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Analysis of the Energy Procreation Using Various Lignocellulosic Biomass as Feedstock

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ABSTRACT:
Lignocellulosic biomasses are regarded as an excellent sourceof energy procreation in this current scenario of energy crisis. Amidst various approaches to energy procreation using biomass as the feedstock, the literature reported that the thermochemical route is the most prevailing. The energy procreation using biomass varies from species to species. Therefore, the understanding of the different properties linked to energy procreation is a mandate to be used as the feedstock for energy recovery. Few of such properties have been reported to be the proximate analysis, compositional analysis, ultimate analysis, bulk density, and calorific value. The present study evaluates the applicability of the four different biomass types for energy procreation applications. Initially, the biomasses were identified by herbarium preparation. Thereafter, the biomasses were evaluated through different characterization techniques to check their applicability tothe energy procreation process. Moreover,an FTIR and XRD analysis of the various biomasses under consideration was also carried out to have a perspective regarding the presence of functional groups. Finally, for defining and estimating the environmental liabilities linked with energy procreation using the selected biomasses, a life cycle analysis was carried out in terms of five midpoint indicators. The obtained results indicated that the environmental liabilities were very less for the defined process.The proposed scheme of the study indicates an environmentally sustainable approach that will in turn promote biomass-based energy solutions.

Keywords: Alternative energy source; Biomass; Calorific value; Energy procreation, Sustainability.

I. INTRODUCTION:

The energy consumption has been multiplied several folds due to various reasons like population explosion, rapid urbanization, modernization, etc (Avtar et al. 2019). As a consequence of this, conventional energy sources like coal and petroleumare depleting at a much faster rate. It has been reported that the reserve of conventional fossil fuels will deplete within a few decades (Raugei et al 2012). Such an imbalance between the demand and supply of energy sources has in turn created a global perturbation. In order to combat such issues, energy procreation using lignocellulosic biomass can be regarded as an excellent option (Den et al. 2018). Moreover, the energy procreation using lignocellulosic biomass will also mitigate the issues related to their storage and management. Furthermore, the energy procreation processes are regarded to be a more environmentally cleaner option due to the lesser emission of harmful gases as compared to the other conventional energy feedstocks (Cheng et al. 2020).

There are various pathways for the energy procreation process like the biological and thermochemical pathways. The thermochemical pathways are mostly adopted since such processes are linked with relatively fast reaction rates andensure better energy returns (Devis et al. 2011). The energy procreation from biomass depends upon the type of biomass. Different categories of biomasses like agricultural residues, woody biomass, and perennial crops have been reported to have different energy returns (Commandre et al. 2015). Various properties of biomass play an important role in their energy content. Proximate analysis is an important parameter in this regard. The proximate analysis of biomass is measured in terms of volatile matter, fixed carbon, moisture content, and ash content. The presence of higher volatile matter and fixed carbon ensures better energy returns whereas the presence of higher ash content and moisture content ensures lower energy procreation (Bhavsar et al. 2018). The ultimate analysis also plays a vital role in the screening of biomass for energy procreation purposes. The ultimate analysis is measured in terms of carbon, hydrogen, and oxygen content. The presence of higher carbon content and lower oxygen & hydrogen content indicated better energy returns from a particular biomass type (Chelgani et al 2010). The compositional analysis is also an important aspect that defines the acceptance of a biomass type for energy procreation purposes. The compositional analysis of biomass is evaluated in terms of lignin, cellulose, hemicellulose, and extractives. The presence of higher lignin content of a biomass type ensures better energy returns through the thermochemical pathway (Ping et al. 2011). The bulk density also plays a vital role in defining the suitability of a biomass type for the energy procreation process. The higher bulk density ensures better energy returns (Yadav et al. 2020). Finally, the calorific value (in the form of a higher heating value (HHV)) gives a direct insight into the energy content of the biomass category. Moreover, an FTIR and XRD analysis were conducted to have an insight into the presence of the functional components within the biomass specimens under evaluation.

Thus, the present study evaluates the four different biomass types in the context of energy procreation. Initially, the chosen biomasses were systematically classified for better understanding. Thereby, the biomasses were evaluated through various characterization protocols for energy procreation (bulk density, proximate analysis, ultimate analysis, compositional analysis, and calorific value. The obtained results indicated that the biomasses have significant potential to be applied tothe energy procreation process. This study will definitely open new avenues toward the utilization of different biomasses for cleaner energy solutions that in turn depict the novelty of the study.

II. MATERIALS AND METHODS:

Collection of Biomass:

The four different biomass species evaluated in this study were rice husk, wheat straw, coconut wood dust, jackfruit leaf, and waste lemon peel which were procured locally. The main reason for the selection of the biomasses was to cover a vast range of biomass categories. The obtained biomasses were cleaned using distilled water, ground into dust form, and stored in airtight containers. The chemicals required in this study were bought from Nice® Chemicals (Kerala, India). The double-distilled water was obtained in the laboratory by using Borosil® distillation apparatus, Maharashtra, India.

Methods:

The systematic classification of the biomass was obtained from herbarium analysis. The compositional analysis of the biomass was obtained by using earlier literature-reported protocols (Singh et al. 2017). The bulk density of the biomasses under evaluation was evaluated by using standard protocol laid by the American Society for Testing and Materials (ASTM D 854-92). The proximate analysis of the biomass in terms of moisture content, volatile matter, ash content, and fixed carbon was determined by adopting respective ASTM protocols. The elemental analysis of the biomass under evaluation was measured by following standard literature reported protocol (CEN/TS 15104:2005). The calorific value in the form of HHV was measured by using a standard bomb calorimeter by following ASTM Protocol (ASTM D5865-10a). The four different biomass specimens under evaluation were analyzed using infrared spectroscopy (ThermoFisher Scientific NicoletTM iS10 FTIR Spectrometer, USA) and X-ray diffraction analysis (X' Pert Pro, PANalytical, The Netherlands) to determine and characterize the functional groups present within them. Fourier transformed infrared spectrometry records the interaction between the infrared radiation and the sample by measuring the frequency in terms of (wave number) at which the particular sample absorbs the radiation and ultimately records the intensity of the absorption. Each chemical functional group present in the biomass sample absorbs infrared radiation at a particular frequency or wave number. Thus, by performing IR spectroscopy the information about the chemical functional groups present in a biomass sample can be obtained from the spectrogram. Spectroscopy grade Potassium Bromide was mixed with biomass sample to be tested at a ratio of 200:1 weight by weight. The resultant moisture mixed well in mortar and pestle and then the mixture was hydraulically pressed into pellet form. The resultant pellet was placed in the pellet holder of the instrument and the IR spectra of the biomass specimens were collected and recorded at different wave numbers. The four biomass specimens were characterized for carbon crystallinity by using X-ray diffraction. The diffraction pattern was quantified by using an X-ray diffractometer (Bruker D-8), Cork, Milton, O.N. configured with Cu-Kα radiation source generated at 30 kV and 30 mA respectively. A constant scanning speed of angle 2ϴ (ranges between 10-40°) was maintained at 1°/min.

III. RESULT AND DISCUSSION

The four biomass specimens used in this study were systematically classified by preparing herbarium sheets. Such initiative would be helpful towards the identification of the exact systematic details of the different biomasses evaluated in this study. The obtained results have been presented in Table 1.

Table 1. Systematic classification of the different biomass specimens evaluated in this study.

Biomass	**Kingdom**	**Class**	**Order**	**Family**	**Genus**	**Species**
Rice Husk	Plantae	Monocotyledonae	Poales	Poaceae	Oryza	O. sativa
Wheat Straw	Plantae	Liliopsida	Poales	Poaceae	Triticum	T. aestivum
Jackfruit Leaf	Plantae	Dicotyledonae	Rosales	Moraceae	Artocarpus	A.heterophyllus
Waste Lemon Peel	Plantae	Magnoliopsida	Sapindales	Rutaceae	Citrus	C. limon

The result portrayed in the Table 1 revealed that a spectrum of biomass of different categoriesfor energy procreation has been chosen in this study. Accordingly, the study would definitely add a value proposition to the existing literature pool.

The bulk density of the different biomass specimens under the purview of this study was carried out by standard operating procedure ASTM D 854-92. The bulk density is an influential attribute of particular biomass material in the purview of energy procreation. It has also been reported to have an immense impact regard to theirmanagement, transport, and repository outlay. The presence of a higher bulk density of a particular biomass category also indicates better energy procreation potential (Hamzah et al. 2019). The bulk density of the different studied biomass specimens has been indicated in Figure 1.The obtained results indicated that the bulk density of all the biomasses evaluated in this study has ample potential for energyprocreation in the purview of bulk density. Thus, the selection of these biomasses can be utilized for energy procreation purposes which in turn justifies the proper selection of biomasses in this study.

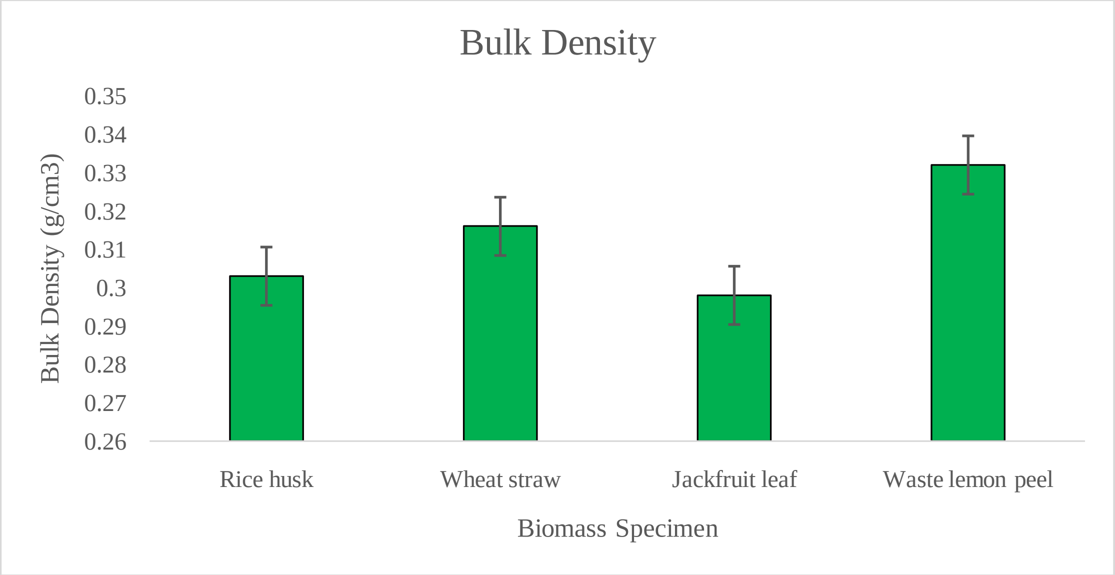

Figure 1. Bulk density of different biomass under evaluation.

The proximate analysis of the biomasses under evaluation wascarried out by adopting standard literature reported protocols as detailed in the materials and methods section. The obtained results have been presented in Table 2.

Table 2 Proximate composition of different biomass specimens under evaluation

Biomass Specimen	Moisture content (%)	Volatile matter (%)	Ash content (%)	Fixed Carbon (%)
Rice Husk	11.045 ± 0.678	60.898 ± 1.208	14.224 ± 0.498	13.833 ± 0.318
Wheat Straw	12.128 ± 0.562	59.802 ± 1.133	13.604 ± 0.512	14.466 ± 0.472
Jackfruit Leaf	13.004 ± 0.514	69.064 ± 1.344	2.802 ± 0.096	15.130 ± 0.411
Waste Lemon Peel	15.078 ± 0.588	65.904 ± 1.098	5.792 ± 0.201	13.226 ± 0.208

Footnote: All the experiments were carried out in triplicates and the resulting mean value along with the standard deviation has been provided

The results obtained from the proximate analysis indicated that all the biomass has notable moisture content within them (more than 10%). Accordingly, it is preferable to dry the biomasses under the sun prior to being applied for the energy procreation process. The presence of higher volatile matter and fixed carbon content indicates that the waste biomasses considered in the study can be utilized for energy procreation as per previous literature reports (Kim et al. 2014). However, the ash content of the biomasses considered in the study has relatively higher ash content, which might clog the energy generation system. Thus, specific biomass pretreatment could be adopted to lower the ash content of the biomass under evaluation to be applied for energy procreation purposes. Accordingly, it could be established that the biomasses evaluated in this study possess potential cognizance to be utilized for the energy procreation process. This will also mitigate the issues related to their storage, management, and disposal.

The elemental analysis of the different biomass under evaluation was also carried out by following the standard literature reported protocol as mentioned in the material and method section. The obtained results have been presented in Table 3.

Table 3 Elemental analysis (Ultimate analysis) of different biomass specimens under evaluation

Biomass Specimen	Carbon content (%)	Hydrogen content (%)	Oxygen content (%)
Rice Husk	34.052 ± 0.565	5.343 ± 0.121	32.008 ± 0.787
Wheat Straw	35.112 ± 0.489	6.232 ± 0.098	33.412 ± 0.602
Jackfruit Leaf	34.334 ± 0.342	6.565 ± 0.112	33. 908 ± 0.518

Waste Lemon Peel	33.408 ± 0.422	5.676 ± 0.086	34.124 ± 0.602

Footnote: All the experiments were carried out in triplicates and the resulting mean value along with the standard deviation has been provided

The results indicated in Table 3 indicated that the different biomass specimens evaluated in this study contained a significant amount of carbon content which in turn indicates their applicability for energy procreation applications. The amount of oxygen and hydrogen content of the biomass evaluated in this study is also reported to be less compared to their carbon content which again establishes their suitability for energy procreation purposes. The results obtained from the bulk density and proximate analysis are also found to be in sink with results obtained from the elemental analysis. Thus, utilizing the enlisted biomasses for energy procreation would be an excellent initiative toward the search for green and sustainable alternative sources of energy.

The compositional analysis of the different biomass specimens under evaluation was carried out in terms of lignin, cellulose, and hemicellulose to estimate the energy procreation potential of the biomass. The obtained results have been indicated in Table 4. The obtained results indicated that the different biomass evaluated in this study has a significant amount of cellulose and hemicellulose content within them. These cellulosic components can be harnessed to produce bioethanol by using a biochemical pathway which is a source of clean energy. On the contrary, the biomasses studied in this paper also contain a significant amount of lignin within them, which can be harnessed to produce energy by adopting various thermochemical pathways. Accordingly, the biomasses evaluated in this study can be used for energy procreation applications.

Table 4 Compositional analysis of different biomass specimens under evaluation

Biomass Specimen	**Lignin (%)**	**Cellulose (%)**	**Hemicellulose (%)**
Rice Husk	18.787 ± 0.676	34.676 ± 0.962	15.204 ± 0.056
Wheat Straw	19.898 ± 0.702	32.887 ± 0.986	16.228 ± 0.098
Jackfruit Leaf	11.672 ± 0.528	41.556 ± 1.022	18.228 ± 0.062
Waste Lemon Peel	8.343 ± 0.482	38.602 ± 1.002	13.662 ± 0.034

Footnote: All the experiments were carried out in triplicates and the resulting mean value along with the standard deviation has been provided

Finally, to estimate the energy content of the different biomasses under consideration, the calorific value of the different biomasses was measured in terms of higher heating value or HHV. The result obtained has been in Figure 2.It is evident from the data presented in Figure 2, that the energy content of the different biomass specimens evaluated in this study varied within the range of 14.5-15.5 MJ/kg. The results in turn indicate that the waste biomasses can be an excellent source for energy procreation. Such a utilization pathway will not only help in finding an alternative source of energy but will also mitigate the issues related to their storage, management, and disposal. The results obtained from other characterization methods in this study like proximate analysis, bulk density analysis, ultimate analysis, and compositional analysis also indicated a similar drift.

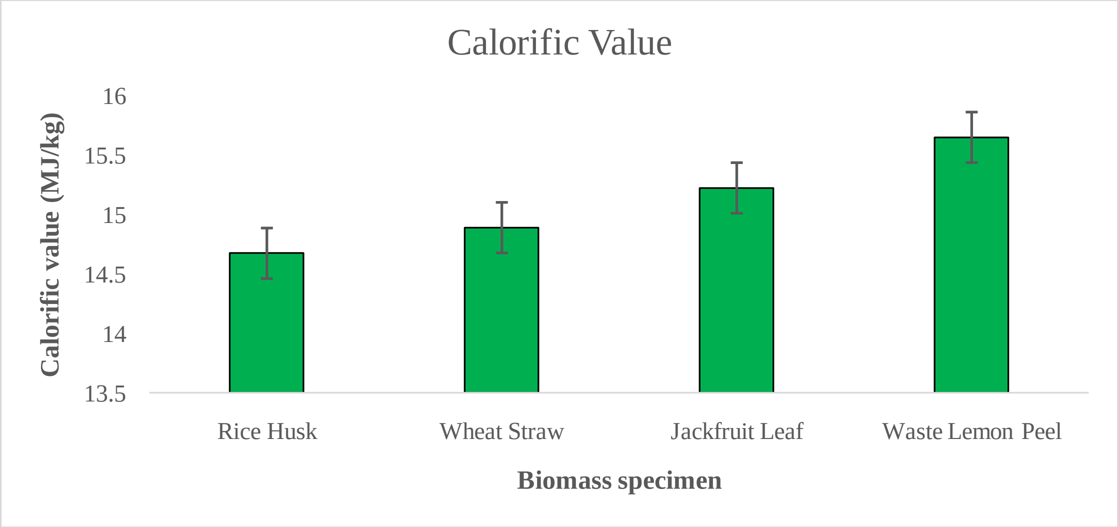

Figure 2 Calorific Value of different biomass under evaluation

The Fourier transformed infra-red spectroscopy was carried out for the studied biomass samples in order to put a deep insight regarding the functional groups present within them and has been indicated in Figure 3. It was noticed that the four biomass samples showed a spectrum peak at different wavelengths such as 480, 1097, 1440, 1500-1600, 1750, 2800-2950, 3150-3400 cm^{-1}. The investigation showed the existence of diversified structural carbohydrates such as lignin, cellulose, and hemicellulose (Singh et al. 2017). The corresponding spectral peaks were accredited analogous to their particular wave number and has been indicated in Table 5.

Table 5 Accredited functional group with analogous wave number of different biomass samples.

Band accreditation	**Band position**
Aromatic ring	480 cm^{-1}
C-C stretching	554 cm^{-1}
C-H alkene stretching,	625 cm^{-1}
C-H alkenes bends, C-H phenyl ring substitution bands	674 cm^{-1}
C-H alkynes bends	782 cm^{-1}
C-O-C symmetric stretching	1097 cm^{-1}
Carboxylic acid	1175 cm^{-1}
Aromatic C-O stretching	1280 cm^{-1}
Alkanes C-H scissoring and bending, aliphatic C-H stretching	1442 cm^{-1}
N-H amines	1516 cm^{-1}
C-H phenyl ring substitution overtones	1668 cm^{-1}
Aldehyde, ketones, esters, carboxylic acid	1745 cm^{-1}
Alkanes	2860 cm^{-1}
Aliphatic C-H stretching	2928 cm^{-1}
-OH stretching	3150-3400 cm^{-1}

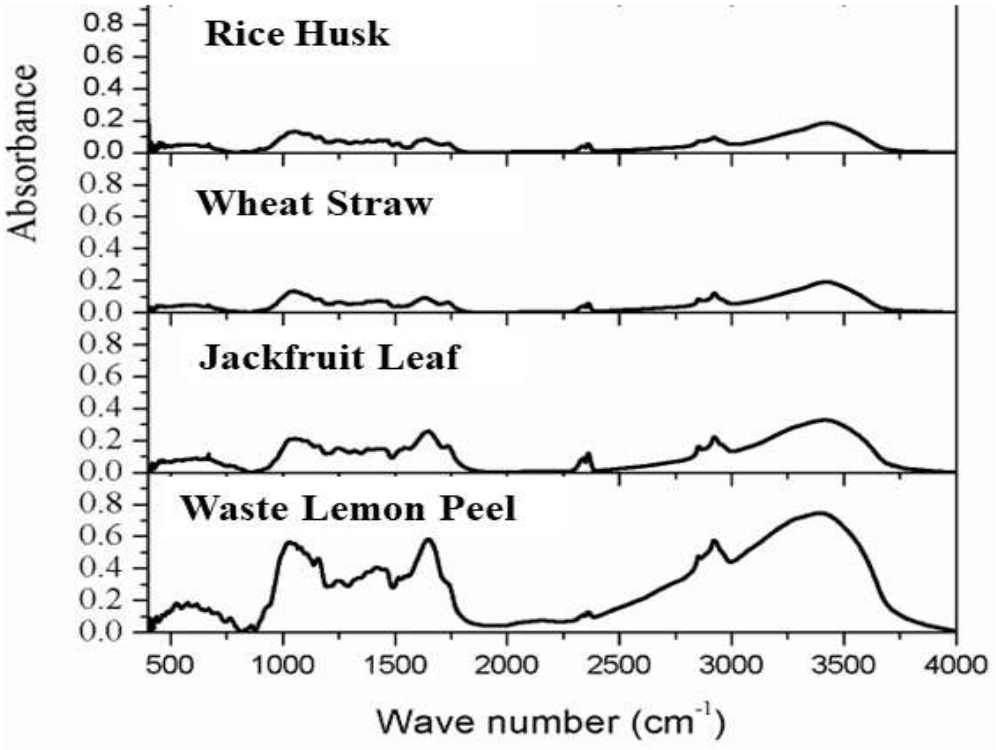

Figure 3 FTIR plot of different biomasses under evaluation

The X-ray diffraction (XRD) analysis of the biomass specimens under evaluation was carried out and has been resented in Figure 4. The presence of wax content, cellulose content, and the bonding between the lignin and cellulosic compartment contributes to the overall crystallinity of lignocellulosic biomass (Bright et al. 2021). Distinct cellulosic peaks were observed around 2ϴ = 22° which indicated the existence of cellulose within the biomass specimens. The spectral peak corresponding to hemicellulose was noted at 2ϴ = 16.6°(Singh et al. 2017).

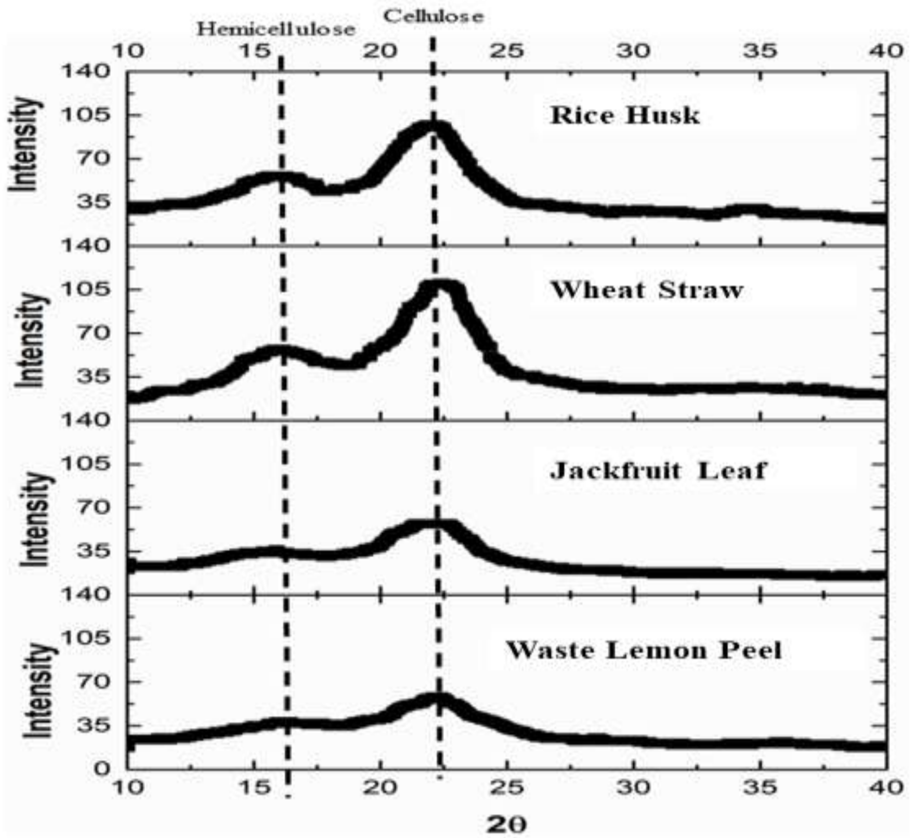

Figure 4 XRD analysis of different biomass specimens under evaluation.

Sustainability Analysis

Defining the environmental liabilities of any particular process is of utmost importance. For the purpose of scaling up at an industrial level, a process needs to be environmentally clean (Frondel et al. 2007). Accordingly, the extended aim of this study was framed toward defining the environmental burdens linked with the proposed scheme of study. Life cycle analysis (LCA) is a widely practiced route for defining the environmental sustainability of a process (Witjes et al. 2016). The analysis of the LCA was conducted by setting up the system boundaries, analysis of the inventory, analysis of the potential environmental impacts, and finally interpreting the obtained results (Khasreen et al. 2009). The entire simulation was conducted by using the educational version of the Gabi® software package (Thinkstep Corporation, Germany) using the US-LCA® and Eco-Invent® databases. The LCA study was presented in terms of 5 different midpoint indicators which have been detailed in Table 6. The choice of the midpoint indicators was done as per the exhaustive literature survey (Mehmati et al. 2018).

Table 6 List of different LCA impact categories (PEI) used in this study

Potential environmental impact (PEI)	**Unit**
Global warming potential (GWP)	kg CO_2 equivalent
Acidification potential (AP)	kg SO_2 equivalent
Eutrophication potential (EP)	kg phosphate equivalent
Ozone depletion potential (ODP)	kg R11 equivalent
Human toxicity potential (HTP)	kg DCB equivalent

Setting up the system boundary is an important attribute of defining the LCA study. The system boundary adopted in this study has been presented in Figure 5.

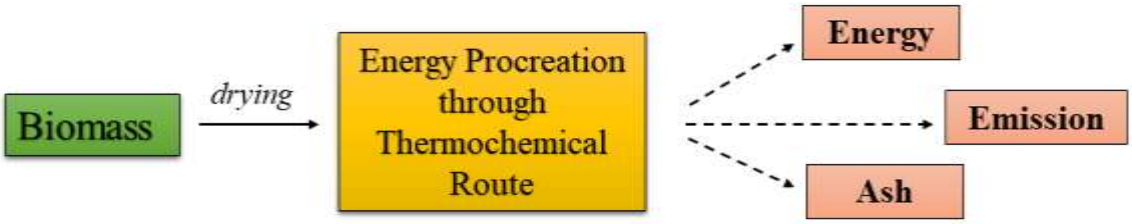

Figure 5 Defining the system boundary of the energy procreation process adopted in this study.

The inputs used for the LCA have been presented in Table 7. The various parameters considered in this study were the moisture content, ash content, and the calorific value corresponding to individual biomass categories.One ton of each biomass specimen was considered as the unit mass. The respective biomasses were dried and was processed for energy procreation using thermochemical pathway. The resultant outcomes were energy, emissions and ash. All the relevant data were obtained from the proximate composition and calorific value of the biomasses which have been presented in Table 2 and Figure 2.The results obtained from the simulation studies in terms of 5 different midpoint indicators has been presented in Table 7.

Table 7 Sustainable analysis for the proposed scheme of energy procreation study

Biomass	**GWP**	**AP**	**EP**	**ODP**	**HTP**
Rice Husk	0.98	0.021	0.00719	NG*	0.0678
Wheat Straw	1.02	0.022	0.00654	NG*	0.0789
Jackfruit Leaf	1.14	0.022	0.00678	NG*	0.0764
Waste Lemon Peel	1.03	0.024	0.00662	NG*	0.0652

Footnote:NG indicated negligible emission.

The results gleaned in Table 7 indicated that the energy procreation process using different biomass categories as feedstock has very less environmental burdens. Almost all the midpoint indicators have minimumor negligible values which in turn makes the overall process more acceptable for further industrial upscaling.However, the major drawback of biomass-based energy procreation is the management of residual ash which is generated in a significant amount and needs to be removed from time to time, else those ash might clog the energy procreation system. The presence of relatively higher moisture content within the biomass is another major drawback to be applied for energy procreation purposes. However, being widely available, cheap, and having fewerenvironmental burdens, makes lignocellulosic biomasses the fuel for the future.

IV. CONCLUSION

The prevailing inquiry forges a contemporary approach to explore unfamiliar crude materials up for grabs in India in the context of energy procreation. Four different biomass samples were guesstimated on the footings of disparate singularities like bulk density, proximate analysis, ultimate analysis, compositional analysis, and calorific value. The obtained results were moreover juxtaposed. The presence of different compositional functionalities within the biomasses under evaluation wasconfirmed by FTIR and XRD analysis. The LCA study also indicated that the overall process has very less environmental burdens. Therefore, it may be summarized that the biomass specimens under evaluationhave a colossal inherent in the context of renewable energy restoration. All these biomass samples are autochthonous to the North-Eastern part of India. As imminent anticipation akin delve into can be enumerated to the bibliography of the biomass in context to bioenergy extraction.

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