320	420	80	20
3	150	340	440	75	25
4	200	350	450	73	27
	At 22% O_2 (refer to Fig. 8)				
1	50	300	400	85	15
2	100	330	420	85	15
3	150	350	430	80	20
4	200	350	440	78	27
	At 28% O_2 (refer to Fig. 9)				
1	50	300	360	90	10
2	100	320	400	86	14
3	150	340	410	85	15
4	200	350	440	84	16
	At 35% O_2 (refer to Fig. 10)				
1	50	300	375	90	10
2	100	325	400	85	15
3	150	330	410	85	15
4	200	350	425	84	16

The residual RH ash from the first test which was zero O_2 % and 200 °C/min. was subjected to four different testes as given in Figs. 11-14. The objective of these tests is to study the effect of the oxygen composition ratio on the combustion processes of the ash itselfand also how to approach the complete combustion (based on the weight of the ash). Higher oxygen ratio means lower ash weight ratio as shown in Fig. 14.

4. CONCLUSIONS

The effect of combustion heating rates, oxygen composition on rice husk combustion (weight sample ratio vs. combustion temperatures, ignition temperatures and the ash weight ratio) was presented in this paper. From the results it can be concluded that the increase of the oxygen composition ratio in the air tends to decrease the ignition temperature and the ash weight percentage ratio. The ash weight ratio increased by increasing the combustion heating rates values due to the incomplete

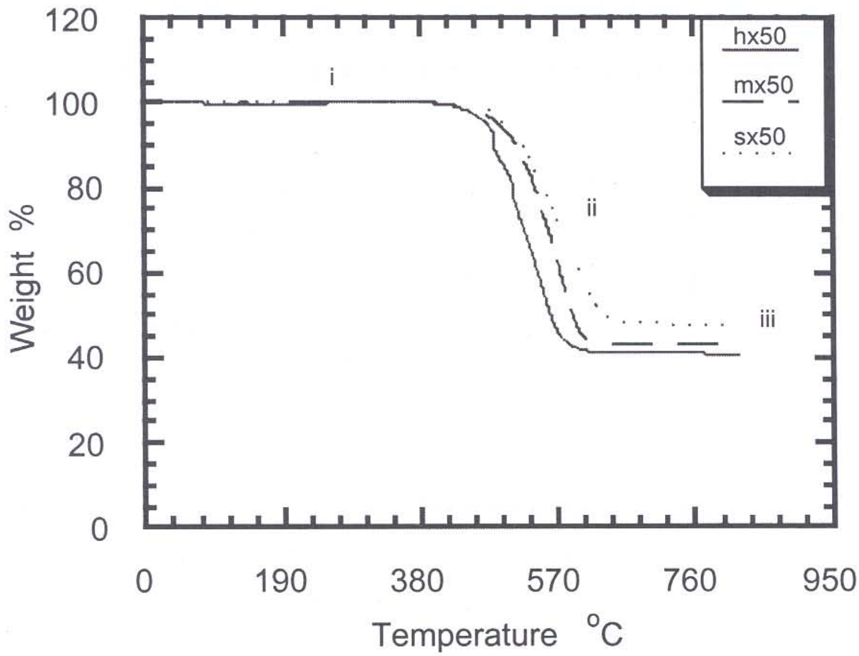

Fig. 11. Weight ratio vs. temperature at constant heating rate 50 °C/min. of the second phase combustion (the first phase was at zero O_2 %, 200 °C/min.).

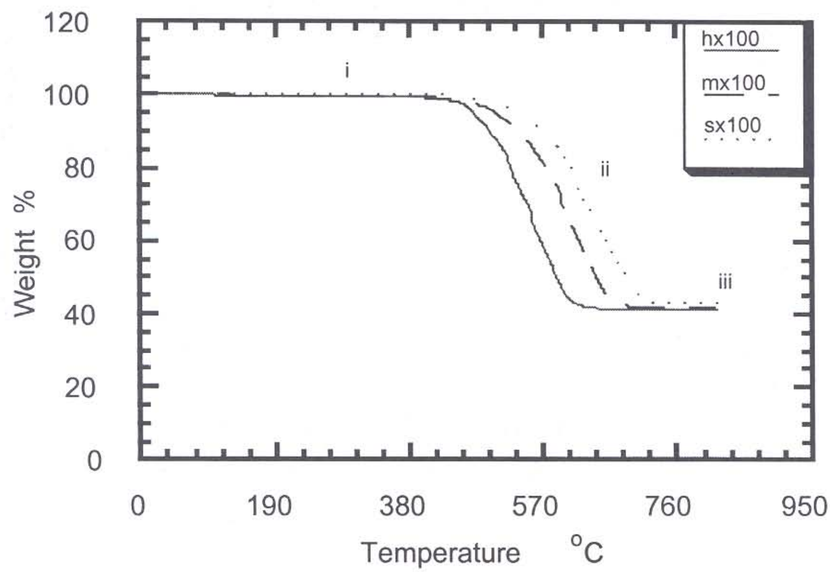

Fig. 12. Weight ratio vs. temperature at constant heating rate 100 °C/min. of the second phase combustion (the first phase was at zero O_2 %, 200 °C/min.).

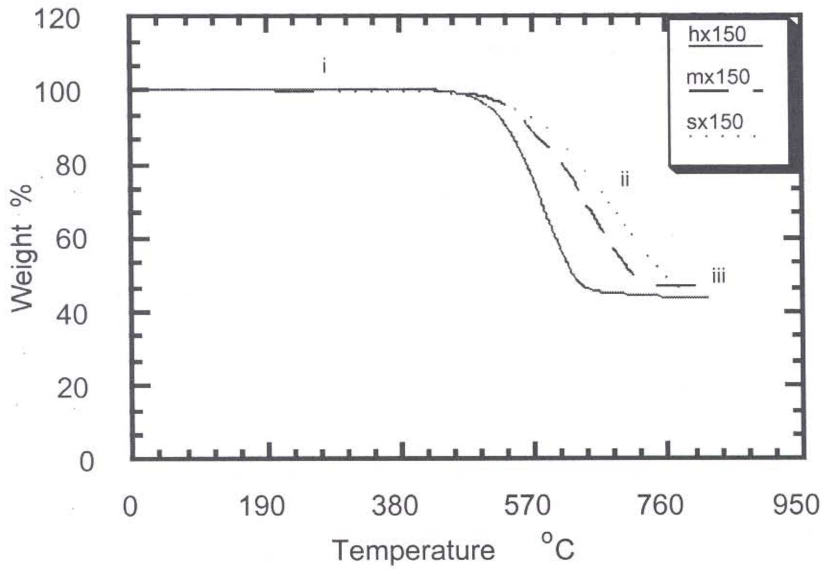

Fig. 13. Weight ratio vs. temperature at constant heating rate 150 °C/min. of the second phase combustion (the first phase was at zero O_2 %, 200 °C/min.).

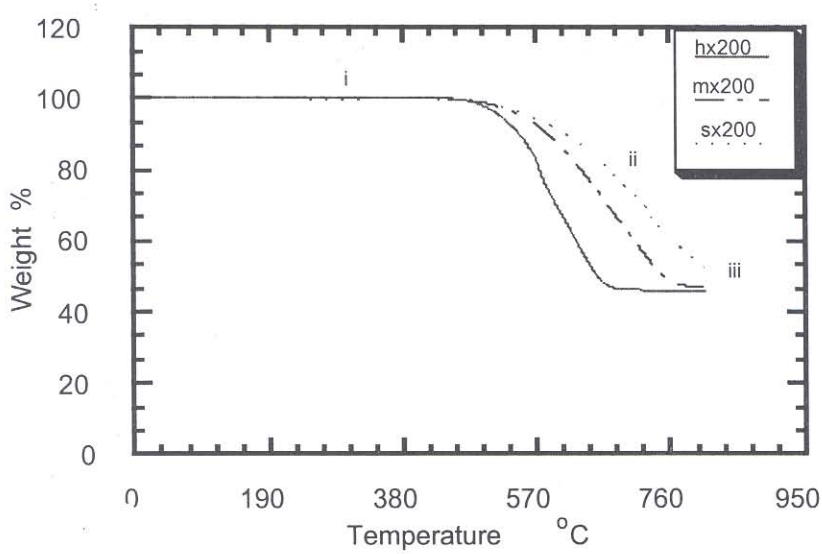

Fig. 14. Weight ratio vs. temperature at constant heating rate 200 °C/min. of the second phase combustion (the first phase was at zero O_2 %, 200 °C/min.).

combustion of the RH under high heating rate values. Since the combustion processes occur in three stages, detailed investigations for each stage will be further conducted in the laboratory. The results discussed here will be used to design optimal process conditions for rice husk combustor for energy.

5. ACKNOWLEDGMENT

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