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Lignocellulose biodegradation: An advance technology for sustainable environment

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ABSTRACT

The ever increasing energy load has attracted significant attention on the development and growth of renewable resources. Many workers have reported conversion of waste materials to useful compost. Lignocellulose consists of the three constituents indicated as cellulose, hemicelluloses and lignin. Lignocellulosic biomass can be reused in the production of chemicals and fuels. Cellulose and hemicellulose can be degraded into sugars, which are preliminary source for fermentation, biocatalytic and chemocatalytic processes to value-added products. A large number of microorganisms including bacteria and fungi are capable of producing cellulases and hemicellulases but only a limited number of these microorganisms are capable of producing lignin degrading enzymes. There are numerous methods available for the isolation of lignocellulose degrading microbial consortium. Lignocellulose compounds are most abundant agricultural residues present in the world. In this short review, updated account is presented on various aspects of lignocellulose compounds which can be utilized by fungi, actinomycetes and bacteria. The lignocellulytic utilizing microbial consortium can be used for the conversion of biomass feedstock to useful bio-based products. The use of farming crop wastes involves a separation of the polymeric compounds - cellulose and hemicelluloses. This approach comes under sustainable "green" biotechnology.

KEY WORDS: LIGNOCELLULOSE, RICE STRAW, FERMENTATION, CELLULASES AND HEMICELLULASES

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INTRODUCTION

Lignocellulosic biomass consists mainly of cellulose (35–50%), hemicellulose (25–30%) and lignin (25–30%). The plant biomass is a carbon source for bio-refinery industry, considered as sustainable and environmental friendly substitute to the current petroleum platform (Kamm *et al.,* 2004). The composition of lignocelluloses not only depends upon the species but also on the different parts of the plant, their age and growth conditions (Jorgensen, 2003). The large quantity of lignocellulosic materials create them potentially inexpensive and easily available natural resources for the production of high value compounds and biofuels. The degradation of cellulose, hemicelluloses and lignin are extremely slow. The various microorganisms are capable of growing on lignocellulosic materials and produce a wide range of enzymes that could be of scientific or industrial importance, (Varma et al. 2017 Tolalpa et al. 2018) .

Cellulose

It is homopolysaccharide constituent of the fiber wall, consists of D-glucose linked together by ß-1, 4-glycosidic bonds. Cellulose form intra- or intermolecular hydrogen bonds resulting in the formation of cellulose microfibrils. Due to hydrogen bond it is not soluble in most solvents and resistance against microbial degradation (Jorgensen, 2003). It is hydrolyzed by cellulase, 1, 4-ß-cellobiosidase and ß-glucosidase (Schmidt, 2006). Cellulases hydrolyses cellulose consists of cellobiohydrolases, endoglucanases and ß-glucosidase. The cellobiohydrolase and endoglucanase function together for hydrolyzing 1, 4-ß-D-glycosidic linkages in cellulose, cello-oligomers and other ß-D-glucans and to form cellobiose from the non-reducing ends, which are degraded by ß-glucosidase to glucose units.

Hemicellulose

It consists of monomeric residues, like D-glucuronic acid, D-mannose, D-arabinose, D-glucose and D-xylose. They have lesser degree of polymerization in comparison to cellulose, with side chains that can be acetylated. They are classified according to the monomeric sugar in the backbone of the polymer, e.g. mannan (ß-1, 4-linked mannose) or xylan (ß-1, 4-linked xylose) hemicelluloses. The main chains of glucose and mannose residues are generally associated with ß-(1, 4) bond. The side chain is attached to main chain via a-(1, 6) bonds in galactoglucomannan. Xylan can be degraded by endo-1, 4-ß-xylanase and 1, 4-ß-xylosidase to xylose (Jorgensen, 2003). Due to more heterogenous nature of hemicellulose, a combination of enzymes is necessary for its degradation, such as endoxylanases, ß-xylosidases, endomannanases, ß-mannosidases, a-L-arabinofuranosidases and a-galactosidases.

Lignin

It is very much hydrophobic and forms an amorphous complex with hemicelluloses enclosing cellulose and make unavailable to microbial utilization of available carbohydrates within the wood cell wall. It is jointing component to attach cells and harden the cell wall of xylem, which is accountable for the smooth movement of water from roots to leaves. Its aromatic rings are responsible to create it trickier to degrade (Schmidt, 2006). Ester linkages take place among the free carboxy group in hemicellulose and the benzyl groups in lignin, the lignicarbohydrate complex (LCC), embeds the cellulose, which is resposibe for giving protection against microbial and chemical degradation (Jeffries, 1994). The lignin is not to be utilized by most of the microorganisms due to its phenylpropane units in the structure (Schmidt, 2006). Now days there are huge attention in isolating organisms able to degrade lignin, in the cleaving of the chemical bonds that are present between lignin and hemicelluloses. The continuous utilization of these compounds is extremely slow. The microorganisms isolated from from soil and rumens are capable to degrade in to sugars, which can be utilized as energy and carbon source by a variety of microorganisms for the production of different products.

Role of microbial consortium in utilization of lignocellulose biomass

Kumar et al. (2001) isolated *Branhamella catarrhal*, *Brochothrix sp., Micrococcus luteus* and *Bacillus firmus* from cane sugar factory effluent contaminated soil. All microbes can use cinnamic acid as sole carbon source with significant inhibition after addition of glucose. The *B. catarrhalis* and *Brochothrix sp.* were able of metabolizing ferulic acid but not in the presence of glucose. The lignocellulolytic enzyme profiles of five strains of *Agaricus* and four strains of *Pleurotus* were determined by Rana and Rana in 2004. The crude enzyme from the colonized substrate was used to analysis the enzymatic activities. All strains of *Agaricus* showed higher level of cellulases activities in comparison of *Pleurotus* strains. The *Pleurotus sp.* exhibits high ligninases activity. The difference in lignocellulolytic enzyme summary was present both at interspecies and intraspecies point. The lignocellulose utilization in solid state fermentation in sugarcane bagasse and rice straw by *Aspergillus* tamari was isolated by Umasaravanan *et al.* (2010). The microorganisms isolated from marine environment which can utilize the lignocellulosic biomass were showed by Sethi et al. (2013).

The organisms showing maximum degradation were recognized as *Bacillus pumilus* and *Mesorhizzobium sp.,* as well two fungal sp. recognized as *Aspergillus niger* and *Trichodermaviride*. The organisms showed different levels of utilization at different time point in a diversity of substrates. The thermophilic microbial consortium was isolated by Malik et al. (2015) from sugarcane industry mature compost. The consortium was able to degrade rice straw. The lignin can be productively degraded by white-rot fungi, producing a number of oxidoreductases, enzymes able to attack phenolic structures. Varma et al. (2017) studied about those microbes which were actively involved in lignocelluloses degradation during drum composting of mixed organic waste i.e. saw dust, cattle manure, dry leaves and vegetable waste in a 550 L rotary drum composter.

An anaerobic thermophilic bacterial strains for ethanol production from D-xylose was reported by Sommer et al. (2004). Lu et al. (2004) reported *Clostridium phytofermentans*, responsible for the maximum number of enzymes for the utilization of lignocellulosic biomass between sequenced *Clostridial* genomes. The *Clostridium thermocellum* generate a collection of cellulolytic and hemicellulolytic enzymes in a multienzyme complex system are known as cellulosome. The cellulosome was firstly reported in anaerobic bacteria such *as Clostridium thermocellum* in 1983 and then in anaerobic fungi in 1992 (Wilson et al., 1992). Abd-Elsalam et al. (2009) isolated bacterial strains KafAH19 degrade synthetic lignin and use as a carbon source. The strain was biochemically characterized as gram-positive rod. By using 16S rDNA sequencing the culture was recognized as *Bacillus sp.*. The lignocellulose utilizing microbes by using a selective media using lignin, xylan and cellulose as selective substrates was isolated by Wahyudi et al. (2010). The isolates were recognized as *Enterococcus casseliflavus/gallinarum* sp. Wongwilaiwalin et al. (2010) worked on thermophilic lignocellulose utilizing microbial consortium and multi-species lignocellulolytic enzymatic involvement. Gontikaki et al. (2015) observed that the proficient degradation of terr OC in the marine environment could be fuelled by labile marine based objects by treating coastal sediments with 13C-lignocellulose, as a proxy for terrOC, in the presence and absence of unlabelled diatom detritus that acted as the important inducer. The amount of priming was viewed by the differentiation in lignocellulose mineralisation between diatom-amended treatments and controls in aerobic sediment slurries.

Ransom-Jones et al. (2017) have reported that landfill sites symbolize a repository of uncultivated lignocellulose-degrading Microbes such as *Firmicutes*, *Bacteroidetes*, *Spirochaetes*, and *Fibrobacteres,* which are rich source for biomass degradation. According to Cortes-Tolalpa et al. (2017), Lignocellulosic biomass (LCB) is a striking source of carbon for the production of sugars and other useful chemicals. Due to its innate density and heterogeneity, proficient biodegradation requires the actions of diverse and various types of hydrolytic enzymes. So, they observed that the wheat straw degradation potential of synthetic microbial consortia composed of bacteria and fungi.

Alessi et al. (2018) explored the enzymatic degradation of lignin which is complicated due to its structural complexity, lack of hydrolysable linkages and insoluble nature and also discuss the developments in the degradation of lignin by microorganisms and the catabolic pathways for degradation of lignin. Mohn et al. (2018) illustrate that by applying stable isotope probing (SIP) coupled with amplicon and shotgun metagenomics, it is possible to recognize and describe the functional attributes of cellulose, hemicelluloses and lignin - degrading bacteria and fungi. The halotolerant lignocellulose degrading microbial consortia was isolated by Cortes-Tolalpa et al. (2018) by feeding a salt marsh soil microbiome on an intractable carbon and energy source, i.e., wheat straw.

Conclusion and future prospects

Lignocellulose compounds are most abundant agricultural residues present in the world. There are various reports that lignocellulose compounds can be utilized by fungi, action mycetes and bacteria. The lingo cellulytic utilizing microbial consortium can be used for the conversion of biomass feedstock to useful bio-based products. The use of farming crop wastes involves a separation of the polymeric compounds - cellulose and hemicelluloses. This approach comes under sustainable "green" biotechnology.

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