

Fungi based valorization of wheat straw and rice straw for cellulase and xylanase production

Arti Devi ^a, Anita Singh ^{a,b,*}, Richa Kothari ^a

^a Department of Environmental Sciences, Central University of Jammu, Jammu 180011, Jammu and Kashmir, India

^b Department of Environmental Studies, Central University of Haryana, Jant-Pali, Mahendergarh 123031, Haryana, India

ARTICLE INFO

Keywords:

Fungi
Cellulase
Albezia lebbeck
Ramichloridium apiculatum
Xylanase

ABSTRACT

A total of 29 fungal species were isolated from different ecological habitats of Jammu region and screened for cellulase and xylanase production. The potent fungal species were identified as *Aspergillus flavus*, *Aspergillus terreus*, *Ramichloridium apiculatum*, *Fusarium pallidoroseum* and were compared with the commercially available strains. Out of these, *A. flavus* and *A. terreus* exhibit significant cellulolytic and xylanolytic activities on alkali pretreated wheat straw. *R. apiculatum* was first time reported for cellulolytic and xylanolytic activities in the present study. The maximum xylanolytic activity was shown by *A. flavus* ITCC 11854.23 as 4.68 U/ml when utilizing alkali treated rice straw. In this investigation, the enzymatic activities of the isolated strains outperformed the commercial strains. This study provides a baseline to extract enzymes from these potential fungal species on utilizing low-cost substrates to make the industrial processes more economic and sustainable.

1. Introduction

Waste management and energy security are the foremost challenges in today's world. Biomass is a bio-resource present in copious amount contains a lot of energy in it which can be used for the production of bioenergy and also solves waste management issue. The agricultural biomass left after grains harvesting is burnt in North India on fields to prepare the soil for cultivation of following crop. This biomass burning poses threat to the atmosphere as lot of particulate matter and trace gases were emitted from burning of the agricultural waste left behind after harvesting. It also degrades soil fertility [1]. Bread basket of India i. e. Punjab, Haryana and Western Uttar Pradesh is a localized hotspot for burning of biomass [2].

Biofuel production from lignocellulosic biomass is a sustainable and green concept. India is the 2nd biggest global cultivator of rice after China, which generates a lot of rice straw, i.e. 130 million tons along with it [3]. Wheat straw is also a major crop residue generated in India. Wheat production is estimated about 1127.43 lakh metric tonnes during 2022–2023 that produced huge quantity of wheat biomass along with it [4,5]. The UT of Jammu and Kashmir generates 851.74 kt and 1082.66 kt of rice and wheat biomass in the year 2019–2020 having power potentials of 19.69 and 29.23 MWe, respectively [6,7]. Wheat and rice

biomass made of three chief components i.e. cellulose, hemicellulose, and lignin. The accessibility of cellulose and hemicellulose requires the elimination of lignin. Therefore, pretreatment of the biomass is crucial for the lignin solubilization process. The most frequently used chemical method to solubilize lignin is an alkali pretreatment. Due to its low cost and adaptability for mass production, sodium hydroxide is primarily utilized for alkali treatment [8].

The cellulose is a complex structured polymer composed of glucose units, while hemicellulose is a branched chain of five and six carbon sugars [9]. To get the bioenergy and bio-products from cellulose and hemicellulose, cellulolytic and hemicellulolytic enzymes are needed to convert it into a more usable and simpler form. The usage of biomass is profitable from an economic and environmental perspective as it reduces the burning rate which decreases the amount of particulate matter emissions [10]. Xylan is among the one of the abundant components of lignocellulosic biomass next to cellulose made of linear chain of D-xylose units. Cellulase transforms the cellulose into glucose and xylanase is required to hydrolyze hemicellulose into its monomeric sugar. These enzymes are in high demand because of their industrial use in many processes like biofuel production, biopulping, ink removal, fiber softening, biopolishing, biomass hydrolysis, denim fading, bioscouring, and improving aroma and flavor in wine and brewery industries [11,12]. But

* Corresponding author at: Department of Environmental Sciences, Central University of Jammu, Jammu 180011, Jammu and Kashmir, India.

E-mail address: anitasaharan@gmail.com (A. Singh).

¹ ORCID: 0000-0003-1564-5904

<https://doi.org/10.1016/j.scenv.2024.100077>

Received 5 October 2023; Received in revised form 20 January 2024; Accepted 27 January 2024

Available online 30 January 2024

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these enzymes are quite expensive, making the process of biofuel production exorbitant. So, extracting these hydrolytic enzymes from biological suppliers, i.e., bacteria, yeast, and fungi can reduce the cost of their production. Fungal species are better producers of cellulolytic enzymes compared to bacteria and yeast [13].

Industrially cellulase can be produced by the process of submerged fermentation (SmF), although solid-state fermentation (SSF) is getting interest from last two decades. Submerged fermentation process does not face any mass transfer and heat removal issues. It is a homogenized process that provides a continuous supply of oxygen and control over several factors of the process [13]. Cellulase from microorganisms in high titers is necessary for the cost reduction and production process [14]. From an industrial point of view, fungi are at the center focus as the enzyme production from them is crucial for industrial operations. The requirement of these enzymes is at the foremost front and their influence will be more in the forthcoming years [15]. Considering the importance of fungi at industrial and agricultural sectors, the present study aims at isolating and screening of cellulolytic and xylanolytic potent fungal strains for further biotechnological applications.

2. Materials and method

2.1. Collection of samples

Samples were randomly taken from different ecological habitats of fungi i.e. soil samples from Chogan Slathia (CS), Talab Tillo, Nai Basti, Satwari, Gadigarh, Digiana, Bisnah, Sarore, Natral, Rahya Mohr (RM), Rahya railway crossing (RC), Suchani, CUJ campus, Muthi, SMVDU campus, Akhnoor, Barian, Sangrampur; sediment samples from the ponds of Suchani and Rahya which were named as ST and RT, respectively; and tree bark samples from *Mangifera indica* (MI), *Grevillea robusta* (GR), *Albizia lebbbeck* (2 samples were taken from different trees named as AL1 and AL2) and *Delonix regia* (DR) trees in the Jammu region of the Union territory of Jammu and Kashmir. Collected samples were kept in poly bags at room temperature.

2.2. Isolation of fungi

Isolation of fungal species from the collected samples were made by enriching the samples with fungal media broth composed of sodium nitrate (0.2%), dipotassium hydrogen phosphate (0.1%), magnesium sulphate heptahydrate (0.05%), potassium chloride (0.05%), ferrous sulphate hepta hydrate (0.001%), glucose (1%) and peptone (0.5%) at 30 °C and 120 rpm for 48 h. After visible growth of the fungi in the broth, the aliquot (1 ml) was taken out to spread on the potato dextrose agar plates. The culture plates underwent incubation at 30 °C for about 48 h. The fungal colonies were purified by streak plate culture method. The purified strains were compared for enzyme production.

2.3. Qualitative screening

The isolated and purified strains were screened for cellulolytic and xylanolytic activity by inoculated the strains on the media plates with same composition (as mentioned in Section 2.2) along with 0.6% (w/v) of the CMC (carboxymethyl cellulose) and 0.5% (w/v) xylan from beechwood, respectively. The plates were put in an incubator at 30 °C for 48h for fungal growth and were immersed in the Congo red solution (0.1%). In due course of time, the plates were rinsed with sodium chloride (1% w/v) solution and noticed for the presence of clear zone that shows the utilization of CMC and xylan by the respective enzyme.

2.4. Quantitative screening of fungi for enzyme production

2.4.1. Substrate pretreatment

The crop residues i.e. wheat straw (WS) and rice straw (RS) were collected from Suchani village, district Samba, Jammu and Kashmir,

India. The collected substrates were grinded and sieved to 1 mm size. The sieved biomass was pretreated with solution of 2% sodium hydroxide (1:10 w/v) and sterilized at 121 °C and 15 psi pressure for 20 min in an autoclave [16].

2.4.2. Submerged fermentation

The quantitative screening of the isolated strains for enzyme production were performed under submerged condition using 1% WS and RS as substrates, respectively in 100 ml Czapeck dox media broth composed of sodium nitrate (0.3%), potassium chloride (0.05%), iron (II) sulfate heptahydrate (0.001%), and epsomite (0.05%) in 250 ml erlenmeyer flask initially at 5.5 pH [17]. Before inoculation with 1% fungal spores, sterilization of the media containing flask were made for a period of 20 min at 121 °C. The flasks were placed at 30 °C and 120 rpm for 5 days in an incubator [18]. After a period of time (5 days), the culture was passed through muslin cloth and the crude enzyme was extracted through centrifugation at 3000 rpm for 20 min which were kept at 4 °C for further analysis.

2.4.3. Analysis

The Goering and Van Soest [19] approach was used to find the proportions of cellulose, hemicellulose, and lignin. The analysis of all the samples of the crude enzyme was made by following the method of Ghose [20]. FPase (Filter paper) activity was estimated by mixing the 0.05 g of the Whatman filter paper no. 1 with 1000 microlitres of the Sodium citrate buffer (4.8 pH) and 500 microlitres of the extracted crude enzyme. The prepared blend was placed in an incubator at 50 °C for 1 h to react. Endo β -1, 4-glucanase was measured by conducting carboxymethyl cellulase (CMCase) activity assay by mixing the 500 microlitres of the enzyme and incubated at 50 °C for half an hour [20]. Xylanase activity was determined by mixing 1% xylan solution and enzyme in the ratio 1:1 (0.5 ml each) [21]. The mixture was put in an incubator at 50 °C for 30 min. To terminate the reactions, 3000 microlitres of the 3, 5- dinitrosalicylic acid (DNS) was added and boiled for 5 min for the development of the color. After cooling, each assay sample's absorbance was assessed on Spectrophotometer at 540 nm. A standard plot was made against the known levels of dextrose concentration. The enzyme activities were calculated mentioned by [22,23].

2.5. Comparison of isolated strains with commercially available strains

Four fungal strains i.e. *Trichoderma gamsii* ITCC 8186, *Fusarium oxysporum* ITCC 5598, *Aspergillus niger* ITCC 6560, and *Rhizopus oryzae* ITCC 6003 were procured from Indian type Culture Collection (ITCC) and Identification/Culture Supply Services, Division of Plant Pathology, Indian Agricultural Research Institute (IARI), New Delhi and one fungal strain i.e. *Trichoderma reesei* NCIM 1186 was procured from NCIM Resource Centre, CSIR-National Chemical Laboratory, Pune. All the procured strains were revived and screened for enzymatic activity as per the protocol mentioned in sub section qualitative and quantitative screening. In the present work, 29 strains of fungi were isolated in total and compared with commercial strains for enzyme production.

3. Results and discussion

Soil and decaying plant matter are habitats of many different microorganisms. Fungi also colonize the plant waste and form synergistic relationships with it. They produce an intricate combination of enzymes responsible for the plant's polysaccharide hydrolysis to stay alive [24]. Therefore, it is necessary to screen out the potential strains that secrete a large quantity of hydrolytic enzymes for their biotechnological applicability, as each species produces a variable amount of these enzymes. In this study, fungal species were isolated on PDA plates and screened for the zone of hydrolysis on CMC and xylan-supplemented media and their results are discussed below in detail.

3.1. Fungi isolation

In total, twenty-nine fungal strains were obtained from distinct areas of the Jammu region. Out of which, 8 were isolated from tree barks, 19 from soil samples, and 2 from sediment samples, as shown in Fig. 1.

3.2. Qualitative screening

All the isolates and procured strains were screened for cellulase and xylanase production, which showed positive results for both enzymes except Gadigarh and AL2 green isolates. The qualitative profile for enzymatic activity is illustrated in Table 1. The zone of hydrolysis for cellulase activity was found to be positive for each fungal strain. For xylanase activity, all the strains showed a positive response except the isolated strain from Gadigarh, which showed a negative response on the xylan agar plate and AL2 green strain showed very little growth, which is difficult to measure with a scale. The clear zone only distinguishes the producer strains from the non-producer isolates [25]. So, there is a need for quantitative analysis to distinguish the higher producers of cellulase and xylanase.

3.3. Pretreatment

Both substrates were pretreated with 2% sodium hydroxide (NaOH) because alkali treatment alters the physical makeup of biomass, making

its constituent parts more accessible for enzymatic hydrolysis. Significant reactions that occur throughout the alkali pretreatment involve the dissolution of lignin and hemicellulose and the breakdown of the intermolecular ester linkages [26]. For the purpose of releasing sugars and removing lignin, alkali pretreatment is suitable for both wheat straw and rice straw [27,28]. The cellulose and hemicellulose content increased and the lignin content decreased after being treated with 2% NaOH, which improved the yield of reducing sugars as reported by Adeyemi et al., [29]. As per the study of Kim and Han [30], the ideal NaOH concentration to obtain the highest glucose yield from rice straw is 2.96% at 81.79 °C. The compositional characterization of untreated and alkali treated WS and RS was analyzed. Lignin, hemicellulose, and cellulose content of both substrates pre- and post-treatment are illustrated in Table 2. After pretreatment, both RS and WS had a rise in cellulose content of 19.4% and 18.7%, respectively, whereas hemicellulose increased by 15.8% and 13.3% for both substrates, respectively. A decrease in lignin and an enhancement in the cellulose and hemicellulose amounts can facilitate the enzymatic digestibility of the biomass.

3.4. Quantitative screening

Quantification of cellulolytic and xylanolytic activity of the isolated as well as commercial fungal strains was made under submerged fermentation on two substrates, i.e., WS and RS, as both are available in abundance and cheap in nature (Figs. 2 and 3). All the strains producing



Fig. 1. Fungal isolates from different ecological habitats (Soil, sediments and Tree bark). (1) CS (2) Talab Tillo (3) Nai basti (4) Satwari (5) Gadigarh (6) Digiana (7) Bisnah (8) Sarore (9) Natral (10) RM1 (11) RM2 (12) RC (13) Suchani (14) CUJ campus (15) Muthi (16) SMVDU campus (17) Akhnoor (18) Barian (19) Sangrampur (20) RT (21) ST (22) *Mangifera indica* (23) *Grevillea robusta* (24) AL1 green (25) AL1 white (26) AL1 black (27) AL2 green (28) AL2 white (29) *Delonix regia*.

Table 1
Qualitative profile of cellulase and xylanase produced by fungi.

S. No.	Source Soil	Zone of hydrolysis (mm)	
		Cellulase activity	Xylanase activity
1	CS	1	2
2	Talab Tillo	8	1
3	Nai Basti	2	1
4	Satwari	3	4
5	Gadigarh	2	Nil
6	Digiana	2	1
7	RM 1	2	1
8	RC	1	2
9	Suchani	8	1
10	CUJ campus	2	1
11	Muthi	8	7
12	SMVDU campus	1	2
13	Akhnoor	1	3
14	Barian	1	2
15	Sangrampur	5	2
Sediments			
16	ST	2	1
Tree barks			
17	<i>Grevillea robusta</i>	2	1
18	AL1 Green	2	2
19	AL1 White	1	2
20	AL2 Green	1	Below detection limit
21	<i>Delonix regia</i>	4	1
Commercially available strains			
22	<i>Trichoderma gamsii</i> ITCC 8186	3	1
23	<i>Fusarium oxysporum</i> ITCC 5598	4	2
24	<i>Trichoderma reesei</i> NCIM 1186	1	2

Table 2
Effect of pretreatment on the composition of wheat straw and rice straw.

Feedstock	Cellulose (%)	Hemicellulose (%)	Lignin (%)
Untreated rice straw	37.5 ± 1.3	19.6 ± 1.1	9.8 ± 0.8
Alkali pretreated rice straw	44.8 ± 1.6	22.7 ± 1.1	4.6 ± 0.5
Untreated wheat straw	41.7 ± 1.5	23.9 ± 1.3	13.4 ± 1.1
Alkali pretreated Wheat straw	49.5 ± 1.5	27.1 ± 1.5	5.3 ± 0.8

CMCase, FPase, and xylanase on wheat straw are in the range of 0.17–2.03 U/ml, 0.137–1.169 U/ml, and 0.33–4.03 U/ml, respectively. It has been investigated that the FPase activity of the 64 cellulolytic fungi ranges between 0–0.259 U/ml [14]. On utilization of wheat straw, the highest and lowest CMCase activity were shown by AL1 green

(2.03 U/ml), and Gadigarh isolate (0.179 U/ml), respectively. Considerable CMCase activity was also observed for Digiana (1.33 U/ml) and Satwari (1.7 U/ml) isolates. Akhnoor isolate showed the maximum FPase activity (1.169 U/ml), and ST isolate showed the lowest, i.e., 0.137 U/ml. CS (1.03 U/ml) and AL1 green (0.99 U/ml) isolates also showed good enzymatic (FPase) activity. Satwari isolate (4.03 U/ml) showed the highest xylanolytic activity, and Gadigarh isolate (0.33 U/ml) showed the lowest activity on wheat straw under submerged fermentation. Isolates from AL1 green (2.81 U/ml), Akhnoor (2.96 U/ml), and Sangrampur (2.28 U/ml) also produce a good quantity of xylanase.

The FPase, CMCase, and xylanase activity of the isolated strains on rice straw was observed to be in the range of 0.174–0.512 U/ml, 0.163–1.07 U/ml, and 0.321–4.68 U/ml. The maximum CMCase activity of isolates on rice straw was observed for Sangrampur, and minimum for Natral, i.e., 1.07 U/ml and 0.163 U/ml, respectively. Significant activity of AL1 green (0.92 U/ml), and Satwari (0.70 U/ml) was also observed. Highest FPase activity was observed for RT isolate (0.512 U/ml) and lowest for AL1 white (0.174 U/ml). Other strains, like AL2 green, Suchani, and Sangrampur also showed considerable enzymatic activity. The xylanase activity of Akhnoor isolate (4.68 U/ml) was observed maximum and minimum for Gadigarh (0.321 U/ml) isolates. It has been observed that Sangrampur (2.64 U/ml), RT (1.70 U/ml), AL1 green (1.83 U/ml) isolates are also good producers of xylanase.

3.5. Identification of fungi

On the basis of quantitative screening, six fungal isolates, i.e., AL1 green, Satwari, CS, RM2, Akhnoor, and Sangrampur were selected for identification because these isolates showed potential for both cellulolytic and xylanolytic enzymes. These were identified as *Aspergillus flavus* ITCC 11694.22, *Aspergillus terreus* ITCC 11690.22, *Ramichloridium apiculatum* ITCC 11852.23, *Fusarium pallidoroseum* ITCC 11855.23, *A. flavus* ITCC 11854.23, and *A. terreus* ITCC 11853.23, respectively, from ITCC and IARI, New Delhi, on the basis of their phenotypic and physiological characteristics. The results for both species of *Aspergillus* were slightly different from the each other because of their different sources of isolation. Gautam et al., [31] isolated and screened 20 fungal isolates of *A. flavus* resulting in minimum and maximum cellulase activity of 0.81 IU/ml and 6.43 IU/ml, respectively using wheat bran under SmF conditions. Sharma and Bajaj [32] isolated *A. terreus* S9 from mushroom compost and produced a process apt xylanase.

Although various studies were present on the species identified, but geographical locations greatly affect the fungal species communities. The reason behind the variation in similar fungal species in different

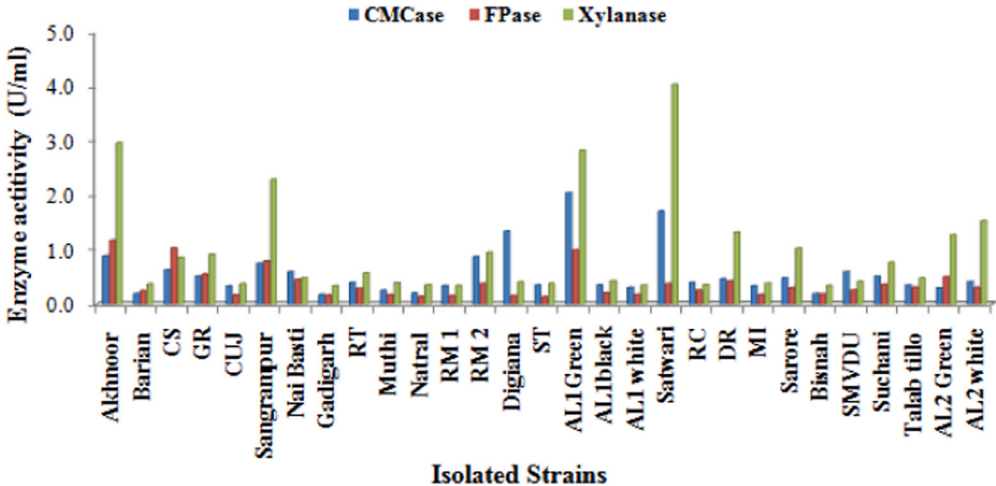


Fig. 2. Enzymatic activity of the isolated strains on wheat straw.

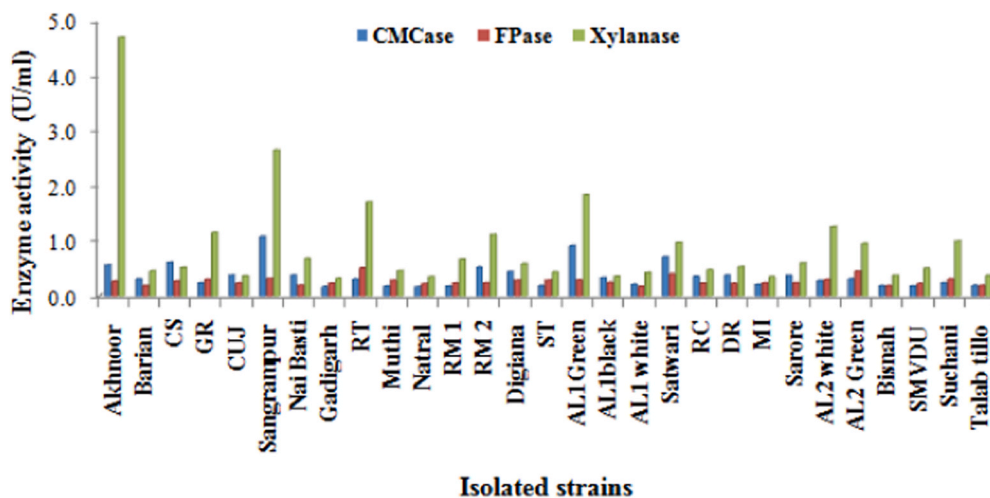


Fig. 3. Enzymatic activity of the isolated strains on rice straw.

locations was the varying environmental conditions [33]. In order to evolve and adapt, fungal species potentially facilitate lifestyle transitions by showing metabolic versatility [34]. In a study reported by [35], it was mentioned that fungal species with high ability and a wide range of enzyme production have diverse forms, while those fungi explored previously for industrial purposes were quite low in enzymatic parameters. In addition to this, the secondary metabolite production by fungi was regulated by environmental conditions like light and temperature [36]. As mentioned in the above studies, the metabolic activities of the fungal species vary as per the environmental conditions of the particular locations. So, in the present study, fungal species were explored in the ecological habitats of the Jammu region (not extensively explored for enzyme-producing fungi priorly) for the production of enzymes utilizing alkali pretreated wheat straw and rice straw.

3.6. Comparison of isolated strain with commercial strains

Five different strains were selected and procured for the production of enzyme (Figs. 4 and 5) and compared with the isolated strains. Out of five, *F. oxysporum* ITCC 5598 and *R. oryzae* ITCC 6003 showed a significant enzyme activity on wheat straw (Fig. 4). With rice straw as substrate, FPase, CMCase and xylanase activity of *R. oryzae* ITCC 6003 was found 0.31 U/ml, 0.85 U/ml, 2.42 U/ml, respectively (Fig. 5). Cellulase activity of *Rhizopus* and *Aspergillus* species ranged between 0.11–1.5 U/ml and 0.01–1.0 U/ml, respectively which was reported by Chandel et al. [37]. Our results for both the *Aspergillus* strains were greater utilizing wheat straw and rice straw (Fig. 6). Enzymatic activities of *F. oxysporum* ITCC 5598 was observed as 1.46 U/ml (CMCase),

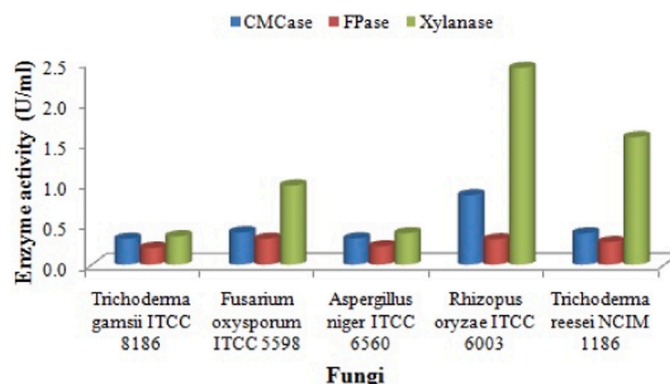


Fig. 5. Enzymatic activity of the commercially available fungal strains on rice straw.

0.78 U/ml (FPase) and 0.50 U/ml (xylanase) on wheat straw. M'Barek et al. [38] in his study obtained 0.28 IU/ml of endoglucanase activity for *F. oxysporum* on utilizing czapekdox liquid media supplemented with cellulose. Using CMC as a carbon source, *F. oxysporum* showed FPase activity and CMCase activity varied between 0.149–0.171 U/ml and 0.303–0.728 U/ml, respectively, during the incubation period from 24 to 120 h [39]. The results obtained from *F. oxysporum* ITCC 5598 in our study, i.e., 1.46 U/ml CMCase and 0.78 U/ml FPase on wheat straw, are in agreement with these aforementioned studies for *F. oxysporum* specie. *T. gamsii* SGSPf7 has been reported to produce 0.025 U/ml of FPase which is quite lower than the strain used in the present study on rice straw i.e. 0.20 U/ml [40]. *A. niger* ITCC 6560 and *T. reesei* NCIM 1186 produced FPase activity on WS and RS of 0.26 U/ml and 0.22 U/ml; 0.24 U/ml and 0.27 U/ml, respectively. Septiani et al. [41] conducted research on the production of cellulase on CMC media from *A. niger* UICC371 and *T. reesei* and quantified FPase activity of both species at 0.131 U/ml and 0.106 U/ml, respectively.

Comparing the fungal isolates with commercially procured strains on utilization of wheat straw revealed that the CMCase activity of *A. flavus* ITCC 11694.22 and *A. terreus* ITCC 11690.22 isolates was higher than that of procured fungi with the highest enzyme activities, i.e., *F. oxysporum* ITCC 5598 and *R. oryzae* ITCC 6003 species (Fig. 6). Despite the lower CMCase activity of *F. oxysporum* ITCC 5598 (1.46 U/ml) than the isolated strain in the present study, it showed better results than the study of Deb Dutta et al. [42] which evaluated the cellulolytic activity of *F. oxysporum* SF0801 at about 0.445 IU/ml. *R. oryzae* ITCC 6003 (0.97 U/ml) had lower FPase activity than *A. flavus* ITCC 11854.23

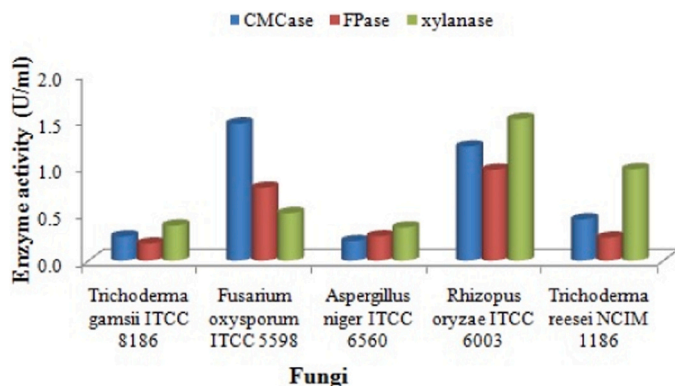


Fig. 4. Enzymatic activity of the commercially available fungal strains on wheat straw.

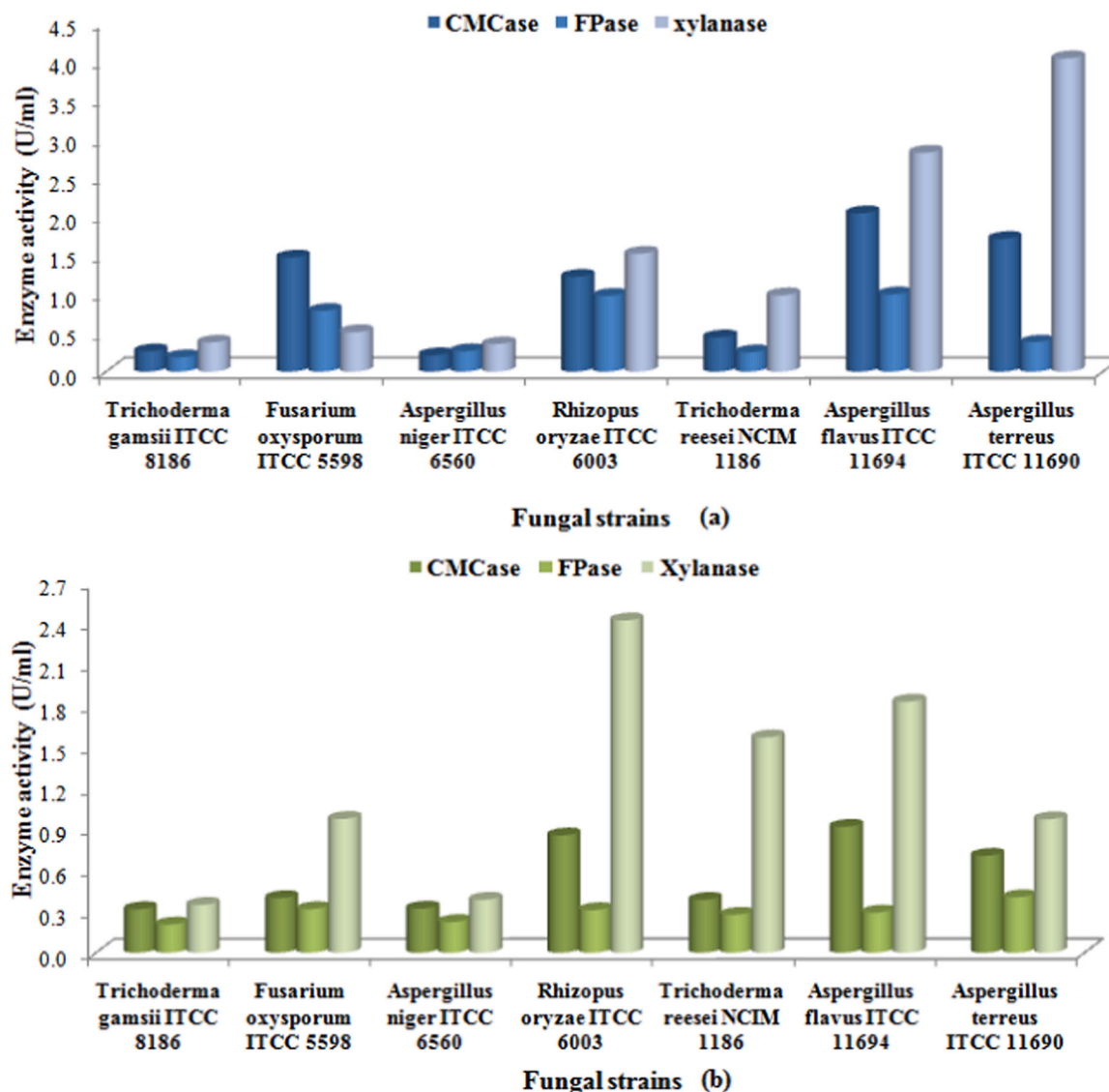


Fig. 6. Comparison of the isolated strains with the procured strains on (a) wheat straw (b) rice straw.

(1.16 U/ml) and *R. apiculatum* ITCC 11852.23 (1.03 U/ml). *A. flavus* ITCC 11694.22 (0.99 U/ml) and *R. oryzae* ITCC 6003 (0.97 U/ml) showed similar results for FPase activity (Fig. 6). The activities (FPase) of *A. terreus* ITCC 11853.23 (0.79 U/ml) isolate and *F. oxysporum* ITCC 5598 (0.78 U/ml) were comparable to each other. *A. terreus* MS105 showed endoglucanase and FPase activity of about 0.47 IU/ml and 0.295 IU/ml, respectively, in media broth containing CMC [43]. The filter paper activity of *A. terreus* was 10.96 U/g, obtained by Narra et al. [44] at optimized conditions of 5 g substrate concentration, pH 5, and inoculum size of 1×10^5 spores. Our results for *A. terreus* were better than the aforementioned studies. The xylanase activity of both *Aspergillus* species isolated from different locations in our study was higher than that of all the procured strains. *A. flavus* and *A. terreus* had a higher degradation potential for wheat and rice residues [45]. *A. flavus* KUB2 on sugarcane bagasse and rice straw under SmF conditions resulted in cellulolytic activity of 0.21 U/ml CMCase and 0.08 U/ml FPase, respectively [46]. The highest xylanase activity was 59.726 U/g obtained on Mandals medium [47]. Utilizing wheat bran as the *flavus* produced cellulase about 3.3 IU/ml at 4% inoculum size [48]. The cellulolytic and xylanolytic activities of *F. pallidoroseum* ITCC 11855.23 were higher compared to those of *A. niger* ITCC 6560, and *T. gamsii* ITCC 8186, but they showed less cellulolytic activity and more xylanolytic

activity than those of *F. oxysporum* ITCC 5598. Sharma and Sumbali [49] reported a cellulolytic activity of 0.44 $\mu\text{mol/ml/min}$ for *F. pallidoroseum*, which supported the results observed for *F. pallidoroseum* ITCC11855.23 (0.87 U/ml) isolated in our study. It has been observed by Bertonha et al. [50] that xylanase from *Fusarium* species range between 4.69 - 125 U/g on the substrate i.e., a blend of sugarcane bagasse and wheat bran under SSF conditions. *A. niger* on alkali-pretreated soybean hulls resulted in endoglucanase and total cellulase activity of 9.91 U/g and 6.20 U/g, respectively [51]. The xylanase activity of *A. niger* NFCCI 4113 on rice straw and wheat straw was observed as 6.58 IU/ml and 7.28 IU/ml, respectively, which was higher than the activities evaluated in our study [52]. This might be due to the differential operational conditions and the species adaptation to its environment. The outcomes observed in the present study for both species of *A. flavus* and *A. terreus* were better than those of the procured strains. The reason for increased enzyme production in our study may be the difference in the source of isolation because environmental parameters impact the growth and development of fungi.

On utilizing the rice straw as a carbon source, the CMCase activity of *A. terreus* ITCC 11853.23 and *A. flavus* ITCC 11694.22 was higher as compared to *R. oryzae* ITCC 6003. Singh et al. [53] studied *A. flavus* for enzyme production on pretreated rice straw under SSF, which resulted

in the highest enzymatic activity of 0.098 IU/ml CMCase, 1.99 IU/ml FPase and 1.63 IU/ml xylanase. Total cellulase activity and endoglucanase activity of *A. terreus* D34 on rice straw were 4.62 FPU/g and 96.6 U/g, respectively [54]. *A. terreus* was examined for cellulase, and xylanase production resulted in an enzymatic activity of 2.7 U/ml and 3.4 U/ml [55]. Ezeilo et al., [56] produced cellulase by utilizing raw oil palm frond leaves as feedstock under SSF from *R. oryzae* UC2 and yielded CMCase and FPase activity of about 94.68 U/g and 25.46 U/g, respectively. The reason behind the variation in the enzymatic activity of the aforementioned studies and the present study might be the differential experimental conditions such as substrate, temperature, and different fermentation conditions (inoculum size, rotation per minute, etc.). *F. oxysporum* ITCC 5598 and *T. reesei* NCIM 1186 also showed considerable CMCase activity, but *A. terreus* ITCC 11853.23 produced more than the aforementioned commercial strains. It has been observed that *A. terreus* ITCC 11853.23 showed higher enzymatic activity than *A. niger* ITCC 6560 and *T. gamsii* ITCC 8186 species. It has been found by Blaszczyk et al., [57], that *T. gamsii* AN327 isolate was the efficient producer of cellulase. Our results were superior to the outcomes of the Goyari et al. [58] study on cellulolytic microorganisms in Indo-Burma biodiversity hotspot, in which FPase production from *T. gamsii* was obtained about 0.04 U/ml. Maximum cellulolytic activity by *A. niger* CECT 2700 was 6.23 U/g on sugarcane bagasse [59]. On alkali pretreated rice straw, *A. niger* ITCC 302 and *A. acculatus* ITCC 5078 resulted in 2.16 and 1.75 IU/ml of FPase activity, respectively [60]. Both species of *Fusarium* showed comparable enzymatic (xylanase) activities, i.e., 0.97 U/ml and 1.11 U/ml for *F. oxysporum* ITCC 5598 and *F. pallidoroseum* ITCC 11855.23, respectively. Similarly, the xylanase activity of *F. oxysporum* on corn fiber xylan ranged from 2.25 U/mg to 2.88 U/mg [61]. The xylanase activity of *A. flavus* ITCC 11854.23 was observed to be higher than that of the commercial strains. Cellulolytic activity of *R. apiculatum* ITCC 11852.23 was higher than *T. reesei* NCIM 1186 (0.38 U/ml) but less than *A. terreus* ITCC 11853.23, while *A. flavus* ITCC 11694.22 results for FPase activity were observed to be almost similar to that of *T. reesei* NCIM 1186 (0.27 U/ml). Maibam et al. [62] studied *T. reesei* NCIM 1186, utilizing sugarcane bagasse for cellulase production, which resulted in 0.18 U/ml of CMCase activity and 0.34 U/ml of FPase activity. Filter paper activity of *T. reesei* NCIM 1186 on alkali pretreated rice straw was found to be 2.23 IU/ml after 72 h of incubation and 1.97 IU/ml by *T. reesei* 992 which is higher than the FPase activity (0.27 U/ml) obtained in our study [60].

R. apiculatum was not yet mentioned in the research publications for cellulolytic and xylanolytic activities. The enzymatic activity of *R. apiculatum* ITCC 11852.23 was reported for the first time in our study. But it has been observed that *R. apiculatum* showed better enzymatic activity than the commercial strains, i.e., *Trichoderma gamsii* ITCC 8186 and *Aspergillus niger* ITCC 6560. Higher enzymatic activities than the above-mentioned commercial strains showed that it has a great potential for enzyme production. Hence, more studies need to be done on *R. apiculatum* in future, like optimization of parameters to check the impact of operational and nutritional parameters to show that it will be a significant producer of these enzymes using WS and RS. The xylanase activity of *T. reesei* NCIM 1186 (1.57 U/ml) was higher than the *R. apiculatum* ITCC 11852.23 (0.51 U/ml) and *F. pallidoroseum* ITCC11855.23 (1.11 U/ml). Xylanase activity of *Aspergillus* and *Trichoderma* species was reported to range from 0.27 to 7.65 U/ml after 24 h of incubation on corn cob [63]. It has been concluded from the above comparative study that the isolated species of *Aspergillus* have more enzymatic potential than the procured strains. It has also been observed that these species showed higher enzymatic activity on wheat straw rather than rice straw. The reason might be the increased cellulose and hemicellulose content in wheat straw than the rice straw before and after alkali pretreatment.

4. Conclusion

Cellulolytic and xylanolytic enzymes play a crucial role in the various processes of industries. Fungi are a great source for obtaining these enzymes, as they provide an economical and eco-friendly approach to their production. So, 29 strains of fungi were isolated and examined for cellulase and xylanase production on wheat and rice straw. *A. flavus* ITCC 11694.22 and *A. terreus* ITCC11690.22 were found to be potent strains for the production of these enzymes and showed cellulase and xylanase activity of about 2.03 U/ml and 2.81 U/ml; 1.70 U/ml and 4.03 U/ml, respectively, on wheat straw. *F. oxysporum* ITCC 5598 and *R. oryzae* ITCC 6003 also produced significant amounts of cellulase and xylanase. *R. apiculatum* ITCC 11852.23 was also first time reported for cellulolytic and xylanolytic enzyme activity in this study. It has been found that the enzymatic activities of the isolated strains in the present study were better when compared with commercially available strains. It has been concluded from the quantitative analysis that the results were better in the case of wheat straw compared to rice straw. Further, optimization of parameters like pH, temperature, inoculum size, and carbon concentration, etc. is required for the hyperproduction of cellulase for their biotechnological applicability in industries.

Ethics approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Funding

The author (Anita Singh) would like to acknowledge SERB grant (ECR/2018/000672) for providing financial support to carry out this work.

Declaration of Competing Interest

The authors declare no competing interests.

Data availability

All data and material used for preparing the manuscript appear in the submitted article.

Acknowledgement

The author (Arti Devi) as a senior research fellow would like to acknowledge Ministry of Social Justice and empowerment, Government of India for National Fellowship scheme for OBC (NF-OBC).

Consent for publication

All authors give consent for publication.

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