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CATEGORICAL ASSESSMENT AND CHARACTERIZATION OF CONVENTIONAL AND UNCONVENTIONAL BIOMASS RESOURCES IN BANGLADESH

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Abstract: With the rapid industrial growth, the need for renewable energy sources is rising fast. Being a developing country, Bangladesh aims towards industrial expansion, which is always followed by increased energy consumption. Considering the fact that fossil fuel is not sustainable and biomass sources are abundant and offer more versatility, the latter have become an attractive alternative to petroleum-based products. Moreover, utilization of biomass also seems promising because of biodegradability and lower greenhouse gas emissions, ensuring reduced environmental pollution, a grave concern with fossil-fuel technology. Biomass can range from agricultural byproducts to industrial and municipal wastes, however, very few biomass sources are currently being used in Bangladesh. Moreover, biomass can also be utilized to derive valuable chemicals, which are potential raw materials in several existing industries in Bangladesh. Despite having massive potential in Bangladesh, there haven't been organized studies on feedstock types, quantities, characterization and applications. Here we present an organized study to identify potential biomass sources and their available quantities. Considering specific waste fractions from varying sources, total amount of utilizable biomass resources have been calculated. A categorized proximate analysis data summary of varying biomass is also prepared that can be consulted in the future studies to calculate the theoretical possible production of energy as well as useful bio-chemicals based on efficient bio-processing techniques. This work is intended to benchmark the current efforts, and would add valuable information resources for the ongoing research towards achieving energy-sustainability and energy-security in Bangladesh.

Keywords: *Biomass; Renewable Energy; Proximate Analysis; Waste Residue.*

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INTRODUCTION

Being a developing country, Bangladesh is mostly dependent on fossil fuel and very specific forest biomass for its energy requirement. Rapid population growth has always been and will remain one of the key drivers of energy demand, along with economic and social development. In 2010, 520 Quadrillion Btu of energy was used all over the world and the demand is continuously increasing[1]. The main limitation of fossil fuel is that this is not renewable and the fuel reserves are concentrated in a small number of countries. 80% of the coal reserves are located in just six countries and the European Union (EU) has 4% of the global stock[2]. Besides, Emissions of carbon dioxide due to the use of fossil fuel adversely affect the climate causing global warming[3]. Therefore, alternative energy options such as biomass is one of the most promising avenue researchers are looking into. Biomass is a combination of varying organic compounds, which is abundant in nature, yet barely being used up to its potential. Currently, biomass accounts for 7-10 % of primary global energy consumption[4,5]. Liquid transportation fuels, such as ethanol and biodiesel, are the most popular biomass-based energy alternatives, albeit these currently comprise only 2% of world biomass energy and have potential to contribute substantially[6,7]. As biomass sources are relatively abundant and offer more feedstock versatility, these resources have become an attractive alternative to petroleum-based products. Moreover, utilization of biomass also seems promising because of biodegradability and lower greenhouse gas emission ensuring reduced environmental pollution, which is a grave concern in fossil-fuel technology. Biomass is not only an important source of energy but also a source of different valuable chemicals. Biomass consists of different celluloses, hemicelluloses and some other carbohydrates[8]. Efficient utilization of available biomass can be useful to reduce the foreign dependency in terms of industrial raw materials and other biomass-derived chemicals.

Because of industrialization and population growth, energy demand is rising in Bangladesh as well. The total amount of biomass fuel consumed in the country in the year 2000 was approximately 45 million ton. These are the principal sources of energy supply in rural areas contributing more than 90% to the primary total energy supply[9]. Small biogas plants are being introduced for generating energy utilizing biomass[10]. Despite having massive potential in Bangladesh, there hasn't been any organized study performed on feedstock types, quantities and characterization. Few studies have been reported focusing only on electricity production without considering other applications or the individual contributions of variety of resources [11,12]; whereas some other studies have not considered the distinct characteristics of different feedstock resources [13,14,15]. Here we present an organized study to summarize the availability of different biomass resources in Bangladesh including their gross available quantity, basic properties and proximate analysis data and total available quantity of waste resources to be utilized. This will help to enrich the quantitative knowledgebase regarding available biomass in Bangladesh and to estimate the potential contribution of biomass as fossil fuel alternative. This will pave the path to a more detailed assessment, characterization, and also inspire the Government and private entrepreneurs to focus on the conventional and unconventional biomass based industries and power plants in Bangladesh.

METHODOLOGY

In brief, major sources of potential biomass have been identified from literatures. These were categorized in a systematic manner based on types and locations of sources. Gross quantity of production of those crops, fruits, vegetables, livestock, poultry, fisheries and municipal waste were estimated from recent reliable statistics and literature. Utilizing reasonable field and processing waste fractions from literature, total amount of possible waste were calculated. Some of the local and South Asianliterature were consulted to calculate proximate analysis data of available biomass. For similar type of bio-waste, a range of proximate analysis data is reported instead of a single value.

BIOMASS UTILIZATION IN BANGLADESH

Biomass has always been used in Bangladesh for a variety of human needs, but, it was limited to only few applications using very few varieties. Majority of biomass in Bangladesh is consumed for rural cooking and the rest is consumed for urban cooking, agro-based industries and other commercial establishments as shown in Figure 1(a) [16]. Bangladesh is a small yet resourceful country that produces copious quantities of fruits, vegetables, trees, fishes etc., which are very good sources of biomass. Of the total area of Bangladesh, agricultural land constitutes 65% of its geographic surface, while forest lands account for approximately 17% [17].

Apart from basic crops, Bangladesh alsoproduces large variety of fruits, pulses, oilseeds, spices and vegetables. In 2011-12, the country produced in total 45 million metric ton of major crops including rice, wheat, potato, barley, jower, bazar, maize etc. [17]. A significant portion of the produces is not consumable and can be utilized for different purposes. It has been considered that only 35% of field crop residues can be removed without adverse effects on the future yields[18]. However, crop processing residues mostly have 100% recovery factor [19]. Figure 1(b) shows the total amount of bio-waste produced in 2011-12 in different sectors. In 2005, total fuel wood production in Bangladesh was 27.66 million m^3, whereas per capita consumption rate was 0.18 m^3[20]. Alongside crops and wood, people in rural area, rear different types of animals, and a large number of poultry farms are also being operated in urban and semi-urban areas. However,a significant portion of this massive amount of residue produced from these crops and cattle are mostly wasted and thus remain unutilized. In addition, large amount of municipal solid waste is generated every year, and 70% [21] to almost 100% [19] are recoverable as potential biomass. If these wastes were properly managed, these could be a good biomass resource for energy and biochemical production.

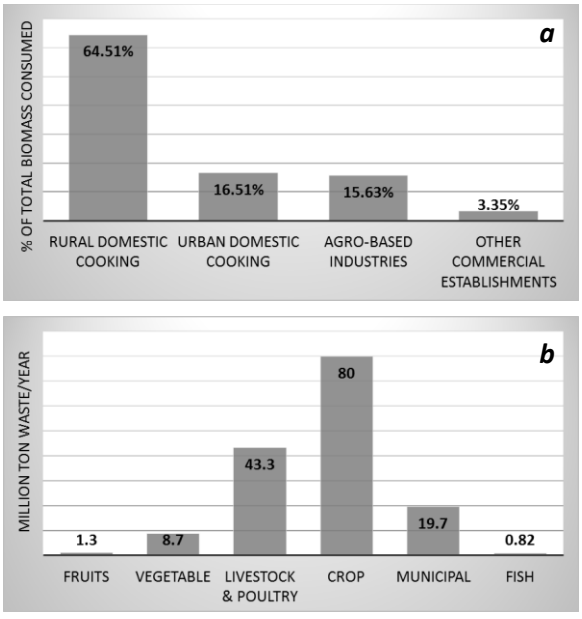

Figure 1: (a) Typical Distribution of Biomass Consumption in Bangladesh [16,22,23]; (b) Yearly Production of Various Biowaste from Different Sectors in Bangladesh in 2011-12 [17,24]

Industrial growth and highly dense population of Bangladesh are making the economic and energy condition critical. According to the World Bank, in 2011, only 62% of the population had access to electricity with a per capita availability of 321 kWh per annum, which is very low in comparison to the other countries in the world[25]. Though, situation has improved in terms of electricity generation, this is mostly dependent on the available natural gas, which is not abundant. To address this challenge and combat future energy crisis, it is high time to focus on abundant sources of biomass for energy generation. On the other side, efficient utilization of available biomass can be useful to manufacture some raw and intermediate components of different industries. Utilizing biomass as a source of energy as well as useful bio-chemicals can change the scenario dramatically, if proper measures are taken.

TYPES AND AVAILABILITY OF BIOMASS IN BANGLADESH

In Bangladesh, agricultural, forest and municipal waste components are the major sources of biomass, which can be converted into biochemical products and energy. Trees and their residues are already popular as source of energy, especially in rural cooking. Biogas from animal waste is also being practiced in a smaller scale in some regions. However, there are large number of unutilized sources of potential biomass that can be used as source of energy. Figure 2(a) shows yearly production of different raw biomass in 2011-12 that generate large amount of bio-waste during harvesting and processing.

Bangladesh is an agrarian country and has achieved food sufficiency for several years. Though, rice is the major crop in the country, wheat, pulses, oil seeds, tobacco, sugarcane, tea, jute, maize, barley etc. are also produced here in significant quantities. These crops generate different types of wastes like straw, husk, stalk, bagasse etc. Apart from huge volume of field residue, a significant amount of processing residue is also produced in different crop processing mills. In 2011-12, Bangladesh produced 45 Million ton of major crops that generated approximately 80 million ton of field and processing residue [17].

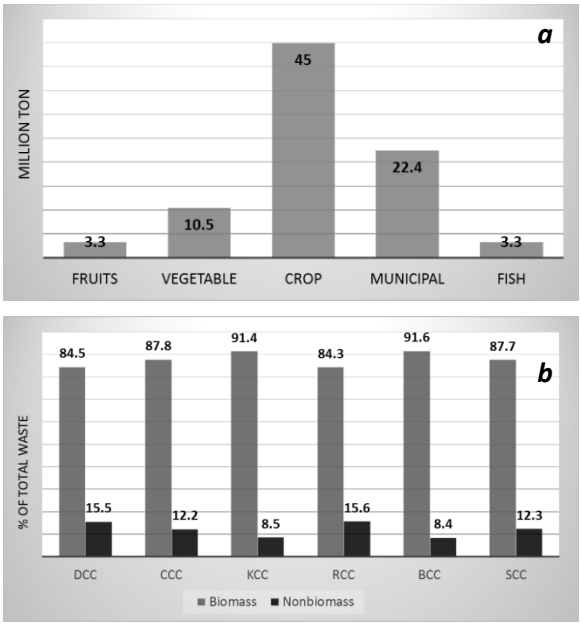

Figure 2: (a) Different Types of Biomass Production in Bangladesh in 2012-13; (b) Composition of Waste Generated in Different Municipal Corporations[26]; DCC: Dhaka, CCC: Chittagong, KCC: Khulna, RCC: Rajshahi, BCC: Barisal and SCC: Sylhet City Corporation

Bangladesh produces a large variety of seasonal and year round fruits. These fruits have significant fraction (as high as 60%) that is not consumable and thus considered as waste. In 2011-12, 3.3 Million ton of different fruits were produced in Bangladesh. These fruits are potential sources of bio-waste that can contribute to the total amount of accessible biomass every year in Bangladesh[17]. Considering average process residue index (PRI) from literature, 1.3 million ton of waste was

generated from these fruits in 2011-12 (Figure 1). Vegetable residues are one of the major components of typical kitchen waste and can be utilized as biomass as well. Different types of vegetables are grown in different parts of the country. In 2011-12, 10.5 million ton vegetables were produced and approximately 8.7 million ton wastes were generated from these in the field and during processing[17]. Like fruits, most of the PRI were obtained from literature and few were assumed based on physical similarity with other vegetables with known PRI.

Another good source of biomass available around the country is the municipal waste that contains various organic and kitchen waste. However, currently, assessment is limited to only cities and towns because of lack of proper waste management scheme in rural areas. In Bangladesh, there are eleven city corporations and 64 district towns. Unfortunately, detailed waste management information is available only for 6 major municipal corporations. As those are the six major and largest city corporations, they can be considered as representative of the whole country. In 2011-12, total Municipal waste generation in Bangladesh was 22.5 million ton[27]. Municipal wastes typically contain a wide variety of materials and a substantial part of those are not organic, and thus cannot be used as biomass. Figure 2(b) shows the typical biomass and non-biomass distribution of municipal waste in six different city corporations. On average, about 87.9% of municipal wastes are bio-wastes and also good biomass source. Thus, in 2011-12, at least about 19.7 million ton potential biomass were generated from municipal wastes.

Forest biomass is the most commonly used biomass resource in Bangladesh, however, this only includes fuel wood and small amount of twigs and leaves. Apart from these, there are different sources of forest residues that can be considered as potential biomass. In 2005, 28.4 million cubic meter nonfuel wood was processed in Bangladesh that produced a large amount of saw dust, wood chips and bark [28]. A comparison of different kinds of wood produced in Bangladesh is shown in Figure 3(a). Altogether, this amount of forest resource generates 80.4 million ton of useable biomass including saw dust, bark, leaves and twigs. In terms of energy, this alone is the source of 1.21 Zetta-joule energy.

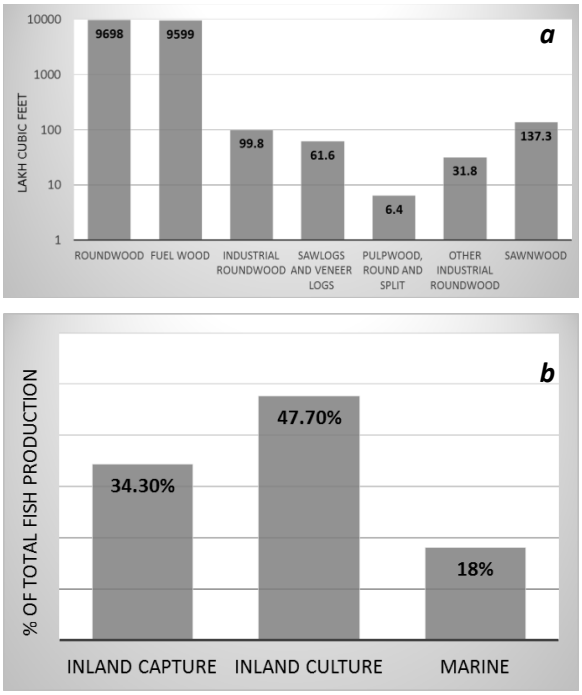

Figure 3: (a) Production of Different Woods in Bangladesh in 2005 [28]; (b) Region-based Distribution of Fish Production in Bangladesh [24]

In Bangladesh, many people in the village rear up domestic animals for agricultural need as well as to finance themselves. Besides, there are many poultry farms and animal husbandries in rural and urban areas. Livestock and poultry are great sources of biomass waste. There were 43.3 million ton of varying animal wastes

produced in 2011-12 in Bangladesh, of which roughly 75% came from livestock and rest from the poultry[24]. If all of these were utilized as energy resources, around 650 Peta-joule energy would have been available per year.

Though, Bangladesh is an agriculture-based country, industry is also growing day by day. Different types of industries have been established that generate significant volume of waste every day. However, only some specific industries such as jute, textile, and sugar industries generate waste that can be used as biomass. Bangladesh produces significantly large amount of fish every year. Though almost half of total fish production comes from inland culture, some are inland captures and from sea as well. Figure 3(b) shows the fraction of total fish production from different regions during 2010-11. Bangladesh also has export-oriented fisheries and fish processing industries. In 2011-12, more than 80 thousand ton of fish was exported from Bangladesh [17]. Because of the lack of specific waste fraction data for varying fish types, it is assumed that 25% of raw fish is discarded as waste. Therefore, it is estimated that in 2011-12, approximately 815 thousand ton waste was produced from fish processing in Bangladesh.

CHARACTERISTICS OF AVAILABLE BIOMASS

Apart from biomass availability, it is also very important to determine the properties of those biomasses. The feasibility of any biomass as an alternative fuel is dependent on its characteristics such as energy content or heating value, carbon content, volatile content, elemental composition etc. These properties are generally classified as proximate and ultimate characteristics. Proximate analysis is easy to carry out as it needs the usage of common laboratory equipment whereas ultimate analysis and direct measurement of heating value requires more advanced technology[29]. However, it is also possible to estimate the energy content from proximate analysis data using empirical equations. In this paper, the available biomass in Bangladesh have been categorized into few major sections and range of proximate analysis data for these biomass are listed from literature. There have been very few experiments carried out on the proximate analysis of available biomass in Bangladesh, hence while tabulating the data we have vastly used the published data of other countries.

Table 1: Proximate Analysis Data of Major Biomass Resources[30,31,32,33,34,35,36,37,38,39,40]

Waste	**MC**	**Ash**	**VM**	**Fixed Carbon**
Cereal Straw	7.8-9.5	12.4-13.4	58.1-64.5	12.7-21.7
Banana waste mixed	7.9-11.4	5.7-18.3	70.1-72.0	0.3-14.4
Mango waste mixed	34.0-42.2	1.7-2.3	46.8-51.7	8.7-12.7
Citrus waste mixed	7.1-17.7	2.9-8.8	56.2-71.7	15.5-23.2
Vegetable waste mixed	19.2-19.5	9.8-11.6	50.9-59.2	11.5-18.3
Livestock	13.9-47.8	10.9-13.7	34-60.5	7.3-11.9
Poultry	19.3	17.5	52.9	10.3
Forest bio-waste	10.2-20.4	0.6-1.4	54.6-72.9	12.7-23.8
Mixed Paper	3.0-4.1	81.5-80.5	6.8-6.7	8.7-8.6

Table 1 shows proximate analysis data of some major biomass resources available in large quantities in Bangladesh and Table 2 shows similar data for some of the processing residues. It has been noted that

the moisture content (MC) of fruit and vegetable waste varies vastly from 7-42%, whereas for crop residues the data is in a small range of 7.2-9.5%, and for forest biomass it ranges from 10-20%. Biomass with moisture level below 50% is effectively used in combustion but below 20% is advisable to use as fuel[41,42]. Very high moisture content is not desirable as it implies less heating value[34]. In the data obtained, volatile matter (VM) ranged from 6% to as high as 77% depending on the origin. Most of them follow the generally expected range, between 50% and 80%. Upon analyzing the data obtained for ash content one can observe that most of the analyzed samples have very low ash contents, except for mixed Paper, which has a very high ash content of over 80%.

Table 2: Proximate Analysis Data of Several Processing Biomass Resources[29,39]

Name of crop	MC	Ash	VM	Fixed carbon
Oil Seeds/soybean cake (dry basis)	-	7.14	76.86	16
Rice husk/bran	7.2	16.4	61.8	14.6
Coconut coir	13.4	2.4	56.7	27.5
Sugarcane bagasse	9.5	1.9	75	13.6
Sawdust	13.8	0.6	72.9	12.7

Proximate analysis data can be further utilized to estimate ultimate analysis data using some empirical correlations and computational assumptions. This will save a lot of time and effort that might have been required for experimental ultimate analysis. In addition, a detailed biomass characterization will facilitate a more accurate estimation of current biomass potential as energy source and as feedstock for useful bio-chemical production. Ethanol, organic acids and ester are few examples of bio-chemicals that can be manufactured from recyclable biomass resources. Trisodium citrate is a widely used food-grade preservative that can also be produced from sugar-based biomass. The total annual recoverable rate of biomass in Bangladesh is approximately 150 million ton per year (Figure 1b). Using the lower calorific values of the individual biomass components, the total available energy potential is about 1500 Peta-joul. Currently, part of the forest and agricultural residues are being used as energy sources in rural areas. Remaining residues, most of the municipal waste and animal secretions can still be utilized for energy generation and useful bio-chemical production.

CONCLUSION

Despite having massive potential, biomass is not being utilized efficiently in Bangladesh. Though, a large faction of rural population are dependent on biomass, this mostly includes wood and other forest residue. A large portion of biomass resources remained unutilized due to lack of proper awareness and initiatives. Apart from energy generation, these biomass resources in turn might be used as raw materials for the production of diverse chemicals such as different alcohols, organic acids and esters, which have a huge market demand. Therefore, production of biomass-derived chemicals is also a very promising avenue on which Bangladesh can focus as well. To facilitate future research regarding biomass for different applications, a systematic and categorized assessment of major conventional and unconventional biomass resources are performed in this study. This assessment and proximate analysis data will be useful to predict ultimate analysis of biomass using well-established correlations. Therefore, theoretical potential in terms of energy and useful bio-chemicals can also be estimated more accurately. This study offers

valuable information resources for the ongoing research towards achieving energy-sustainability and industrial growth in Bangladesh.

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