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Retraction

Retracted: Cashew Nut Shell Waste: Availability in Small-Scale Cashew Processing Industries and Its Fuel Properties for Gasification

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This paper entitled "Cashew nut shell waste: availability in small-scale cashew processing industries and its fuel properties for gasification" has been retracted as it was submitted for publication without the acknowledgement of Biofuel Laboratory, CIAE Bhopal. Additionally, it was found to contain a substantial amount of material from the Proceeding, S. Gangil, A. K. Dubey, Thermo Gravimetric Properties of Cashew Shell Cake Proceedings of the 44th Annual Convention & Symposium of ISAE, New Delhi, India, IARI, pp. 4.17, January 2010 [1].

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[1] A. Mohod, S. Jain, and A. Powar, "Cashew nut shell waste: availability in small-scale cashew processing industries and its fuel properties for gasification," *ISRN Renewable Energy*, vol. 2011, Article ID 346191, 4 pages, 2011.

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Research Article

Cashew Nut Shell Waste: Availability in Small-Scale Cashew Processing Industries and Its Fuel Properties for Gasification

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The energy and mass flow of the steam cooking operation of three readily defined small-scale cashew processing industries was studied to estimate the availability of cashew nut shell. The proximate analysis of cashew shell waste was carried out using ASTMD 73–75 method. The calorific value of the cashew shell was carried out using bomb calorimeter (ASTME 711). The thermogravimetric analysis of the cashew shell was carried out using TG-FTIR with 10°C/minute heating rate. The study revealed that, the small-scale cashew processing industries followed steam-cooking process with average energy consumption accounted to be 2969.7 MJ per 1000 kg of raw cashew seed. The cashew shell waste generated in small-scale cashew processing industries was found to be 67.5% of total weight of cashew seed, which can be utilized as fuel for thermal energy supply. The average higher calorific value of the cashew nut shell was found to be 4890 kcal/kg. The thermogravimetric analysis revealed that 85% weight of cashew nut shell has been degraded at 500°C and in 13 minutes. The availability and fuel analysis of the cashew shell as a fuel revealed its suitability as a supplementary fuel for thermal application through pyrolysis in the industry.

1. Introduction

India is the largest producer and processor of cashews (*Anacardium occidentale L.*) in the world. Total area in India under cashew cultivation is about 8,68,000 ha with annual production of 6,65,000 tons giving average productivity 860 kg per hectare. India processed about 11,38,000 tones of raw cashew nut seeds through 3650 cashew processing mills scattered in many states of country [1]. The cashew mill in India employed different unit operations/methodology for processing and depending on variety of raw material, location, technological mechanization, and availability of secured energy supply. The most energy and time intensive unit operations in cashew processing are drying of raw seed in open sun, steaming of raw nut and kernel drying with electrical energy [2]. The steaming of raw cashew nut seed prior to cutting and shelling operation is widely adopted method in small-scale cashew nut processing mills. The cutting and shelling operation performed in the mill generates huge quantity of the cashew nut shell that is, about 67% of total weight of raw cashew nut seeds. A wide disparity in energy consumption to produce the same quantity of similar products in cashew processing was observed. The wide variations in energy intensity of these cashew mills reveal the scope for energy conservation to be in the order of 30 to 48%. [3]. The energy audit is an effective tool to explore the relationship between the energy consumed and production. It identifies the patterns, type, and efficiency of energy use, particularly in its more energy intensive processes [4]. The study of thermal energy consumption for steam generation with estimation and analysis of fuel properties of cashew nut shell may reveal the suitability of cashew nut shell as alternative feed stock. The generalized process flow chart of unit operations performed in the small-scale cashew nut processing industries is shown in Figure 1.

2. Methodology

The energy audit of three (03) small-scale cashew nut processing industries having fuel-based baby boiler and

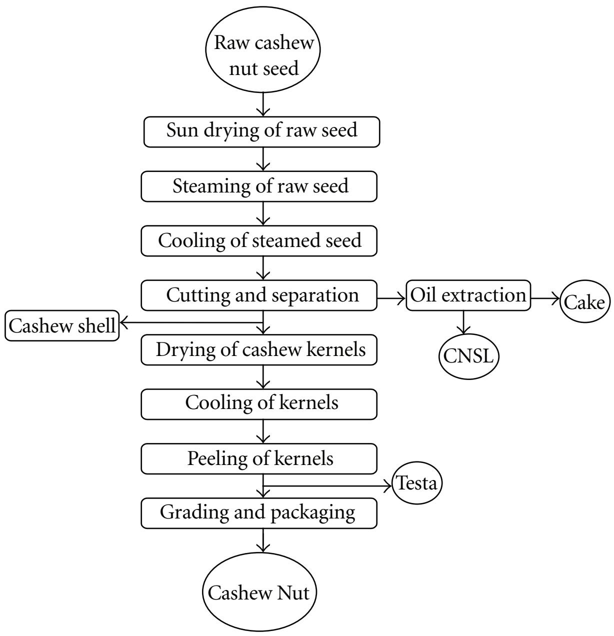

Figure 1: Generalized process flow chart of small-scale cashew processing industries.

60 kg/batch raw seed holding capacity steam cooker was carried out. The energy and mass flow of the steam cooking operation along with operational parameters was studied using maxi energy audit tool. The input raw material and output material and byproduct of steaming and cutting and separation operation was measured. The waste cashew shell was estimated in term of kg/1000 kg of raw cashew nut seeds. The known quantity of biomass fuel was measured before the utilization and the fuel consumption was noted by considering the balance amount of fuel after completion of the unit operation. The time required for the completion of the unit operation was measured using the electronics stopwatch. The number of labour engaged for the particular unit operation and the actual time spent to accomplish the task was noted using the electronic stopwatch. The energy used in the form of sources for unit operation in term joule per batch at rated capacity was converted into energy intensity, that is, Mega joule per 1000 kg of raw cashew seed. The energy used for steaming operation was computed as total energy for steaming operation,

$$\begin{aligned} E_{\mathrm{SRf}} &= \text{Thermal energy} + \text{Manual energy}, \\ E_{\mathrm{SRf}} &= W_{\mathrm{SRf}}\, C_{\mathrm{SRf}} + 3.6\,[0.075 N_{\mathrm{SRm}} t_{\mathrm{SRm}}], \end{aligned} \tag{1}$$

where E_{SR} is energy requirement for steaming (J), W_{SRf} is quantity of fuel used (kg), C_{SRf} is heating value of fuel used (J/kg), N_{SRm} is number of persons involved, and t_{SRm} is time taken for a particular operation.

Number 3.6 is conversion factor for kW to kJ and 0.075 is the average output of adult man in kW.

2.1. Analysis of Cashew Nut Shell as Fuel. The proximate analysis (fraction of mass of moisture, volatile, ash, and fixed carbon) of a sample of biomass cashew nut shell was carried out using the standard analytical procedures.

The proximate analysis of cashew nut shell waste was carried out using the analytical method ASTM-D-3173 to 3175 [5]. The fixed carbon was determined by difference. The higher heating value of solid fuels was determined by experiment of bomb calorimeter (ASTME-711). The thermogravimetric analysis (TGA) of cashew nut shell was carried using Pyrix-6 of Parkin Elemer, USA analyzer to study the thermal decomposition behavior of cashew nut shell in relation to the thermal gasification.

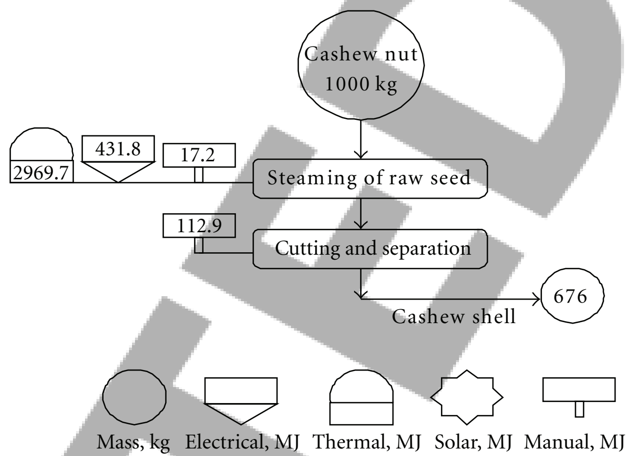

Figure 2: Energy and mass flow of steaming and cutting operation in sscp industries.

3. Results and Discussion

3.1. Estimation of Energy for Steaming and Mass of Cashew Shell Waste. The result obtained from the maxi energy audit of the steaming of raw seed and cutting and separation operation in small-scale cashew processing industries is summarized in Table 1.

It is observed that the steaming of raw seed appears to be the energy-intensive operation with total energy used of about 2986.8 MJ/1000 kg of raw seeds in 60-kg/batch capacity industries. The thermal energy used for the steaming of raw cashew seed using the baby boiler operated on the biomass was found to be 2969.7 MJ/1000 kg of raw cashew seeds. The energy used and input, out of mass for steaming and cutting and separation operation is shown in Figure 2.

3.2. Analysis of Cashew Nut Shell. The result obtained from the proximate analysis (fraction of mass of moisture, volatile, ash, and fixed carbon) and heating value of cashew nut shell is summarized in Table 2.

The proximate analysis of cashew nut shell revealed the suitability of the fuel for gasification. It is observed that the average moisture content of cashew nut shell waste was found to be 6.47%. The moisture content of the fuels under study is in the acceptable limit (below 15%) to ensure free flow and good quality gas production. The average of volatile matter content in cashew nut shell was found to be 72%.

Table 1: Energy consumption(MJ/1000 kg) for steaming in sscpi (60 kg/batch).

Unit operations	Energy consumption MJ/1000 kg of raw seed				
	Solar	Thermal	Electrical	Manual	Total
Steaming of raw seed	—	2969.70	—	17.18	2986.88
Cutting and separation	—	—	—	112.91	112.91

Table 2: Proximate analysis and heating value of cashew nut shell.

SN	Property	Cashew nut shell
1	Moisture Content, %	06.47 (ASTMD-3173)
2	Volatile Matter, %	72.00 (ASTMD-3175)
3	Ash Content, %	01.05 (ASTMD-3174)
4	Fixed Carbon, %	20.48 (By difference)
5	Higher Heating Value, Kcal/M^3	4890.23 (ASTME711)

The higher amount of volatile matter revealed the suitability of the fuel for gasification. Also the data indicated that, the average ash content of the cashew nut shell was found to be 1.05% which revealed their suitability for the gasification with minimum blocking of flow of air and fuel, formation of clinkers, and so forth. The most desirable component, which governed the suitability of the fuel for gasification, that the average fixed carbon was found to be 20.48% in cashew nut shell. The heating value of fuel is the major factor determining the suitability of fuel for gasification. The results obtained showed that the average higher heating value of the cashew nut shell was found to be 4890.23 kcal/Kg. The result obtained from the laboratory testing of the characterization of the biomass fuel for gasification is found similar to that of the earlier studies carried out [4, 6–8].

3.3. Thermogravimetric Analysis of Deoiled Cashew Shell. The thermogram was obtained in inert an environment for cashew nut shell using the heating rate (HR) of 1°C/min by raising the temperature from 33°C to 1000°C. The result obtained from the thermogravimetric analysis of the cashew nut shell in term of percentage weight loss with respect to time and temperature is summarized in Table 3. The variation of the percentage weight loss with respect to time of thermal decomposing and rise in temperature to cause the thermal decomposing were shown in Figures 3 and 4, respectively.

It is observed that, the moisture removal lasted up to 250°C at the heating rate of 1°C/min. The release of lighter volatiles initiated in the range of 220 to 280°C and continued up to 340 to 380°C. There was lag of 40°C between the cellulosic and hemicellulosic decomposition of material. The lighter volatile noticed in the range of 44–52%. The analysis for oxidation temperature (T_0) at the HR indicated that T_0 increase with HR. The quantum of T_0 variation indicated that the cashew nut shell is gasifiable as similar to that of wood.

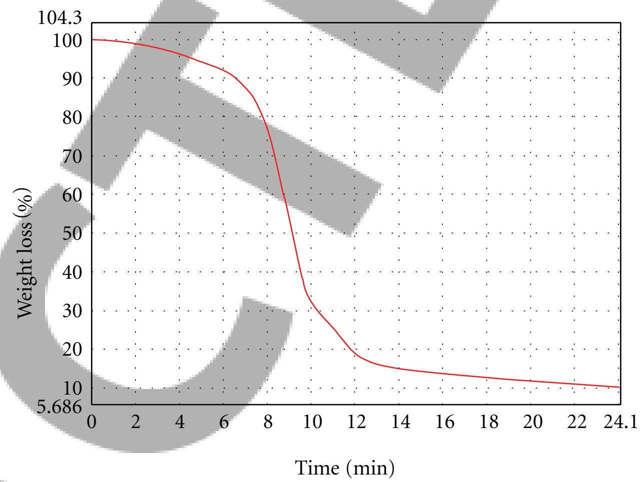

Figure 3: Variation of weight loss of cashew nut shell with decomposition time.

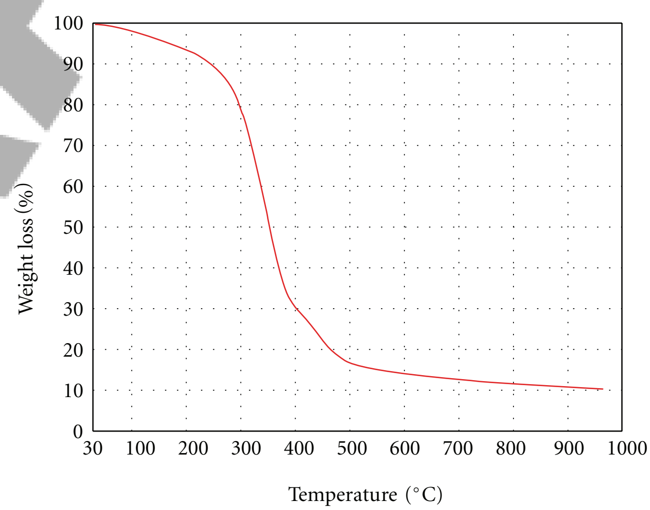

Figure 4: Variation of weight loss of cashew nut shell with rise in temperature.

4. Conclusion

The study revealed that the thermal energy used for the steaming of raw cashew seed using the baby boiler operated on the biomass could be meeting from the cashew shell waste generated in the industries itself. The cashew shell waste generated in small-scale cashew processing industries was found to be 67.5% of total weight of cashew seed, which

Table 3: Percentage weight loss of cashew nut shell with time and temperature.

Sr. no.	Time, Min.	Derivative weight Loss, %	Temperature, °C	Derivative weight loss, %
1	0.00	99.8594	33.02	99.8594
2	1.00	99.5045	73.02	98.8434
4	3.00	97.7344	143.02	96.1639
6	5.00	94.1190	223.02	92.0153
8	7.00	87.7241	303.02	78.1301
10	9.00	53.5274	383.02	34.8903
12	11.00	25.4211	463.02	20.5359
14	13.00	15.9919	543.02	15.2336
16	15.00	14.1733	623.02	13.7513
18	17.00	12.9808	703.02	12.6772
20	19.00	12.0732	783.02	11.8267
22	21.00	11.2810	863.02	11.0794
24	23.00	10.5957	943.02	10.3922
25	24.00	10.2130	966.02	10.1759

can be utilized as fuel for thermal energy supply. The average higher calorific value of the cashew nut shell was found to be 4890 kcal/kg. The thermogravimetric analysis revealed that0 85% weight of cashew nut shell has been degraded at 500°C and in 13 minutes. The fuel properties of the cashew nut shell waste available in the industries revealed its suitability for gasification. The proper utilization of the cashew nut shell waste through gasification route will conserve the biomass fuel and make the industries self-sustainable for thermal energy.

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