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Agricultural Waste Utilization for the Production of Alcohol- A Review

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Abstract

Waste is any substance that is discarded as worthless, defective, and of no use. Agriculture waste, Domestic waste, Industrial waste, and commercial waste are the types of waste. Agricultural waste is unwanted or unsalable material, cheaply available, and has the potential to produce energy that occurs during harvesting and processing. The agriculture and industry-based waste produced during the growing and processing of raw materials like cereals, fruits, vegetables, meat, fish, and poultry are the residues. Including rice bran, wheat bran, wheat straw, sugar cane bagasse, and sugar cane molasses. Produced waste from agriculture has a good potential to convert into energy and is also rich in some residue like cellulose, lignocellulose, and hemicellulose. As for alcohol production sugar or starches are required but with the use of recent technologies developed by scientists can produce lignocellulosic waste. Various pre-treatment methods were developed by scientists for alcohol production. Presence of residue and good potential the waste can be utilized for various products like alcohol production, methane production, organic chemicals, biofuels, biogas, enzymes, vitamins, antioxidants, fermented products by solid-state fermentation, and animal feed. The following paper concerns the studies made on agriculture waste utilization and different types of pre-treatment methods used for accelerating yield of the alcohol production.

INTRODUCTION

Waste is an unwanted and unsalable material and is regarded when that substance is no more of any use it can be produced anywhere in factories, during processing, or by agriculture and also produce in a house. Waste that we see in our surroundings is also known as garbage. Sources of waste can be classified into industrial, commercial, domestic, and agricultural. The produced solid, wet waste, and also gaseous streams have the greatest potential for the production of biofuels and energy. Each year 20% of waste has been recycled and in huge amount is still sent to landfills or dumping areas (Shehrawat, P. S., & Sindhu, N. 2015). Agriculture waste can be in any form liquid or solid produced as a result of cultivation processes such as fertilizers, pesticides, crop residues, and animal waste. It is part of an ecological cycle in which everything is cycled and recycled in which interdependent relationship is a maintained in the ecosystem. Major producers of rice straw and wheat straw are in Asia and corn straw and bagasse in America. Through waste management, all the waste is placed in the right place and at the right time for the best utility to convert it into useful products and control pollution. Generally, 140 billion metric tons of biomass is generated every year from agriculture, Ministry of New and Renewable Energy (MNRE), Govt of India has estimated that about 500 MT of crop residue is generated every year. These wastes are destroyed by burning or burying, where it will decay and cause environmental pollution (Russ & Meyer-Pittroff, 2004). Waste generated by crops contains lignocellulosic materials and has a great potential to convert into energy or can be converted or utilized for a beneficial purpose. Biomass is waste produced from animal waste or crop residues. In past, Agro-waste were either burnt, buried underground, or naturally converted into organic fertilizers under favorable condition. But nowadays, generating energy because it carries great potential to convert into energy, due to its availability throughout the world in abundant quantity. Like other renewable sources, agricultural waste can be converted into alcohol as it is

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rich in lignocellulosic materials. It is renewable energy produced from a plant material known as biomass or lignocellulosic waste. The most common alcohol produced is ethanol i.e., CH3CH2OH (Hegde, S et al., 2018).

The demand for alcohol is enhancing day by day because of the exponential growth of industrial development and population. Production of alcohol from lignocellulosic materials like corn stalks, corn cobs, corn husks, fruit peels, rice straw, wheat straw, sugarcane bagasse, and sugarcane bark faces challenges (Bhatia, L et al., 2012). Sugar cane and corn were primarily used as food and feed and were unable to meet the global demand. Alcohol production from agricultural waste is cellulose-rich, cost-effective, renewable, and abundant (Sarkar et al., 2012). Cellulosic agricultural waste is generated in many agricultural countries like India which are used for the production of bioenergy in the form of bioethanol by hydrolysis and fermentation technologies with the help of microbial and catalytic enzymes (Saranraj, P., & Stella, D. 2012). Second-generation or advanced biofuels are an alternative to petroleum-based fuels which are derived from lignocellulosic biomass. As per researchers, it is a sustainable option to tackle the problems associated with rising crude oil prices, global warming, and diminishing petroleum reserves. The waste utilizing technology is feasible to produce energy in the future (Saini et al., 2015). Alcohol production from agricultural waste like sugar cane waste, and corn waste are a good substrate and it is potentially, effective, and recommended as cost-effective and doesn't produce any harm to the environment (Braide et al., 2016).

METHOD OF PRODUCTION

Fermentation is the common method for developing alcohol by using bacterial yeasts which convert the sugar into alcohol and CO2 by metabolism under environmental conditions (Sun & Cheng, 2002;Bharathiraja, B et al., 2014). Most alcohols are made from starches or sugars but recent scientists are started to develop technologies that allow for to produce from cellulose and hemicellulose. It is an anaerobic fermentation corresponding to EMP (Embden-Meyerhoff pathway). It is the same fermentation method used to produce alcoholic beverages.

As per (Martín et al., 2002) till now the problem faced by the alcohol industry is that the Saccharomyces cerevisiae is unable to convert complex sugars into alcohol as lignocelluosic waste has a tough crystalline structure surrounded by lignin which makes it difficult for the enzymes (Figure 1).

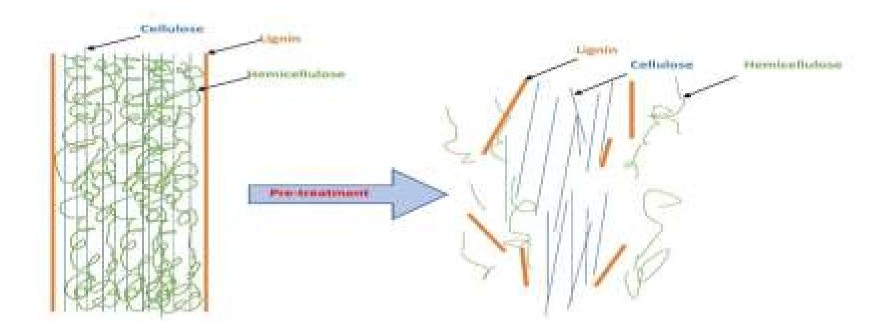

Figure 1- Crystalline structure of lignocellulosic waste

This is overcome by physical, chemical, and biological pre-treatment methods such as acid hydrolysis or by using the microwave. These lignocellulosic waste materials are first hydrolyzed to fermentable sugars by pre-treatment method where it broke down and separates the cellulose, hemicellulose, and lignin, and further cellulose is converted into monomeric sugar by enzymatic saccharification hydrolysis process and subsequently fermented with required yeast species i.e., Saccharomyces cerevisiae to produce alcohol (Gould & Freer, 1984; Ruffell, J et al., 2010). Figure 2 represents different stages of structure breaking of lignocellulosic waste into alcohol

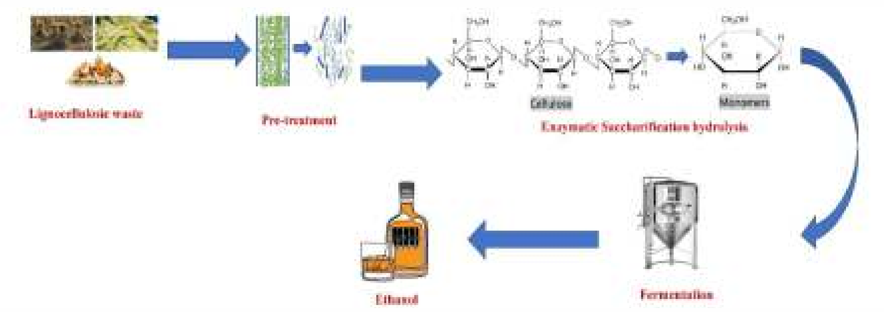

Figure 2– Stages of structure breaking of lignocellulosic waste into alcohol

Optimization of utilizing the pineapple waste for the production of bioethanol by different types of fermentation and saccharification methods like direct fermentation with continuously saccharification process, simultaneous saccharification and fermentation using Saccharomyces bayanus CECT 1926, Saccharomyces cerevisiae CECT 11020, and Saccharomyces cerevisiae CECT 1319. The result shows that using simultaneous saccharification and fermentation method there is an increase in the production of ethanol as compared to the direct fermentation method (Gil, L. S., & Maupoey, P. F. 2018). Clostridial fermentation will increase the Biobutanol production from acid hydrolyzed rice straw which tends to increase the higher alcohol yield and significant sugar yield which makes rice straw waste an alternate source for biobutanol production (Ranjan et al., 2013).

PRE-TREATMENT METHODS TO PRODUCE ALCOHOL

Physical method

Microwave pre-treated banana peels at 160 W for 5 min improves the sugar content by increasing the reducing sugar and glucose by 220 and 150 mg/g to produce biofuels (Mishra, 2015; Bhatia, L., & Paliwal, S. 2010). Production of wine from the banana waste and pineapple waste is pre-treated by infusing pumpkin leaves in the substrates for enhancing the alcohol content from 0.035 to 0.57% and 0.21 to 0.57% (Isitua & Ibeh, 2010). For pre-treatment of the cotton lint fibers, the combined methods used by (Plácido et al., 2013) are ultra-sonification, ligninolytic enzymes which results in a higher yield of ethanol of about 10%, and cellulose conversion as compared to other pre-treatments.

Production of alcohol from agriculture waste by exploiting the thermal energy from cogeneration plants to valorize agriculture waste. Among all these substrates apple, kiwifruit, peaches wastes; and corn threshing residue (CTR) only apple waste and CTR reached the highest ethanol yield. Before fermentation, fruit waste is gelatinized and liquified by adding lysozyme and simultaneous fermentation using spirizyme. Distilling at lower temperatures exploits the warm water from the cogeneration plant which allows for the recovery of 93.5% and 89.59% ethanol (Cutzu & Bardi, 2017). Impregnating agent like hydrogen peroxide to pre-treat the substrate by steam explosion causes an increase in the fermentable sugar concentration i.e., 12% for glucose and 34% for xylose. Hydrogen peroxide does not leave any traces in the substrate after pre-treatment (Verardi et al., 2018). Using Producing alcohol from potato waste in the biofilm reactor will modify the cultural conditions for Saccharomyces cerevisiae. To achieve proper condition biofilm is made of plastic composite supports (PCS) which is composed of polypropylene, soybean hull, soybean flour, yeast extract, and salts for the formation of ethanol with Saccharomyces cerevisiae. Then the optimum condition is found to be pH 4.2, temperature 340C which results in 37.05 g/litre ethanol. This novel technique using a biofilm reactor with PCS improves the ethanol production from potato waste (Izmirlioglu & Demirci, 2016).

Biological method:

India is greatest among the banana producing countries where produced waste from bananas called as banana pseudo stem were commonly used for alcohol production as a lignocellulosic substrate which is pre-treated using two fungal strains Aspergillus ellipticus and Aspergillus fumigatus which produces the cellulolytic enzymes and the strain Saccharomyces cerevisiae NCIM 3570 were used in fermentation to produce ethanol from produced hydrolysates by pre-treating with fungal strains and alkali (Ingale et al., 2014). According to the researcher (Oji et al., 2018) more alcohol yield is produced by using Zymomonas mobilis than produced using Saccharomyces cerevisiae. They Investigated the capabilities of two local yeast strains Zymomonas mobilis and Saccharomyces cerevisiae which is used in the production of bioethanol. As per their study Zymomonas mobilis has a higher sugar consuming ability and also low biomass production and rapid conversion of glucose into ethanol which facilitates by pyruvate decarboxylase and alcohol dehydrogenase enzymes.

For efficient ethanol production (Ahmad et al., 2021) investigated that Saccharomyces cerevisiae is a better choice and the best treatment is carried out by using 25% of inoculum because of the high concentration and at 30°C temperature is best to work for Saccharomyces cerevisiae. Saccharomyces cerevisiae (MTCC 173) with the combination of Pachysolen tannophilus (MTCC 1077) was used for the maximum alcohol yield under optimum conditions. This is an effective and very useful method to produce alcohol as a fuel. Coffee husk is feasible and had the potential to produce ethanol. In this, the yield of fermentation decreases with an increase in the concentration of yeast. The best results are shown by using 3 g of yeast per liter of the substrate and the temperature should maintain is about 30°c (13.6 ± 0.5 g ethanol/litre) (Gouvea et al., 2009).

Chemical method

Arumugam & Manikandan investigated that by treating banana and mango fruit waste with dilute acid and enzymatic hydrolysis gave maximum reducing sugar yield in mixed waste (64.27%), banana waste (36.86%), and low in only mango waste (31.29%). Ethanol yield on fermentation of hydrolysates was maximum as per their study in mixed waste (36.86%) and banana waste (13.84%) (Arumugam & Manikandan, 2011).

Date palm wastes are rich in sugar (glucose, fructose, and sucrose) and also rich in some nutritional compounds. Pakistan is the largest producer of date palm wastes but they have low alcohol production. Sathesh-Prabu & Murugesan (2011) uses NaOH for alcohol production from Sorghum stover in which it is treated for 8 hrs with NaOH to remove the lignin for the production of fuel-grade ethanol (Sathesh-Prabu & Murugesan, 2011).

Optimized acid hydrolysis pre-treatment method (Saleem et al., 2020) with 5% of dilute sulfuric acid hydrolysis on pomegranate peels waste gives the maximum reducing sugars (Glucose) release of 0.56 ± 0.04 mg mL^{-1} at 100 °C of hydrolysis temperature for 30 min with ethanol production of 0.42 ± 0.08 mg ml^{-1} by using Metschnikowia species Y31 as fermentative yeast after an incubation period of 5 days. Acid hydrolysis is an economical way to convert cellulosic wastes into bioethanol. The pre-treated cotton gin with organic acids like lactic acid, oxalic acid, citric acid, and maleic acid removes lignin and hemicellulose as fermentable sugar. The pre-treated biomass with maleic acid gives maximum saccharification yield slightly higher than the sulfuric acid and fermentation with sequential use of yeast strains (Saccharomyces cerevisiae and Pichia stipites) is efficient for bioethanol production (Sahu & Pramanik, 2018). Production of bioethanol from concentrated rice straw hydrolysate gives a high ethanol yield by using a combination of Saccharomyces cerevisiae and Pichia stipites which convert the hexose and pentose sugar into alcohol than by using monoculture of Saccharomyces cerevisiae (Yadav, K. S et al., 2011).

Fermenting rice straw substrate containing a mixture of glucose and xylose in which heat inactivate the Saccharomyces cerevisiae before the addition of Pichia stipites and this start to full conversion of glucose and xylose into ethanol present in the hydrolysates which are pre-treated with lime and neutralized with CO2 after the saccharification and fermentation (Li et al., 2011).

Lignocellulosic and starchy materials containing kitchen garden waste also had the potential for producing ethanol and biogas. Pre-treated waste with sulfuric acid under moderate conditions will improve the ethanol yield. From one ton of kitchen waste, 163.3 liters of ethanol will produce with some biomethane by fermentation (Karimi & Karimi, 2018).

Utilizing a by-product of coffee pulp and mucilage can be used for the preparation of fermented alcoholic beverages as well also for ethanol for energy. It is a novel and eco-friendly raw material for the beverage industry which reduce the environmental threat. (KC, Y et al., 2021). Enhancement in the production of ethanol from grape waste on addition Benzylpenicillin with Saccharomyces cerevisiae during fermentation. The best ethanol production rate is produced at pH 5 with 16% sugar concentration at 350C (Raikar & S, 2012). Using cellulase enzymes that are immobilized by MnO2 nanoparticles are more thermostable than free enzymes. It is reusable and stable at an optimum temperature of 700C for 2 hrs and also increases the bioethanol production yield up to 21.9 g/lit (Cherian et al., 2015). Incorporation of 15% dried cauliflower waste into the dilute molasses with 0.2% of yeast extract will enhance the ethanol production during fermentation by 36% using Saccharomyces cerevisiae as compared to the molasses alone (Dhillon et al., 2007). Ethanol Production from the wheat straw hydrolysate which is pre-treated with alkali peroxide and saccharified enzymatically by recombinant ethanol producing bacterial strain i.e., Escherichia coli FBR5. This ethanologenic bacteria has the ability to ferment sugars like pentoses and hexoses under a semi-anaerobic condition and there is no loss of ethanol productivity (Saha & Cotta, 2011). Table 1 represents Substrate and Pre-treatment used to produce alcohol.

Table 1- Substrate and Pre-treatment used to produce alcohol

Sr no.	Substrates used	Pre-treatment method used	Alcohol produced	References
1.	Banana Pseudo stem	Used two fungal strains Aspergillus ellipticus and Aspergillus fumigatus	17.1 g/L	(Ingale et al., 2014)
2.	Banana and pineapple waste	Pre-treated by infusing pumpkin leaves in substrates	0.035 to 0.57% and 0.21 to 0.57%	(Isitua & Ibeh, 2010)
3.	Sorghum stover	Treated with alkali (2 % NaOH for 8 hrs)	68 and 56 g/L	(Sathesh-Prabu & Murugesan, 2011)
4.	Pomegranate peels	Acid hydrolysis pre-treatment method with 5% of dilute sulfuric acid	0.42 ± 0.08 g g^{-1} by using Metschnikowia species Y31 as fermentative yeast	(Sathesh-Prabu & Murugesan, 2011)
5.	Cotton gin	Combination of ultra-sonification, ligninolytic enzymes And also, with Organic acids like lactic acid and citric acid.	10%	(Sahu & Pramanik, 2018)

Sr no.	Substrates used	Pre-treatment method used	Alcohol produced	References
6.	Kitchen garden waste	Pre-treated waste with sulfuric acid	163.3 liter of ethanol/per ton	(Karimi & Karimi, 2018)
7.	Molasses	Pre-treated with 15% dried cauliflower waste	36%	(Dhillon et al., 2007)

CONCLUSION:

As seen from the stated review focused on the utilization of agricultural waste for alcohol production, newer developed technologies in process as well as product development required to increase the market value of the product. As seen in this study the lignocellulosic waste is used mostly for ethanol production. The alcohol production from lignocellulosic waste seems difficult so scientists developed some pre-treatment methods mentioned in the review. Each pre-treatment has its own merits and demerits, but some researchers have used it in the combination of different pre-treatment methods like dilute acid and enzymatic hydrolysis which improves the Agro-waste digestibility. The result was seeming to be good than using a single pre-treatment method. The simultaneous saccharification and fermentation process shows an increase in alcohol production as compared to direct or separate saccharification fermentation.

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