Sustainable management of Rice Straw to decrease stubble burning in North-Western regions of India: A review

Comment [D1]: Title has two aspects stubble burning and rice straw.
But, the manuscript deals only about rice straw uses.
Either the title must be changed or also write about rice stubble management.
The content of the manuscript is inferior than the words sustainable and management.
As this is a very important problem, the reader expects more. Think more and improve the manuscript.

Abstract

After sugarcane bagasse and maize straw, rice straw (RS) is globally the third largest form of agricultural residue while, in India, it is the largest form of agricultural residue. In the north-western states of India wheat is taken as a rabi crop and surplus rice straw is a focal issue associated with storage of rice straw, removal of entire straw from the field, and very little time between the cultivation of the crop hence rice straw burning becomes cheap, quick and efficient way for preparing bed for sowing of wheat. Open burning of crop residue kills beneficial soil microflora, degrades soil, and adds to detrimental greenhouse gases such as SO_2, NO_2, CH_4, N_2O, CO, and hydrocarbons and particulate matter in the atmosphere. As a result, burning rice straw is a major source of pollution in the environment. This review looked into rice straw alternatives that were less harmful to the environment, such as RS biochar production, RS as industrial waste adsorbents, RS based bio-methanation, heavy metal amelioration, RS bricks and RS based bioethanol production.

Keyword- Rice straw, biochar, bio-methanation, bio-ethanol, straw burning

Introduction

Rice, the principal crop of Indian subcontinent covering 43.79 Mha with the 1st advanced estimate of 107.43 Mt (Anonymous, 2021) is the staple food source for the burgeoning population of the nation. Plethora of farmers, with the support of Governments MSP and monsoon rainfall undertake Rice farming as a viable option, which it is. Same goes for farmers of Northern India, but little did they know such an innocuous practice would translate into a catastrophe, which would strangle the Capital of India for a gasp of air. When cereal crops are harvested, we are left with agricultural waste or crop residue as straw. It is a non-edible product, often left in the field after harvesting. Traditionally, paddy straw was seen as a versatile by-product of rice cultivation because it was used in many ways including fodder for livestock and as a building material. However, the increase in productivity and area under cultivation of rice has led to a huge production of rice straw. Moreover, mechanization decreased the animal dependency and hence the feed requirement. So, the most effective way of disposing of the residue is seen as burning of biomass in the paddy field. It is important to mention that open field burning is a widely practiced method all over the world; however, its intensity varies. Taking farmers view into account, burning is not only a cost-effective method but it acts as an effective pest control procedure Dobermann and Witt (2000). The short-term effects of burning seem more desirable than those from soil incorporation due to the immobilization of inorganic nitrogen which occurs in the latter stage and can adversely affect productivity in the short term. Also, it helps to reduce diseases that

Comment [D2]: Burning rice straw in India is a traditional practice? Please indicate in the manuscript.

may occur due to reinfection from inoculum in the straw biomass. Stubble burning, incessant especially in Rice-Wheat cropping zone releases enough pollutants into the air which has turned the situation into an endemic. According to CPCB's Air Quality Management Data, New Delhi (Nehru Nagar) has Air Quality Index (AQI) of 395 on 9th of December, 2021 which fall under category of very poor. Government has stepped up on toes to tackle the menace, but only providing agricultural implements at subsidized cost is not a solution as it increases inflation, also implements experience depreciation and soon wear out and some of the marginal farmers cannot afford these implements even at the subsidized cost. A sustainable, long lasting and holistic solution should also include supporting development of enterprises or even practices which utilize the remnant of RS. Some of the applications of RS would be as industrial waste adsorbent, biochar, bio-methanation, heavy metal amelioration, RS bricks and use in paper and pulp industry.

Comment [D3]: For rice-rice or rice-wheat cropping system?

Biochar

Comment [D4]: Only advantages of Biochar mentioned? What about diadvantages and how to implement it?

Biochar is a product of organic material which was subjected to a heat treatment under restricted oxygen supply, commonly at temperatures below 700°C (Lehmann and Joseph, 2009). Biochar is a byproduct of biomass pyrolysis (or gasification) to produce biofuels, as well as an intentional primary product from the partial pyrolysis of biomass (Lehmann and Joseph, 2009). Generally, Rice Straw biochar is alkaline, regardless of pyrolysis temperature and residence time. Alkaline biochar can be used as a soil amendment for neutralizing acidity, improving soil fertility and sequestering C in acidic soils. Dong *et al*. (2018) demonstrated that rice straw biochar enhanced rice production and nitrogen retention in a waterlogged paddy field. Cui *et al*. (2017) found a significant reduction in CH4 emissions, global warming potential and greenhouse gas intensity when a cold waterlogged paddy field was applied with at least 2 t/ha rice straw biochar in North China. It appears that a cold waterlogged paddy field may benefit from rice straw biochar amendment (Si *et al*., 2018). Pore sizes of biochar buried in soil is of importance as it will allow colonization by soil microbes that are small enough to enter the spaces available while at the same time will not allow grazing predators of larger sizes to follow (Warnock *et al.*, 2007). Many soils treated with biochar support enhanced plant growth due to improved physical and chemical properties (Lehmann and Joseph, 2009).

Industrial Waste adsorbent

1. Organic Dyes

Some of agricultural wastes have bilateral role as low-cost substances and strong absorbent for some organic pollutants like basic dyes - which have an acute toxicities and carcinogenic nature- from contaminated aqueous bodies (Allam *et al*., 2018).

Dyes are synthetic and aromatic compounds in nature used widely in such industries of textile, food, plastics, cosmetics and tannery industries and come out in wastewater discharged from those industries (Zhang *et al*., 2011). Around 2% of dyes produced annually are discharged as effluents from textile, food, plastics, cosmetics and tannery industries (Mohandass and Ganesan, 2017). Their stable chemical structures make them more difficult to chemical, photochemical or microbial degradation (Ranga and Sanghavi, 2017). Most of these dyes have hazardous effects on human health and aquatic ecosystems may be due to partial treatment methods before disposal (Kushwaha *et al.*, 2010).

In an experiment conducted by (Umpuch *et al*., 2015) it was demonstrated how adsorbing efficacy of RS can be increased.

The modification of rice straw with a cationic surfactant enhanced the sorption efficiency for Yellow20 dye from 36.44% of the dye being removed before modification to 96.01% after the surface property of the adsorbent was altered from hydrophilic to hydrophobic as shown in Fig. 1 (Umpuch, 2015).

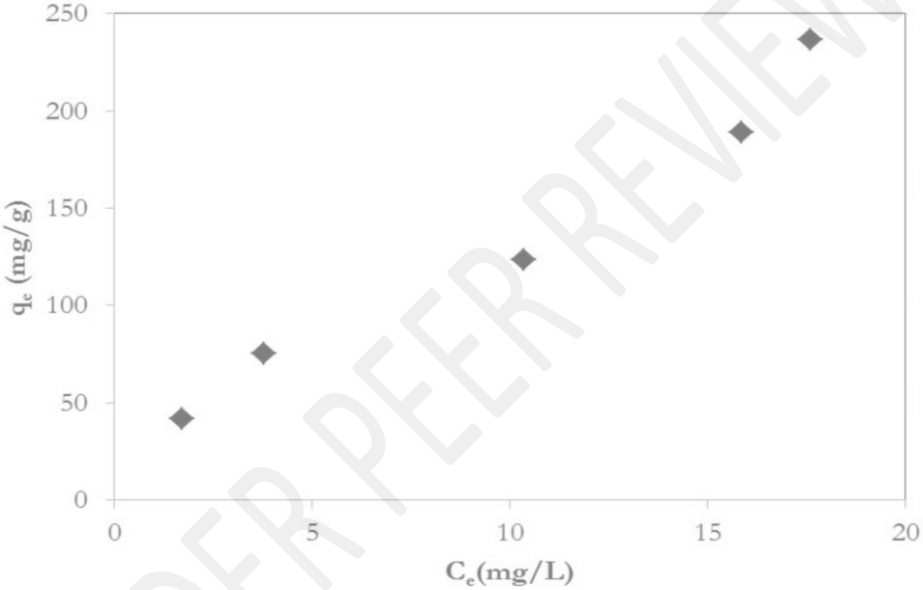


Fig. 1: Adsorption isotherm of the dye sorption by the organo-rice straw with increasing contact time. Source: **(Umpuch, 2015)**.

2. Phenol

Pollution by phenols is an important environmental issue. Phenolic compounds are common contaminant in wastewater. Phenol is very soluble in water and its presence in water supplies is noticed as bad taste and odor in concentration as low as 5 µg/L (Rengaraj *et al*., 2002). Phenols as a class of organics are similar in structure to the more common herbicides and insecticides in that they are resistant to biodegradation (Mahvi *et al.*, 2004). They are widely used for the commercial production of a wide variety of resins including phenolic resins, which are used as construction materials for automobiles and appliances, epoxy resins and adhesives and polyamides for various applications (Banat *et al.*, 2000)

Phenol removal efficiency of different selected adsorbents with increasing adsorbent dosage is presented in Fig. 2. For both particle sizes, phenol adsorption capacity observed to increase in the order of, thermally treated (ash)>physically treated>raw rice straw. Ash of >1 mm rice straw particles showed the highest phenol removal efficiency of 84.07 % for 2.5 g adsorbent dose at equilibrium among all types of adsorbents studied. Thermal treatment (ashing) of raw rice straw destructs the organic matrix that causes an increase in the surface area for adsorption of phenol.

Comment [D5]: But, how to deal with phenol containing rice-straw?

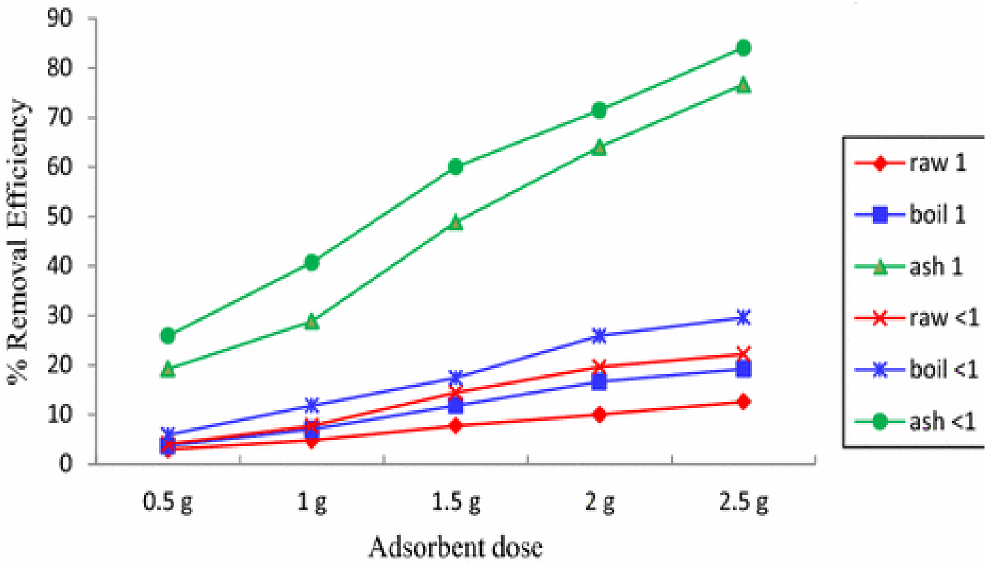


Fig 2. Percentage removal of phenol with different adsorbent dosage for different adsorbents; Contact Time- 24 hours

Bio-methanation

Comment [D6]: Trivedi et al., 2017 are the pioneers of this concept and methodology?

Trivedi *et al.* (2017) stated that the anaerobic digestion technology is a most efficient way in terms of energy output/input ratio for handling biomass resources to produce energy and bio-fertilizer. Bio-methanation of paddy straw presented by Trivedi *et al.* (2017) consists of actual field experimental data taken from demonstration scale bio-methanation plant at Fazilka, Punjab Paddy straw was received in bales from the entire region of Fazilka, Punjab, and was stored in the storage unit. Further, the paddy straw is manually spread over the width of the conveyer belt, to be fed into the pulverization unit, for its size reduction to a level of 3–5 mm.

Table 1: Energy analysis of paddy straw-based biogas power production.

Unit	Power Consumption (kWh/h)	Operating time (hr)	Total power consumption
Energy Input			

Paddy straw pre-treatment (pulverization)	94.00	10.00	940.00
Substrate feeding unit	23.00	10.00	230.00
H_2S scrubbing unit	13.75	10.00	137.50
Bio-fertilizer unit	13.75	10.00	137.50
Total energy input (kWh)		**1,445**	
Energy output (kWh)		**8,000**	
Net energy gain (kWh)		**6,555**	
Output/Input		**5.5**	

Source: Trivedi *et al.* (2017)

Table 2: Cost–benefit analysis of paddy straw-based biogas power production.

	Rs/10 tonne paddy straw	**Rate (Rs/unit)**
Output		
Electricity (8,000 kWh)	60,000	7.5 /kWh
Bio-fertilizer (5.0t)	35,000	7.0/kg
Input		
Paddy straw cost	-15,000	1,500/tonne
Paddy straw pretreatment	-7,050	
Substrate feeding unit	-1,725	
H_2S Scrubbing unit	-1,031	
Bio-fertilizer unit	-1,031	
Net benefit	**69,163**	
Output/Input	**3.6**	

Source: Trivedi *et al.* (2017)

For the energy balance, calculations are made from the point of paddy straw pretreatment for biogas production. From Tables 1 and 2, it is evident that the conversion of paddy straw to biogas via pulverization achieves a net positive energy of 655 kWh/tonne and cost benefit of 6,916/tonne of paddy straw. It was revealed that the use of rice straw for biogas production can generate a positive net energy balance between 70 per cent and 80 per cent (Trivedi *et al.*, 2017).

Heavy Metal amelioration

The presence of heavy metals in the water environment is a major concern due to their toxic effects since they cause severe health problems to animals and human beings. Many industrial processes produce aqueous effluents containing toxic metal contaminants. According to the World Health Organization (WHO), the metals of most immediate concern are aluminum, chromium, manganese, iron, cobalt, nickel, copper, zinc, cadmium, mercury and lead. Cadmium and cadmium compounds are especially dangerous and highly toxic. Cadmium toxicity contributes to many health conditions, including the major killer diseases such as heart disease, cancer and diabetes. Cadmium concentrates in the kidney, liver and various other organs and is considered more toxic than either lead or mercury.

1. Nickel and Cadmium

The potential use of rice straw as an adsorbent for Nickel and Cadmium was studied by Sayed *et al.* (2010) and it was found that rice straw is an effective adsorbent for the two metal ions, especially for Cadmium, the maximum adsorption capacities for Ni and Cd were 35.08 and 144.19 mg/g, respectively. The sorption capacity was strongly dependent on the adsorbent dosage; initial metal ions concentration and initial pH. The experimental data well fitted to the Langmuir and Freundlich equations, with good correlation coefficients. The study of the thermodynamic parameters indicated that the adsorption process was thermodynamically spontaneous under natural conditions and the adsorption is exothermic in nature.

2. Chromium

The structure of rice straw fiber is modified by opening the bond of cellulose molecular chain, introducing new functional groups, changing inherent characteristics of cellulose. The cellulose adsorbent with high adsorption capacity is prepared, and used to simulate adsorption study of marine heavy metal Cr wastewater. Through static adsorption experiments, the adsorption performance of modified rice straw for Cr in simulated waste water and the removal mechanism are studied by Leiming *et al.* (2018).

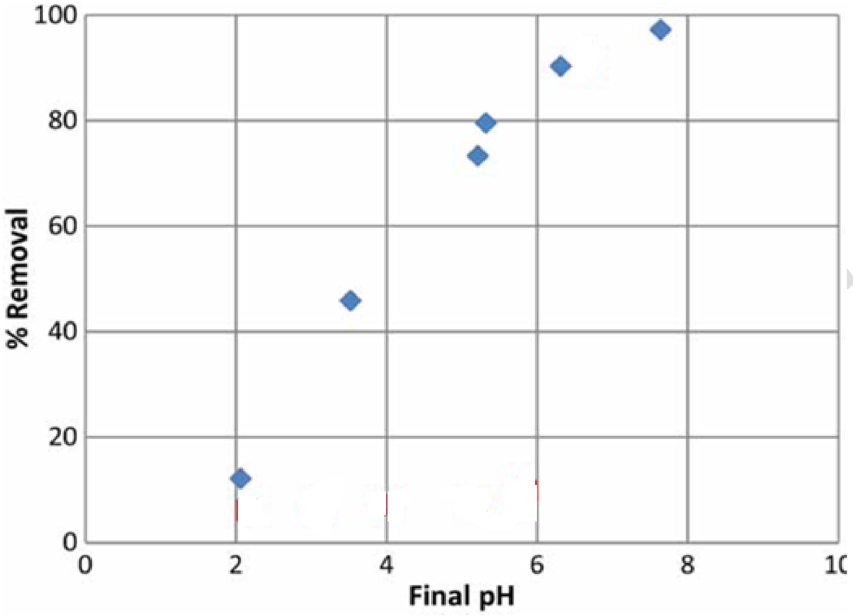
With the increase of straw dosage, the removal efficiency of Cr and the yield of the modified straw are generally rising and then decreasing. When the straw dosage is increased from 5 g to 7 g, the removal rate of Cr is augmented from 85.5% to 92.5%; when the straw dosage is 6.5 g, the removal rate and duct yield reach the highest point; when the straw dosage is continually increased, the removal rate decreases sharply, and the yield is reduced (Leiming *et al.*, 2018).

3. Lead

Lead is a heavy metal which is utilized in several industries and can have severe impact on the environment and human health. Research work has been carried out lately on the feasibility of using various low-cost materials in the removal of heavy metals from wastewater. Lead is one of the most toxic heavy metals that threaten human health and the environment (Kardam *et al*., 2014). It is extremely harmful to the nervous system and the immune system. Industrial applications that utilize Pb in their processes include battery manufacturing, electroplating, etrochemical processes, printing pigments and fuels

In a study conducted by Amer *et al.* (2017), Fig. 3 presents the change in the removal efficiency of Pb versus the final pH of solutions containing rice straw. It also shows the change in Pb removal as affected by solution pH in solutions without rice straw (control). The amount of metal removal by rice straw was greatly affected by varying the pH of a solution. At a low pH in the range of 2–3.5, adsorption of Pb using rice straw was relatively low, in the range of 12–45%. At higher pH (3.5 to 6), the percentage of Pb removal increased remarkably – to around 90%, as presented in Figure 3.

Fig 3. Final pH of the solution vs. the percentage removal of Pb (II) (dose 2 g/l, contact Time: 4 h, C_0: 40 mg/l).



Source: Amer *et al.* (2017)

Rice Straw – Bricks

The research on wall made of rice straws, commonly called as straw bale, is necessary to be developed, since the use of straws as mixed material of lightweight concrete will create an eco-architecture building (Sumarni and Wijanarko, 2018).

This wall of straws is developed in countries such as China, United States, and Australia. The building wall is made by spinning rice straws into hays with an approximate length of 30-60 cm. Then, the hays are placed into a wall frame and then covered with wire mesh to strengthen it. It is then plastered with mortar. Because the weight of the structure is reduced, the workload will also be smaller so that the structure is expected to be safer and very suitable for housing in earthquake prone areas. Implementation on building materials especially for wall-shaped brick is more environmentally friendly than clay brick (Sumarni and Wijanarko, 2018).

Table 3: Variations of straw hay bale

No Variation	Volume of straw hays (m^3)	Size of hay straw length*width*height (mm)	Quantity
1	0.000000	0	3
2	0.000625	250*50*50	3

3	0.000750	300*50*50	3
4	0.000875	350*50*50	3
5	0.001250	250*50*100	3
6	0.001500	300*50*100	3
7	0.001750	350*50*100	3
8	0.001875	250*50*150	3
9	0.002250	300*50*150	3
10	0.002625	350*50*150	3

Source: Sumarni and Wijanarko, 2018

Compressive strength of concrete bricks is the amount of load per area unit which cause the specimen to break if it is loaded with certain amount of compressive force produced by compressing machine. Non-structural lightweight concrete has the compressive strength between 0.35 – 6.9 MPa and specific gravity under 1900 kg/m3.

The compressive strength of concrete bricks without straws was 5.896 MPa, while straw variation no. 7 (From Table no. 3) with the volume of 0.00175 m3 had the maximum compressive strength of 1.92 MPa (Sumarni and Wijanarko, 2018). It was an ideal variation for compressive strength value. The value itself met the requirements as non-structural lightweight concrete (Dobrowolski, 1998)

Bioethanol

Rice straw can potentially produce 205 billion-liter bioethanol per year in the world, which is about 5% of total of consumption. It is the largest amount from a single biomass feedstock. Rice straw predominantly contains cellulose 32-47%, hemicelluloses 19-27%, lignin 5-24% and ashes 18.8%. The carbohydrate of rice straw involves glucose 41-43.4%, xylose 14.8-20.2%, arabinose 2.7-4.5%, mannose 1.8% and galactose 0.4% (Roberto *et al.*, 2003).

Rice straw has heterogeneous complex structure in which hard cellulose fiber due to the crystal structure and entangled lignin and hemicellulose is contained. In the bioconversion to ethanol from lignocellulose, pretreatment by physical and/or chemical method is necessary to break the strong structure and obtain fermentable sugars easily by biocatalyst such as cellulase, xylanase, ligninase, etc. Especially, among the chemical treatments, alkali treatments using NaOH, KOH, CaOH, and Na2CO3 are more effective than other chemical treatments, because it is able to break the ester bonds between lignin, hemicellulose, and cellulose, so that lignin and a part of hemicelluloses are concurrently removed (Khaleghian *et al.*, 2015).

As lignocellulosic biomass such as rice straw contains a great deal of xylose, use of xylose-fermenting microorganism is necessary to achieve efficient ethanol production from such materials. *Mucor* sp. of parental strain is known as ethanol-producing fungus which is able to ferment not only glucose but also xylose and other monosaccharides included *N*-acetyl glucosamine (Inokuma *et al.*, 2013).

Below the consecutive methods and findings of Takano and Hoshino (2018) have been mentioned to briefly summarize their findings on production of ethanol from Rice straw.

Table 4: Comparison of SSF of several pre-treated rice straws by various strains

Treatment	Cellulase	Strain	Maximum ethanol concentration (g/L)	Productivity (g/L/h)	Temperature (°C)	pH	References
H2SO4	BTLX	*Saccharomyces cerevisiae*	6.83	0.284	38	5.0	Karimi *et al*. (2006)
		Mucor indicus	7.79	0.649	38	5.5	
		Rhizopus oryzae	9.2	0.383	38	5.5	
NH_3	Celluclast 1.5 L Accellerase 1500 Novozyme 188 Xylanase	*S. cerevisiae*	12.7	0.250	38	4.8	Ko *et al.* (2009)
H_2SO_4 and NaOH	Crude cellulase from *Aspergillus* and *Trichoderma*	*Kluveromyces* sp.	23.2	0.386	42	4.8	Narra *et al.* (2015)
NaOH	Accellerase 1000	*S. cerevisiae and Scheffersomy-ces stipitis*	28.6	0.777	38	5.0	Suriyachai *et al*. (2013)
NaOH	Celluclast 1.5 L Novozyme 188 Pectinase	*Pichia kudriavzevii*	24.3	1.01	40	4.0	Oberoi *et al*. (2012)
NaOH	Cellulase T Cellulase Onozuka 3S Pectinase	*M. circinelloides*	30.6	0.850	28	5.5	Takano and Hoshino (2018)

Rice straw is one of the desirable bio-mass as good feedstock of ethanol production and has been investigated by combining several treatments and fermenting microorganisms. Table 4 shows the comparison of various SSFs using pretreated rice straws under close conditions to this study. All conditions were related in ethanol production strongly. Various enzyme reagents were used for each report and these performed well on hydrolysis of these substrates. However, it was doubtful whether these were really suitable for the substrates, because many amount of dose can achieve high degradation of biomass even if enzyme was not match to the substrates. We suggested effective selection and optimization methods to resolve that matter, which induced effective SSF with low dose of the reagents. As shown in Table 4, alkali pretreatment of rice straw led to higher ethanol productions and that yields comparatively more than acid treatment. Particularly, these yields were significantly higher than of acid treatment processes. Since alkali

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treatment can break crystal structure and soften the fiber, the advantage induced good hydrolysis and subsequent fermentation. Our study reported the highest ethanol production and yield among these reports, because optimization of enzyme mixture affected highly to hydrolysis of the straw. In addition, it was reason that the fungus used in this study could convert not only glucose and xylose to ethanol, but also secrete slightly several cellulases which helped fermentable sugar production. Productivities were relatively high on SSF with Mucor fungi from the results of these reports.

Comment [D9]: Indicate the species.

The pretreatment method of alkali (NaOH) with heating resulted in effective lignin removal from raw rice straw and making a high sugar content material. Multivariate analysis could suggest several required enzymatic activities and derive a selection of appropriate reagents for the pretreated rice straw. Three kinds of desired reagents were selected from 15 kinds of commercial enzyme reagents based on the analysis. DOE with RSM proposed an optimum ratio of enzyme cocktail consisted of the three reagents for effective production of fermentable sugar from the alkali-treated straw. The enzyme cocktail constructed by these statistical approaches advanced hydrolysis efficiency to 83.3% at 2 g-protein/L from low efficiencies with each reagent alone. SSF of the alkali-treated straw using a novel pentose-fermenting fungus with the cocktail achieved high ethanol production with the fermenting efficiency of 90% of fermentable sugar basis.

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Conclusion

Rice straw use optimization is not solely the duty of farmers; the government should enact laws and regulations to prevent stubble burning. There must be public awareness about RS management, as well as mandatory RS management training for farmers. Farmers can also benefit financially from the use of RS. RS can be used for production of biochar which will help in alleviating soil health and also increase carbon sequestration while putting the RS to good use. Using RS as industrial waste adsorbent is also as option for both harmful organic dyes and heavy metals present in industrial effluents. Lightweight bricks using concrete and RS should also be promoted as they inflict least damage in earthquake prone areas being lightweight and also since RS bricks are cheaper to make, they can also be used for making cheap bricks for makeshift homes. Also, RS can be used as a fuel for a variety of reasons, including reducing greenhouse and other harmful gases. In this approach, the ecosystem can be safeguarded against future pollution crises. RS should be able to be moved from the field to the factory with minimal effort, else all efforts would be in vain. Private players must form up units locally and employ their new and old technologies for greater farming practice. RS has already been mentioned as a possible substitute for nonrenewable energy fuel using processes of bio-methanation and formation of bioethanol. These actions help to preserve the environment for future generations. In the future, small power thermal plants may be able to run on stubble instead of coal. Subsidies should be implemented by the government to encourage the use of these biofuels. Local governments in India and other countries can be more responsible when it comes to enacting particular regulations. In Bangladesh and Indonesia, some NGOs (Non-Governmental Organizations) have begun to provide microfinance for small-scale renewable energy projects.

REFERENCES

Allam, A. M., Mohamed, M. K., Zahran, H. F., Sheikh, M. H. El, and Abdelnour, G. B. (2018). Some Organic Pollutants from Aqueous Solutions. *Bioscience Research*, 15(3):1826-1831.

Amer, H., El-Gendy, A., and El-Haggar, S. (2017). Removal of lead (II) from aqueous solutions using rice straw. *Water Science and Technology*, *76*(5), 1011–1021.

Anonymous, 2021. Annual Report 2020-2021. Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India.

Banat, F.A., Al-Bashir, B., Al-Asheh, S., Hayajneh, O. (2000). Adsorption of phenol by bentonite. *Environmental pollution*, 107:391–398

Cui, Y.F., Meng, J., Wang, Q.X., Zhang, W.M., Cheng, X.Y., Chen, W.F. 2017. Effects of straw and biochar addition on soil nitrogen, carbon, and super rice yield in cold waterlogged paddy soils of North China. J. Integr. Agric., 16, 1064–1074.

Dobermann A and Witt C. 2000. The potential impact of crop intensification on carbon and nitrogen cycling in intensive rice systems. In: Carbon and nitrogen dynamics in flooded soils: 1-25. International Rice Research Institute, Los Baños, Philippines.

Dobrowolski, A.J. 1998. Concrete Contruction Hand Book Mc. Graw-Hill Companies Inc New York.

Dong, L., Linghu, W., Zhao, D., Mou, Y., Hu, B., Asiri, A. M., … Wang, J. (2018). Performance of biochar derived from rice straw for removal of Ni(II) in batch experiments. *Water Science and Technology*, *2017*(3), 824–834.

Inokuma K, Takano M, Hoshino K (2013) Direct ethanol production from N-acetylglucosamine and chitin substrates by Mucor species. *Biochemical Engineering Journal* 72:24–32.

Kardam, A., Raj, K. R., Srivastava, S. & Srivastava, M. M. 2014. Nanocellulose fibers for biosorption of cadmium, nickel, and lead ions from aqueous solution. Clean Technologies and Environmental Policy 16 (2), 385–393.

Karimi, K., Emtiazi, G., Taherzadeh, M.J. (2006). Ethanol production from dilute-acid pretreated rice straw by simultaneous saccharifcation and fermentation with Mucor indicus, Rhizopus oryzae, and Saccharomyces cerevisiae. *Enzyme Microb Technol.* 40:138–144.

Khaleghian, H., Karimi, K., Behzad, T. (2015). Ethanol production from rice straw by sodium carbonate pretreatment and *Mucor hiemalis* fermentation. *Industrial Crops and Products* 76:1079–1085.

Ko, J.K., Bak, J.S., Jung, M.W., Lee, H.J., Choi, I.G., Kim, T.H. and Kim, K.H. (2009). Ethanol production from rice straw using optimized aqueous-ammonia soaking pretreat-ment and simultaneous saccharifcation and fermentation processes. *Bioresource Technology*. 100:4374–4380.

Kushwaha, Jai, Srivastava, Vimal and Mall, Indra. (2010). Organics removal from dairy wastewater by electrochemical treatment and residue disposal. *Separation and Purification Technology*. 76. 198–205.

Lehmann, Johannes & Joseph, S. (2009). Biochar for environmental management: An introduction. Biochar for environmental management. Science and technology. Earthscan Publishers Ltd.

Leiming, Fu, Liu, Y., Wang, Z., Chen, Y., and He, C. (2018). Ion Adsorption of Rice Straw to Marine Heavy Metal Polluted Waste Water. *Journal of Coastal Research*, 83, 359.

Mahvi AH, Maleki A, Eslami A. (2004). Potential of rice husk and rice husk ash for phenol removal in aqueous systems. *Journal of Applied Sciences*, **1**: 321–326.

Mohandass, P. and Ganesan T.K. 2017. Removal of Methylene Blue Dye from Waste Water Using Agro–Waste as Low-Cost Adsorbent.Int J Innov Res Sci Eng & Tech. 6(3): 3426-3431.

Narra, M., James, J.P. and Balasubramanian V. 2015. Simultaneous saccharifcation and fermentation of delignifed lignocellulosic biomass at high solid loadings by a newly isolated thermotolerant Kluyveromyces sp. for ethanol production. *Bioresource Technology*. 179:331–338.

Oberoi, H.S., Babbar, N., Sandhu, S.K., Dhaliwal, S.S., Kaur, U., Chadha, B.S. and Bhargav, V.K. 2012. Ethanol production from alkali-treated rice straw via simultaneous saccharifcation and fermentation using newly isolated thermotolerant Pichia kudriavzevii HOP-1. *Journal of Industrial Microbiology and Biotechnology*. 39:557–566

Ranga S.V., and Sanghavi, L.K. 2017. Dye Waste Water Treatment Using Agro Waste: Green Adsorption. Int J Innov Res Sci Eng & Tech. 6(1): 14-18.

Rengaraj S, Moon SH, Sivabalan R, Arabindoo B, Murugesan V (2002) Agricultural solid waste for the removal of organics: adsorption of phenol from water and wastewater by palm seed coat activated carbon. Waste Manag 22:543–548

Roberto, I.C., Mussatto, S.I., Rodrigues, R.C. (2003). Dilute-acid hy-drolysis for optimization of xylose recovery from rice straw in a semi-pilot reactor. Ind Crops Prod 7:171-176.

Sayed, El, G. O., Dessouki, H. A. and S.S. Ibrahim (2010). Biosorption Of Ni (II) And Cd (II) Ions From Aqueous Solutions Onto Rice Straw. *Chemical Sciences Journal*, *1*(1), 1–11.

Si, L., Xie, Y., Ma, Q., and Wu, L. (2018). The short-term effects of rice straw biochar, nitrogen and phosphorus fertilizer on rice yield and soil properties in a cold waterlogged paddy field. *Sustainability (Switzerland)*, *10*(2), 1–17.

Sumarni, S., and Wijanarko, W. (2018). Preparation and Mechanical Properties of Pressed Straw Concrete Brick. *IOP Conference Series: Materials Science and Engineering*, 333(1).

Suriyachai, N., Weerasaia, K., Laosiripojana, N., Champreda, V. and Unrean, P. 2013. Optimized simultaneous saccharifcation and co-fermentation of rice straw for ethanol production by Saccharomyces cerevisiae and Schefersomyces stipitis co-culture using design of experiments. *Bioresource Technology*.142:171–178.

Takano, M., and 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).

Trivedi, Abhinav, Chandra, Ram, Jha, Bhaskar, Ranjan, Amit, Vijay, Virendra Kumar. (2017). Energy Generation from Paddy Straw an Analysis of Bioenergy Models. *Akshay Urja*. **10**. 22-27.

Umpuch, C. (2015). Removal of yellow20 dye from aqueous solution using organo-rice straw: Characteristic, kinetic and equilibrium studies. *Engineering Journal*, *19*(2), 59–69.

Warnock, D.D., Lehmann, J., Kuyper, T.W., Rillig, M.C., 2007. Mycorrhizal responses to biochar in soil–concepts and mechanisms. Plant and Soil 300, 9-20

Zhang H., Tang Y., Liu X., Ke Z., Su X., Cai D., Wang X, Liu Y., Huang Q. & Yu Z. 2011. Improved Adsorptive Capacity of Pine Wood Decayed by Fungi Poriacocos for Removal of Malachite Green from Aqueous Solutions. Desal. 274: 97-104