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ANALYSIS OF WASTE TO ENERGY OPPORTUNITIES IN CASSAVA SAGO INDUSTRY

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Abstract- **Cassava to the sago processing industry in India is one of the energy-intensive and waste generating industries. These wastes can be converted into energy and have the potential to reduce greenhouse gas emissions. This study analyzes the waste to energy opportunities in a factory that produces sago from cassava. The sago producing process includes peeling, washing, rasping, straining, and sedimentation. During the production of one tonne of sago, 0.246 tonne peel and 2.91 tonne wet pulp, and 12.67 tonne wastewater generated. The possible waste to energy options for each waste were identified and discussed. Among all the options identified, producing biogas using the cassava peel, cassava pulp, and wastewater has high potential. The biogas could be easily generated and used to satisfy the heating and electricity requirements of the industry.**

Keywords – Cassava, Sago production, waste to energy, opportunities, biogas

I. INTRODUCTION

Waste generation is increasing in industries through industrial activities due to population increase in developing countries like India. One such industry is the agro-food processing industry.According to the Ministry of New and Renewable Energy (MNRE), the Electricity potential from total industrial wastes is about 1300MWe[1]. The electricity generation potential from industrial waste and urban waste in India is 1300 MWe and 1700 MWe. MNRE has initiated national programs on energy recovery from industrial wastes. The programs promote setting up of waste-to-energy factories, and various financial incentives and subsidies provided. National Thermal Power Corporation Limited (NTPC) has called nation-wide and global players to set up a hundred waste to energy eco-friendly plants under Swachh Bharath's mission all over India. The Indian government also provides a capital subsidy of ₹1 crore/MWe for low energy density and difficult industrial wastes such as dairy, tannery, slaughterhouse, paper, pharmaceutical, textile, and others ₹ 0.5 crore/MWe to promote biogas generation from industrial waste [1].

Cassava is a tropical crop grown in marginal lands, especially in subtropical and tropical zones in Asia, South Africa, and South America. Many industrial products produced using cassava. Cassava industry generates relatively large quantities of wastes, and they are hydrolyzable easily [2]. Cassava waste is an alternate and strategic source of non-conventional energy, increasing the possibility that it could be used universally to reduce fossil fuel dependence [3]. Production of sago from cassava is an energy-intensive process. The generation of wastewater with high organic content and solid wastes in the cassava sago industry causes water and environmental pollution. Cassava wastes can be converted to energy, and this has the potential to reduce greenhouse gases. This study attempted to identify and assess the waste generated in the sago production process and analyze waste to energy opportunities.

II. SAGO PRODUCTION

Cassava is a tuber that is grown in subtropical and tropical regions as an annual crop extensively. It can resist adverse biotic and abiotic stresses, adaptable to drought, marginal lands, and hilly area conditions. It is a significant source of one of the macronutrients, which is essential for health and living. India produces 13% of

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the total cassava from Asia. In India, Kerala, Tamilnadu, and Andhra Pradesh produce 43.33%, 40%, and 8.4% of the cassava.

There are two types of cassava, i.e., sweet and bitter. Usually, sweet one is consumed than bitter because of high cyanide content [4]. Cassava also used as a raw material in industries in Thailand, Vietnam, Indonesia, and India. The products obtained from the cassava are sago, cassava starch, biodegradable plastics, chips, flour, and pellets. Cassava flour used to make glucose, soup, textile, plywood, pudding, sausages, ice creams, noodles, and other foods [5]. In India, Maharashtra, Gujarat, Madya Pradesh, and other states treat sago produced from cassava as staple food [4].

The sago making process consists of peeling and washing, rasping, separation of pulp, dewatering, roasting, drying, polishing, dry inspection, and packing. The fresh cassava delivered from the farm sent into the root washers, which contains a stone catching system then the washed roots were employed to primary peeling system input. Then the peeled roots were ground in a crusher by adding water to facilitate the separation of starch and pulp. Then the ground mixture is sent into the shaking screens where the milk separated from it. The milk passes through tunnels and flows into the tanks finally. The milk is sedimented to obtain wet starch with desired moisture content. Sago was made through wet starch using shaking screens. The globules or sago (raw) subjected to steamer and frying systems based on their requirement. Traditional gravity settling method or conventional sedimentation to separate starch from starch water mixture.

III. WASTE GENERATION

The sago industry in India is seasonal, running for only six months of the year from November to February and July to September. The wastes identified during the sago making process are cassava peel, cassava pulp, wastewater, dirty starch, oversized products, and broken sago.

a) Cassava peel:
The cassava skin thickness is about 2.2 mm. The average weight share of cassava skin is around 15% of the tuber [6]. In the situation of peeling with hand, it constitutes about 20-35% weight of cassava tuber [7]. The cassava peel comprises of 10.38% hemicellulose, 7.64% lignin, and 43.62% cellulose. Around 9% of the cassava processed obtained as cassava peel [8].

b) Cassava pulp:
The pulp is the solid fibrous waste discharged from the cassava starch and sago factories, which contains around 55% unextracted starch [9]. It is also called as cassava Thippi or cassava pomace or cassava bagasse. The characteristics and look of this residue vary with plant age, time of harvest, factory equipment, and method used [10]. About 0.95-2.86 tonne of cassava pulp generated during the processing of one tonne of cassava starch. Cassava pulp significantly used as cattle feed, and the powder extracted from this residue known as pulp flour or Thippi flour used for various pasting purposes.

c) Wastewater:
For one tonne of cassava roots, 20-25 m^3 of effluent produced. From one m^3 of sago effluent having COD of 7200-8300 mg/L range, 0.76 m^3 of biogas can be produced [11].

The amount of waste generated estimated and waste to energy opportunities identified by carrying out an energy audit in a sago producing factory in Andhra Pradesh. The factory produces two types of sago, namely Nylon and common sago or Mothi by steamer and fryer.

The amount of water used estimated to be around 342 m^3 for crushing and 324 m^3 for shaking screens. For sago making (before cooking), the starch has to be wet, and that moisture content was found to be 47.1%. For the sago process, sago globules shape would not be achieved, and moisture content of 35 to 48% is an acceptable range, and if the desired moisture was not achieved, then the water sprinkled to make the starch wetter.

As per the mass balance carried out at the factory, 2.73 tonne of fresh cassava with 60% moisture content and 14.23 tonne of water are used to produce one tonne of raw sago. During this process, 0.246 tonne of peel with a moisture content of 69.3%, 2.915 tonne wet pulp, 12.67 tonne of wastewater, 0.071 tonne of dirt, and 0.052 tonne of broken and uneven sago generated.

IV. WASTE TO ENERGY OPPORTUNITIES

Using cassava waste for energy production offers vast opportunities due to the enormous availability of this inexpensive raw material in cassava-growing countries [4]. Both thermochemical and biochemical technologies can be used to convert cassava waste into useful energy forms [12].

a) Cassava peel

Cassava peel is lignocellulosic biomass with a high moisture content which has been extensively used as a feedstock for the thermochemical and biochemical conversions. The possible waste to energy options for cassava peel are the thermochemical options of producing bio-oil through pyrolysis, combustion, and activated carbon. And also the production of biohydrogen through dark fermentation, bioethanol through fermentation and biogas through anaerobic digestion. Lignocellulosic material of cassava peel can be used in bioethanol production [13].

Bio-oil was generated in a fixed bed reactor using cassava peel through pyrolysis by Ki et al. [14]. Cassava peel is heated in the absence of air in a fixed bed reactor with a heating rate of 20°C/min to get the required temperature of 400°C to 600°C. Pyrolysis has yield 24.2% solid, 51.2% liquid (bio-oil), and 24.5% gas. The heating value of bio-oil is 27.43 MJ/kg. Pyrolysis is not well-established in India.

A feedstock with lower ash, moisture, and sulfur content, and higher volatile matter is preferred for gasification. Fresh cassava peel is not suitable for gasification because of around 60% moisture content it has. Dried (to around 20% moisture content) cassava peel is preferred for gasification since it has low ash content and low sulfur content. A blend of cassava peels and a mixture of sawdust (30%) and wood shavings(70%) in 1:1 proportion was successfully used for gasification. Fresh cassava peel has a high moisture content, which makes it not suitable for combustion. Activated carbon from cassava peel obtained by two methods, i.e., physical activation and chemical activation.

Cassava peel is used as a co-substrate to generate biogas [15]. Anaerobic digestion is a well-established technology in India. The government is providing policies and support to implement this technology. The biogas produced in the sago industry could also be used to produce heat and electricity needed in the industry.

Cassava peels sundried for two weeks and hydrolyzed with the Aspergillus Niger resulted in more fats and crude protein and less ash and crude fiber [7]. Cassava peel may function as a good carbon source for yeast fermentation in the case of bioethanol production. Enzyme hydrolysis of cassava peel is done by washing and sun-dried for three days [2]. The technology for producing bioethanol from the peel is commercially not available.

b) Cassava pulp:

The cassava pulp is mostly suitable for biochemical conversions and not preferred for thermochemical conversions as it has a high amount of starch content. The possible waste to energy options are biogas production through anaerobic digestion, bioethanol through fermentation and biohydrogen through dark fermentation.

Cassava pulp-based biogas production is well developed in Thailand [16]. Cassava pulp very much satisfies the requirement for the generation of biogas as it has a chemical oxygen demand of 1251g/kg (dry) and volatile solids (VS) of 98% [16]. One tonne of cassava wet pulp can generate 14 m^3 of biogas per day through the two-stage anaerobic system with HRT of 12 days and OLR of 0.417 g COD/l-day [17]. Biogas through anaerobic digestion is a very well-known technology in India. Much of the sago industry's energy requirement could be satisfied by generating biogas using the cassava peel.

Cassava pulp comprises of nearly 60% plentiful starch and nearly 20% cellulose fiber. Strain K7G (Saccharomyces cerevisiae Kyokai no.7) effectively fermented cellulase pre-treated cassava pulp to produce ethanol [18].

Fresh cassava pulp from the cassava starch processing plant is successfully tested to produce pellets in Vietnam [19]. However, the pulp has to be dried before producing the pellets. Wet cassava pulp is dewatered before mixing it with dried cassava starch to enhance bonding and strength, which results in attenuation in the rate of breakage in transportation and drying time [19].

Biohydrogen is produced through dark fermentation and photosynthetic (photo-fermentation) methods with carbohydrate-rich biomass as a non-conventional source [20]. Biohydrogen can be produced through batch dark fermentation by means of cassava hydrolysate and through the process of acid hydrolysis of pulp [21]. Biochemical methods are anticipated to be less energy-intensive compared with thermochemical methods of hydrogen production [22]. Since dark fermentation does not depend on the sun, it gives a high constant producing rate of hydrogen whole day [20]. Dark fermentation technology is still in the research and demonstration stage.

c) Wastewater:
Processing of one tonne of cassava tubers requires about 4.5 m^3 water. The average water requirement is estimated to be in the range of 5-7 m^3 per tonne of cassava processed. About 95% of the used water discharged as effluent [23]. A considerable amount of wastewater with high organic content generated from cassava to the sago processing industry. The reported COD and BOD values of the wastewater from the sago industry varies in the range of 2286-13,180 mg/L and 840-5735 mg/L, respectively [11, 24 – 27].

Biogas production through anaerobic digestion and biohydrogen through dark fermentation are the possible options for converting the wastewater into energy. Considering the higher BOD and COD values of the wastewater, biogas production through anaerobic digestion is the most appropriate option for converting the sago processing wastewater into energy.

Sreethawong et al.[20] used an anaerobic sludge batch reactor to generate the hydrogen from wastewater. They studied the optimum conditions of COD loading rate, C:N ratio, number of cycles per day. The COD loading rate of 30 kg/m^3d and six cycles per day were delivered as optimum for hydrogen generation. The Specific hydrogen Production rate (SHPR) was found to be 3800 ml H_2/l d or 388 ml H_2/g VSS d. Hydrogen yield was 186 ml H_2/g COD removed. The scope of hydrogen energy is limited to research, development, and demonstration stage, and there is no usage of hydrogen in the sago industry. Microalgae could be produced using the cassava wastewater, and the microalgae could be used to produce hydrogen.

V. CONCLUSION

Cassava sago industries are one of the energy-intensive and waste generating industries in India. Waste to energy opportunities in a sago factory was analyzed by identifying the waste generated and carrying out an energy audit. Cassava peel, wet pulp, and wastewater were identified as wastes. It was estimated that during one tonne of sago production, 0.246 tonne peel, 2.91 tonne of wet pulp, and 12.67 tonne of wastewater generated. Among all the wastes, the wet pulp has high energy potential. Biogas production using the peel, wet pulp, and wastewater is an attractive option that converts the waste to energy. The biogas could be easily used to satisfy the industry's energy requirements.

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