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Review Article

Paddy Straw Management: A Potential Approach to Sustainable Agriculture

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ABSTRACT

Paddy straw is the vegetative part of rice plant which is left behind after harvesting the grains. It is the most abundant lignocellulosic waste material amounting to 731 million tons/year. Management of paddy straw remains a challenge in Asia where more rice is grown each year to meet rising hunger demands. The widespread burning of paddy straw in the open air is a major factor causing air pollution that is associated with a number of health issues. Researchers, engineers, and entrepreneurs are developing a range of possible solutions that turn paddy straw into a commodity with the help of which sustainable value chains can be built to benefit the environment. This waste to wealth approach can prove beneficial in the coming time. This review paper presents an overview of some efficient paddy straw management practices for the benefit of mankind and sustainable agriculture.

Keywords: Biochar, Biofuel, Pollution, Paddy straw

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the primary staple food for more than half of the world's population. It is believed that rice is the first cultivated crop in the world. 90-95% of the total rice produced in the world is in Asia (Arunakumara et al., 2013; Rathna Priya et al., 2019). Rice, wheat, and maize are the world's three leading food crops and together constitute 51% of total calories consumed (Madhukar, 2022). Rice is one of the most widely consumed grains in the world. China ranks first and India ranks second in rice consumption worldwide (Shahbandeh, 2022). The global rice production in the year 2021-2022 is mentioned as 509.87 million tons, 2.63 million tons more than the previous year 2020-2021 ("Production volume of milled rice worldwide 2021/22, Statista", 2022). Total production of rice in India during 2020-21 is estimated to be 121.46 million tonnes. It is higher by 9.01 million tonnes than the last five years' average production of 112.44 million tonnes (Ministry of Agriculture & Farmers Welfare, 2021). West Bengal is the largest rice producing state accounting for about 13.95% of total rice output in the country followed by Uttar Pradesh (13.75 million tonnes) and Punjab (12 million tonnes) competing for the second and third position, respectively. Tamil Nadu, Andhra Pradesh, Bihar, Chhattisgarh, Odisha, Assam and Kerala are the other major rice producing states in India (TractorGuru, 2021).

2. OVERVIEW OF PADDY MANAGEMENT OPTIONS

Globally, 731 million tons (MT) of paddy straw is produced, while India contributes around 126.6 million tons. 60% of the lignocellulosic waste is burnt in open air in most parts of the country as a compulsion. This leads to an increase in the greenhouse gases emission of 7300 kg CO_2-equivalent/hectare (Bhattacharyya et al., 2021). The large amount of straw left spread out in the field is highly unprofitable. The infield options adopted by the farmers after harvesting the grains are burning, incorporation, mulching, manual collection etc. These processes are cumbersome and also cause pollution. For reducing the time and labour cost farmers adopts the options of open field burning or pile burning, which is majorly responsible for the emission of greenhouse gases (Abdurrahman et al., 2020). In addition, it is also responsible for soil infertility and nutrient imbalance (AMK, 2020). Therefore, it has become important to explore sustainable solutions and implement them effectively. There are many economically viable options available such as biochar production, mushroom production, microbial degradation, bio decomposer etc. In the next section, we will be discussing some of these options.

2.1. Production of Biochar

Biochar is a pyrolyzed biomass prepared by vegetative waste such as paddy straw under limited anaerobic conditions. Biochar is marked as a promising sorbent material for reducing the bioavailability of heavy metals (Shahin, 2018). Extensive studies are being carried out on the sustainable potential of biochar in the reduction of bioavailability or movement of heavy metals in the soil (Haider et al., 2022). Biochar reduces the mobility of heavy metals or ions in the soil through various mechanisms such as cation exchange, precipitation, complexation or physical adsorption etc. (Ambaye et al., 2020). In the latest studies bioremediation of lead, zinc and copper adsorption are mentioned, but a common problem mentioned in all the studies was that the pyrolysis temperature influences the properties of biochar. Biochar were prepared at different temperatures i.e. 300 ^{0}C, 500 ^{0}C, 700 ^{0}C in a study conducted in China and it was concluded that the biochars produced at higher temperatures had high alkaline value and was effective in immobilizing the heavy metal especially lead, which is present in higher amount in contaminated soil (Shen et al., 2019).

At higher temperatures, the volatile, organic matter, and functional groups are decreased while aromatic carbon content is increased. The loss of functional group leads to an increase in the biochar's total pH value which plays a crucial role in the adsorption of inorganic contaminants. It was also observed that the surface area of the biochar increased as the carbonization temperature increased (Shahin, 2018). However, producing biochars at different carbonization temperatures is an energy-intensive process. Hydrothermal carbonization is a low-energy alternative for transforming lignocellulosic waste into solid, liquid, or gaseous products (Czerwińska et al., 2022). It is a thermochemical process that is used in the conversion of biomass and organic waste. Biochar is porous and economical and has a broad range of applications, including water and air purification, soil amendment, catalyst etc. (Sakhiya et al., 2021).

2.2. Bio-energy Production

In the era defined by energy dearth and the increasing fossil fuel demand and prices, alternative renewable sources of energy have to be marked in order to meet the continuously rising demand. Paddy straw is considered a potential candidate for bioenergy production. Bioethanol is used as alternative energy for fuel, making it a promising candidate for sustainable energy. Out of all the liquid fuels that can be produced from paddy straw, bioethanol is more desirable because of its higher octane number. But there are some limitations in the process of converting paddy straw to bioethanol. For converting paddy straw lignocellulose to ethanol, pre-treatment is required that involves physical as well as chemical processes. For ethanol production, the next step is the enzymatic hydrolysis of paddy straw rich in lignocellulosic waste material (i.e. xylose). Hence, xylose fermenting microorganisms are required to achieve efficient ethanol production (Komesu et al., 2020). Fungus *Mucor circinelloides* is a mutant used for ethanol production. It not only ferments glucose, but also xylose as well as N-acetyl glucosamine. The strain is also known as ethanol-producing fungus. It is able to secrete cellulase (endo-β-glucanase, cellobiohydrolase, β-glucosidase) and xylanase (endo-β-xylanase, β-xylosidase) and can directly grow on polysaccharides. Furthermore, it has tolerance for fermentation inhibitors such as furfural and 5-HMF produced by pre-treatment with high temperature and pressure (Takano & Hoshino, 2018). *Trichoderma viride* and *Phanerochaete chrysosporium* are the two other promising fungal strains for the successful degradation of the straw and ethanol production (Chen et al., 2019).

2.3. Production of Syngas

The mixture of hydrogen (H_2) and carbon monoxide (CO) is known as syngas. It is popularly called synthesis gas and is a product of coal gasification (Maguyon-Detras et al., 2019). Coal being a highly exploited fossil fuel, is not a viable option to produce syngas. Therefore, recent studies are now focussed on the production of syngas from paddy straw in carbon dioxide (CO_2) mediated environment. The anthropogenic CO_2 emitted by fossil fuels can be used for the production of synthesis gas. The power generation from this alternative significantly contributes to the mitigation of greenhouse gas emissions and biomass waste production (Jung et al., 2020).

2.4. Production of Silica Nanoparticle

Paddy straw has an abundant content of silica (10-15%) that can be extracted. Water-soluble silicic acid is polymerized into polysilicic acid that is precipitated and deposited on the outer cell wall as amorphous silica (Van Soest, 2006). Silica can be extracted by various methods such as hydrolysis of paddy straw by microbes (Wattanasiriwech et al., 2010) or alkaline pretreatment of paddy straw with hydrogen peroxide/potassium hydroxide (Talib et al., 2018; Nandiyanto et al., 2016). The silica nanoparticles obtained from paddy straw using simple extraction method are stable and can be used in composite material, biotechnology related material, environment treatment components etc. (Uda et al., 2020).

2.5. Microbial Degradation of Rice Straw

Lignocellulosic content of rice straw is composed of three types of polymers - cellulose, hemicellulose and lignin. Different non-covalent forces and covalent cross-linkages make it difficult for soil microorganisms to digest it. There are reports of a variety of bacterial strains that degrade lignin and cellulose. The strains include *Bacillus*, *Pseudomonas,* and *Acintobacteria, Clostridium.* These micro-organisms can digest different cross-linkages and thus can digest lignin and cellulose (Xu et al., 2021).

Recently, Indian Agriculture Research Institute (IARI) introduced 'PUSA decomposer'. These are the microbial capsules having seven fungal strains which can be used to degrade rice crop residue such as paddy straw. The effect of the bio-decomposer was first observed in the field of Najafgarh block in Delhi, India. It has been asserted that only four capsules are required to turn a hectare of farm waste into usable compost (Zaidi, 2021). The decomposition capsules have no side effects as they contain eco-friendly fungi and also they are inexpensive. It involves preparing a liquid formulation using decomposer capsules and fermenting it over 8-10 days. Thereafter, the mixture is sprayed on fields having crop stubble to ensure speedy bio-decomposition of the stubble.

2.6. Government Intervention for Efficient Paddy Straw Management

Open-field crop burning is hazardous to the environment and hence the Government of India has taken some steps to stop the burning process. Some of the laws introduced are a) The Section 144 of Civil Procedure Code (CPC) to ban the burning of rice crops; b) The Air Prevention and Control of Pollution Act, 1981; c) The Environment Protection Act, 1986; d) The National Tribunal Act, 1995; and e) The National Environment Appellate Authority Act, 1997. Not only the central government but the state government of Rajasthan, Uttar Pradesh, Haryana, and Punjab have also implored the National Green Tribunal (NGT) to limit the crop residue burning and also to spread awareness among the farmers to stop crop burning. The government also introduced biogas plants in villages and introduced bio compost methods. Several schemes such as The Rashtriya Krishi Vikas Yojana (RKVY), the State Plan Scheme of Additional Central Assistance proposed by the Government have played a crucial role in reducing crop burning practices in India. Recently Ministry of Agriculture established a program called the National Policy for Management of Crop Residue (NPMCR) which keeps a track of crop residue through the National Remote Sensing Agency (NRSA) (Zaidi, 2021).

3. CONCLUSION

This review article focuses on some of the sustainable techniques to manage paddy straw to prevent air pollution. Steady deterioration of air quality has been recorded in recent years which is a matter of grave concern. Farmers in India tend to burn crops due to the fact that it's inexpensive, time friendly, and less strenuous. The management of crop waste is a huge task in India and other Asian countries. The technologies mentioned above can be potential solutions to manage the rice straw. The Indian Agricultural Research Institute (IARI) is constantly promoting research and various innovative measures to manage crop residue. Central and state government should take a step forward in laying blueprints on how these technologies can be set up and implemented. This waste-to-wealth approach can prove to be beneficial for the farmers as well as the environment.

CONFLICT OF INTEREST

None

REFERENCES

Abdurrahman, M., Chaki, S., & Saini, G. (2020). Stubble burning: Effects on health & environment, regulations and management practices. *Environmental Advances*, *2*, 100011. doi: 10.1016/j.envadv.2020.100011

Ambaye, T., Vaccari, M., van Hullebusch, E., Amrane, A., & Rtimi, S. (2020). Mechanisms and adsorption capacities of biochar for the removal of organic and inorganic pollutants from industrial wastewater. *International Journal Of Environmental Science And Technology*, *18*(10), 3273-3294. doi: 10.1007/s13762-020-03060-w

AMK, E. (2020). Environmental and Health Impact of Open Burning Rice Straw. *Egyptian Journal of Occupational Medicine*, *44*(3), 679-708. doi: 10.21608/ejom.2020.118349

Arunakumara, K., Walpola, B., & Yoon, M. (2013). Current status of heavy metal contamination in Asia's rice lands. *Reviews In Environmental Science And Bio/Technology, 12*(4), 355-377. doi: 10.1007/s11157-013-9323-1

Bhattacharyya, P., Bisen, J., Bhaduri, D., Priyadarsini, S., Munda, S., Chakraborti, M., et al. (2021). Turn the wheel from waste to wealth: Economic and environmental gain of sustainable rice straw management practices over field burning in reference to India. *Science of The Total Environment*, *775*, 145896. doi: 10.1016/j.scitotenv.2021.145896

Chen, K. J., Tang, J. C., Xu, B. H., Lan, S. L., & Cao, Y. (2019). Degradation enhancement of rice straw by co-culture of *Phanerochaete chrysosporium* and *Trichoderma viride*. *Scientific reports*, *9(1)*, 1-7.

Czerwińska, K., Śliz, M., & Wilk, M. (2022). Hydrothermal carbonization process: Fundamentals, main parameter characteristics and possible applications including an effective method of SARS-CoV-2 mitigation in sewage sludge. A review. *Renewable and Sustainable Energy Reviews*, *154*, 111873. doi: 10.1016/j.rser.2021.111873

TractorGuru (2021). Top 10 rice producing states in India with rice cultivation method. Retrieved from https://www.tractorfirst.com/blog/top-10-rice-producing-states-in-india-with-rice-cultivation-method/.

Haider, F., Wang, X., Farooq, M., Hussain, S., Cheema, S., Ain, N. et al. (2022). Biochar application for the remediation of trace metals in contaminated soils: Implications for stress tolerance and crop production. *Ecotoxicology And Environmental Safety*, *230*, 113165. doi: 10.1016/j.ecoenv.2022.113165

Jung, S., Lee, S., Park, Y., Lee, K., & Kwon, E. (2020). CO_2-Mediated catalytic pyrolysis of rice straw for syngas production and power generation. *Energy Conversion and Management*, *220*, 113057. doi: 10.1016/j.enconman.2020.113057

Komesu, A., Oliveira, J., Neto, J., Penteado, E., Diniz, A., & da Silva Martins, L. (2020). Xylose fermentation to bioethanol production using genetic engineering microorganisms. In: *Genetic and Metabolic Engineering For Improved Biofuel Production From Lignocellulosic Biomass*, pp 143-154. Elsevier. doi: 10.1016/b978-0-12-817953-6.00010-5

Madhukar, K. (2022). The World's Top 3 Major Crops- Wheat, Rice, &Maize; Find Interesting Statistics Inside. Retrieved from https://krishijagran.com/agriculture-world/the-world-s-top-3-major-crops-wheat-rice-maize-find-interesting-statistics-inside/

Maguyon-Detras, M., Migo, M., Van Hung, N., & Gummert, M. (2019). Thermochemical Conversion of Rice Straw. In: Gummert, M., Hung, N., Chivenge, P., Douthwaite, B. (eds). *Sustainable Rice Straw Management*, pp 43-64. Springer, Cham. doi: 10.1007/978-3-030-32373-8_4

Ministry of Agriculture and Farmers Welfare releases Third Advance Estimates of Principal Crops for 2020-21. (2021). Retrieved from https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1721692#:~:text=Total%20production%20of%20Rice%20during,production%20of%20112.44%20million%20tonnes

Nandiyanto, A. B. D., Rahman, T., Fadhlulloh, M. A., Abdullah, A. G., Hamidah, I., & Mulyanti, B. (2016, April). Synthesis of silica particles from rice straw waste using a simple extraction method. In IOP Conference Series: Materials Science and Engineering (Vol. 128, No. 1, p. 012040). IOP Publishing.

Production volume of milled rice worldwide 2021/22. Statista. (2022). Retrieved from https://www.statista.com/statistics/271972/world-husked-rice-production-volume-since-2008/

Rathna Priya, T. S., Nelson, A. R. L. E., Ravichandran, K., & Antony, U. (2019). Nutritional and functional properties of coloured rice varieties of South India: A review. *Journal of Ethnic Foods*, *6*, 11. doi: 10.1186/s42779-019-0017-3

Sakhiya, A., Baghel, P., Anand, A., Vijay, V., & Kaushal, P. (2021). A comparative study of physical and chemical activation of rice straw derived biochar to enhance Zn+2 adsorption. *Bioresource Technology Reports*, *15*, 100774. doi: 10.1016/j.biteb.2021.100774

Shahbandeh, M. (2022). Rice - statistics & facts. Retrieved from https://www.statista.com/topics/1443/rice/#topicHeader__wrapper

Shahin, F. (2018). Removal of heavy metals and hormones from wastewater using rice husk and rice straw biochar packed columns. (Doctoral dissertation, University of Guelph) Retrieved from https://atrium.lib.uoguelph.ca/xmlui/bitstream/handle/10214/12157/Shahin_Faisal_201801_MASc.pdf?sequence=1&isAllowed=y

Shen, Z., Hou, D., Jin, F., Shi, J., Fan, X., Tsang, D., & Alessi, D. (2019). Effect of production temperature on lead removal mechanisms by rice straw biochars. *Science of the Total Environment*, *655*, 751-758. doi: 10.1016/j.scitotenv.2018.11.282

Takano, M., & Hoshino, K. (2018). Bioethanol production from rice straw by simultaneous saccharification and fermentation with statistical optimized cellulase cocktail and fermenting fungus. *Bioresources And Bioprocessing*, *5*(1), 1-12. doi: 10.1186/s40643-018-0203-y

Talib, N. A., Ahmad, A., Setapar, S. M., Khamis, A. K., Lokhat, D., & Rafatullah, M. (2018). Removal of silica from rice straw by using alkaline hydrogen peroxide solution in a fixed bed column. *J. Mater. Environ. Sci., 9,* 864-8 72.

Uda, M. N. A., Gopinath, S. C., Hashim, U., Halim, N. H., Parmin, N. A., Afnan Uda, M. N., & Anbu, P. (2021). Production and characterization of silica nanoparticles from fly ash: Conversion of agro-waste into resource. *Preparative Biochemistry & Biotechnology, 51(1),* 86-95. doi: 10.1080/10826068.2020.1793174

Van Soest, P. J. (2006). Rice straw, the role of silica and treatments to improve quality. *Animal Feed Science Technology*, *130*, 137-71.

Wattanasiriwech, S., Wattanasiriwech, D., & Svasti, J. (2010). Production of amorphous silica nanoparticles from rice straw with microbial hydrolysis pretreatment. *Journal of Non-crystalline Solids*, *356*, 1228-32.

Xu, C., Su, X., Wang, J., Zhang, F., Shen, G., Yuan, Y. et al. (2021). Characteristics and functional bacteria in a microbial consortium for rice straw lignin-degrading. *Bioresource Technology*, *331*, 125066. doi: 10.1016/j.biortech.2021.125066

Zaidi, S. (2021). Rice Crop Residue burning and alternative measures by India: A Review. *Journal of Scientific Research*, *65*(02), 132-137. doi: 10.37398/jsr.2021.650227

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