Sustainable Practices for Management of Rice Straw

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Abstract : Rice, one of the staple food which provides calorie intake and nutrition to the most of the population in the world. The paddy crop produces higher grains yield in comparison with the other cereals crops such as maize, wheat etc. so it provides food to the more people per hectare of land. The cultivation of paddy crop results in different types of residues like rice straw, stubbles, roots and rice husk etc. which have substantial amount of energy potential. It has been estimated that one ton of paddy crop produces almost 290 kg straw which has potential to generate 100 kWh of power. However, such a huge potential of biomass energy is wasted by the farmers in open field burning either due to lack of knowledge or unwillingness to utilize this energy in sustainable ways, resulting in air pollution and causing severe health problems such as respiratory problems, eyes irritation, lung infection etc. This paper aims to review the proper utilization of rice straw in a sustainable way .

***IndexTerms* – Anaerobic Digestion, Lignocellulosic biomass, Pyrolysis, Biochar .**

I. Introduction

Rice, the major food crop in most of the developing countries, with total estimation of about 751.9 million tonnes , out of which 715.2 million tonnes being produced by the developing countries and with the share of just about 25.1 million tonnes is being contributed by developed countries in year 2016 (FAO, 2016).Rice produces higher grain yields per hectare of land as compared with other cereals crops such as wheat, maize etc. which provides nutrition and calorie intake to the most of the population in the world. As the human population going to accelerate so does the demand of food and energy is going to increase proportionally

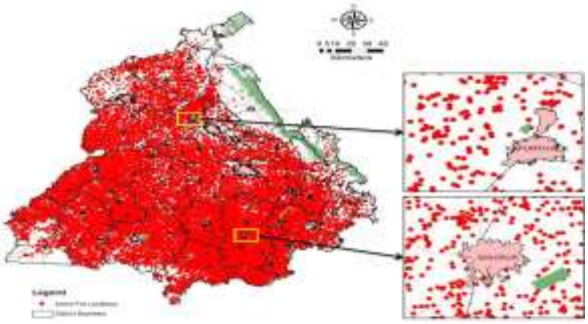
China leads in the rice production in the world, being followed by India. India being an agrarian country acquires nearly 43.85million hectares of land to produce rice crop with yield of about 104.798 million tonnes of rice(Agriculture Statiscal Book, 2017). Each one kilogram of milled rice produces 0.7 to 1.4 kilo of straw depending on the variety of rice which has huge amount of energy potential. Earlier, the world heavily relied on the fossil fuels such as on coal, petroleum crude oil, and natural gas for the requirements of energy. As energy is required to for the development of industry and to meet the increasing demand of population. Further, Fossil fuels takes million years for its formation in the earth and their reserves are finite. Because of their continuous consumption these are moving towards depletions faster, so with the scarcity of deletion of fossil fuel reserves wasting such a huge amount of energy potential through burning is not sustainable step for the future of mankind.

Rice by-products such as stubble, roots, straw etc. which remains in the fields after harvesting the crop is of great concern to the farmers. Due to present rice-wheat cropping system being followed by major northwestern states(Panjab Singh et. al,2017) of India such as Punjab , Uttar Pradesh, Haryana, Uttarakhand time period between the harvesting of rice crop and sowing of new crop i.e wheat is very less ranging between 10 to 20 days and farmers wants their field to get ready for the new crop as early as possible. Therefore, they find the burning of left over residue in the fields as most easiest, cheapest and quickest way to get rid of it unaware of the fact that it causes not only wastage of energy but also causes severe environment pollution.

1.1 Pollution Caused by Residue Burning

This rice-wheat cropping system in northwestern states results in about 34 million tonnes of rice residues and Punjab, being the major contributor provides 65% of this residue alone. It has been estimated that around 23 million tones of rice residues are burnt annually in these northwestern states of India. The burning hot spots across one of leading agriculture state of India(Punjab) as detected by VIIRS Punjab from 27th September to 19th November, 2017(Fig.1) results severe environment pollution not only in the state itself but also in the neighbouring states like Delhi, Chandigarh etc.

Fig.1 Active fire locations detected by VIIRS in Punjab from 27 September to 19 November 2017



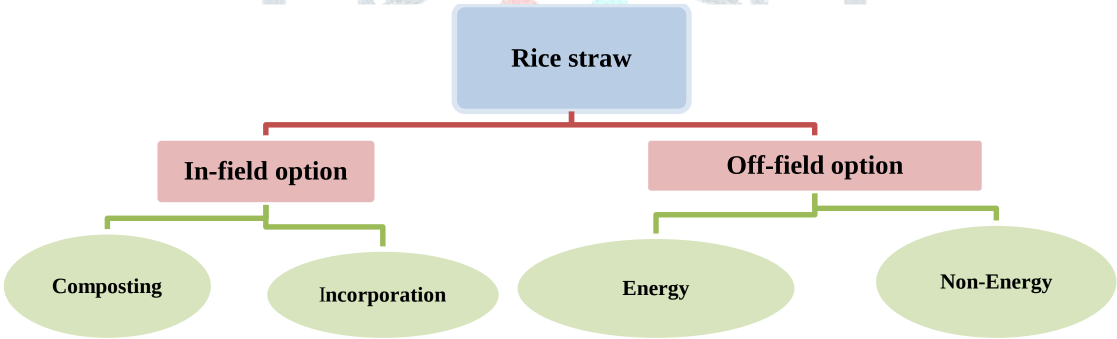
Burning of crop residues not only contributes to the emission of harmful gases such as CO, N_2O, NO_X,(Gadde et.al.,2009) black carbon clouds , volatile organic compounds, $PM_{2.5}$, CH_4, SO_2 etc. which contributes to global warming but as causes loss of important soil nutrients such as almost complete loss of Nitrogen, about 20 % loss of Potassium, 25 % loss of Phosphorous and loss of S varies between 5 to 60%. Data estimation shows that one tone of rice residue burning results in 1460 kg CO_2, 60 kg CO, 0.2 kg SO_2, 13 kg particulate matters, 3.5 kg NO_x . It has been noticed that black carbon emission due to residue burning warms the lower atmosphere and acts as second highest contributor to the global warming after CO_2.

Further, it has been observed that residues burning during the months between September to November and April to June due to existing rice-wheat cropping system resulted in air becoming the most polluted in the month of November and June in the neighboring States like Delhi, Chandigarh. In November, 2016 Delhi air becomes most polluted in the world resulting the Government to declare an emergency as precautionary measure to protect the local population from severe health hazards being caused by air pollution(Singh, 2018) such as eyes irritation, respiratory problems , lung problems like asthma etc. Rice residue burning causes more severe affect on the children health as they are more sensitive to the air pollution which results in some unrecoverable influence on their pulmonary functions. In rural areas of Punjab, there is increase in medical and health related expenditure which amounts to be nearly 7.61 crores annually along with the loss of working days during rice residue burning period between September to November. Therefore, the need of hour is to provide the farmers with friendly and cost effective management of rice residue in a sustainable way.

2. Sustainable Practices for Rice Straw Management

Rice straw, being lignocellulosic nature biomass is comprised of : lignin , hemicellulose and cellulose. Lignin is the outer boundary which provides protection to the cellulose and hemicelluloses(Samra et.al.,2003). Earlier, rice straw was not consider to be suitable for energy because of its complex structure that makes decomposition difficult. So, most commonly used practices includes livestock fodder , roof thatching , mushroom cultivation, furnace fuel etc. Therefore sustainable practices for rice straw management can be classified into two categories (Fig.2): (i) on-field management options such as incorporation(in-situ), composting (ii) off field management practices such as electricity generation through anaerobic digestion, production of bio-oil or gasification.

Fig 2. Classification of Management options



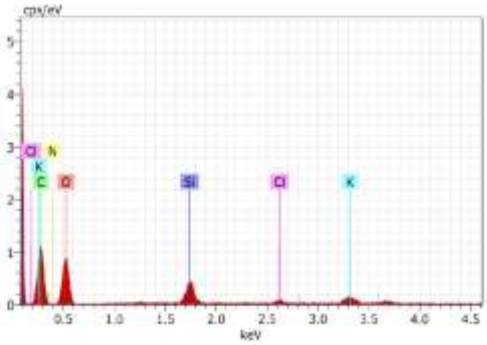
2.1 On-Field Management of Rice Residue

Incorporation (in-situ) and composting (ex-situ) are the two most promising on-field management options for the surface retention and to address the problem of residue burning. Incorporation returns back the most important nutrients into the soil and also helps to conserve the nutrients for long time. Sustainable utilization of rice straw is essential for the improvement of soil health and production of crops. Benefits of straw incorporation depend on amount, type of soil, sand time of application apart from temperature, moisture, aeration and tillage. As 5 tons crop of paddy crop (rice and straw) removes about 150 kg of N, 20 kg of P, 150 kg K and 20 kg S(Ponnamperum,1984) from soil. However, characterization of rice straw (Fig.3) through SEM with EDX represents the various element percentage presents in one of the sample collected from village of Mohali District of Punjab which shows that it contains 42.72% carbon, 47.63% oxygen, 5.04% silicon, 3.43% potassium, 0.69% chlorine and 0.50% nitrogen . Thus Rice straw through incorporation supplies macronutrients to the succeeding crop and act as good source of fertilizer . Incorporation of both residues increases organic C and total N as compared to removal or burning of straw (Dhiman *et al*., 2000).

However, incorporation and composting are energy and cost intensive options as incorporation requires certain extra tillage along with chopper to reduces residue size and more irrigation and urea is required to fasten the process of decomposition. Moreover, the time between rice to wheat cropping system is very small and composting takes a long period of about month even more than that for preparing the organic fertilizer. That's why these two practices are not common among the farmers.

With the advancement of technology, the turbo Happy Seeder is considered to be a significant innovative technology for in-situ residue management. For the efficient use of this technology the rice residue is uniformly spread across the field along with sowing of wheat crop. Thus mulch acts as material to preserve the moisture content of the soil, prevents the weed growth in the field and also prevents from termite attack. It also helps to improve the soil health, soil biodiversity, productivity potential and enriches the soil with organic matter by the time. Use of this technology also helps to reduce the pollution caused by burning of crop residues.

Fig.3 Characterization Of Rice Straw through SEM with EDX



2.2 Off-Field Management of Rice Residue

With advancement of technology the energy requirements around the world has been increased many folds. At present, fossil fuel resources are not regarded as sustainable in ecological and environmental point of views. Therefore researchers are emphasizing on alternative sources of energy. Biomass such as rice straw has immense potential and can be considered as best option for meeting the demand and insurance of future energy supply in a sustainable manner. With the improved technology the collection of rice straw from field became easier and cheaper as compared to manual collection resulting in effective utilization of straw to full-fill energy requirements.

Anaerobic digestion, a proven technology through which biomass can be converted into energy. This is an eco-friendly natural process in which different micro-organism degrade organic matter into intermediate products such as sugar, fatty acids and amino acids through process known as hydrolysis. Further, acidogenic and acetogenic bacteria acts on these substances and results into hydrogen , acetic acid and carbon dioxide(Zaho et.al.,2010) Then methogensis bacteria acts on it and these are converted into renewable resource of energy known as biogas. Biogas, mainly composed of methane and carbon dioxide with small amounts of hydrogen sulphide, ammonia and water vapour. It has been observed that during decomposition of rice straw through anaerobic digestion 80% of methane comes from acetic acid and remaining from carbon dioxide and hydrogen (Glissmann & Conrad, 2000). Due to the availability of abundance rice straw, it is selected as most favorable lignocelulosic biomass for energy production. Biogas produced from feedstock can be used to generate electricity which provides clean and renewable energy source. However, its high lignin content slows down its decomposition through anaerobic digestion. Therefore, certain pretreatment methods which includes physical , chemical and biological pre-treatment are required to break-down the lignin so as to make the decomposition faster . Physical-Pretreatment of residue results in size reduction of rice straw so as to increase the surface area which eventually makes the organic matter more readily available for the microorganism to decompose(Zihao et al.2010). Chemical pretreatment of straw with acids , alkali and ionic pretreatment makes the degradability of organic matter faster (Cann et al.,1994) . In addition to pretrearment of rice straw there are several other factors which effects the biogas production such as pH of buffer solution, temperature, C:N ratios , HRT time.

The ideal pH for rice straw digestion was determined by several researchers ranges between 6.5 to 7.3 . (Zihao et al.2010). So in order to maintain a neutral or slightly alkaline pH during the anaerobic digestion process , the system needs an appropriate buffering agent. It has been observed that due to chemical pretreatment the pH becomes either very less or very high depending on types of chemical used and co-digestion of the residues with animal manure helps to adjust the pH between optimal range required in anaerobic digestion process.

During various studies on rice straw it has been observed that biogas production is maximum when carbon to nitrogen ratio lies between 25 to 30:1(Tanimu et al. 2014). However, C:N ratio of pure rice straw residue is higher, as it 85.44:1 for the above said sample of rice straw. Carbon to nitrogen ratio can be improved by co-digestion of straw with animal waste. Co-digestion of rice straw with cow dung in 1:2 adjusts the C:N ratio equals to 29.6:1 which results in improved biogas production from rice straw.

Temperature plays a crucial role in the anaerobic digestion process, it has a strong influence not only on the quality but also on the quantity of biogas production. The various researchers found mesophilic range (35^0C to 40^0 C) as optimum temperature for biogas production through anerobic digestion of straw(Torres-Castillo et al.1995). However, in the recent studies on rice straw (Ghatak & Mahanta,2014) observed that biogas production higher at thermophilic temperature ranges from 50 to 55^0C. India is located in the region where climate is warm most and temperature lies in meshophilic range for most of the times of year therefore, it favours the utilization of rice straw for biogas production through anaerobic digestion process.

Hydraulic retention time(HRT) depicts the average time for which a given quantity of slurry remains in digester to be acted upon by bacteria in anaerobic process. Higher the temperature of the slurry in the digester lower the hydraulic retention time.

Depending upon the operating temperature and design of the digester, HRT usually varies between 20 to 120 days,(Samboo et al. 1995) . In India, as weather is warm for most of the period in a year so it takes around 40-60 days as HRT and in colder countries it takes around 100 days as HRT period to take place anaerobic digestion process.

Biomass so available can also be used to produce bio-oil through the pyrolysis. Bio-oil, a high density liquid having heating value of about 55% as compared with petroleum based diesel. However, the bio-oil is produced from Bagasse, wheat straw, rice hulls mainly its feasibility with rice straw needs to be assessed. As bio-oil is free from certain air polluting gases such as SO_2 emissions and produces low NO_2. Therefore, research is going on to produce bio-oil from crop residues economically viable.

Non-Energy Use of Rice Straw

Alternative non-energy uses of rice straw includes mushroom production , biochar, animal fodder production, paper production. The paddy straw can be used to cultivate mushroom because of its short incubation period of 14 days. Around 50-100kg of mushroom per 1 ton of dried straw can be produced. In Punjab about 20,000 meteric tones of straw is used for mushroom cultivation. Although mushroom can be produced on number of crop residues, but yield is less than that with rice starw. It has been observed that paddy straw contributes to 16% of total mushroom cultivation in the world.

Biochar basically , a charcoal is produced by the thermal decomposition of organic materials or biomass under limited supply of oxygen at temperature from 500 to 700^0 C(Weixiang & Yingxu, 2012). Rich in carbon biochar can be utilized to improve the soil productivity , carbon storage, enhanced biogas production from cow dung and reduced green house gases emission etc. Pyrolysis temperature has great influence on the characteristics of rice straw derived biochar. Studies reveals that biochar derived at 400^0 C pyrolysis has high alkalinity, extractable cations, high level of available phosphorous which indicates that rice straw derived biochar has great potential to act as fertilizer and for further soil amendments.

Rice straw, due to high silica content in it is difficult to digest and lacks in important essential nutrients required by growing cattle.However, stems of rice straw has better digestibility as they have lower silica content as compared to leaves which have higher silica content and are considered as poor feed for animals. Rice straw after pretreatment with urea and other chemicals such as NaOH can enhance the nutrition value of straw as fodder for animals.

Rice straw along with wheat straw in 40: 60 ratio also contributes for paper production. The sludge so formed in paper and pulp industry is further subjected to bio-methanization to produce energy. Some of the paper industries are full-filling their 60% of energy requirements through this method.

Conclusion

Due to lack of knowledge such a huge amount of biomass potential is wasted in the open field burning. So, the government should organize more workshops to make farmers aware about the losses incurred due to burning of straw and hazardous impact on health due to environment pollution being caused by it. The government should also encourage the farmers to "earn do not burn" from the available resources of energy in the form of straw. In most of the developing , countries like India almost 70% of the population lives in villages which lacks in basic amenities such as electricity, employability and opportunities to enhance their skills. Biomass is an important renewable source of energy which is mainly presents in the villages. Although rice straw is available in abundance in India but its energy potential is not properly utilized due to challenges faced by its proper utilization which includes are :

- Exact figure on the availability of rice straw is not present
- Due to current rice wheat cropping system the time for its proper collection and management is very less.
- Due to certain problems associated with its collection, storage and processing.
- Conversion of biomass into electricity is cost effective due to non-availability of proper energy conversion system in decentralized manner.

However, biomass gasification based decentralized power generation has many advantages over other sources of renewable energy resource such as its duration of operation is highly flexible and it can be installed at any village where sufficient biomass is available or 2-3 villages can be combined together for sufficient supply of biomass for power generation. Moreover , Decentralized power generation through biomass will also create employment opportunities in the rural areas.

References :

[1] www.FAO.org

[2] www.mospi.nic.in/stastical-year-book-india.

[3] Oanh N.T.K , Bich T L, Tipayarom D, Manadhar B R, Prapat P., Simpson C. D, Liu L., J.S.2011. Characterization of particulate matter emission from open burning of rice straw. Atomspheric Environment,493:502

[4] Gadde B, Bonnet S, Menke C, Garivait S.2009. Air pollutant emissions from rice straw open field burning in India, Thailand and the Philippines. Environment Pollution. 1554:1558.

[5] Singh F.P. 2018. Stubble Burning in India side effects and alternatives.AGU International journal of Research in Social Sciences and Humanities. 6: 296-302

[6] Samra J S, Singh B, Kumar K.. 2003. Improving the productivity and sustainability of rice, wheat systems: issues and impact, American society of Agronomy.173:195.

[7] Singh P. 2017. Innovative viable solution to Rice Residue Burning in Rice-Wheat cropping system through concurrent use of super straw management system-fitted Combines and Turbo Happy Seeder. National Academy of Agriculture Sciences, New Delhi. 1-16.

[8] Ponnamperuma F N. 1984. Straw as source of nutrients for wetland rice.Organic matter and rice. International Rice Research Institute , Los Banos. Philippines.117:135.

[9] Zhao R, Zhang Z, Zhang R, Li M, Lei Z, Utsumi M. 2010.Methane production from rice straw pretreated by mixture of acetic-propionic acid. Bioresource Technology.101:990.

[10] Cann IK , Kobayashi Y, Wakita M, Hoshino S. 1994. Effect of three chemical treatments on in vitro fermentation of rice straw by mixed rumen microbes in the presence or absence of anaerobic rumen fungi . Reproduced Nutrition Development.34:47.

[11] Glissmann K, Conard R.2000. Fermentation pattern of methanogenic degradation of rice straw in anoxic paddy soil. FEMS Microbiology Ecol. 31:117.

[12] Torres-Castillo R, Libares-Luengo P, Mata-Alvarez J. 1995. Temperature effect on anaerobic digestion of bedding straw in a one phase system at different inoculums concentrations. Agriculture , Ecosystems and Environment. 54:55.

[13] Mahanta P., Saha U.K., Dewan A., Kalita P. 2004The Influence of temperature and total solid concentration on the gas production rate of biogas digester, Journal of Energy in Southern Africa,15,112-117.

[14]Ghatak M., Mahanta P.2014. Kinetic Assessment of Biogas Production from Lignocellulosic Biomasses, International Journal of Engineering and Advanced Technology.244-249.

[15] Tanimu Musa I, Ghazi Tinia I., Harun Razif M., Idris A. 2014. Effect of Carbon to Nitrogen Ratio of Food Waste on Biogas Methane Production in a Batch Mesophilic Anaerobic Digester, International Journal of Innovation, Management and Technology, 5(2):16-119.

[16] Sambo A.S.,Garba B., Danshehu B. G.1995. Effect of some Operating parameters on Biogas Production Rate, Renewable Energy, 6(3): 343-344.

[17] Dorbe P., Nicolae F., Matei F. 2014. Main factors affecting biogas production – an overview, Romanian Biotechnological Letters, 19(3): 9283-9296.

[18] Garba B. 1996. Effect of temperature and retention period on biogas production from lignocellulosic material, Renewable Energy, 9(1-4): 938-940.

[19] Dhiman S P, Nandal D P and Hari O. 2000. Productivity of rice(Oryza sativa)- Wheat(Triticum aestivum) cropping system as affected by its residue management and fertility levels. Indian Journal Of Agronomy.1-5.

[20] Chandra R, Takeuchi H., Hasegawa T.2012. Methane production from lignocellulosic agriculture crop wastes : A review in context to second generation of biofuel prodiction. Renewable and Sustainable Energy Reviews.1462:1476(2012).

[21] Weixiang Wu., Yingxu C. 2012. Chemical characterization of rice straw-derived biochar for soil amendment. Biomass and Bioenergy. 47: 268-276.