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INTRODUCTION
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The imminent shortage of fossil fuels and plant based proteins and their escalating prices have renewed interest in the microbial production of liquid fuels, proteins and organic chemicals from biomass (Fan et al., 1982; Allen et al., 1983). This has led to the utilization of surplus agricultural produce (grain and cane juice etc.) for its bioconversion into ethanol and other organic chemicals (Takagi, 1987). Since these starting raw materials are a part of the food chain, lignocellulosic biomass (as forest and agricultural residues) which is renewable, most abundant and lowcost energy resource on the earth (Mishra et al., 1984), has long been the subject of interest for its conversion to fermentable sugars and later to commercially useful products (Reese, 1963).

The net annual production of plant biomass on world scale has been estimated to be $1.841 \times 10^9$ tons and more than half of this is in the form of lignocellulosases (Tangnu, 1982). Literature survey revealed that while extensive work has been done on the utilization of agricultural wastes (Shamala and Sreekantiah, 1987; Khan et al., 1986), comparatively little work has been done on the lignocellulosases of forest origin for their saccharification (hydrolysis) and fermentation of the hydrolysates for production of economically useful products (Yu et al., 1987). The entire Himalayan region is rich in forests and about 38.7 per cent geographical area of Himachal Pradesh is covered by forests (Khosla, 1984). Therefore it would be worthwhile exploring the easily available local raw materials (forest residues) and to evolve technologies for their microbial conversion to ethanol, single cell proteins and industrially important chemicals.

The lignocellulosic forest waste primarily consists of cellulose, hemicellulose and lignin in the ratio of 4:3:3 (Datta, 1981) and is degraded in the soil by various types of microorganisms. This biodegradation of lignocellulososes is of ecological significance since it decomposes pollution causing
organic wastes and keeps the carbon cycle operative in nature (Alexander, 1977; Knapp, 1985, Lachke, 1989). The types of microorganisms engaged in the biodegradation of plant biomass vary with forest vegetation from one region to the other. Several reports are available on the cellulolytic microorganisms and the degradation and utilization of cellulosic fraction of the biomass, but comparatively less attention has been given to the hemicellulose and its utilization (Ryu and Mandels, 1980; Khan et al., 1986).

The hemicelluloses, the second most abundant polysaccharides in nature comprising of 15-35% of the agricultural and forestry residues are inexpensive and serve as renewable reservoir for production of several useful microbial products (Tangnu, 1982). Moreover, the hemicelluloses have relatively an open structure in comparison to celluloses which facilitates the diffusion of hydrolytic agents (acids or enzymes) into the polymer thus resulting in rapid saccharification. The fermentable sugars can be released more readily with better yield (80-90%) from hemicelluloses by acid or enzymic hydrolysis as compared to glucose yield (50%) from cellulose (Lachke, 1989). Some of the commonly occurring hemicelluloses of lignocellulosic biomass are xylan, mannan arabinoxylan, glucomannan and glucuronoxylan (Kollman and Côté, 1968). Depending upon the biomass source, the hemicellulosic fraction can be as high as 85% xylan (Lachke, 1989). Due to easy availability and regenerative potential of forest biomass, and abundance of xylan in lignocellulosic materials, the present problem "Biodegradation of physico-chemically treated forest biomass by xylanolytic microorganisms" was selected. Since there is no report on the xylan degrading microbial flora of temperate region, xylanolytic bacterial and fungal strains have been isolated from forest soil around Shimla.

Xylan (a primary backbone component of hemicelluloses) is a high molecular weight linear polymer of D-xylose linked by β-1,4 linkages (Whistler and Richards, 1970). The large sized
xylan molecules cannot permeate through the microbial cell membranes. Thus xylanolytic organisms release extracellular enzymes called xylanases in their surrounding which hydrolyse these complex biopolymers into their corresponding monomers. Among several xylanolytic microorganisms isolated from various habitats only a few strains have been reported as hyper xylanase producers (Uchino and Nakane, 1981; Poutanen et al., 1986,87). Therefore in the present studies, an attempt was made to screen the xylanolytic bacterial and fungal isolates for the extracellular production of xylanase.

The exudation of enzyme from the microbial cell depends upon the composition of growth medium, pH, substrate concentration, size of the inoculum and the temperature of incubation (Sleat et al., 1984; Duff et al., 1987). Thus efforts were made in the present investigations to optimise conditions for xylanase production by the hyper xylanase producing Flavobacterium sp. and Aspergillus niger by altering the culture conditions i.e. type of medium, pH, concentration of xylan, size of inoculum and temperature of incubation.

Hemicellulose in the biomass is associated with lignin and cellulose which limits its enzymic hydrolysis. To enhance the degradation or enzymic hydrolysis of lignocelluloses, certain physical, chemical and biological pretreatments of the biomass have been proposed (Rexen, 1983; Takagi, 1987; Khan et al., 1986; Tangnu, 1982) which make the biomass more susceptible for enzymatic degradation. In the present studies different forest residues (wood, bark and needles of various trees) were treated physically (gamma irradiations) and chemically (H₂O₂+Mn⁺⁺, H₂O₂+Co⁺⁺) and the biodegradation of these pretreated materials by the hyper xylanase producing strains of Flavobacterium sp. and A. niger were studied.

The ever expanding human population on earth and unpredictable weather for agriculture have resulted in shorter supplies of proteins of plant and animal origin, and consequently price of protein rich food commodities is
dramatically fluctuating in world markets (Norris, 1981; Agrawal, 1989). The microbiologists have helped in solving the problem of dwindling protein supplies by growing microorganisms on waste materials for their protein contents (Litchfield, 1979; Prendergast et al., 1983). The microbial proteins thus produced are popularly known as single cell proteins i.e. SCP. Efforts have been made in the present investigations to convert lignocellulosic biomass (physico-chemically treated) into SCP either by growing yeasts (Candida utilis, C. tropicalis, Saccharomyces cerevisiae, S. cerevisiae var. ellipsoideus) in co-culture with the xylanolytic isolates (Flavobacterium sp. and A. niger) or in the culture supernatant of these isolates.

Extensive research in the area of energy has revealed that ethanol can emerge as a substitute for liquid petroleum (Khan et al., 1984; Bostid Report, 1982; Agrawal, 1989). At present production of ethanol is primarily based on the non-renewable petroleum byproducts (Raven and Johnson, 1986). In order to ease our dependence on non-renewable resources for ethanol, its production from starch and sugar rich agricultural produce has been proposed (Nicolini et al., 1983; Zadrazil, 1980). Since these raw materials are items of foodbowl, it is not wise to convert food into fuel. Therefore, the technology of ethanol production from the lignocellulosic biomass is gaining importance. Production of ethanol from biomass is a two step process first being saccharification (i.e. hydrolysis of polymers into fermentable sugars) and the second fermentation (Zetalaki-Horvath, 1984; Khan et al., 1986). In the present studies the pretreated forest biomass materials were saccharified and the culture supernatants obtained were further used for ethanol production by using several yeast species (Candida tropicalis, C. utilis, C. shehatae, Pichia stipitis, Pachysolen tannophilus).

The purified xylanases are becoming a subject of increasing importance in biotechnology because of their
potential applications in saccharification of lignocellulosic biomass, preparation of protoplast, clarification of fruit juices and manufacture of coffee (Biely, 1985; Yu et al., 1987). In the present investigations the extracellularly released xylanases from Flavobacterium sp. and A. niger have been partially purified and the activities of these partially purified enzyme preparations have been assayed at various temperatures, pH, and substrate concentrations. The partially purified xylanases have also been employed for saccharification of physico-chemically pretreated forest biomass samples.

Thus investigations have been carried out to isolate potent xylanolytic microbial isolates from forest soil of Shimla, to identify suitable forest biomass susceptible to the hydrolytic action of xylanolytic microbes and to improve the biodegradation of this biomass by subjecting it to physical and chemical pretreatments. The results are presented here.