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Thermal Characteristics of Rice Hulls

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Evaluation of the thermal characteristics of rice hulls is described. Decomposition was negligible below 200°C, but on heating above 200°C, the amount of volatile matter evolved increased steadily with increasing temperature up to 450°C, where > 90% of the total volatile matter was separated. Decomposition is rapid and is temperature dependent. The effect of temperature on the composition of the residues is also described. The carbon content of the residues increased while the oxygen and hydrogen content decreased sharply when the temperature of pyrolysis was increased.

1. Introduction

Industrial utilisation of rice hulls in combustion to liberate energy,[1] the controlled combustion to obtain carbon-free ash and the pyrolysis of hulls to obtain either char or gaseous and liquid products requires the knowledge of their thermal characteristics.[2]

The thermal characteristics measured here are: the volatile matter, the char, the loss in weight on thermal treatment and the effect of thermal treatment on the composition of the hulls residue.

2. Experimental and results

2.1. Materials

Rice hulls were obtained from Rashid Rice Mills, Egypt. Their average chemical composition was 37.7% C, 5.2% H_2, 36.6% O_2, 0.5% N_2 and 20% ash. The average silica content of the ash was 94%.

2.2. Total volatile matter

The total volatile matter of rice hulls was determined by heating the sample at 800–850°C for 7 min. The loss in weight based on dry matter is defined as the total volatile matter. The total volatile matter of rice hulls was found to be in the range 60.2–62.6%. The organic matter in the residue after removing all the volatile matter was 49.7% and ash in the residue was 50.3%.

2.3. The char of rice hulls

The char of hulls was evaluated by combustion of the hulls at 800°C in the presence of oxygen (in an open furnace). The char (based on oven dry basis) was 32.3%, organic matter in char was 38.0%, and the ash in char was 62.0%.

The char obtained from traditional rice hull furnaces contained about 36–40% organic matter of which the main part was carbon. Accordingly, the presence of a high percentage of organic matter in the residue reflects the degree of heat losses due to incomplete burning of the raw material. Thus, Maheshwari and Ojha[3] reported that the losses in heat due to the unburned carbon in refuse constitutes 16.11–20.22% in RPEC rice hulls fired furnace (Indian type furnace).

2.4. The loss in weight on thermal treatment

The loss in weight on thermal treatment of hulls was determined by bringing the sample to the

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required temperature over 40 min, and then maintaining this temperature for a further 15 min in the absence of air. The loss in weight in the absence of air is equivalent to the volatile matter evolved under the given conditions. The loss in weight on a dry matter basis is illustrated in Figure 1 from which it is clear that decomposition of hulls is negligible below 200°C. The sample heated at 200°C was darkish yellow. On heating at temperatures above 200°C, the volatile matter evolved increased steadily with increasing temperature up to 450°C. At this temperature >90% of the total volatile matter was separated. Thermal decomposition occurred rapidly and was temperature dependent.

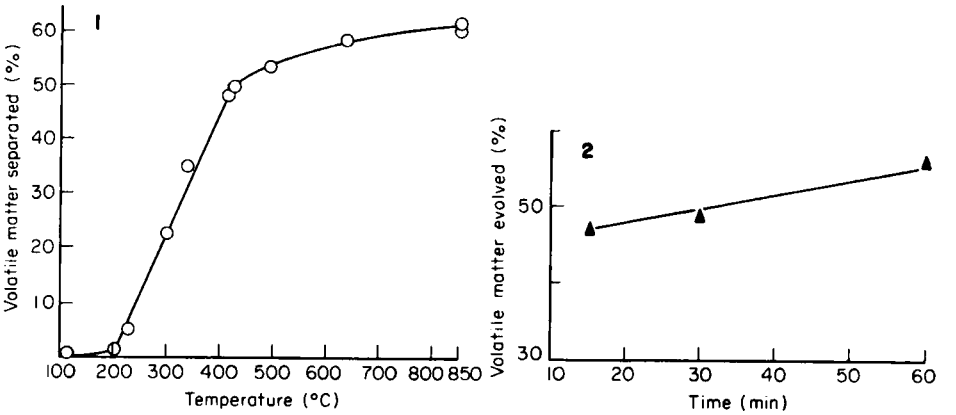

Figure 1. The amount of volatile matter separated as a function of temperature. Time at maximum temperature was 15 min.

Figure 2. Effect of the time of pyrolysis on the amount of volatile matter evolved.

The effect of time on the amount of volatile matter evolved is illustrated in Figure 2 for hulls heated at 400°C. The volatile matter evolved increased slightly with time increasing from 15 to 60 min. Part of the increase in weight loss can be attributed to the unavoidable oxidation reactions which may occur, especially during longer periods of treatment.

The effect of temperature on the loss of weight of rice hulls in controlled oxygen atmospheres is illustrated in Figure 3. In this case the loss in weight can be attributed to the evolution of volatile matter and also to the oxidation reactions occurring at such high temperatures. As expected, the loss in weight in this case was much higher than the loss in weight in the case of thermal treatment in the absence of air.

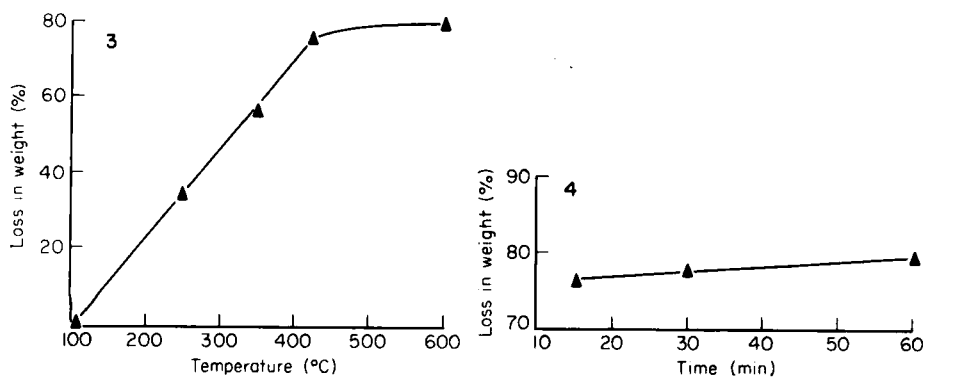

Figure 3. Effect of temperature on the loss of weight of hulls in the presence of air. Time at maximum temperature was 15 min.

Figure 4. Effect of time on the loss of weight in the case of heating at 400°C in a controlled oxygen atmosphere.

The effect of time on the loss of weight in the case of heating the hulls at 400°C in a controlled oxygen atmosphere is illustrated in Figure 4. This negligible effect of time can be attributed mainly to the oxidation reactions occurring in the presence of oxygen and not due to the thermal decomposition and evolution of volatile matter.

2.5. Effect of thermal treatment on the composition of rice hull residues

The effect of the temperature of pyrolysis on the composition of rice hull residues was studied. The carbon and hydrogen contents were evaluated by microanalysis. The ash content was determined by ignition at 850°C. Oxygen was determined by difference. Other components (N_2, S, etc.) were ignored, as they constituted $<0.5\%$.

The effect of the temperature of pyrolysis on the composition of rice hull residues is illustrated in Figure 5. The carbon content of the residues increased, while the oxygen and hydrogen contents of the residues decreased with increasing temperature. This sharp decrease in the oxygen and hydrogen

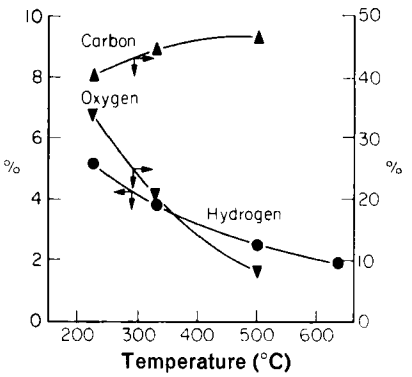

Figure 5. Effect of the temperature of pyrolysis on carbon, hydrogen and oxygen contents of hulls.

contents in the temperature range 200–280°C may be attributed to the formation of water vapour, carbon dioxide, formic and acetic acid as reported in cases of wood pyrolysis[4–6]. The material slowly became charred. The carbon content increased due to the decline in the oxygen and hydrogen contents of the hulls. However, the increase in carbon content was not too great, due to the formation of carbon compounds, such as carbon dioxide, formic and acetic acids. At temperatures in the range 280–500°C, combustible gases and vapours such as carbon monoxide, hydrogen, methane, formaldehyde, and formic and acetic acids, diluted with carbon dioxide and water vapour,[4,7] and entrained droplets of tars, were separated. Thus, a decline in the hydrogen and oxygen contents of the residue was to be expected. The decline in the carbon content of the residue due to the formation of carbon compounds was accompanied by the decrease in oxygen and hydrogen contents, and accordingly the carbon content of the residue indicated only a small increase. As a result of the losses in the organic material, the ash content of the residue increased.

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