

## Exploitation of Lignin-Derivatives for Polyhydroxyalkanoate Production Using Eco-Biotechnological Approach

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The alarming depletion of fossil fuel reserves, limited resources and environmental pollution has forced us to look for biological alternatives of energy [1-4]. This has led to various start-up plants, pilot scale projects and research work primarily based on waste biomass. Being of biological origin, it is considered to be a renewable and sustainable resource for the production of Bioenergy and biofuels. The US government has also taken initiatives comprising of aggressive goals of enhanced biofuel usage. The California Energy Commission has recommended the use of biofuels within on-road transportation fuels, up to 30% by 2030 [5]. Although, most of the efforts were implied upon bio-ethanol production, however, its low energy density is a significant disadvantage. In contrast, many other biofuels demonstrate advantages like high energy density, long C-chains and lower oxygen numbers. Therefore, development of hydrocarbon fuels as an aid for gasoline, jet, as well as biodiesel, has attracted great consideration. In this context, exploitation of polyhydroxyalkanoates (PHAs) as a source for biodiesel and/or hydrocarbon fuels has gained momentum in the past few decades. Bacteria are natural producers of fatty acids and PHAs [4,6-8], which have enormous production potential for hydrocarbon fuels [9]. However, there are quite a few problems which should be resolved in order to produce the hydrocarbons at commercial scale. Almost all the biological alternatives to biofuels have been limited primarily by the substrate costs and extraction. In this respect, the two globally abundant resources, i.e. cellulose and lignin holds the potential to supply the need. Among the inexpensive substrates cellulose has remained the topmost choice from the industrial view point. On the other hand, Lignin, that has great value as a substrate got very limited opportunities for microbial transformation into value-added fuels and fuel intermediates. Only a handful of microbes are known to metabolize lignin-derived monomers by means of the  $\beta$ -ketoacid pathway [10-12]. Currently, lignin is scarcely used during lignocellulosic fermentations and is yet to be exploited for PHA production. To achieve the target of utilizing lignin as a substrate for PHA and other biofuel production, the composition of lignin degradation intermediates and the toxicity of these compounds on PHA producing bacteria should be investigated.

Such strategies can be combined in a bio-refinery perspective to obtain (i) readily metabolizable carbon sources such as pentoses, and hexoses of lignocellulosic biomass for production of ethanol, butanol, butanediol,  $H_2$ ,  $CH_4$  etc., (ii) PHA and other hydrocarbons from the pre-treated lignin rich part, and (iii) -bio-oil and biochar from the residual leftovers through pyrolysis.

### Lignin: Potential biomass

Lightning is one of the major parts of plant biomass. It is considered to be the second most abundant natural polymer on the earth. The lignin has always been found to be physically associated with cellulose and hemicellulose. Amount of lignin found in a particular biomass varies, depending upon the source. The lignin content in softwoods are usually higher (25 - 32%) compared to hardwoods (18 - 25%), and almost negligible in grasses. On the other hand, mosses and green algae is almost devoid of lignin. It has been an evolutionary advantage for higher plants in order to transport water in a structured manner. Besides that, lignin protects the cellulosic/polysaccharides component, as it is hard to decompose. The degradation of lignin is very slow in nature and thus, it usually constitutes a big fraction of humic acid (soil). It possesses quite complex composition owing to the heterogenous building blocks such as p-hydroxyphenyl, guaiacyl and syringyl. The building blocks or monomers originate from the shikimate pathway, which involves the conversion of phenylalanine to cinnamic acid

by enzyme phenylalanine lyase. Later, through a multi-step process gets converted to the basic building blocks. The coupling of monomers into a polymer (lignin) takes place by enzymatic oxidation (Ralph, *et al.* 2004).

The rapidly increasing trend of using lignocellulosic biomass leads to produce lignin to the tune of 130 million tons (Abdelaziz, *et al.* 2016). The lignin generation is expected to rise massively owing to the establishment of Biorefinery concepts and other 2<sup>nd</sup> generation fuels. Such lignin, also termed as 'Technical lignin' is structurally different from 'Native lignin', which is dependent on the separation method used. However, the usage of technical lignin has been increasing slowly, besides its direct on-site use of steam and electricity generation. Thus, there is a large scope of valorizing this complex polymer into value added products by biological routes. Such approach would basically comprise of depolymerization and subsequent bioconversion of the lignin-derivatives for various purposes. The coming decade will hopefully allow us to witness the bio-revolution in the area of energy and sustainable economy [13-23].

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