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Characterization of selected raw material for pelletization

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Abstract
This paper deals with the characterization of raw material used for pelletization i.e., mixture of Shredded Cashew leaves litter (S.C.L.L), wet dung and water in different proportion combination. The study involved seven different combinations of these proportions, denoted as C_1 (500:400:100), C_2 (500:380:120), C_3 (500:420:80), C_4 (520:380:100), C_5 (480:420:100), C_6 (480:400:120), and C_7 (520:400:80) respectively. The moisture content of the raw material in these seven different combinations ranged from 2.60% to 7.53%, Volatile matter was found to be between 65.00% to 74.60%, while ash content varied from 3.43% to 12.7%. The fixed carbon content ranged from 14.5%, to 22.6%. Among these combinations, C_7 (520:400:80) exhibited the highest higher calorific value (HCV) and bulk density were 3214.9 kcal/kg and 306 kg/m^3 respectively.

Keywords: Cashew leaves litter, characterization, proximate analysis, calorific value, bulk density

1. Introduction

India is now the greatest producer, processor, consumer, and exporter of cashews in the world with 8.55 lakh ha area and a total annual production 6.20 lakh MT of raw nuts with productivity of 800 kg/ha. (Raykar *et al*. 2022) [10]. Cashew tree is an evergreen, huge tree that may reach to height of 14 m and has a thin, sometimes crooked trunk. The leaves have smooth edges, are spirally organized, elliptic to obovate in shape, and measure 4 to 22 cm in length and 2 to 15 cm in width. Cashew is farmed in the tropical regions between 25°N and 25°S and is well suited to hot lowland settings with a noticeable dry season. The conventional cashew tree grows to a height of up to 14 m, begins producing after three years, and takes eight years to produce enough for a commercial harvest (Annonymus) [1]. The standard planting method for cashew trees uses a square system and a spacing of 7 to 9 m. The optimum distance between plants is either 7.5 m × 7.5 m (175 plants/ha) or 8 m × 8 m (156 plants/ha) (Annonymus) [2].

The organic biomass in cashew plants has a huge potential for recycling from cashew plants that are 10 to 40 years old, which can produce 1.38 to 5.20 t/ha of cashew leaf litter per year. Due to high lignin content and lack of collection facility, falling cashew leaves frequently end up in garbage in cashew fields where they are not valuable as crop manure (Kalaivanan *et al*. 2017) [9]. The average value of the moisture content, volatile matter, ash content, fixed carbon, calorific value and bulk density of shredded cashew leaves litter were 10.86%, 65.33%, 6.9%, 16.87%, 4278.3% and 257 kg/m^3. The higher calorific value of cashew leaves litter indicates that the suitability of material for pelletization. (Annonymus) [3]

2. Materials and Methods

The raw material cashew leaves litter, wet dung and water were manually collected. Collected material (cashew leaves litter) was dried for two months in solar tunnel dryer. After drying and shredding of cashew leaves litter by shredder the proximate analysis of combination of raw material of seven different combinations was carried out. The raw material combination of percentage of shredded cashew leaves litter, wet dung and water shown in Table 1.

2.1 Raw material characterization for pelletization

Raw material characterization is carried out in terms of proximate analysis, calorific value and bulk density.

Table 1: Raw material combination percentage of shredded cashew leaves litter, wet dung and water

Combination No.	Shredded cashew leaves litter (g)	Wet Dung (g)	Water (g)	Treatments (g)
C_1	500	400	100	500:400:100
C_2	500	380	120	500:380:120
C_3	500	420	80	500:420:80
C_4	520	380	100	520:380:100
C_5	480	420	100	480:420:100
C_6	480	400	120	480:400:120
C_7	520	400	80	520:400:80

2.2 Proximate analysis of raw material combination
While using any biomass as a fuel, proximate analysis of fuel was important parameter for knowing the suitability and quality of fuel. It included moisture content, volatile matter, ash content and fixed carbon on percentage. The proximate analysis was completed by using standard procedure as follow.

2.2.1 Moisture Content
The moisture content of biomass was measured by oven dry method. Initially the sample with the known weight was kept in oven at 105 ºC for one hour. Then the oven dry sample weighed (ASTM D-3173). The moisture content of sample calculated by using following formula:

$$\text{Moisture content\%} = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \quad \text{.....(1)}$$

Where,
w_1 = weight of empty crucible, g
w_2 = weight of the crucible + initial weight of sample, g
w_3 = weight of the crucible + weight of dried sample, g

2.2.2 Volatile Matter
The dried sample left in the crucible was covered with a lid and placed in muffle furnace, maintained at 950 ± 20 ºC for 7 minutes (ASTM D-3175). The crucible was cooled first in air, then inside desiccators and weighed again. Loss in weight was reported as volatile matter on percentage basis.

$$\text{Volatile matter (\%)} = \frac{W_3 - W_4}{W_2 - W_1} \quad \text{......(2)}$$

Where,
w_4 = weight of crucible + weight of sample after heating in muffle

2.2.3 Ash Content
The residual sample in the crucible was heated without lid in a muffle furnace at 700 ºC ± 50 ºC for 90 minutes (ASTM D-3174). The crucible was then taken out, cool initially in air, then in desiccator and weighed. Heating, cooling and weighing was repeated, till a constant weight was obtained. The residue was reported as ash on percentage basis.

$$\text{Ash content (\%)} = \frac{W_5 - W_1}{W_2 - W_1} \quad \text{.....(3)}$$

Where,
w_5 = weight of crucible + weight of sample after heating in muffle furnace (ash), g

2.2.4 Fixed Carbon Content
The fixed carbon content was calculated by applying mass balance for the C.L.L sample. The fixed carbon content was estimated by using the following formula.

$$\text{Fixed Carbon} = 100 - \text{\% of (MC + VM + AC)} \quad \text{......(4)}$$

Where,
FC = Fixed Carbon, %
MC = Moisture Content, %
VM = Volatile Matter, %
AC = Ash Content, %

2.2.5 Calorific value
The higher heating value of material was determined by using of bomb calorimeter (ASTME-711), where the combustion was carried out in environment with 25 atmospheric pressures of oxygen to ensure complete combustion. Water equivalent of the apparatus was determined by burning a known weight (1.0gm.) of pure and dry benzoic acid in powdered form in the bomb under identical condition. The rise in temperature was noted for 5 minutes. The standard calorific value of benzoic acid was taken as 6324 kcal/kg, since all other values in the formula were known. So, water equivalent was calculated. The higher calorific value of solid fuel using the bomb calorimeter experiment was determined as,

$$\text{Calorific value (kcal/kg)} = \frac{(W+w) \times (T_2 - T_1)}{X} \quad \text{.....(5)}$$

Where,
W = Mass of water placed in calorimeter, g
w = Water equivalent of apparatus, g
T_1 = Initial temperature of water in calorimeter, ˚C
T_2= Final temperature of water in calorimeter, ˚C
X = Mass of fuel sample taken in crucible, g

2.2.6 Bulk density
The bulk density of material was determined as per the standard procedure. A cylindrically shaped container of fixed volume was used for determination. The container was weighed empty to determine its weight and then it was filled with the sample, after completely filling the container, excess material at the top was removed by moving a straight edge over the container and weighed once again. The bulk density was determined by dividing the mass of the material by the volume of the container. The bulk density was calculated by using the formula, (Bhavsar *et al*. 2018) [7]

$$\text{Bulk density (kg/m}^3) = \frac{\text{Weight of sample}}{\text{Volume of container}} \quad \text{.....(6)}$$

3. Results and Discussion
3.1 Proximate analysis of mixed raw material used for pelletization
From Fig 1 it is observed that the variation of moisture content, volatile matter, ash content and fixed carbon in raw material used for making pellets for seven combinations were found to be in the range of 2.60% to 7.53%, 65.00% to 74.60%, 3.43% to 12.7% and 14.5%, to 22.6% respectively.

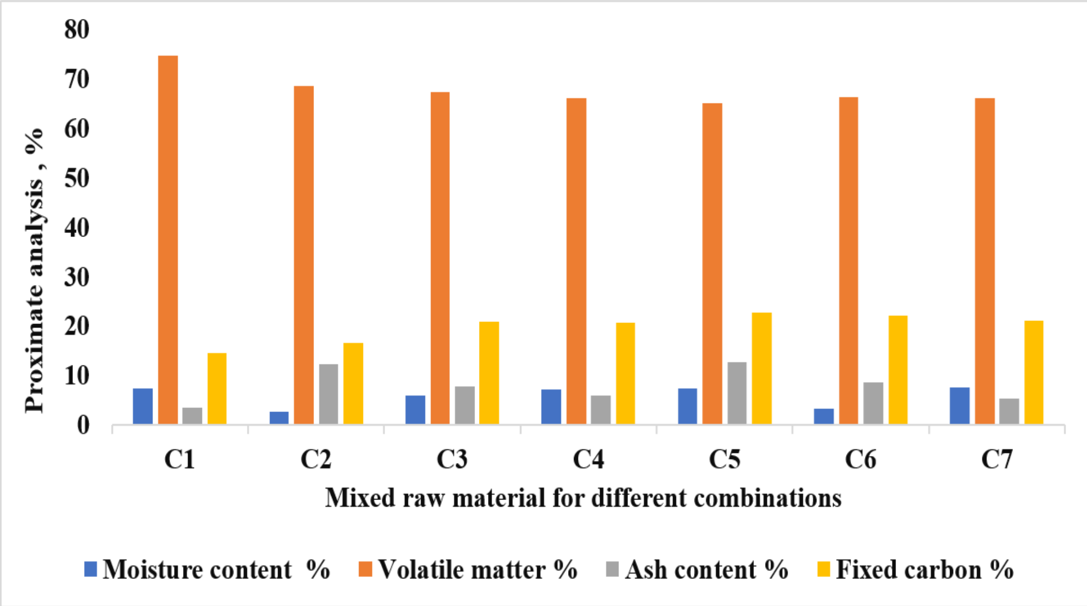

Fig 1: Proximate analysis of different combinations of raw material for making pellet

It was also observed that the moisture content of all mixed raw material for making pellets was found to be in the acceptable limit between 8 to 12% for further suitability for making pellets and also for thermal application of pellets.
The value of ash content 3.43% of combination C_1 was found minimum among from all raw material combinations. The value of ash content 12.7% of combination C_5 was found maximum among from all combinations. The lower ash content of raw material indicates that the material is suitable for making pellets. The value of fixed carbon 14.5% of combination C_1 was found minimum among from all the mixed raw material combinations. The value of fixed carbon 22.6% of combination C_5 was found maximum among from all the mixed raw material combinations. The higher carbon content 22.6% could be help for increasing energy in terms of calorific value for making pellets. The lower amount of ash content and higher fixed carbon in mixed raw material combinations indicated that material was suitable for pelletization by Annonymus [3].

3.2 Calorific value of mixed raw material used for pelletization

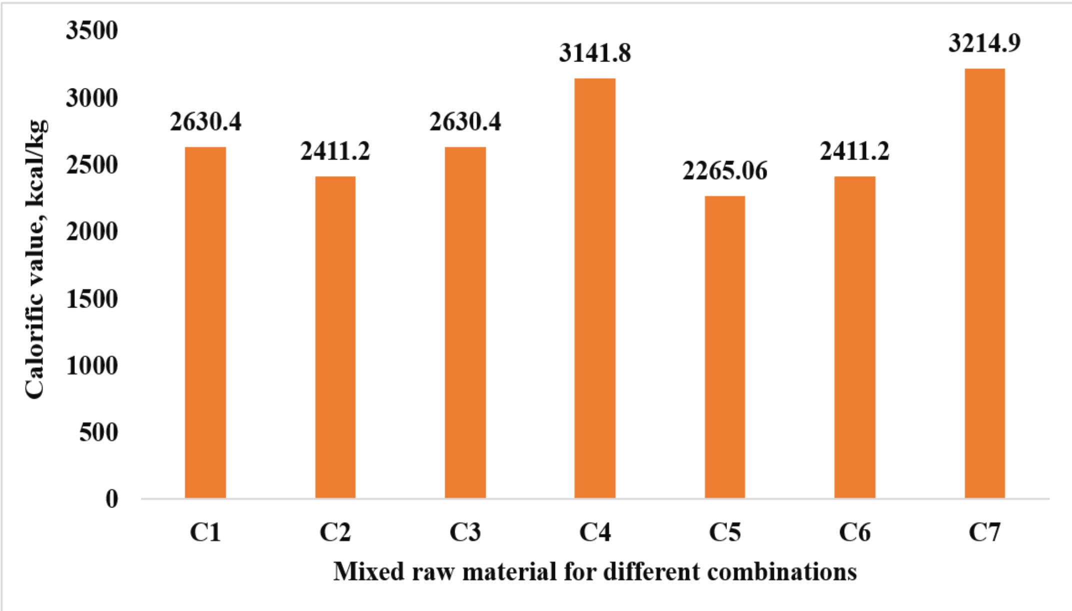

Fig 2: Calorific value of different combinations of raw material for making pellets

From Fig 2 it was observed that the average calorific value of mixed raw material was found to be in the range of 2265.06 kcal/kg to 3214.9 kcal/kg. The calorific value 2265.06 kcal/kg of combination C_5 was found minimum among from all the mixed raw material combinations. The calorific value 3214.9 kcal/kg of combination C_7 was found maximum among from all the mixed raw material combinations. The combination containing higher S.C.L.L. percentage having higher calorific value. The higher calorific value of the combination indicates the suitability of material for pelletization (Annonymus) [3]. The combination C_5 shows minimum calorific value because of in this mixture ash content and fixed carbon content was found maximum among all seven combinations.

3.3 Bulk density of mixed raw material used for pelletization

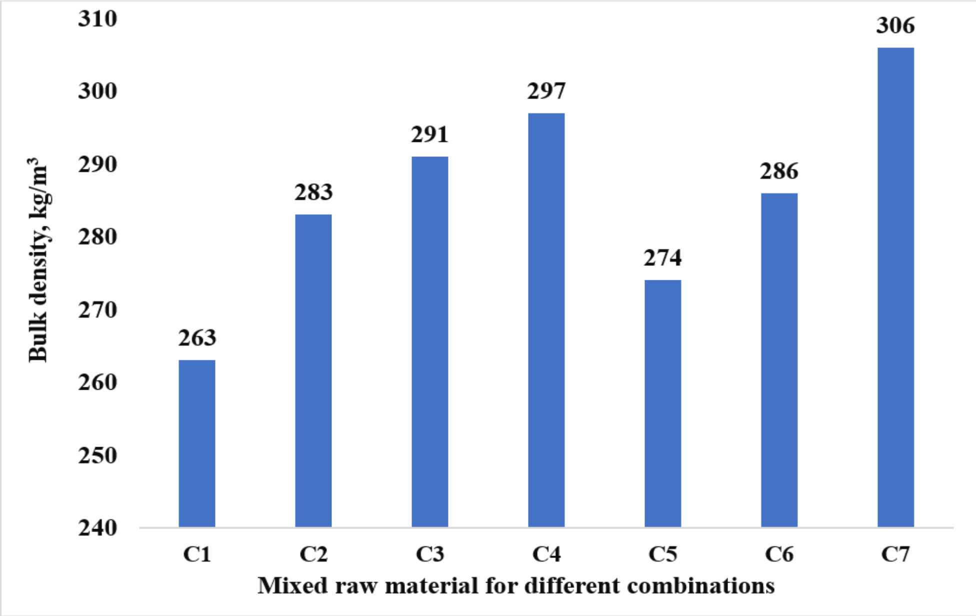

Fig 3: Bulk density of different combinations of raw material for making pellets

From Fig 3 it was observed that the average value of bulk density of mixed raw material was found to be in the range of 263 kg/m^3 to 306 kg/m^3. It was observed from all combinations the lowest bulk density 263 kg/m^3 was found in combination C_1 as lignocellulosic biomass has low bulk density. It was also observed that the highest bulk density 306 kg/m^3 was found in the combination C_7. The combination C_7 shows the highest bulk density because of this combination consist of higher percentage of S.C.L.L. and lower percentage of water than rest of all six combinations. Physically compacting the loose biomass into pellets can increase bulk density by up to 10 times and mechanical densification increases feedstock homogeneity, durability, and storage capacity in addition to bulk density by Crawford *et al*. 2015 [8]. The results that suggested the necessity of pelletization of these shredded cashew leaves litter to reduce storage and transportation cost.

4. Conclusions

- The moisture content of mixed raw material used for making pellets for seven combinations was found in the range of 2.60% to 7.53%, volatile matter was found in the range of 65.00% to 74.60%, ash content was found in the range of 3.43% to 12.7% and fixed carbon was found in the range of 14.5% to 22.6%.
- For mixed raw material before pelletization the maximum calorific value was found 3214.9 kcal/kg in C_7 combination. The minimum calorific value was found 2265.06 kcal/kg in C_5 combination.
- For mixed raw material before pelletization the maximum bulk density 306 kg/m^3 in C_7 combination. The minimum bulk density was found 286 kg/m^3 in C_6 combination.

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