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Physico-chemical characterisation of Indian biomass ashes

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Abstract

India stands fourth in biomass utilisation for various purposes like domestic, commercial and industrial applications. While extensive studies have been made for coal ash characterisation and utilisation, studies on characterisation of biomass ash and its utilisation has not been addressed. In this paper, biomass ash from five sources i.e. rice husk, bagasse, groundnut shell, cashewnut shell, and arecanut shell have been characterised. Chemical composition analysis, particle size analysis, thermal analysis, and microstructure analysis were carried out. Results show that in all ashes silica is the major compound with particle size ranging from 15 to 30 μm and having irregular shape. Ash powders originating from cashewnut shell, arecanut shell and groundnut shell also have compounds of calcium, magnesium and potassium. Bagasse and cashewnut shell ashes have high LOI due to presence of unburnt carbon, P_2O_5 and other volatiles.

Keywords: Biomass ash; Chemical analysis; Thermal analysis; Particle size analysis; SEM

1. Introduction

Sustainable development and increasing fuel demand necessitates the identification of possible energy sources. Biomass forms like firewood, agricultural wastes, crop stalks, and agro residues occupy a major role in this scenario. Biomass are utilised for both power production and thermal applications. Globally, biomass accounts for 14% of the total energy supply. Indian biomass potential is estimated at 16 GW (excluding co-generation) with an installed capacity of 0.630 GW; India stands fourth globally in generating power through biomass [1]. In India, agricultural wastes form a major biomass source with 400 Mt of annual production and these are utilised for various applications.

Some of the common agricultural wastes include bagasse, rice husk, cashewnut shell, arecanut shell and groundnut shell. Bagasse is the fibrous residue from sugarcane juice extraction and is one of the most valuable byproducts in sugar mills. Bagasse has a calorific value of 8021 kJ/kg and is utilised as a fuel in boilers to generate steam and electricity through co-generation. Rice husk is generated during milling of rice, which occurs during raw rice or parboiled rice production. Raw rice production involves direct milling of paddy. In this process, about 78% by weight is received as rice, broken rice and bran. The balance 22% of the weight of paddy is obtained as husk. Rice husk is utilised in rice mill furnaces for paddy processing.

India is one of the major cashew growing countries and produced 4.6 million tonnes in 2005. The shell is the outer skin of cashew kernel. The cashewnut shell is used for extracting cashewnut shell oil or as a fuel for thermal applications in cashewnut processing industries for roasting and in other industries. Arecanut or betelnut is the seed of areca palm. The shell is used as a fuel in the processing of arecanut. Groundnut shell is used as a fuel for thermal applications in many sectors such as silk yarn processing plants.

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Table 1
Source of biomass ash

Ash type	Location	Utilisation
Arecanut	North East India	Arecanut processing
Bagasse	North India	Co-generation in sugar mill
Cashewnut shell	West India	Cashew processing
Groundnut shell	South India	Silk yarn processing
Rice husk	North and North East India	Rice mill furnace

The use of these biomass as fuel generates large amount of residual ash which causes serious environmental problems. Biomass ash does not contain toxic metals like in the case of coal ash. The ash forming constituents in biomass fuels are quite diverse depending on the type of biomass, type of soil and harvesting [2]. In general, the major ash forming inorganic elements in biomass fuels are Ca, K, Na, Si and P and some of these act as important nutrients for the biomass [3]. However, some biomass fuels have high silicon content (e.g. rice husk) while some have high alkali metal content (wood). While the elemental composition of the ash is determined by the inorganic constituents in the parent biomass, the crystallinity and mineralogy dep\ends on the combustion technique used.

Compared to coal fly ash where significant research has already taken place and high utilisation figures are already reported in several countries [4–6], commercial utilisation of biomass ash is not widely reported. However, several research efforts are underway for applications such as adsorbent, raw material for ceramics, cement and concrete additive, material recovery, etc. based on its characteristics. The composition, surface area, presence of unburnt material, etc. play a role in determining the application.

Bagasse fly ash has been examined as an adsorbent as well as an additive in cement and concrete [7–10]. However, its high carbon content can cause a hindrance in its application for concrete. Rice husk with its high silica content has been used as an insulator, adsorbent, cement and concrete additive and as a substitute for silica [11]. Studies on ash from arecanut shell, cashewnut shell and groundnut shell ash are limited [9].

This paper reports the investigation on characteristics of biomass ashes from five common agro-residue sources of India i.e. rice husk, bagasse, groundnut shell, cashewnut shell, and arecanut shell. Characterisation involves chemical composition and phase analysis, particle size analysis, thermal analysis, and morphological analysis. This will enable other value added applications for these ash powders to be developed and provide inputs for determining the processing conditions.

2. Experiment

Biomass ashes of rice husk, bagasse, groundnut shell, cashewnut shell, and arecanut shell used in various combustion processes were obtained. Table 1 gives the details of the sample source.

2.1. Ash preparation

The as received ash was ball milled in a roller mill using ceramic balls. After ball milling, the powders were passed through a 38 μm sieve and were subsequently used for analysis. For some analysis, the powders were heated at 450 °C until constant weight was obtained, to remove the volatiles and unburnt carbon.

2.2. Ash characterisation

Chemical analysis of ashes was determined using X-ray fluorescence (Spectro, X-LAB-2000). The phases present

Table 2
Elemental composition of ash powders determined by XRF analysis

Compound	Percentage				
	Groundnut	Bagasse	Arecanut	Cashew shell[a]	Rice husk
SiO_2	43.13	65.03	42.45	8.18	93.52
Al_2O_3	10.71	0.49	3.85	3.06	0.01
Fe_2O_3	3.96	0.49	4.20	2.06	0.51
TiO_2	0.55	0.08	0.07	0.12	0.04
P_2O_5	4.19	1.14	7.29	14.67	1.06
CaO	10.81	2.75	1.23	7.52	0.68
MgO	6.10	3.26	0.48	10.66	0.47
Na_2O	5.60	0.06	0.20	5.25	0.40
K_2O	9.61	1.73	18.91	21.66	2.40
Cl	1.44	0.12	3.70	1.99	0.11
LOI	3.90	24.84	12.51	20.56	0.80
MnO			0.02	0.20	
SO_3			5.09	4.07	

[a] Ash powder heated to 450 °C before analysis.