Agriways ISSN (Print) 2321-8614 & ISSN (Online) 2454-2318
(A Multidisciplinary Peer –Reviewed Refereed Journal)
www.agriwaysjournal.com Vol 10 Issue 02 July-Dec 2022

Agricultural Biomass Management Options

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Abstract:
The paper gives an overview of various management options for agricultural biomass. This has been accomplished with theoretical underpinning. The details of in-situ and ex-situ management have been divulged on. The in-situ management options have been detailed as; incorporation/ mulching of biomass and incorporation of biochar. The conversion of agricultural residues into energy comes under ex-situ management options. An overview of thermochemical and biochemical conversion has been given. The thermochemical conversion processes include conversion of biomass to energy via direct combustion, pyrolysis/liquefaction, and gasification. The biochemical process, that includes anaerobic digestion and fermentation, converts the agricultural biomass into valuable substances. Biogas production is the outcome of anaerobic digestion of biomass and bioethanol can be produced by microbial fermentation. Some of the other options, which have been used over the years, i.e., the use of crop residues as livestock feed, animal bedding, packing material and for mushroom cultivation have also been highlighted.

Keywords : Bio-mass, Management, In-situ, Ex-situ, Residue

Date of Submission: 017-11-2022 **Date of Acceptance: 15-12-2022**

1. Introduction and Methodology

The use of biomass in the energy sector is being increasingly propagated. The state of Punjab has won accolades for its stupendous performance not only in the agriculture sector but has made rapid strides in other sectors as well leading to a significant increase in the energy demand. The demand for electrical power in the state has increased due to increasing mechanization of farm operations, growth in the number of industries, and improvement in the standard of living. Agricultural biomass has an enormous potential for energy generation in Punjab. Prudent use of available crop biomass could go a long way in alleviating the environmental hazards of non-renewable energy sources particularly related to climate change. Punjab being an agricultural state, can count down on crop biomass resources, which can be put to more efficient use to provide sustainable energy base to the state. Against this backdrop, the present paper offers an inventory of viable and sustainable agricultural biomass management options, backed up with research findings. The formulations of the present study have been based on secondary data and information.

2. Results & Discussion

2.1 BIOMASS MANAGEMENT OPTIONS

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The biomass residue is an immense storehouse of energy that can be fruitfully used for myriad purposes. The state of Punjab endowed with different types of soil and climatic conditions, support cultivation of diverse crops resulting in the production of a variety of agricultural residues such as straw, stalk, bagasse, tops, leaves, and shells, etc. These agricultural residues can be divided into two different categories i.e., on-farm residues or field-based residues and processing residues synonymously termed as off-farm residues. Similarly, the biomass generated at the farm level can be managed by two approaches i.e.

i. In- situ management i.e. on the farm management

ii. Ex-situ management which refers to off the farm management

The discussion that follows focuses on these two management approaches and gives an overview of the options available for the management of biomass under these two approaches (Fig 1).

2.1.1 In-Situ management

In-situ means "in the natural or original position or place" (Merriam-Webster, 2020). In-situ management of biomass implies that the biomass generated on-farm will be managed at the farm itself in a sustainable form. The in-situ management options have been detailed as under:

2.1.1.1 Incorporation and mulching of biomass

The agricultural biomass is a rich source of various nutrients and organic carbon, which makes them a fascinating option for their use as fertilizers. However, the quantum, form, and bulky nature of biomass restrict the use of such options. Of late, various machinery and techniques have been developed, which if deployed can overcome this problem. The agricultural biomass can thereby be directly incorporated, mulched, or used to prepare biochar that can serve as fertilizers and soil health boosters.

Agricultural equipment such as Straw Chopper, Super Straw Management System, Mulcher- cum-Spreader, Rotavators, Reversible MB Plough, etc. can be used for incorporating or mulching agricultural residues while Happy Seeder and Zero-till Seed Drill, etc. are to be used for efficient sowing of next crop. Continuous incorporation of crop residues (usually rich in the organic nutrient) over the 3-4 years increases the soil fertility, productivity, and crop yield while tackling the issue of post-harvest residue management (CII-NITI Aayog 2018). In mulching, layer of biomass is added to the surface of the soil that suppresses weeds and prevents water loss through evaporation from the soil. The organic biomass such as paddy straw can be used as organic mulches instead of fabric sheet or inorganic mulches (CITE, 2008) that results in reduced usage of fertilizers, irrigation, and higher yield. In Punjab, happy seeder with CH-SMS (Combine Harvester along with Super Straw Management System) is recommended to cut the paddy straw into small pieces and spread the same in the field (*Kharif* 2019). The use of agricultural equipment (such as Happy Seeder) for biomass incorporation was also emphasized to state farmers for enhancing soil quality and yield (The Tribune,Nov 11, 2019). The study conducted by scientists of Punjab Agricultural university, Ludhiana to evaluate the effect of Happy Seeder technology. revealed yield enhancement to the tune of 7 to10 per cent in Happy Seeder sown fields as compared to no-tillage conventional system (Singh *et al.*2009). A study was conducted and reported in CII Foundation Project Report (2019), which included 60 farmers and 522 acres agricultural land of district Ludhiana, out of which 16 farmers and

154.5 acres of land was subjected to burning of paddy straw followed by the sowing of wheat while rest of the land was subjected to the incorporation of paddy followed by wheat sowing. The economic analysis of both land-use practices showed that the total expenditure on paddy harvest and wheat sowing was approximately equal, with the reduced land fallow period between paddy harvest and wheat sowing in residue incorporated fields (2-3 days instead of 7 days inthe case of burning) as well as reduced weedicide consumption. Twenty-two farmers, out of 60 were convinced with the results of residue incorporation and wished to try the practice in upcoming years (CIIFR, 2019). The findings of this study can be strengthened with the success story of Mansa district farmer, who had continuously incorporated paddy residue (CR212, heavy subtle producing variety) for seven years in his fields and was bestowed with the National Award by Indian Council of Agricultural Research (ICAR), New Delhi. The farmer highlighted that the addition of straw with super SMS not only strengthened the soil health and hence required fewer agrochemicals (fertilizer/pesticides) with a cleaner environment (The Tribune, September 11, 2019). Many other progressive farmers of Punjab have been adopting these techniques, two farmers of Hoshiarpur district had successfully sown wheat crop after incorporating paddy straw using Happy Seeder and had improved the soil fertility, health and crop productivity (Changi Kheti, 2018). In 2017, another farmer from Hoshiarpur district used chopped paddy straw for the mulching of the sweet pea field, which enhanced its economic benefit from the crop (Changi Kheti, Sept 2018, PAU).

2.1.1.2 Incorporation of bio-char

The burning of straw residue through slow pyrolysis (heating in absence of oxygen) to produce bio-char is another very efficient way to utilize residue. The bio-char is enriched in organic carbon, potassium, phosphorous and other nutrients and is equivalent to activated carbon having fine-grained charcoal texture with the potential to store carbon in the soil for a longer duration. The process of production of biochar requires a small area (10 ft diameter and 14 ft height) for brick and clay *Prali* kiln, which can accommodate 12 q of rice straw (CII-NITI Aayog 2018). The slow-burning of this residue results in 6.5 quintal bio-char in 10-12 hours period. The incorporation of two tons of biochar can replace one-third consumption of urea and renders the benefit of ten per cent more green yield and significantly enhanced soil health in three years (The Tribune, September 2019).

2.1.2 Ex Situ management

"The conservation/management of components of biological diversity outside their natural habitats" is known as ex-situ management of biomass (Convention on Biological Diversity (CBD, 1992). The agricultural residue generated on the farm is bulky hence difficult to store and transport for its efficient utilization. However, various agricultural equipment such as baling, briquetting and pelletizing machines have been made available nowadays to efficiently collect, package into a compact mass and transport crop residue to ex-situ management sites viz. paper/ cardboard manufacturing units, power plants or briquetting units (CII-NITI Aayog 2018). In briquetting, the crop residue is compressed in 6:1 ratio through hydraulic machines and press, which results in the production of 2-4 inch cylinders shaped briquettes. The briquettes can be used in various thermal applications such as industrial boilers, furnaces as well as in power plants.There were 3000 brick kilns spread all over the State, which consume 20 lakh tons of coal per annum (high calorific value) as fuel which can be supplemented with rice straw briquettes (CII-NITI Aayog 2018). The effectively collected and packaged agricultural biomass can be utilized by way of various ex-situ management options, as discussed below.

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2.1.2.1Residue to fuel production

India being an agriculture-led country produces a huge quantity of crop residues, which necessitates efficient management systems for transforming these residues treated as a waste to energy. Conversion of biomass to fuel energy is all the more beneficial to a developing country like India, that has always been facing a fuel crisis due to its dependence on Gulf countries to meet the energy demands of the progressive nation (Masera *et al.*2015). The agricultural residues can be converted into energy majorly via two approaches i.e. thermo chemical conversion and biochemical conversion, the details of which are as follows.

2.1.2.1.1Thermo chemical conversion

Thermo chemical processes convert chemical energy store in biomass to heat electricity or mechanical power. The thermo chemical conversion processes include conversion of biomass to energy via

a) Direct combustion

b) Pyrolysis/liquefaction, and

c) Gasification

a) **Direct combustion** method is the most widely used method worldwide. As high as 97 per cent of bioenergy all over the world is produced by direct combustion. Indirect combustion methods intended to use biomass in a boiler, contributing to the production of steam, which can be used to produce heat electricity concurrently to run the turbine. Thermo chemical processes include extreme conditions such as supercritical temperature and pressure that can be used to generate important bio-based products.

b) **Pyrolysis/liquefaction** entails thermal degradation of agricultural residues at a very high temperature of 350-550°C, under high pressure and no oxygen (Simonyan and Fasina 2013), resulting into formation of three fractions: liquid fraction (known as ***bio-oil***), solid (ash known as ***biochar***) and gaseous fractions. In fast pyrolysis, two-third of the fraction, which is liquid in nature, can be used in engines, machinery, and multitudes of other applications (IRENA, 2013). A study conducted by Nixon *et al.*(2014) emphasized that the pyrolysis process can be used for producing biofuels (pyrolysis oil, bio-char, bio-gas) by utilizingrice and wheat straw. The deployment of a small scale mobile pyrolysis plant can generate biochar (to be used as a fertilizer) and pyrolysis oil (can act as an alternative to diesel in small generators) and at the same time would engage rural communities of the state.

c) **Gasification** is a thermo-chemical process, wherein the partial combustion of crop residues forms gas. The main issue hampering in biomass gasification for power generation is the issue of purification of gas. The 'producer gas' generation is the outcome of feeding crop biomass into the gasifiers. The 'producer gas' thus generated is fed into the engines coupled with alternators for electricity generation. In some of the states, the task of the generation of 'Producer Gas' is already underway by installing gasifiers of more than 1 MW capacity. A total of 300 kWh of electricity can be obtained by a ton of biomass. The gasification technology can fruitfully utilize the pellets and briquettes of crop biomass. The 'producer gas' thus generated needs to be cleaned using bio-filters and can be effectively utilized in specially designed gas engines for electricity generation.

A power plant running on 'producer gas' generated from biomass has already been developed by The Central Institute of Agricultural Engineering (CIAE), Bhopal, India.

2.1.2.1.2Biochemical conversion

Agricultural biomass is usually composed of cellulose, hemicellulose, and lignin. The biochemical processes primarily target hemicellulose to access cellulose; however, lignin fractions are converted into important fuel source via thermochemical transformation (above discussed). Anaerobic digestion and fermentation are the two biochemical methods available to convert agricultural biomass into a valuable substance.

a) **Biogas production** is the outcome of the anaerobic digestion of biomass by microorganisms in the absence of oxygen. The biogas thus produced can be a good source of fuel for the generation of heat and energy. Although the anaerobic digestion of rice straw has been attempted earlier also, its renewable energy potential is yet to be analyzed. In India, under the Swachh Bharat Yojna, Agro Gas (2G Bio CNG), Pune, Maharashtra, produced anaerobic digestion based bio-CNG from the agricultural residue (10% moisture level). The plant had a maximum capacity of 35 t/year (100kg/day) from principal feedstocks producing 12000m^3/day 2G bio CNG along with digestate (250t/day), which can be used as fertilizer. In Punjab Agricultural University, Ludhiana a dry fermentation anaerobic digestion biogas plant based on rice straw and cow dung in 80: 20 ratio has been successfully producing bio-gas in the range of 4-5m^3/day for 3-4 months (equivalent to 2-4 cylinders of LPG/month). This technology has been recommended by the Research Evaluation Committee (REC) of the university and five such plants were successfully running in the state in rural areas (NITI AAYOG, 2018). The by-product slurry is a rich source of nitrogen that can be used as fertilizer in farmer's fields.

b) **Bioethanol production** can be produced by microbial fermentation of lignocellulose biomass by following three steps, i.e. pretreatment, enzymatic hydrolysis, and finally fermentation. The first step entails involve sievingand palletization of biomass for the ease in transportation and reduction in expenses and handlingfees. The second step involves the transformation of cellulose and hemicellulose biomass intoglucose, pentoses, and hexoses. In the final step, glucose is fermented into ethanol by a suitablemicroorganism.

The DBT-ICT 2G-Ethanol Technology has been validated and demonstrated at a scale of 10 tons of biomass per day at India Glycols Ltd. site at Kashipur, Uttarakhand, India. The technology and plant design are feedstock flexible i.e. any biomass feedstock from hardwood chips and cotton stalk to soft bagasse and rice straw can be processed. The technology employs continuous processing from biomass size reduction to fermentation; and converts biomass feed to alcohol within 24 hours compared to other technologies that take anywhere from 3 to 5 days. The plant design with a low footprint also has unique features such as advanced reactor design and separation technologies with slurry-flow rapid reaction regime operations. The technology is Zero-Liquid Discharge where >95% of water is recycled. The plant has a capacity of 450 tons of biomass per day. The continuous flow plant operated up to 7 days non-stop with feedstocks including bagasse, rice straw, cotton stalk, and wheat straw, with alcohol yield in the range of 240-300 L/ton biomass (success stories). A similar set up based on rice straw biomass has been initiated in Punjab, in district Bathinda with a capacity of 100KL/ day by Hindustan Petroleum Corporation Ltd (HPCL), (IEA 2020).

2.2OTHER MANAGEMENT OPTIONS

Some of the other options for crop biomass management are there, which have been used over the years. These are outlined below

2.2.1 Livestock feed

It is a very common method to utilize agricultural residues effectively as fodder to animals. Wheat straw has been generally used as fodder for animals. High selenium content in paddy residue and low degradability by ruminal microorganisms limits its consumption as a fodder. High selenium causes selenosis and causes degnala disease within eight weeks of consumption of rice straw (Wadhwa and Bakshi, 2017). Moreover, it contains high oxalates, which also reduces the absorption of calcium in the body. However, Rajasthan University of Veterinary & Animal Sciences, Bikaner, has shown that addition of urea and open fermentation of rice straw (3.5:96.5::urea: straw) for nine days can enhance its nutritive value and digestibility for cattle. Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana also suggested that urea treated paddy straw can be utilized as basal ration which can cause an average increase of 500gm weight of buffaloes, thus benefitting in buffalo fattening protocol for higher meat production (The Tribune 2019). A 270-day growth study conducted by GADVASU on male Murrah buffalo calves revealed that feeding of treated rice straw led to 50 per cent more weight gain per day in an animal (Wadhwa *et al.*2010). The study conducted by Kaur (2017) on crop residue management in Punjab also reported that all the sampled farmers were against the burning of crop residue in principle, but the majority of them could not find any solution at the individual level and were seeking government assistance to dispose it off. About 29 per cent of them suggested utilizing it as animal feed.

2.2.2 Animal bedding

The use of paddy straw as a bedding material for cattle is another effective way to utilize it. In a 60 days study conducted by state veterinary university GADVASU, Ludhiana, bedding of 30 cm during winter season increased approximately 17.1 per cent milk yield and 0.75 per cent weight gain while cattle without bedding had a weight loss of 1.27 per cent (The Tribune 2019). A study conducted by Guru Angad Dev Veterinary and Animal Sciences University(GADVASU), Ludhiana in collaboration with Punjab Agricultural university (PAU), Ludhiana, revealed that rice straw used as bedding of animal (10-15 kg straw/animal/day) can trap the urine and feces of animals. This bedding can be composted in open by maintaining 70-80% moisture and regular turning, the compost resulting from this process is relatively more enriched in nutrients as compared to farmyard manure (Singh *et al.*2009).

2.2.3 Paper/Board/Eco-panel making

The use of crop biomass in paper and board making units in the state of Punjab is very common. It has been reported that these units are already using around 0.1 million tons of paddy straw per annum. The process of conversion of paddy straw into paper involves resizing the straw followed by preparation of straw pulp by the soda pulping process in batch rotary digesters for delignification and cooking with sodium hydroxide. The straw after digestion is washed in a multi-stage washer with a counter-current system. Paddy straw pulps are blended with high strength material such as waste cloth and used gunny bag pulps for paper making. From one ton of stubble, 500 kg of the pulp can be produced. The pulp that is made from the paddy waste can be sold for Rs. 45 per kg. Another good

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option is to use paddy straw for making eco-panels which can be used as panels and partitions in place of wood/plyboard. The technology has already been established abroad but its cost-effectiveness in the country is yet to be assessed. The technology developed by Central Pulp and Paper Research Institute, Uttar Pradesh, India can successfully remove more than 90 per cent of silica from rice straw black liquor. Using one ton of rice straw, the paper production saves approximately 0.7 tons of wood (Dixit *et al.*2009)

2.2.4 Packing Material

Use of paddy straw as packing and filling material as an alternative to thermocol (having adverse environmental implications) and other materials such as plastic or paper needs can be advocated, wherever feasible. Wheat straw can be used to enhance the shelf life of apples and for giving them shiny look. Mohali based National Agri-Food Biotechnology Institute (NABI) has developed edible coating materials from wheat straw and oat bran. This technology increases the shelf life of apple by 35-40 days and peaches by 8-10 days (The Tribune, Jul17, 2018).

2.2.5 Mushroom growing

There is some potential to use paddy straw as a medium for growing mushrooms. At present, it is not being used in the State for this purpose. PAU, Ludhiana, has recommended the use of paddy straw (with/without wheat straw) for the cultivation of button mushrooms *(Agaricus bisporus)* and oyster mushrooms *(Pleurotus* spp.) in winters and paddy-straw mushroom *(Volvariella volvacea, V.diplasia)* in summers. The leftover of paddy straw after harvesting mushroom can be used as manure (after composting) in other crops which would save expenses on chemical fertilizers (The Tribune 2019)

2.2.6 Building of composite materials

Resistance to bacterial decomposition, high tensile modulus, and high silica content of rice straw makes it a favorable substrate to use as filler in building composite material, with an additional potential benefit of flame retardant in building industry. The rice straw composite materials are having good thermal insulation, intended for improvement of the energy efficiency in eco-buildings (Wadhwa and Bakshi 2017).

3. Conclusions

The use of biomass in the energy sector is being increasingly propagated but the efforts to use it to its utmost potential have seen more failures than successes due to several challenges.Perusal of the relevant literature conclusively establishes the immense potential of Punjab agriculture in terms of conversion of agricultural biomass to energy. The analysis boils down to a crucial narrative of on-farm biomass availability in Punjab that two major crops of Punjab i.e. paddy and wheat together account for 92.1 per cent of the state's energy potential. However, the effective use of this potential calls for a reorientation of the policy priorities to make use of this biomass potential judiciously by targeted technology deployment right from the field to the conversion facility. There is a critical need for a bio-energy roadmap with an integrated approach, where the efforts of all the stakeholders from the field of agriculture, infrastructure, environment, technology and innovation, energy are directed towards sustainable action.

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