Faculty of Agriculture, University of Poonch Rawalakot
Jammu Kashmir Journal of Agriculture
ISSN: 2312-9344 (Online), 2313-1241 (Print)
https://jkjagri.com/index.php/journal

BIOMASS PROCESSING TECHNOLOGY FOR CONVERTING CROPS RESIDUES INTO BIOFUEL: PAK-TURKIYE PERSPECTIVES

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A B S T R A C T

Globally, climate change and global warming have adversely influenced the functioning and productivity of all sectors which have compromised the food security, sustainability of farming systems and means of livelihood. The open field burning of residues or leftovers of crops such as maize, wheat, cotton, rice and sugarcane are causing environmental degradation by contributing greenhouse gases emission from agricultural fields. The net result is incidence of frequent diseases, droughts, floods and heat waves along with persistent poor air quality owing to prevalence of smog. Up till now, no legislation has remained effective in preventing farmers from clearing the fields through burning of crop left-overs and this scenario necessitates development of sustainable crop residues management strategies which are not only low-tech but also impart some marketable worth to these left-overs. The conversion of biopolymers of cellulose, lignin, hemicellulose and lignocellulosic biomass might be utilized for biofuel production. However, presence of carbohydrates prevents effective fermentation and there is dire need to develop an effective protocol for separating them from crops wastes in order to prepare biofuel. An amalgamation of engineering-cum-socio-environmental approaches might serve as a potent strategy to combat climate change and environmental degradation along with providing economical biofuel.

Keywords: Biopolymers; Cellulose; Crops left-overs; Lignin; Hemicellulose; Lignocellulosic

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Article history
Received: March 4th, 2023
Revised: April 7th, 2023
Accepted: April 13th, 2023

INTRODUCTION

Globally, agro-based economies are characterized with year-round farming activities which generate hefty amounts of agricultural wastes especially crop residues or leftover retained the agricultural field after extracting economic yield. The crops harvest wastes, also termed as crop residues CRs includes field residues left in the agricultural fields and orchards after the economic yield has been harvested. For instance, stalks, stubble, leaves and seed pods are the predominant forms of crops left-overs, while sugarcane bagasse and molasses may be quoted as examples for processed residues (Chanthawong and Dhakal, 2016; Yusuf et al., 2011). Figure 1 depicts major constituents of the crop residues which need to be separated for conversion into biofuel and other processed products.

Owing to absence of sustainable management practices, hundreds of metric tons of crop wastes are burned in open field every year causing greenhouse gases emissions and air pollution. In Indo-Pak subcontinent and Turkiye (Ozturk et al., 2017; Yadav et al., 2020), crops leftovers burning has become a leading factor for environmental pollution and posing serious threat to human health. Previously, composting of crop residues for manures preparation, biochar production and utilization as mulching material have not significantly helped to curtail the issue. In Pakistan, diesel and fuel oil based thermal power plants have been constructed to meet the immediate energy needs of rapidly increasing population. The abundant utilization of fossil fuels for generating electricity has multiplied CO_2 emissions leading to 177 million tons annually (Elder and Hayashi, 2018). The per capita CO_2 emission is estimated to increase further as numerous coal and gas-fired power

plants are becoming functional to fulfil energy demand of the industry and domestic use.

The crops left-overs might be beneficially utilized in raw form and especially after industrial processing. Few instances of crops residues utilization can be for livestock feed, mulching material, composted manure etc., however farmers are more interested in disposing these in open field burning in order to clear the field for sowing o the next crop (Nansaior et al., 2013; Tock et al., 2010). More importantly, expenditures are involved in appropriately disposing off the crop residues by going through different operations such as collection, transportation and processing may incur more cost in comparison to the revenue generated from the beneficial use of such wastes (Stougie et al., 2018). One of the classic examples whereby low economic returns have prevented the sustainable utilization of crops left-overs which have led to environmental chaos in Indo-Pak sub-continent.

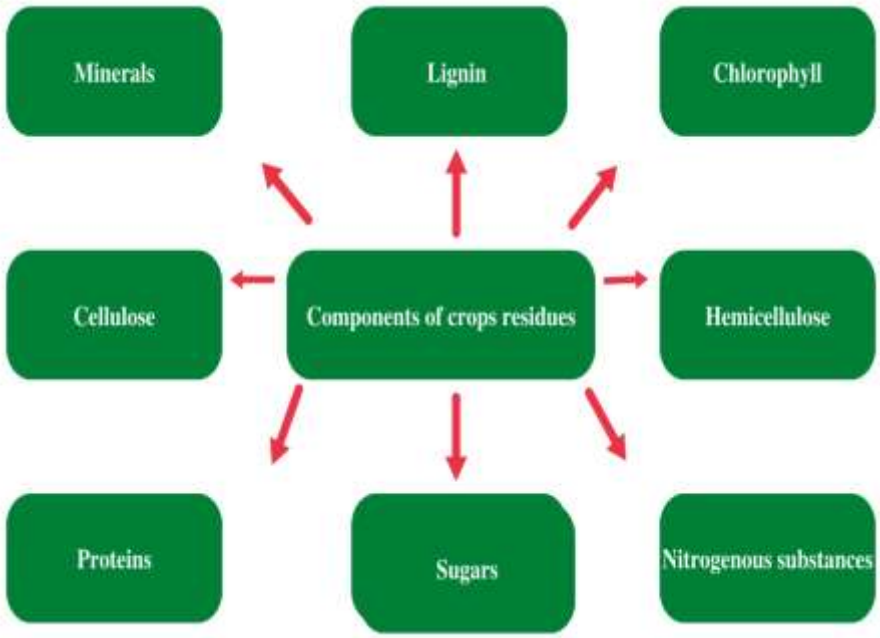

Figure1. Different components and constituents of crops left-overs.

This review briefly synthesizes literature on implications of open field burning of crops residues and prevalent management options for crops leftovers along with objectively evaluating the development of eco-friendly and low-tech protocol for converting these residues into biofuel. Along with being an environmental concern, crops residues management is vital keeping in view that these are vital constituents of agriculture and their production cannot be avoided whatsoever. Secondly owing to their organic composition, crops residues hold potential to be used for society's benefit. Last but not least, this topic is of interest for broader audience beyond Pakistan and Turkiye as unsustainable management practices especially open field burning of crop residues have led to serious and adverse environmental impacts of greater multitude.

Implications of open field burning of crop left-overs

These crop residues are natural resources that traditionally contribute to the soil fertility and stability if incorporated directly into the soil or in composted from which then increase irrigation efficiency. However, economic constraints and more importantly, the modern intensive farming systems have imposed practical and technical limitations to such sustainable practices. Interestingly, crop residues are primarily comprised of cellulose, hemicellulose and lignin along with minor contents of sugars, protein and nitrogenous materials, pectin, chlorophyll and numerous inorganic minerals. In contrast to cellulose and hemicellulose, lignin tends to provide structural support for being impermeable. It resists fermentation due to its resistance against the chemical and biological degradation. The crops non-food-based portion including stems, stalks, straws and husk are categorized under lingo-cellulosic biomass (Li and Loo, 2014). Different implications of open field burning of crop residues on humans, soil and

environment have been presented in Figure 2.

The open field burning of crop residues has given rise to a variety of environmental problems. The prime adverse impact is the emissions of greenhouse gases emission which is contributing to global warming and triggering the climate change phenomenon. In addition, it has resulted in significant increment in particulate matter and smog leading to health hazards, biodiversity losses in agricultural lands along with soil fertility deterioration. The burning of CRs generates hefty quantities of air pollutants including CO_2, CO, NH3, non-methane hydrocarbons and volatile organic compounds. This controlled burning also results in the loss of organic carbon and soil nutrients especially nitrogen. It has been inferred that 98.4 million tons of crop residues burning generated over 8.5, 141 million tons of CO and CO_2. The air pollutants emitted as a result of crop residues burning is generally 17-20 times higher than emissions from vehicles, garbage burning and industries emissions.

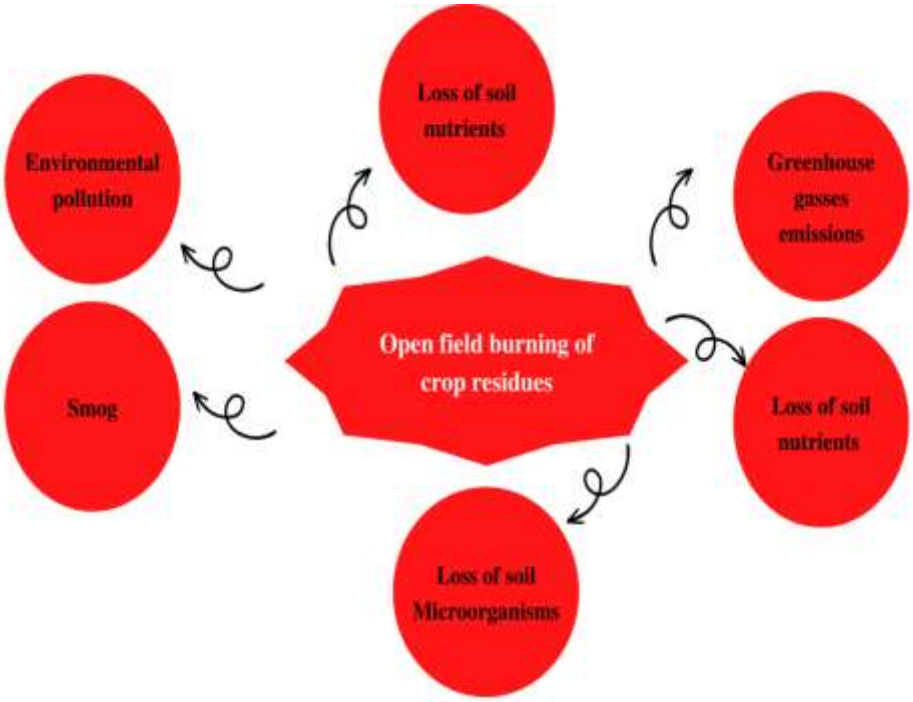

Figure 2. Different implications of open field burning of crop residues on humans, soil and environment.

The World Health Organization WHO has set the standard of permissible particulate matter levels is 2.5 10 µg/m3, while major cities of Pakistan have the corresponding value of 70-98 µg/m3, which is at least ten times higher than the WHO standard. Additionally, the open field burning of CRs also raises temperature of the subsoil up to 15 cm of depth. Moreover, it reduces the carbon potential of the soil along with killing a major chunk of microflora and fauna which are quite beneficial and essential to maintain soil organic matter by carrying out decomposition of organic matter (Hassan and Kalam, 2013; Sulaiman et al., 2011).

Limited management options for crops residues

Globally, agricultural industry is playing a strategic role in promoting the economic growth of humans on sustainable basis (Lim and Teong, 2010). However, there is has been very scant research pertaining to the management strategies of agricultural waste and the net result is their disposal has become a daunting challenge in developing countries of Asia. One of the most pronounced underlying reasons is that agriculture wastes are not regulated and classified as the municipal solid waste (MSW). On the other hand, the MSW is effectively managed and disposed by public entities especially municipalities (Hamzah et al., 2019). However, in contradiction to MSW, crops left-overs are predominantly handled by the farmers who are inclined towards convenient ways of disposal such as open field burning in order to clear the field for sowing of the next crop. Figure 3 highlights different potential uses of crop residues prevalent in developing countries of South Asia especially Pakistan and India.

Biomass processing technology for biofuel preparation

Lignocellulosic biomasses are carbon neutral and abundantly available renewable bioresource material available on earth. However, the main problem that hinders

its frequent use is the tight bonding within its constituents that include cellulose, hemicellulose, and lignin. The selection of pre-treatment process depends exclusively on the application (Wattana, 2014). Various pre-treatment processes are primarily developed and utilized in effective separation of these interlinked components to take maximum benefit from the constitutes of the lignocellulosic biomasses especially for the production of biofuel. The major pre-treatment methods include physical, chemical, thermophysical, thermochemical, and biological approaches (Giuliano et al., 2018). Different chemical pre-treatments of crop residues in order to improve cellulose availability and separation from the wastes through delignification process has been highlighted in Figure 4, while the use of different microorganism for biomass pre-treatment has been highlighted in Figure 5.

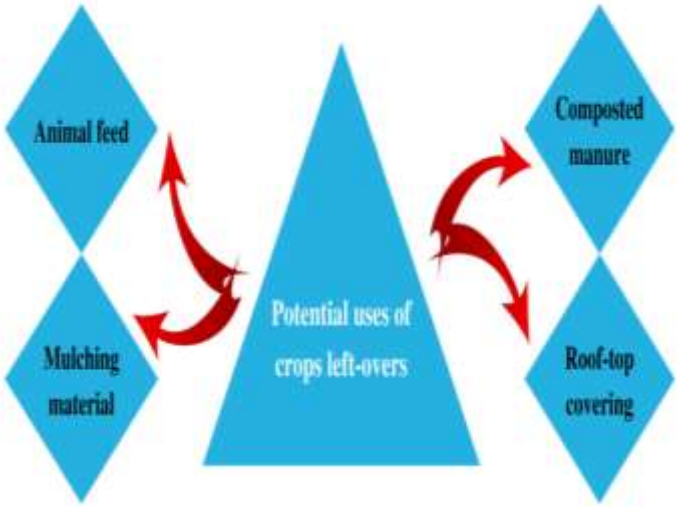

Figure 3. Different potential uses of crop residues prevalent in developing countries of South Asia especially Pakistan and India.

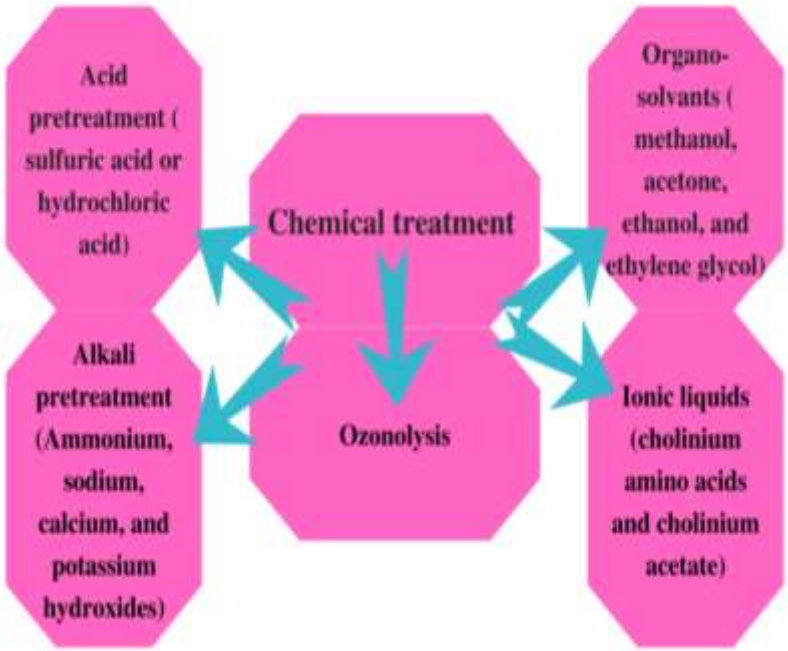

Figure 4. Different chemical pre-treatments of crop residues in order to improve cellulose availability and separation from the wastes through delignification process.

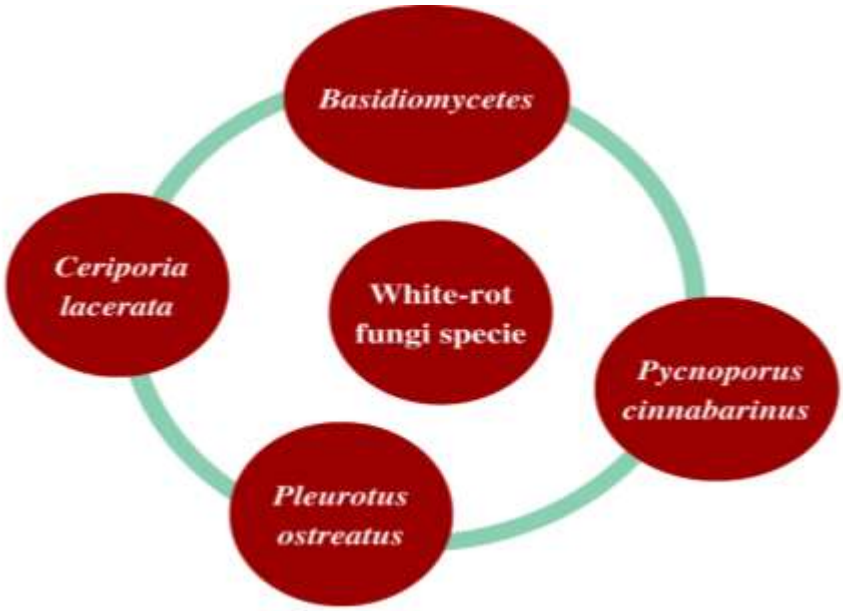

Figure 5. Microorganisms based delignification for improving the availability of cellulose from crops wastes.

Challenges and solutions

Interestingly, very slow pace of evolution in crop residues conversion into biofuel might be attributed to the technical challenges and unavailability of technical experts (Chung, 2013). Owing to lack of locally developed biomass processing technologies, imported technologies imply significantly higher cost of production and maintenance expenditures (Ahorsu et al., 2018). Likewise, an absence of scientific and technical expertise pertaining to technology designs and construction have so far hindered the development of biofuel promotion. The lack of local expertise is probably owing to absence of technical courses of bioenergy in research and degree awarding institutions of Pakistan, while situation in Turkiye is much better. It has become imperative to develop collaborative between both countries at government level work with an aim to provide skilled workforce having requisite training and knowledge inputs.

Another crucial technical barrier posed to bioenergy deployment in Pakistan is related to infrastructure deficiency. Ideally, the distance between the interconnection point of the distribution system and renewable energy plant must be within 10 km in order to avoid power losses (Amran et al., 2018), but the situation in Pakistan is quite discouraging which has prevented the promotion of crop residues conversion into biofuel. However, the financial constraints have remained one of the most dominating challenges confronted to fostering the biomass energy. The economic constraint includes high capital expenditure, lacking experience among investors, absence of financing scheme, and fewer subsidies. This challenge might be addressed by due support from commercial banks and technology manufacturers.

In terms of social issues, the prime challenges for biofuel production from crop residues are pertaining to the market and community acceptance along with socio-political acceptance (Chin et al., 2014). This challenge must be addressed with robust media campaigns in order to increase local awareness regarding crop residues utilization for biofuel production. Although biofuel is perceived as a clean, pro-environment and renewable energy source, there have been numerous environmental challenges such as greater land area conversion for biofuel crops adversely affects the domestic food security. This challenge might be addressed by utilization of crops residues for converting those into biofuel through development of local technologies and experienced workforce (Anuar and Abdullah, 2016). Figure 6 depicts few of the most salient challenges posed to biomass conversion into biofuels in Pakistan and Turkiye perspectives.

CONCLUSIONS

Owing to a variety of advantages offered by bioenergy such as mitigation of climate change, energy security improvement and development of rural means of livelihood, it becomes imperative and undeniable for countries like Pakistan and Turkiye. The abundance of biomass, particularly crops left-overs has the potential for conversion into biofuel; however appropriate pre-treatment of crop

residues is required. It might be inferred that open field burning of crop residues is contributing heavily to smog and other environmental hazards, while their conversion to biofuel can bring numerous benefits. Compared to developed world, carbon tax and pricings could not get significant attraction in many Asian countries, while lack of appropriate technology and technical experts have hindered the advocacy of crop residues conversion into biofuel. Additionally, high capital expenditure, lack of knowledge and awareness of the public, and opposition and reluctance of the market developers which must be addressed in order to prevent open field burning of crop left-overs. In order to these challenges, an amalgamation of pro-farmers, eco-friendly and investors-inclining strategies are the need of time otherwise open field burning of crops left-overs will continue to play havoc with the environmental quality.

Figure 6. Few of the most salient challenges posed to biomass conversion into biofuels in Pakistan and Turkiye perspectives.

CONFLICT OF INTEREST

The authors declared no conflict of interest. The funders had no part in the design, collection analyses and interpretation and writing of short communication.

AUTHOR'S CONTRIBUTION

All authors contributed and supported towards writing of this manuscript.

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