Supplemental Information

Defined enzyme cocktail from the anerobic fungus *Orpinomyces* sp. strain C1A effectively releases sugars from pretreated corn stover and switchgrass

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Supplementary File 1. Protein sequence of all enzymes cloned and expressed in this study.

>EG5
TLLGLAIIGTKAMRNISSKELVKELTIGWSLGNTLDATCFETLNYAKDQTASETCWGNV
KTTQELYYKLNDLGFNTFRIPTTWSGHFGDGPDYKISEAWMKRVHEIVDYALNADGYA
ILNIHHETWNHAFQKNLESAKKILVAIWKQIAAEFADYDEHLIFEGMNEPRKVGDAAEW
NGGDYEGWNFVNEMNDLFVKTIRATGGNNALRHLMIPTYAACVNDGAINNFRFPSGD
DKVIVSLHSYSPYNFALNNGAGAISNFNDGSEIDWVMNTINSSFISKGIPVIIGEFGAMNR
NNEADREKWAEYYIKKATSLGIPCVIWDNGYFEGEGERFGLIDRKSLNVVYPRLVNGL
MKGLGDKKPKTTKVRTTTTTTIQVQPTNNNDCFSTKLGYDCCNGCEVFYTDNDGKWG
VENGNWCG

>Cel6A
PKSSGGSTTTPVNPGDVDATPGDQLTLSGNPFSGVEFYINPYYVAEVDGAIAQMTDSSL
KAKAEKMKTYSNAIWLDTIKNMNSWLESNLKGALAQQTGSKKVLTVFVVYDLPGRDC
HALASNGELLANSSDAQRYKTEYIDVIEKHLKTYKSQPVALIVEPDSLANLVTNLESTPA
CRDSESYYLDGHAYLIKKLGVLPHVAMYLDIGHAFWLGWDDNREKAGKVYAKVIQSG
SPGKVRGFTDNVSNYTPWEDPTLSRGPDTEWNPCPDEKRYLEAMHKDFKAAGISSVYF
VSDTSRNGHKTDRKHPGEWCNQTGVGIGARPQASPISGMDYLDAFYWIKPLGESDGTS
DESAVRFDGYCGHETAMKPAPEAGQWFQKHFEQGLENANPPL

>Cel48
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QPGMSRYNSSSPATYAPEDDDITNYPSKLIFQDGLVGQDPIAAELQQAYGTWDIYAMH
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TEGIDIGSLASIIKGLMWVSMKDGDQEGIDLAVQVMDAIEQYRDDHGYGVEEAREDYA
KFNEEVYIPSGWTGKNAQGANIRNGVKFIDIRPKYKQDPDWPQIENFLNGGEAPRFTYH
RFWAQTEIAVANGLISIYGLSDGSGVVPTKPGSCAAAIKAQGYKCCSANCEVVYTDADG
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MPTDC

>XYL11
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>BGL1

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YHKFDEDIKMMKIMNANHYRFSISWSRLFPDGQAKKVDGEWNVNEAGAQYYDMVIDT
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NEPWVVNCVAGYKNGPGKAPYRCTGEAPRKLANDTTGLDLEGGCSYEIGPSQYTKDSEV
LPANRPPQKLEDVWCSHNILLGHAQAVKVYREKFQKEQKGLIGITIDGEAQIPWEEPGM
SEEEYENNKKYANLAAEFRIGWYSDPVMFGDYPESVKQRNGKDMPVFTDEEKKLLKGS
SSDFLGWNTYTSHWAAQVKNEDGSYVEPPTDEEASYDNSKRDMWDDNCKGRGDGWT
CIPPTLGSQAGSSWNTKYGPTIRVGLNWFSKRYEGIIKNGIIITENGCAQPNYKVSRANDQ
VTLDYWKSIGKEEFADTYDEDIIEDESDLEGTLIHDTYRIDWYKQYLENLRLAYVEDGV
DVRGYMAWSLVDNFEWENGYETRFGMTYIDFYNDKDLKRVPKDSLTFLGQWYLDNV
EQE

>BGL3
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QENNRGASTSNVPEQALWEVYMEPFYRTVVEGEAGTVMASYNAINGTYSTQNKRLLT
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VDPLSAITKRAKKSKISVVSYGEDDAKKAAKVAKKADVAIVFVQADSGEEYITVEGNA
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AITDVLFGDVNPSGHLPYTWAPREDYPTDVKYEPEYPDGGEKMTVYDYNEGLFVGYR
WFDKKEIEPTAFGYGLSYTTFEFSDLEATMEDDGLYVSLTVTNTGKVAGAAVPMIFLSF
PESVKYPIRLFKGFDKVMLKAGESKETTIFIDAHGLSYFDVEKMEYVRPKDGEFTVYAG
SNARDLPLNVKVLANGDEIDSDNDNSDEEINEDIEDVEDSSDDEDEKDLKKRFYKLY

>Swol
MKSIQALGLSLLIAGTYAKCQTGYECCKTCDVSYTDDDGEWGIEDGQWCGIDTEKCNK
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YPCCKTCDSTYEDEDGKWAIENGDWCLLKKSCGDKPVDSTTTKATEPTTKSSGGVSRT
TLADGGILESGVFSTLPPSHTQPPYPHAENTGLASCGAKWTLVDNVCVAMYCEDDLSSE
NCDECGGVAGENGCVSVDPALCKSGIWPEVHDASDQPWKYSRSTHFGLTYGGACGFG
LYGLCTPKFNETGELCQRFCEHYPDLCADPEDISLRGNFCAPNGNYYTQFWSSLPGDYD
NYLSCGECYEVERTLPDGSSYPEGEKTDNIILQVLDSCPCTANAKWCCGSGTDHCNEIDF
KYGCPIPEESFHVDLSDIAMSRLQTNDPYGEMREGVIPIKYKRVPCPVKGNIHVWLRPGA
GPWYFALTVVNVANMGSLVAVEVQQADGKWVPLVRDPNYSSTRPQERYGSWTVKQG
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>Bgxg1
MKSLSLFFAYVLLVTPYLLVKATNVLTVECNNKLRRATHCANGSLYGITETTPRDYKSL
VDPLHPFVMRNPARGGNGNQHPYGDAIKVARRLADTPGALVSVDLPDMLPGWPYRWP
GMQSWLNQVKSFINDKKASGLKNWYGLEIWNEPDGTWNNSNGSFEEMWKQTYQVIR
QADPNEKIIGPCYSWYTDDKLRNFLKYAKANNCLPDIISWHELSGIDGVSSHLRSYREIE

KSLGIPELPISINEYCDAEHELEGQPGSSARFIGKFERYKVDTAMITWWFVPYPGRLGSLL
ATDTQKGAGWYFYKWYGDMTGDMLYVKPPNDNSKLVDGAACL

Table S1. Compositional analysis of pretreated corn stover and switchgrass.

Plant	Pretreatment	Glucan (%)	Hemicellulose (%)	Xylan (%)	Lignin (%)
Corn stover	Untreated	45	36	30	18
	Alkali	55	34	28	9
	Acid	42	25	22	33
	Ionic Liquid	31	26	17	43
Switchgrass	Untreated	40	38	30	23
	Alkali	48	34	30	18
	Acid	56	13	13	31
	Ionic Liquid	33	33	28	35

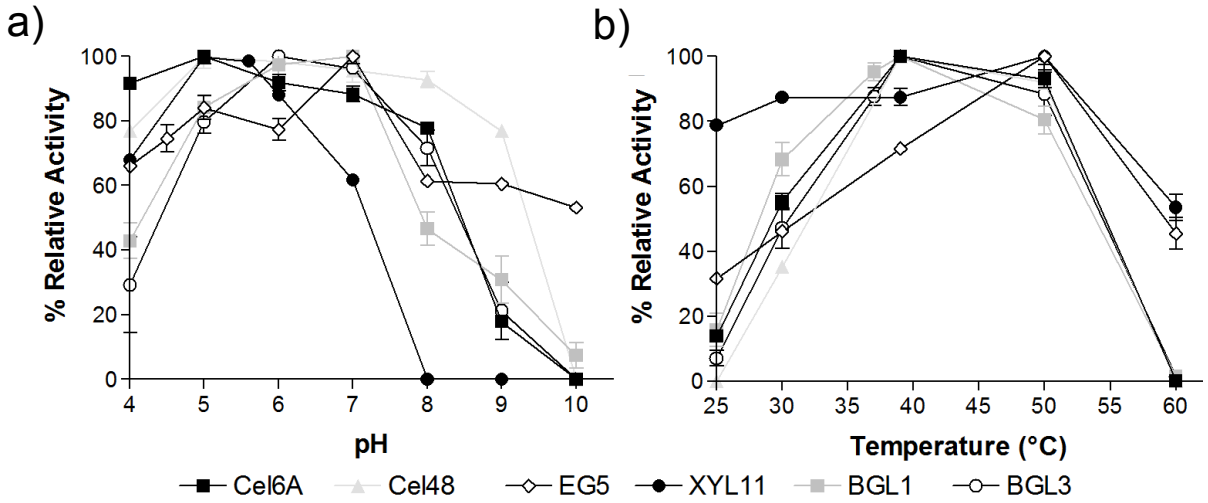

Figure S1. Optimal enzyme conditions. a) Optimal pH and b) Optimal Temperature. For all graphs, all values presented as relative specific activities. Error bars represent standard deviation of triplicate (n=3) samples.

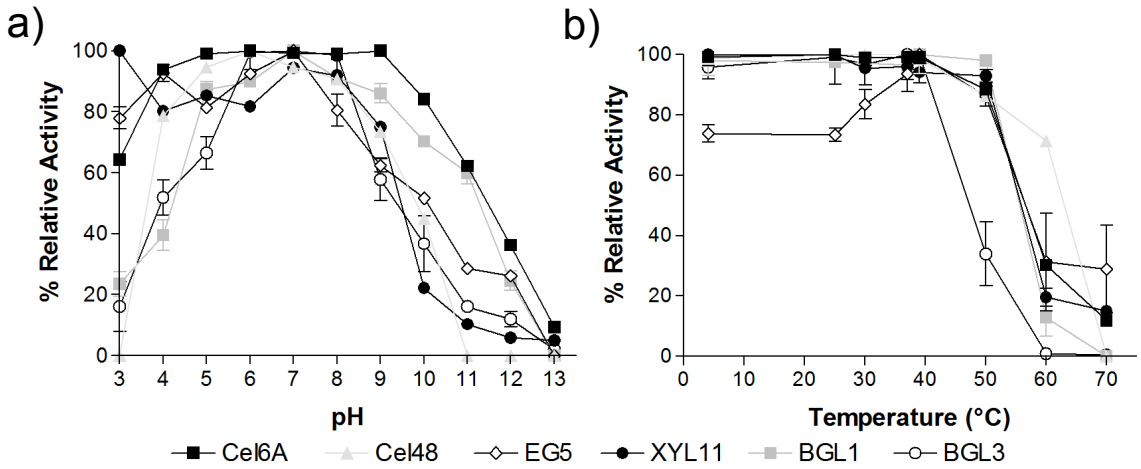

Figure S2. Enzyme stability. a) pH stability and b) thermal stability. For all graphs, all values presented as relative specific activities. Error bars represent standard deviation of triplicate (n=3) samples.

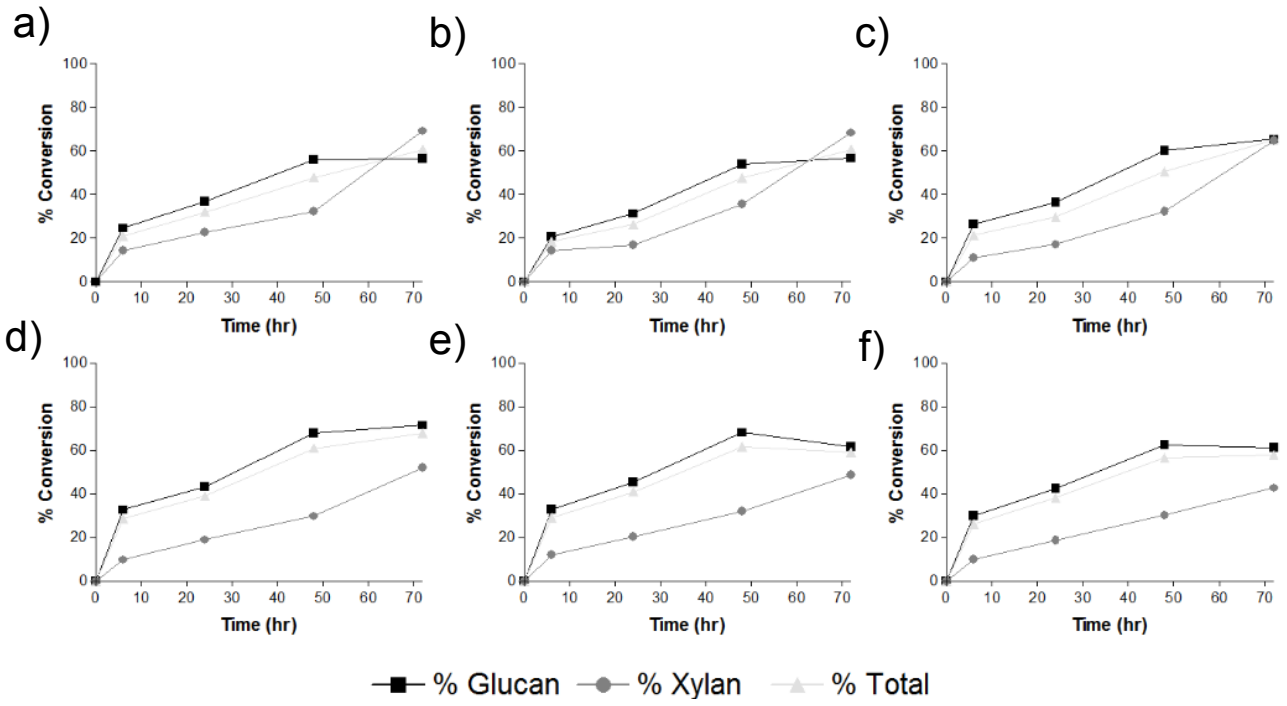

Figure S3. Enzymatic cocktail design examining ratios of cellulose-degrading cocktail and xylan-degrading cocktail on acid-pretreated corn stover (a-c) and switchgrass **(d-f).** Cel6A:EG5:Bgxg1:XYL11.ratios are as follows: **a** and **d**: 30:10:25:35; **b** and **e**: 40:13:23:24; and **c** and **f**: 20:7:27:46.

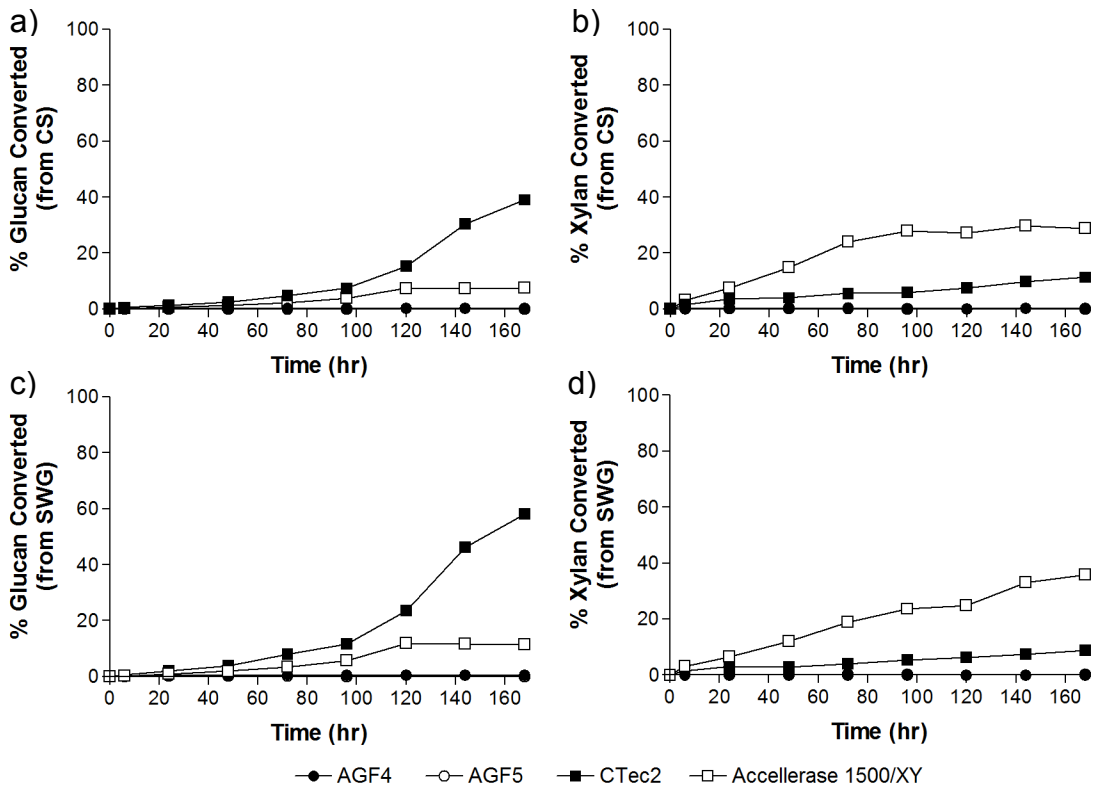

Figure S4. Enzymatic cocktails performance against untreated corn stover (a - glucan, b - xylan), and switchgrass (c - glucan, d - xylan).

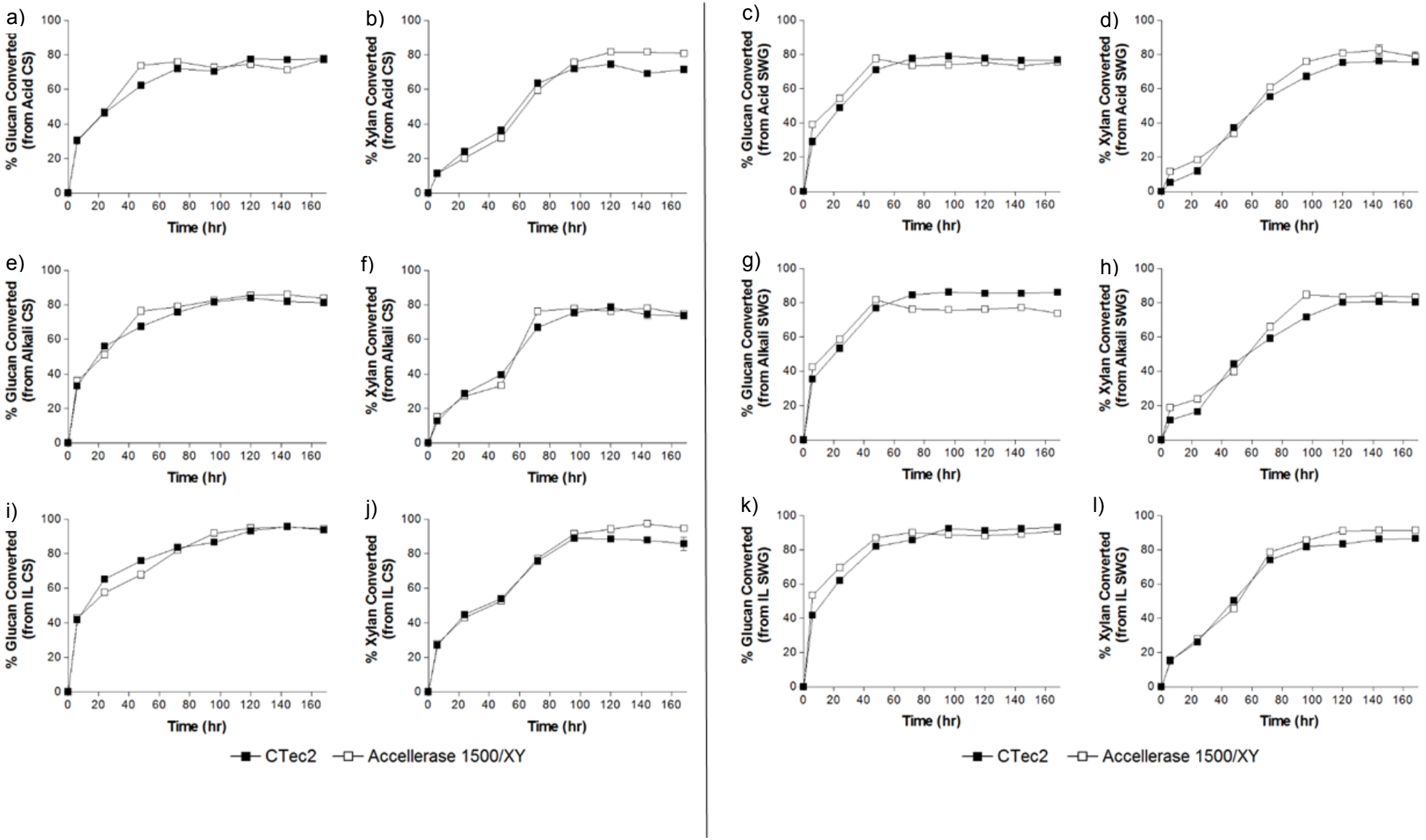

Figure S5. **Commercial enzyme preparations (CTec2 and Accellerase 1500/XY) tested on various pretreatments of corn stover (CS) and switchgrass (SWG). a-b)** Acid-treated corn stover, **c-d)** Acid-treated switchgrass, **e-f)** Alkali-treated corn stover, **g-h)** Alkali-treated switchgrass, **i-j)** Ionic-liquid-treated corn stover, **k-l)** Ionic-liquid-treated switchgrass. For **a, c, e, g, i, k,** the percentage of glucan converted is shown. For **b, d, f, h, j, l,** the percentage of xylan converted is shown.

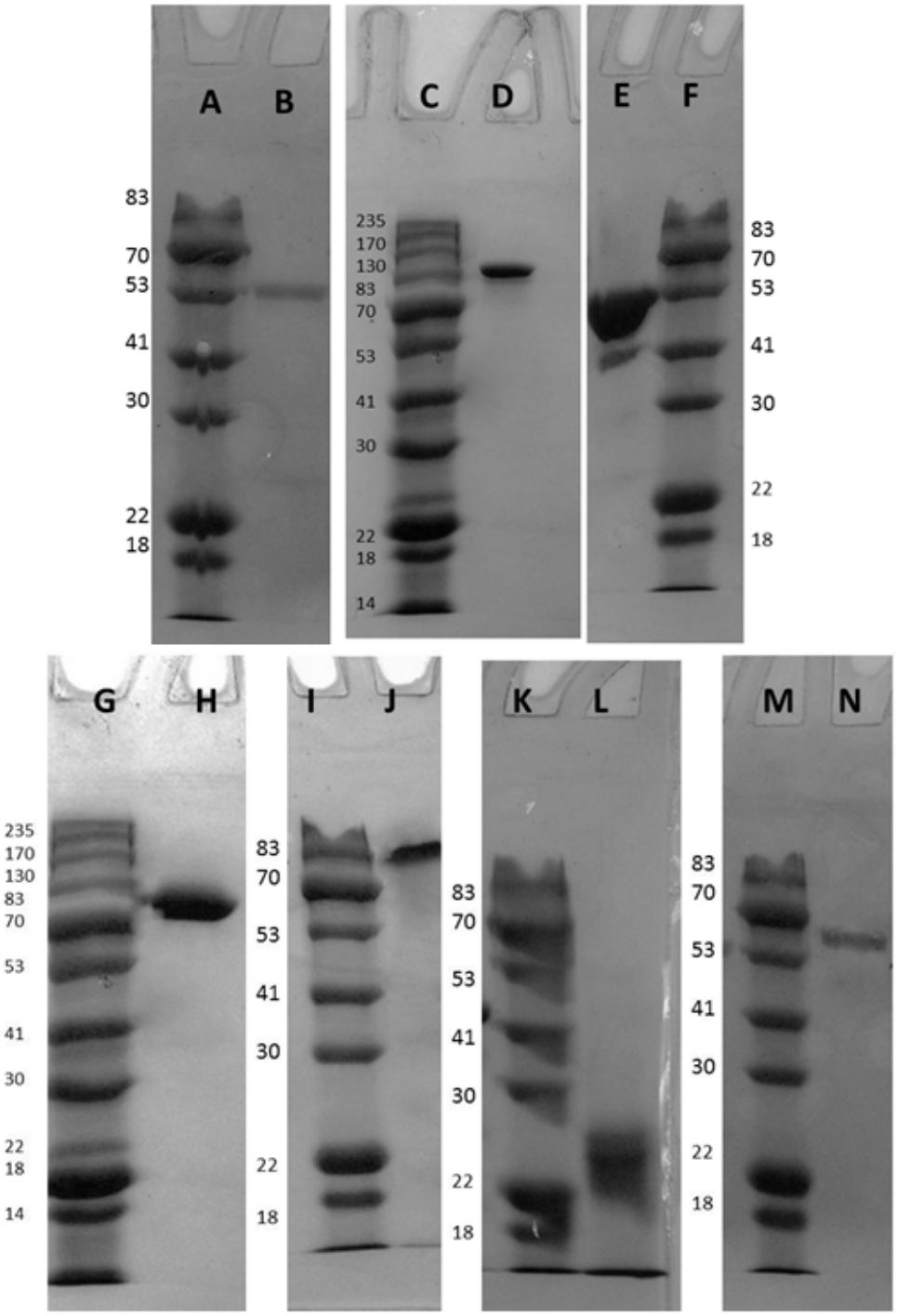

Figure S6. SDS-PAGE analysis of proteins. 12.5% SDS-PAGE analysis of recombinant proteins. *Lane A, C, F, G, I, K,* and *M*: Pre-stained Protein Ladder (Caisson Labs, Smithfield, Utah). *Lane B*: Cel6A, ~55 kDa; *Lane D*: Cel48, ~86 kDa; *Lane E*: EG5, ~49 kDa; *Lane H*: BGL1, ~75 kDa; *Lane J*: BGL3, ~80 kDa; *Lane L*: XYL11, ~25 kDa; *Lane N*: Swol, ~67 kDa. Protein molecular weights shown are consistent with the predicted protein size with linker and double-histidine tag.

Table S2. Properties of enzymes with exoglucanase activity All values listed are from enzymatic activities against Avicel.
"-", not reported in the study. Rows of anaerobic fungi are highlighted.

Origin	Protein Name (Annotation)	Specific Activity (U/mg)	Kinetics Km (mg/mL)	Kinetics Vmax (U/mg)	Optimal pH	pH Stability	Optimal Temp. (°C)	Temp. Stability (°C)	Other Activities	Ref.
Orpinomyces sp. strain C1A	Cel6A	2.03	0.00476	73.5	5	4-10	39	4-50	Cellobiohydrolase	This Study
	Cel48	0.20	1.257	0.218	5	4-9	39	4-60	Cellobiohydrolase Endoglucanase	This Study
Aspergillus nidulans	Exo-I	0.348	50	0.8	5.5	-	50	-	None	[1]
	Exo-II	0.785	38.4	1.3	-	-	-	-	None	[1]
	Exo-III	0.296	37.7	0.2	-	-	-	-	None	[1]
Chrysosporium lucknowense	EG25	0.05	-	-	4.5-6	5-8.5	60-70	60-75	Endoglucanase	[2]
	EG28	0.02	-	-	4.5-6	5-7	60-70	60-75	Endoglucanase Xylanase	[2]
	EG44	0.06	-	-	4.5-6	5-7	60-70	60-75	Endoglucanase Xylanase	[2]
	EG47	0.07	-	-	4.5-6	5-8.5	60-70	60-75	Endoglucanase Xylanase	[2]
	EG51	0.19	-	-	4.5-6	5-7	60-70	60-75	Endoglucanase Xylanase	[2]
	EG60	0.08	-	-	4.5-6	5-7	60-70	60-75	Endoglucanase β-glucosidase	[2]
	CBHI	0.19	-	-	4.5-6	5-7	60-70	60-75	Cellobiohydrolase Endoglucanase β-glucosidase	[2]
	CBHII	0.08	-	-	4.5-6	5-7	60-70	60-75	Endoglucanase Cellobiohydrolase	[2]
Fusarium oxysporum	Xylanase	0.02	-	-	7.4	6-8	50	to 50	Endoglucanase Xylanase	[3]
Fusarium solani	Cellulase	1.34	-	-	5	5-7	65	to 65	β-glucosidase	[4]
Gloeophyllum trabeum	Cel5A	0.0045	-	-	-	-	-	-	Endoglucanase	[5]
	Xyn10A	0.0018	-	-	-	-	-	-	Xylanase	[5]
Humicola grisea	Exoglucanase I	0.00128	-	-	6-8	4-14	55-70	30-75	β-glucosidase Endoglucanase Cellobiohydrolase	[6]
Neocallimastix patricianum	CelA	1.1	-	-	6	5.2-11.3	50	to 70	Endoglucanase	[7]
	CelA	26.8	-	-	-	-	-	-	Endoglucanase	[8]
	CelB	1.4	-	-	-	-	-	-	Endoglucanase Cellobiohydrolase	[8]
	CelC	0.9	-	-	-	-	-	-	Endoglucanase	[8]
	CelD	0.18	-	-	-	-	-	-	Endoglucanase	[9]

									Cellobiohydrolase	
Orpinomyces joyonii	CelA	0.12	-	-	4	3-7	40	to 50	Endoglucanase	[10]
Orpinomyces sp. PC-2	CelA	0.062	-	-	4.8	4.3-6.8	50	to 40	Endoglucanase	[11]
	CelC	0.113	-	-	5.6-6.2	4.6-7	40	to 40	Endoglucanase	[11]
Orpinomyces sp. Y102	CelC7	20.27	-	-	6.5	4-11	40	30-50	Endoglucanase	[12]
Penicillium brasilianum	EGa	0.04	-	-	-	-	-	-	Endoglucanase	[13]
	EGb1	0.02	-	-	-	-	-	-	Endoglucanase	[13]
	EGb2	0.06	-	-	-	-	-	-	Endoglucanase	[13]
	CBHa	0.11	-	-	-	-	-	-	Cellobiohydrolase	[13]
	CBHb	0.07	-	-	-	-	-	-	Cellobiohydrolase	[13]
Penicillium funiculosum	Cellulase	-	172	-	5	-	50	to 60	β-glucosidase Cellobiohydrolase	[14]
Pichia pastoris	EXG1	1.07	3.5	192	-	-	-	-	β-glucosidase β-xylosidase	[15]
Piromyces rhizinflatus	CbhYW23-2	6.2	-	-	6	-	46.4	to 50	Endoglucanase	[16]
Piromyces sp. E2	Cel6A	0.0053	-	-	-	-	-	-	Cellobiohydrolase	[17]
Termitomyces	Cellulase IF	24.6	-	-	4.4	3-5.5	55	to 42	Endoglucanase	[18]
Trichoderma harzianum	EXG	49.2	-	-	5.5	-	28	-	β-glucosidase	[19]
	Cellulase	130	-	-	4-5	-	37-40	to 40	Endoglucanase None	[20]
Trichoderma neapolitana	CelB	0.71	-	-	6-6.6	-	106	to 106	Cellobiohydrolase	[21]
Trichoderma reesei	CBHII	0.001	-	-	-	-	-	-	Cellobiohydrolase	[22]
	EGI	0.4	-	-	-	-	-	-	Endoglucanase	[22]
	XYL9	0.00005	-	-	-	-	-	-	Xylanase	[22]
	XYL5.5	0.00005	-	-	-	-	-	-	Xylanase	[22]
	CBHI	0.0105	-	-	4	2-10	60	to 50	Cellobiohydrolase	[23]
	CBHII	0.0205	-	-	5	3-8	55	to 50	Cellobiohydrolase	[23]
	EGI	0.014	-	-	4	2-8	60	to 45	Endoglucanase Xylanase Cellobiohydrolase	[23]
	EGIII	0.0116	-	-	4	2-6	70	to 55	Endoglucanase	[23]
	CBH I	0.014	-	-	-	-	-	-	Cellobiohydrolase	[24]
	CBH II	0.027	-	-	-	-	-	-	Cellobiohydrolase	[24]
Trichoderma viride	Cel7B (EG I)	0.8	-	-	-	-	-	-	Cellobiohydrolase Endoglucanase	[25]
	Cel2A (EG III)	0.4	-	-	-	-	-	-	Cellobiohydrolase Endoglucanase	[25]
	Cel61A (EG IV)	0.3	-	-	-	-	-	-	Cellobiohydrolase Endoglucanase	[25]
	Cel7A (CBH I)	0.3	-	-	-	-	-	-	Cellobiohydrolase Endoglucanase	[25]
	Cel6A (CBH II)	0.7	-	-	-	-	-	-	Cellobiohydrolase Endoglucanase	[25]

	Cel6B (CBH IIb)	0.2	-	-	-	-	-	-	Cellobiohydrolase Endoglucanase	[25]
Anaerocellum thermophilum	CelA	0.055	-	-	5-6	-	85-95	-	Endoglucanase	[26]
Bacillus amyoliquefaciens	Cellulase	14	-	-	7	4-9	50	40-80	Endoglucanase Cellobiohydrolase Xylanase	[27]
Bacillus sp.	CH43	0.001	-	-	5-6.5	6-10	65	to 50	Endoglucanase	[28]
	HR68	0.0063	-	-	5-6.5	6-8	70	to 50	Endoglucanase	[28]
	E-H	1.1	-	-	-	-	-	-	Endoglucanase	[29]
	E-L	1.1	-	-	-	-	-	-	Endoglucanase	[29]
	Cel	0.014	-	-	-	-	-	-	Cellobiohydrolase	[30]
Bacillus sphaericus	Cellulase	5.76	-	-	8	7-10.5	60	to 70	Endoglucanase	[31]
Bacillus subtilis	Cellulase	2380	-	-	6	6-7.5	50-60	to 50	Endoglucanase	[32]
Caldibacillus cellulovorans	CMCase	1.7	-	-	6.5-7	-	80	to 70	Endoglucanase	[33]
Cellulomonas fimi	Cex	0.00016	-	-	-	6-9	-	-	Endoglucanase	[34-36]
	CenA	0.00218	-	-	-	-	-	-	Endoglucanase	[36]
	CenB	0.00222	-	-	-	-	-	-	Endoglucanase	[36]
	CenC	0.00099	-	-	-	-	-	-	Endoglucanase	[36]
	CenD	0.00242	-	-	-	-	-	-	Endoglucanase	[36]
Clostridium cellulolyticum	CelF	0.0134	2.4	-	5.5-6	-	55	20-45	Endoglucanase	[37]
Clostridium stercorarium	Avicelase II	0.041	-	-	5-6	4.5-7	75	65-80	None	[38]
Clostridium thermocellum	CelJ	0.0098	-	-	6	5-10	60	to 70	None	[39]
	CelS	0.019	-	-	5-6	-	70	-	None	[40]
	Endoglucanase	0.17	-	-	5.2	4.5-7	62	to 70	Endoglucanase	[41]
Pseudomonas fluorescens	Cellulase	6.9	5.3	10	6.5-7	5.8	35	to 50	None	[42]
Ruminococcus flavefaciens	Exo A	0.049	-	-	5	5-5.5	-	-	None	[43]
Streptomyces flavogriseus	Exoglucanase	0.019	-	-	-	-	-	-	None	[44]
Macrotermes mulleri	Cellulase IT	21	-	-	4.4	3-5.5	55	to 42	Endoglucanase	[18]
	Cellulase II	36.2	-	-	4.3-4.5	3-5.5	37	to 42	Endoglucanase	[18]

Table S3. Properties of enzymes with cellobiohydrolase activity. Table is organized by origin, fungal, then bacterial, then plant. All values listed are from enzymatic activities against *p*-nitrophenyl-β-D-cellobioside, PNPC. "-", not reported in the study. Rows of anaerobic fungi are highlighted.

Origin	Protein Name (Annotation)	Specific Activity (U/mg)	Kinetics Km (mM)	Kinetics Vmax (U/mg)	Optimal pH	pH Stability	Optimal Temp. (°C)	Temp. Stability (°C)	Other Activities	Ref.
Orpinomyces sp. strain C1A	Cel6A	2.82	0.228	3.27	5	4-10	39	4-50	Exoglucanase	This Study
	Cel48	0.36	8.98	0.357	5	4-9	39	4-60	Exoglucanase Endoglucanase	This Study
Acremonium persicinum	β-glucosidase	0.00075	0.91	-	5.5	-	-	-	β-glucosidase	[45]
Candida peltata	β-glucosidase	36.7	66	75	5	3.5-6	50	25-45	β-glucosidase	[46]
Chaetomium cellulolyticum	Xylanase 3	0.1	-	-	6-7	-	50	-	Xylanase Arabinosidase	[47]
Gloeophyllum trabeum	Cel5A	0.065	-	-	6-7	-	50	-	Endoglucanase Exoglucanase Xylanase	[5]
	Xyn10A	12	-	-	-	-	-	-	Endoglucanase Exoglucanase Xylanase	[5]
	Cel12A	0.069	-	-	-	-	-	-	Endoglucanase Exoglucanase Xylanase	[5]
Humicola grisea	Endoglucanase I	0.69	-	-	6-7	4-12	40-60	30-65	Exoglucanase Endoglucanase	[6]
	Endoglucanase II	0.8	-	-	5-6	6-10	55	30-55	Exoglucanase Endoglucanase	[6]
	Exoglucanase I	8.09	-	-	6-8	4-14	55-70	30-75	β-glucosidase Endoglucanase	[6]
	β-glucosidase 1	0.91	-	-	4-5	4-12	60-65	30-60	Exoglucanase β-glucosidase β-galactosidase	[6]
	β-glucosidase 2	2.97	-	-	6-8	4-12	60-65	30-50	β-xylosidase β-glucosidase β-galactosidase	[6]
	β-glucosidase 3	3.19	-	-	6-8	4-12	60-65	30-50	β-xylosidase β-glucosidase β-galactosidase	[6]
	β-glucosidase 4	1.8	-	-	6-7	4-12	50-55	30-50	β-xylosidase β-glucosidase β-galactosidase	[6]
	β-glucosidase 5	3.45	-	-	6	4-12	60	30-55	β-xylosidase β-glucosidase	[6]

	β-glucosidase 6	3.72	-	-	6-7	4-12	65-70	30-65	β-galactosidase β-xylosidase β-glucosidase	[6]
	BGL 4	1.8	-	-	6	6-11	55	to 50	β-galactosidase β-xylosidase β-glucosidase	[48]
Neocallimastix patricianum	CelB	1.31	-	-	-	-	-	-	β-galactosidase Endoglucanase	[8]
	CelD	0.169	-	-	-	-	-	-	Exoglucanase Endoglucanase Exoglucanase	[9]
Orpinomyces joyonii	CelB2	4.9	-	-	5.5	5-7.5	40	to 50	Endoglucanase	[49]
Orpinomyces sp. PC-2	CelE	0.2	-	-	-	-	-	-	Endoglucanase	[50]
Paecilomyces thermophile	β-glucosidase	49.1	0.65	272	6.2	5-8.5	75	65-70	β-glucosidase Exoglucanase	[51]
Penicillium brasilianum	EGa	0.34	-	-	-	-	-	-	Exoglucanase	[13]
	EGb1	0.38	-	-	-	-	-	-	Endoglucanase Exoglucanase	[13]
	EGb2	1.16	-	-	-	-	-	-	Endoglucanase Exoglucanase	[13]
	CBHa	2	-	-	-	-	-	-	Endoglucanase Exoglucanase	[13]
	CBHb	0.98	-	-	-	-	-	-	Endoglucanase Exoglucanase	[13]
Penicillium funiculosum	Cellobiohydrolase	0.56	-	-	4-5.5	2.5-5.5	60	to 70	Endoglucanase Exoglucanase	[52]
	Cellulase	-	10	-	5	-	50	to 60	β-glucosidase Exoglucanase	[14]
Phanerochaete chrysosporium	β-glucosidase	33	-	-	4-5.2	4-8	25	to 45	β-glucosidase	[53]
Piromyces equi	Cel5A	0.1	-	-	5.1	5.1-6.4	45	to 50	Endoglucanase	[54]
Sporotrichum thermophile	β-glucosidase I	1	0.83	-	5.4	4-6.5	65	to 65	β-glucosidase	[55]
Stachybotrys sp.	β-glucosidase p21	-	2.22	59	5	5-7	50	to 60	β-glucosidase	[56]
Trichoderma koningii	β-glucosidase	6.6	1.18	-	4-5	4-6	45	to 65	β-glucosidase	[57]
	β-glucosidase II	9.4	0.86	-	4-5	4-6	45	to 65	β-glucosidase	[57]
Trichoderma reesei	BGL 2	0.89	-	-	6	6-11	45	to 45	β-glucosidase	[48]
	CBH I	0.355	-	-	4	2-10	60	to 50	β-galactosidase Endoglucanase	[23]
	EG I	9.19	-	-	4	2-8	60	to 45	β-glucosidase β-glucosidase	[23]
	BGL I	0.894	-	-	4	5-9	70	to 55	Endoglucanase β-glucosidase	[23]
	CBH I	0.00104	-	-	-	-	-	-	β-glucosidase	[58]
	CBH I	0.0103	-	-	-	-	-	-	Endoglucanase Endoglucanase	[59]

	CBH II	0.0064	-	-	-	-	-	-	β-glucosidase Endoglucanase	[59]
	EG I	0.133	-	-	-	-	-	-	β-glucosidase Endoglucanase	[60]
	EG II	0.0075	-	-	-	-	-	-	Exoglucanase Endoglucanase	[60]
	CBH I	0.46	-	-	-	-	-	-	Exoglucanase Exoglucanase	[60]
	CBH II	0.048	-	-	-	-	-	-	Exoglucanase	[60]
Trichoderma viride	Cel7A (CBH I)	2.5	-	-	-	-	-	-	Exoglucanase	[25]
	Cel6A (CBH II)	5.7	-	-	-	-	-	-	Exoglucanase	[25]
	Cel6B (CBH IIb)	1.1	-	-	-	-	-	-	Exoglucanase	[25]
Bacillus amyoliquefaciens	Cellulase	24.6	-	-	7	4-9	50	40-80	Endoglucanase Exoglucanase Xylanase β-glucosidase	[27]
Bacillus sp.	Cel	2.28	-	-	-	-	-	-	Exoglucanase	[30]
	E-H	0.3	-	-	-	-	-	-	Exoglucanase	[29]
	E-L	0.6	-	-	-	-	-	-	Exoglucanase	[29]
Cellulomonas fimi	Exg	3	0.641	-	6	5-9	60	60-75	Exoglucanase	[61]
Clostridium stercorarium	β-glucosidase	10.1	33	-	5.5	5-7	65	to 75	β-glucosidase Exoglucanase	[62]
Clostridium thermocellum	β-glucosidase	33.3	-	-	6-6.5	5.5-7.5	60	to 68.5	β-glucosidase	[63]
	CelJ	0.0041	-	-	6	5-10	60	to 70	Exoglucanase	[39]
Ruminococcus flavefaciens	Exo A	0.298	-	-	5	4.5-5.5	-	-	Exoglucanase	[43]
Thermomonospora fusca	E1	0.04	-	-	-	-	-	-	Endoglucanase	[58]
	E5	0.0148	-	-	-	-	-	-	Endoglucanase	[58]
	E5cd	0.0144	-	-	-	-	-	-	Endoglucanase	[58]
	E6	0.00004	-	-	-	-	-	-	Endoglucanase	[58]
Thermatoga maritima	Cellulase I	0.035	-	-	6-7.5	-	95	to 80	Exoglucanase	[64]
	Cellulase II	0.015	-	-	6-7.5	-	95	to 80	Exoglucanase	[64]
	CelA	7.4	-	-	5	4-7	85-90	to 95	Exoglucanase	[65]
	CelB	0.05	-	-	7	5-9	85-90	to 95	Exoglucanase	[65]
Thermatoga neapolitana	CelA	69.2	0.97	69	6	-	95	to 95	Exoglucanase	[21]
	CelB	18.4	0.3	18	6-6.6	-	106	to 106	Exoglucanase	[21]

Table S4. Properties of enzymes with endoglucanase activity. Table is organized by origin, fungal, then bacterial, then plant. All values listed are from enzymatic activities carboxymethyl cellulose (CMC), unless otherwise noted. "-", not reported in the study. Rows of anaerobic fungi are highlighted. "*" value calculated with CellG3 as substrate.

Origin	Protein Name (Annotation)	Specific Activity (U/mg)	Kinetics Km (mg/mL)	Kinetics Vmax (U/mg)	Optimal pH	pH Stability	Optimal Temp. (°C)	Temp. Stability (°C)	Other Activities	Ref.
Orpinomyces sp. strain C1A	EG5	9.96 *209	0.00027 *0.000004	622 *775	7	3-8	50	4-50	β-glucosidase Xylanase	This Study
	Cel48	*0.045	*30.1	*0.05	5	4-9	39	4-60	Exoglucanase Cellobiohydrolase	This Study
Aspergillus aculeatus	XEG	-	3.6	260	3.4	3-3.8	30	to 50	None	[66]
Aspergillus nidulans	Endo-I	9.15	5	15	6	-	65	-	None	[1]
	Endo-II	8.26	4	12	5	-	50	-	None	[1]
Aspergillus niger	Cellulase	194	-	-	6-7	5-10	70	to 60	None	[67]
	Cellulase	45.2	14.5	85	3.8-4	1-9	45	to 25	None	[68]
	Cellulase	116.8	0.086	-	4	5-8	45-50	to 70	None	[69]
Chaetomonium cellulolyticum	Xylanase 1	0.06	-	-	6-7	-	50	-	Exoglucanase Xylanase	[47]
	Xylanase 2	0.05	-	-	6-7	-	50	-	Exoglucanase Xylanase	[47]
	Xylanase 3	0.03	-	-	6-7	-	50	-	Exoglucanase Xylanase	[47]
Chrysosporium lucknowense	EG25	17	-	-	4.5-6	5-8.5	60-70	60-75	Exoglucanase	[2]
	EG28	11	-	-	4.5-6	5-7	60-70	60-75	Xylanase Exoglucanase	[2]
	EG44	59	-	-	4.5-6	5-7	60-70	60-75	Xylanase Exoglucanase	[2]
	EG47	14	-	-	4.5-6	5-8.5	60-70	60-75	Xylanase Exoglucanase	[2]
	EG51	52	-	-	4.5-6	5-7	60-70	60-75	Xylanase Exoglucanase	[2]
	EG60	12	-	-	4.5-6	5-7	60-70	60-75	Exoglucanase	[2]
	CBH I	0.2	-	-	4.5-6	5-7	60-70	60-75	Cellobiohydrolase Exoglucanase	[2]
	CBH II	1.1	-	-	4.5-6	5-7	60-70	60-75	Cellobiohydrolase Exoglucanase Xylanase	[2]
Cryptococcus sp. S-2	CSCMCase	248.7	-	-	3.5	5.5-7.5	40-50	to 90	None	[70]
Fusarium oxysporum	Xylanase	5	13.1	-	7.4	5.8-8.2	50	to 50	Xylanase Exoglucanase	[3]
Fusarium solani	Cellulase	4.75	-	-	5	5-7	65	to 65	β-glucosidase Cellobiohydrolase Exoglucanase	[4]

Gloeophyllum trabeum	Cel5A	120	-	-	-	-	-	-	Xylanase Exoglucanase	[5]
	Xyn10A	0.95	-	-	-	-	-	-	Xylanase Exoglucanase	[5]
	Cel12A	42	-	-	-	-	-	-	Xylanase Exoglucanase	[5]
Humicola grisea	Endoglucanase 1	9.06	-	-	6-7	4-12	40-60	30-65	None	[6]
	Endoglucanase 2	24.1	-	-	5-6	6-10	55	30-55	None	[6]
Neocallimastix patricianum	CelA	108	-	-	6	5.2-11.3	50	to 70	Exoglucanase	[7]
	CelA	15.1	-	-	-	-	-	-	Exoglucanase	[8]
	CelB	53.6	-	-	-	-	-	-	Exoglucanase Cellobiohydrolase	[8]
	CelC	20.6	-	-	-	-	-	-	Exoglucanase	[8]
	CelD	4.9	-	-	-	-	-	-	Exoglucanase Cellobiohydrolase	[9]
Orpinomyces joyonii	Cellulase	203	0.5	-	5.5	5-7.5	40	to 50	Exoglucanase Cellobiohydrolase Xylanase	[49]
	CelB2	203	-	-	5.5	5-7.5	40	to 50	Cellobiohydrolase	[49]
	CelA	13.2	-	-	4	3-7	40	to 50	Exoglucanase	[10]
Orpinomyces sp. PC-2	CelE	3.2	-	-	-	-	-	-	Cellobiohydrolase	[50]
	CelB	2.9	-	-	-	-	-	-	None	[50]
	CelE	72.5	-	-	6	5.5-7.5	45	40-55	None	[71]
	CelA	1.2	-	-	4.8	4.3-6.8	50	to 40	Exoglucanase	[11]
	CelC	1.1	-	-	5.6-6.2	4.6-7	40	to 40	Exoglucanase	[11]
Orpinomyces sp. Y102	CelC7	25.96	-	-	6.5	4-11	40	30-50	Exoglucanase	[12]
Penicillium brasilianum	EGa	39.8	-	-	-	-	-	-	Exoglucanase	[13]
	EGb1	54	-	-	-	-	-	-	Exoglucanase	[13]
	EGb2	36.3	-	-	-	-	-	-	Exoglucanase	[13]
Penicillium funiculosum	Cellobiohydrolase	0.05	-	-	4-5.5	2.5-5.5	60	to 70	Cellobiohydrolase	[52]
Piromyces equi	Cel5A	3.2	-	-	5.1	5.1-6.4	45	to 50	Cellobiohydrolase	[54]
	Cel45A	42.5	-	-	6.5	5.2-7.9	60	to 65	None	[54]
Piromyces rhizinflatus	CbhYW23-2	6.0	-	-	6	-	46.4	to 50	Endoglucanase	[16]
Termitomyces sp.	Cellulase IF	378	-	-	4.4	2.8-5.5	55	to 42	Exoglucanase	[18]
Thermoascus aurantiacus	Cellulase I	0.525	3.9	6.3	5	6-8	75	to 65	None	[72]
	Cellulase II	0.0031	1.2	1.1	5	2-12	60	to 65	None	[72]
	Cellulase III	0.24	1.9	33	5	6-8	65	to 65	None	[72]
Trichoderma harzianum	Endoglucanase	312.5	-	-	5-5.5	-	40	to 35	None	[20]
	EG	0.63	-	-	5.5	-	-	-	None	[19]
Trichoderma reesei	CBHI	0.0021	-	-	-	-	-	-	Cellobiohydrolase Exoglucanase β-glucosidase Xylanase	[58]

	CBHII	0.0014	-	-	-	-	-	-	Cellobiohydrolase Exoglucanase β-glucosidase Xylanase	[58]
	CBHI	0.2	-	-	-	-	-	-	Cellobiohydrolase Exoglucanase β-glucosidase Xylanase	[59]
	CBHII	21.5	-	-	-	-	-	-	Cellobiohydrolase Exoglucanase β-glucosidase Xylanase	[59]
	EG I	59.8	-	-	4	2-8	60	to 45	Xylanase Exoglucanase β-glucosidase β-xylosidase	[23]
	EG III	30.7	-	-	4	2-6	70	to 55	None	[23]
	EG V	9.22	-	-	4	2-6	50-65	to 80	None	[23]
Trichoderma viride	Cel7B (EG I)	7.6	-	-	-	-	-	-	Exoglucanase Cellobiohydrolase	[25]
	Cel2A (EG III)	2.8	-	-	-	-	-	-	Exoglucanase Cellobiohydrolase	[25]
	Cel61A (EG IV)	1.9	-	-	-	-	-	-	Exoglucanase Cellobiohydrolase	[25]
	Cel6A (CBH II)	0.1	-	-	-	-	-	-	Exoglucanase Cellobiohydrolase	[25]
	CMCase	0.258	0.88	3.5	4	3-7	50	30-70	None	[73]
	Cellulase	105	68	148	6.5	6.5-8	55	45-55	None	[74]
Anaerocellum thermophilum	CelA	1.758	-	-	5-6	-	85-95	-	Exoglucanase Xylanase	[26]
Bacillus sp.	CH43	0.0062	1.5	0.93	5-6.5	6-10	65	to 50	Exoglucanase	[28]
	HR68	0.0159	1.7	1.7	5-6.5	6-8	70	to 50	Exoglucanase	[28]
	Cellulase	58.9	0.48	-	9	6-12	40	to 60	None	[75]
	Cellulase	49.4	11.4	135	8.6-9	5-11	45	to 60	β-glucosidase Cellobiohydrolase Exoglucanase Xylanase	[76]
	E-H	23.5	-	-	-	-	-	-	Exoglucanase Cellobiohydrolase	[29]
	E-L	43.8	-	-	-	-	-	-	Exoglucanase Cellobiohydrolase	[29]
	Cellulase	71	-	-	10	6-10	50	to 60	None	[77]
	Cel	128	-	-	-	-	-	-	Cellobiohydrolase	[30]
	E-I	0.12	-	-	6	5-8	60	to 80	None	[78]

	E-II	60	-	-	7	7-10	50	to 60	None	[78]
	E-III	59	-	-	7	6-10	50	to 60	None	[78]
	Cellulase	246	-	-	6	5-7	50	to 50	None	[79]
Bacillus amyoliquefaciens	Cellulase	100	-	-	7	4-9	50	40-80	Exoglucanase Cellobiohydrolase	[27]
Bacillus pumilus	Cellulase	0.079	-	-	6	5-9	60	30-70	Exoglucanase β-glucosidase	[80]
Bacillus sphaericus	Cellulase	38.4	-	-	8	7-10.5	60	to 70	β-glucosidase	[31]
Bacillus subtilis	CelDR	0.3	-	-	6.5	-	50	to 75	None	[81]
	Cellulase	7001	-	-	6	6-7	50-60	to 50	Exoglucanase	[32]
Caldibacillus cellulovorans	CMCase	30.6	3.4	44.7	6.5-7	-	80	to 70	None	[33]
Cellulomonas fimi	Cex	0.01	-	-	-	6-9	-	-	Exoglucanase	[34-36]
	CenA	0.760	-	-	-	-	-	-	β-glucosidase Cellobiohydrolase Exoglucanase	[36]
	CenB	0.928	-	-	-	-	-	-	β-glucosidase Cellobiohydrolase Exoglucanase	[36]
	CenC	1.016	-	-	-	-	-	-	Exoglucanase	[36]
	CenD	0.01	-	-	-	-	-	-	Exoglucanase	[36]
	Exg	20	3.18	-	6	5-9	-	60-75	Exoglucanase Cellobiohydrolase	[61]
Cellulomonas sp.	Cellulase I	162	-	-	-	-	-	-	None	[82]
	Cellulase CA	136	-	-	-	-	-	-	None	[82]
	Cellulase CB	9.7	-	-	-	-	-	-	None	[82]
Clostridium cellulolyticum	CelF	0.0014	-	-	5.5-6	-	55	20-45	Exoglucanase	[37]
Clostridium thermocellum	CelJ	13.1	4.06	164	6	5-10	60	to 70	Exoglucanase Cellobiohydrolase	[39]
	Endoglucanase	65.1	-	-	5.2	4.5-7	62	to 70	Exoglucanase	[41]
Marinobacter sp.	CMCase	2548.75	-	-	9	4-12	27-35	-	None	[83]
Salinivibrio sp.	Cellulase	32.4	3.03	143	7.5	6.5-8.5	35	10-40	None	[84]
Sinorhizobium fredii	CMCase	3.822	-	-	7	6-9	35	30-45	None	[85]
Thermomonospora curvata	Cellulase	0.3	3.5	213	6	5-8	65	to 65	None	[86]
Thermomonospora fusca	E1	5.41	-	-	-	-	-	-	None	[58]
	E2	0.369	-	-	-	-	-	-	None	[58]
	E2cd	0.344	-	-	-	-	-	-	None	[58]
	E3	0.0013	-	-	-	-	-	-	None	[58]
	E4	0.122	-	-	-	-	-	-	None	[58]
	E5	2.840	-	-	-	-	-	-	None	[58]
	E5cd	2.480	-	-	-	-	-	-	None	[58]
	E6	0.0642	-	-	-	-	-	-	None	[58]
Thermatoga maritima	Cellulase I	1.2	-	-	6-7.5	-	95	to 80	Exoglucanase Cellobiohydrolase	[64]

	Cellulase II	1.5	-	-	6-7.5	-	95	to 80	Exoglucanase	[64]
	CelA	302	-	-	5	4-7	85-90	to 95	Cellobiohydrolase Exoglucanase	[65]
	CelB	0.89	-	-	7	5-9	95	to 95	Cellobiohydrolase Exoglucanase	[65]
Thermatoga neapolitana	CelA	1219	0.25	1219	6	-	95	to 95	Cellobiohydrolase β-glucosidase	[21]
	CelB	1536	0.22	1536	6-6.6	-	106	to 106	Cellobiohydrolase β-glucosidase	[21]
Ergates faber	Cellulase A	30	20	-	4-4.7	-	37	to 55	Cellobiohydrolase None	[87]
	Cellulase B	56	28	-	5.2	-	37	to 45	None	[87]
	Cellulase C	157	6	-	5.2	-	37	to 60	None	[87]
Macrotermes mulleri	Cellulase IT	360	-	-	4.4	2.8-5.5	55	to 42	Exoglucanase	[18]
	Cellulase II	274	-	-	4.3-4.5	2.8-5.5	37	to 42	Exoglucanase	[18]
Panesthia cribrata	EG1	22.2	9.4	1850	-	-	-	-	None	[88]
	EG2	88.3	6.8	3440	-	-	-	-	None	[88]
Panesthia hilaris	Cellulase	150	-	-	5.5	4-7	-	-	None	[89]
Phaseolus vulgaris	Cellulase 4.5	17	-	-	5.7-6.2	6-9	35-43	to 30	None	[90]
	Cellulase 4.8	814	-	-	4.8-5.6	6.5-8	45-60	to 36	None	[90]

Table S5. Properties of enzymes with β-glucosidase activity. Table is organized by origin, fungal, then bacterial, then plant. All values listed are from enzymatic activities against *p*-nitrophenyl-β-D-glucopyranoside, PNPG. "-", not reported in the study. Rows of anaerobic fungi are highlighted.

Origin	Protein Name (Annotation)	Specific Activity (U/mg)	Kinetics Km (mM)	Kinetics Vmax (U/mg)	Optimal pH	pH Stability	Optimal Temp. (°C)	Temp. Stability (°C)	Other Activities	Ref.
Orpinomyces sp. strain C1A	BGL1	1.063	0.164	5.4	7	5-9	39	4-50	None	This Study
	BGL3	0.8	0.275	1.6	6	6-8	39	4-39	β-xylosidase	This study
	EG5	0.29	84	0.45	7	3-8	50	4-50	Endoglucanase Xylanase	This Study
	XYL11	0.22	0.216	0.28	5	3-9	50	4-60	Xylanase	This Study
	Bgxg1	73.4	0.000013	769	6	4-12	39	4-70	β-xylosidase β-galactosidase Xylanase	[91]
Acremonium persicinum	β-glucosidase	0.0183	0.3	-	5.5	-	-	-	Cellobiohydrolase	[45]
Aspergillus fumigatus	β-xylosidase	0.76	-	-	4.5	2-8	75	to 65	β-xylosidase	[92]
	β-Glucosidase	1.03	-	-	4.5	2-8	65	to 60	β-xylosidase	[92]
Aspergillus nidulans	B-Gluco-I	4.52	0.24	8	5	-	65	-	None	[1]
	B-Gluco-II	0.55	0.12	0.7	6	-	35	-	None	[1]
Aspergillus niger	β-xylosidase	0.15	-	-	6.7-7	-	42	to 46	β-xylosidase	[93]
	β-xylosidase 1	0.2	-	-	-	-	-	-	β-xylosidase Arabinosidase	[94]
	β-xylosidase 2	0.3	-	-	-	-	-	-	β-xylosidase Arabinosidase	[94]
Aureobasidium sp.	β-xylosidase	15.6	-	-	3.5	3.5-9	80	to 80	β-xylosidase	[95]
Candida peltata	β-glucosidase	108	2.3	221	5	3.5-6	50	25-45	Cellobiohydrolase	[46]
Chrysosporium lucknowense	EG60	0.12	-	-	4.5-6	5-7	60-70	60-75	Endoglucanase	[2]
	CBH1	0.02	-	-	4.5-6	5-7	60-70	60-75	Cellobiohydrolase	[2]
Fusarium oxysporum	Xylanase	0.9	-	-	7.4	5.8-8.2	50	to 50	Xylanase Endoglucanase Exoglucanase	[3]
Fusarium solani	Cellulase	4.65	-	-	5	5.7	65	to 65	Cellobiohydrolase Endoglucanase Exoglucanase	[4]
Humicola grisea	Exoglucanase 1	1.14	-	-	6-8	4-14	55-70	30-75	Cellobiohydrolase Endoglucanase Exoglucanase	[6]
	β-glucosidase 1	85.7	0.16	64	4.5	4-12	60-65	30-60	Cellobiohydrolase β-galactosidase β-xylosidase	[6]
	β-glucosidase 2	12.5	0.25	21	6-8	4-12	60-65	30-50	Cellobiohydrolase β-galactosidase β-xylosidase	[6]

	β-glucosidase 3	12.6	0.22	23	6-8	4-12	60-65	30-50	Cellobiohydrolase β-galactosidase β-xylosidase	[6]
	β-glucosidase 4	8.34	0.34	8.7	6-7	4-12	50-55	30-50	Cellobiohydrolase β-galactosidase β-xylosidase	[6]
	β-glucosidase 5	17.9	0.56	18	6	4-12	60	30-55	Cellobiohydrolase β-galactosidase β-xylosidase	[6]
	β-glucosidase 6	33.4	0.12	40	6-7	4-12	65-70	30-65	Cellobiohydrolase β-galactosidase β-xylosidase	[6]
	BGL I	26.1	0.34	25	6	6-11	55	to 50	Cellobiohydrolase β-galactosidase	[48]
Neocallimastix frontalis	β-xylosidase	0.2	2.98	0.27	6.4	-	37	to 40	β-xylosidase Arabinosidase	[96]
	β-glucosidase	9.0	0.031	-	-	-	-	-	β-galactosidase Cellobiohydrolas	[97]
	β-glucosidase	15	0.55	-	6	5-8	50	to 40	None	[98]
Orpinomyces sp. strain PC-2	β-glucosidase	33.5	0.39	47.5	6.2	5-8	50	to 65	Cellobiohydrolase	[99]
Paecilomyces thermophila	β-glucosidase	97.2	0.27	780	6.2	5-8.5	75	65-70	Exoglucanase	[51]
Penicillium funiculosum	Cellulase	-	0.77	-	5	-	50	to 60	Cellobiohydrolase Exoglucanase	[14]
Phanerochaete chrysosporium	β-glucosidase	-	0.096	-	4-5.2	4-8	25	to 45	None	[53]
Pichia pastoris X-33	EXG1	37.5	-	-	-	-	-	-	β-xylosidase Exoglucanase	[15]
Piromyces communis	β-glucosidase	20	0.52	-	6	5-8	50	to 40	None	[98]
Piromyces sp. E2	β-glucosidase	0.25	1.0	66.5	5.7-6.3	-	47	to 37	Cellobiohydrolase	[100]
Sphaeromonas communis	β-glucosidase	46	0.51	-	6	5-8	50	to 40	None	[98]
Sporotrichum thermophila	β-glucosidase I	89	0.29	-	5.4	4-6.5	65	to 65	None	[55]
	β-glucosidase A	0.595	0.5	-	5.6	-	50	to 40	None	[101]
	β-glucosidase B	1.295	0.18	-	6.3	-	50	to 40	None	[101]
Stachybotrys sp.	β-glucosidase p21	0.33	0.27	78	5	5-7	50	to 60	None	[56]
Thermoascus aurantiacus	β-glucosidase	232	0.52	6500	5	6-8	70	to 75	None	[72]
	β-glucosidase	0.3	0.11	-	4.5	4.4-5.2	80	70-90	Cellobiohydrolase	[102]
Trichoderma harzianum	BGL	0.35	-	-	-	-	28	-	None	[19]
	β-xylosidase	0.28	-	-	4-4.5	-	60	-	β-xylosidase β-galactosidase Arabinosidase	[103]
Trichoderma koningii	β-glucosidase	16	0.37	-	4-5	4-6	45	to 65	Cellobiohydrolase	[57]
	β-glucosidase II	14	0.85	-	4-5	4-6	45	to 65	Cellobiohydrolase	[57]
Trichoderma reesei	BGL2	23.9	2.22	40	6	6-11	45	to 45	Cellobiohydrolase β-galactosidase	[48]

	BGLI	767.7	-	-	4	5-9	70	to 55	Cellobiohydrlase	[23]
	CBH I	5.5	-	-	-	-	-	-	Cellobiohydrolase	[59]
	CBH II	33	-	-	-	-	-	-	Endoglucanase Cellobiohydrolase	[59]
	CBH III	0.00001	-	-	-	-	-	-	Endoglucanase Cellobiohydrolase	[22]
	EG I	0.00005	-	-	-	-	-	-	Xylanase Mannanase β-xylosidase Exoglucanase Cellobiohydrolase	[22]
	XYL 9	0.00001	-	-	-	-	-	-	Xylanase Mannanase β-xylosidase Exoglucanase	[22]
	XYL 5.5	0.000001	-	-	-	-	-	-	Xylanase Mannanase β-xylosidase	[22]
Trichoderma viride T100-14	β-glucosidase	5.6	-	-	-	-	-	-	Cellobiohydrolase	[25]
Bacillus sp. KSM-S237	Cellulase	5.4	-	-	8.6-9	5-11	45	to 60	Endoglucanase Cellobiohydrolase Exoglucanase Xylanase	[76]
Bacillus pumilus EB3	Cellulase	0.038	-	-	6	5-9	60	30-70	Exoglucanase Endoglucanase	[80]
Bacillus sphaericus JS1	Cellulase	3.07	-	-	8	7-10.5	60	to 70	Endoglucanase	[31]
Cellulomonas fimi	CenA	1.6	-	-	-	-	-	-	Exoglucanase Endoglucanase Cellobiohydrolase	[36]
	Exg	0.9	-	-	6	5-9	-	60-75	Xylanase Endoglucanase Exoglucanase Cellobiohydrolase	[61]
Clostridium stercorarium	β-glucosidase	31.6	0.8	-	5.5	5-7	65	to 75	Cellobiohydrolase	[62]
Clostridium thermocellum	β-glucosidase	127	-	-	6-6.5	5.5-7.5	60	to 68.5	Cellobiohydrolase	[63]
Thermotoga neapolitana	CelA	0.01	-	-	6	-	95	to 95	Endoglucanase Cellobiohydrolase	[21]
	CelB	0.18	-	-	6-6.6	-	106	to 106	Endoglucanase Cellobiohydrolase	[21]
Panesthia cribrata	GD1	9	10.6	-	-	-	-	-	Endoglucanase	[88]
	GD2	3	13.8	-	-	-	-	-	Endoglucanase	[88]

Table S6. Properties of enzymes with β-xylosidase activity. Table is organized by origin, fungal, then bacterial, then plant. All values listed are from enzymatic activities against *p*-nitrophenyl-β-D-xylopyranoside, PNPX. "-", not reported in the study. Rows of anaerobic fungi are highlighted.

Origin	Protein Name (Annotation)	Specific Activity (U/mg)	Kinetics Km (mM)	Kinetics Vmax (U/mg)	Optimal pH	pH Stability	Optimal Temp. (°C)	Temp. Stability (°C)	Other Activities	Ref.
Orpinomyces sp. strain C1A	BGL3	0.06	50.6	0.068	6	6-8	39	4-39	β-xylosidase	This study
	Bgxg1	11.5	0.00485	127	6	4-12	39	4-70	β-glucosidase β-galactosidase Xylanase	[91]
Acremonium persicinum	β-glucosidase	0.002	-	-	5.5	-	-	-	β-glucosidase	[45]
Aspergillus awamori	β-xylosidase	34.1	0.003	476	6.5	-	70	to 70	Xylanase	[104]
Aspergillus carnonarious	β-xylosidase	3.29	0.198	3.64	4	3.5-6.5	60	to 50	Arabinosidase	[105]
Aspergillus fumigatus	β-xylosidase	27.5	2	-	4.5	2-8	75	to 65	β-glucosidase	[92]
	β-Glucosidase	1.03	-	-	4.5	2-8	65	to 60	β-glucosidase	[92]
Aspergillus nidulans	β-xylosidase	1.2	1.1	25.6	5	4-6	50	to 45	None	[106]
Aspergillus niger	β-xylosidase	5.2	0.22	-	6.7-7	-	42	to 46	β-glucosidase	[93]
	β-xylosidase 1	60.2	-	-	-	-	-	-	β-glucosidase Arabinosidase	[94]
	β-xylosidase 2	60.9	-	-	-	-	-	-	β-glucosidase Arabinosidase	[94]
Aspergillus phoenicis	β-xylosidase	821	2.36	-	4-4.5	4-6	75	to 60	None	[107]
Aspergillus pulverulentus	β-xylI	32	-	-	2.5-3.5	1.5-6.5	60	to 50	None	[108]
	β-xylII	12	-	-	4-5	1.5-6.5	60	to 50	None	[108]
Aureobasidium sp.	β-xylosidase	626	2	940	3.5	3.5-9	80	to 80	β-glucosidase	[95]
Aureobasidium pullulans	β-xylosidase	7.3	-	-	4.5	2-9.5	80	to 70	None	[109]
Chaetomonium cellulolyticum	Xylanase 3	0.03	-	-	6-7	-	50	-	Xylanase Arabinosidase Endoglucanase	[47]
Fusarium oxysporum	Xylanase	0.5	-	-	7.4	5.8-8.2	50	to 50	Xylanase Endoglucanase Exoglucanase	[3]
Fusarium proliferatum	β-xylosidase	53	0.77	-	4.5	-	60	-	None	[110]
Fusarium vercillioides	β-xylosidase	57	0.85	-	4.5	-	65	-	None	[111]
Humicola grisea	β-glucosidase 1	4.38	-	-	4.5	4-12	60-65	30-60	β-glucosidase β-galactosidase Cellobiohydrolase	[6]
	β-glucosidase 2	0.07	-	-	6-8	4-12	60-65	30-50	β-glucosidase β-galactosidase Cellobiohydrolase	[6]
	β-glucosidase 3	0.08	-	-	6-8	4-12	60-65	30-50	β-glucosidase β-galactosidase Cellobiohydrolase	[6]

	β-glucosidase 4	0.21	-	-	6-7	4-12	50-55	30-50	β-glucosidase β-galactosidase	[6]
	β-glucosidase 5	0.36	-	-	6	4-12	60	30-55	Cellobiohydrolase β-glucosidase β-galactosidase	[6]
	β-glucosidase 6	0.17	-	-	6-7	4-12	65-70	30-65	Cellobiohydrolase β-glucosidase β-galactosidase	[6]
	β-xylosidase	19.6	1.37	13	6.5	4-9	55	to 50	Cellobiohydrolase None	[112]
Neocallimastix frontalis	β-xylosidase	4.3	0.33	-	6.5	-	35	-	Xylanase	[113]
	β-xylosidase	0.9	2.98	0.27	6.4	-	37	to 40	β-glucosidase	[96]
	β-xylosidase	16	0.34	-	6.5	5-8	35	to 40	Arabinosidase None	[98]
Neocallimastix patriciarum	β-xylosidase I	30.4	0.59	38	6	5-8	50	45-60	Arabinosidase	[114]
	β-xylosidase II	8.7	0.13	8.9	6	5-7	40	25-45	None	[114]
Neurospora crassa	β-xylosidase	0.26	0.047	-	4.5-5	-	55	-	Cellobiohydrolase	[115]
Penicillium wortmanni	Xylosidase 1	22	4.2	42.6	3-4.5	-	55-65	-	None	[116]
	Xylosidase 2	40	2.3	73.2	3-4.5	-	55-65	-	None	[116]
	Xylosidase 3	61.5	1.0	88.2	3-4.5	-	55-65	-	None	[116]
	Xylosidase 4	30.5	3.3	106.6	3-4.5	-	55-65	-	None	[116]
Pichia pastoris X-33	EXG1	11.6	-	-	-	-	-	-	β-glucosidase β-galactosidase	[15]
Piromyces communis	β-xylosidase	28	0.4	-	6.0	5-8	39	to 40	None	[98]
Sphaeromonas communis	β-xylosidase	27	0.36	-	6.5	5-8	39	to 40	None	[98]
Talaomyces emersonii	Xyl I	3.0	0.13	-	2.5	-	60	-	None	[117]
	Xyl II	92.9	32.9	-	4.2	-	78	-	None	[117]
	Xyl III	0.2	1.4	-	3.5	-	67	-	None	[117]
Trichoderma harzianum	β-xylosidase	3.42	0.103	-	4-4.5	-	60	-	β-glucosidase β-galactosidase Arabinosidase	[103]
Trichoderma reesei	CBHII	0.00001	-	-	-	-	-	-	β-glucosidase Mannanase Xylanase Cellobiohydrolase Exoglucanase	[22]
	EGI	0.00001	-	-	-	-	-	-	β-glucosidase Mannanase Xylanase Cellobiohydrolase Exoglucanase	[22]
	XYL 9	0.00002	-	-	-	-	-	-	β-glucosidase Mannanase Xylanase	[22]

	XYL 5.5	0.00005	-	-	-	-	-	-	β-glucosidase	[22]
	β-xylosidase	470	0.08	-	4	3-7	60	to 55	Mannanase Xylanase Arabinosidase	[118]
Trichoderma viride	β-xylosidase	10.8	-	-	3.5	4-5	55	to 65	None	[119]
Bacillus halodurans C-125	BH1068	-	30.1	-	6.5	5-7	47	to 45	None	[120]
Bacillus stearothermophilus	β-xylosidase	34.2	0.0012	-	6	6-8	70	to 60	None	[121]
Bacillus thermantarcticus	β-xylosidase	160	0.5	-	6.0	-	70	to 60	None	[122]
Butyrivibrio fibrisolvens	xylB	8.9	-	-	-	-	-	-	Arabinosidase	[123]
Caulobacter crescentus	CcXynB2	215	9.3	402	6	4.5-7.5	55	to 50	None	[124]
Clostridium stercorarium	β-glucosidase	5.7	-	-	5.5	5-7	65	to 75	β-glucosidase	[62]
	xylA	3.5	2.5	5.9	7	5-10	65	-	Cellobiohydrolase Exoglucanase Arabinosidase	[125]
Geobacillus stearothermophilus	β-xylosidase	133	2.38	147	6.5	5.5-7	70	50-70	None	[126,127]
Ruminococcus flavefaciens	Exo A	0.01	-	-	5	4.5-5.5	-	-	Cellobiohydrolase Exoglucanase	[43]
Thermoanaerobacterium saccharolyticum	β-xylosidase	53.8	28	276	6	6-6.5	65	to 67	None	[128]
Thermoanaerobacter sp.	β-xylosidase	66	0.038	183	5.9	5-8.5	93	to 86	Arabinosidase	[129]
Hordeum vulgare	β-xylosidase	6.06	-	-	-	-	-	-	Arabinosidase	[130]

Table S7. Properties of enzymes with xylanase activity. Table is organized by origin, fungal, then bacterial, then plant. All values listed are from enzymatic activities against xylan. "-", not reported in the study. Rows of anaerobic fungi are highlighted.

Origin	Protein Name (Annotation)	Specific Activity (U/mg)	Kinetics Km (mg/mL)	Kinetics Vmax (U/mg)	Optimal pH	pH Stability	Optimal Temp. (°C)	Temp. Stability (°C)	Other Activities	Ref.
Orpinomyces sp. strain C1A	XYL11	73.5	0.024	370	5	3-9	50	4-60	β-glucosidase	This Study
	EG5	9.37	0.035	36.5	7	3-8	50	4-50	Endoglucanase	This Study
	Bgxg1	10.8	0.038	25.6	6	4-12	39	4-70	β-glucosidase β-glucosidase β-xylosidase β-galactosidase	91
Acrophialophora nainiana	Xyn III	31.25	4.37	0.24	6.5	-	50	to 55	None	131
	Xyn II	33.2	40.9	-	7	-	55	to 55	None	132
	Xyn I	13.6	0.731	-	6	-	50-60	to 50	None	133
Aspergillus awamori	β-xylosidase	1.7	-	-	6.5	-	70	to 70	β-xylosidase	104
Aspergillus niger	Xylanase I	18.9	-	-	6-6.5	-	65-80	to 80	Exoglucanase	93
	Xylanase IA	35.2	-	-	5.5-6	-	65-80	to 80	Exoglucanase	93
	Xylanase II	24.5	-	-	4-4.5	-	65-80	to 80	None	93
	Xylanase IIA	48.0	-	-	4	-	65-80	to 80	None	93
Chaetomonium cellulolyticum	Xylanase 1	22	-	-	6-7	-	50	-	Endoglucanase Exoglucanase	47
	Xylanase 2	18	-	-	6-7	-	50	-	Endoglucanase Exoglucanase	47
	Xylanase 3	11	-	-	6-7	-	50	-	Endoglucanase Arabinosidase	47
Chrysosporium lucknowense	EG28	0.2	-	-	4.5-6	5-7	60-70	60-75	Endoglucanase Exoglucanase	2
	EG44	0.07	-	-	4.5-6	5-7	60-70	60-75	Endoglucanase Exoglucanase	2
	EG47	0.08	-	-	4.5-6	5-8.5	60-70	60-75	Endoglucanase Exoglucanase	2
	EG51	0.18	-	-	4.5-6	5-7	60-70	60-75	Endoglucanase Exoglucanase	2
	CBHII	1.4	-	-	4.5-6	5-7	60-70	60-75	Cellobiohydrolase Exoglucanase	2
Fusarium oxysporum	Xylanase	5.2	3.8	-	7.4	5.8-8.2	50	to 50	Endoglucanase Exoglucanase	3
Gloephyllum trabeum	Cel5A	0.77	-	-	-	-	-	-	Endoglucanase Exoglucanase	5
	Xyn10A	390	-	-	-	-	-	-	Endoglucanase Exoglucanase	5

	Cel12A	0.88	-	-	-	-	-	-	Endoglucanase Exoglucanase	[5]
Humicola grisea	X1	-	7.233		5		50	to 50	None	[134]
	X2	10.23	10.87	-	4.5-6.5	-	55-60	to 60	None	[134]
	Xylanase	169.4	3.3	229	5.5	-	70	to 50	None	[135]
Neocallimastix frontalis	Xylanase	0.36	1.13	-	6	3-8	50	to 40	None	[136]
Orpinomyces joyonii	Cellulase	5.2	-	-	5.5	5-7.5	40	to 50	Exoglucanase Endoglucanase Cellobiohydrolase	[49]
Paecilomyces thermophila	Xylanase	2063	2	2344	7	6-10	75-80	to 75	None	[137]
Penicillium brasilianum	XYL	279	-	-	-	-	-	-	None	[13]
Penicillium citrinum	Xylanase	360.7	-	-	8.5	4-10	50	0-60	None	[138]
Piromyces communis	Xylanase	0.37	1	-	5.5	-	50	-	None	[136]
Sphaeromonas communis	Xylanase	0.43	0.98	-	6	-	50	-	None	[136]
Trichoderma harzianum	XYL2	-	13.66	-	5	3.5-6.5	45	to 50	None	[139]
	Xylanase	2400	-	-	-	-	-	-	None	[140]
Trichoderma reesei	EG I	0.55	-	-	-	-	-	-	Endoglucanase Cellobiohydrolase β-glucosidase	[60]
	EG II	0.003	-	-	-	-	-	-	Endoglucanase Cellobiohydrolase β-glucosidase	[60]
	CBH I	0.0003	-	-	-	-	-	-	Endoglucanase Cellobiohydrolase β-glucosidase	[60]
	CBH II	0.002	-	-	-	-	-	-	Endoglucanase Cellobiohydrolase β-glucosidase	[60]
	CBH III	0.0002	-	-	-	-	-	-	Endoglucanase β-glucosidase β-xylosidase	[22]
	EG I	0.29	-	-	-	-	-	-	Endoglucanase β-glucosidase β-xylosidase	[22]
	XYL 9	11.33	-	-	-	-	-	-	Endoglucanase β-glucosidase β-xylosidase	[22]
	XYL 5.5	3.855	-	-	-	-	-	-	Endoglucanase β-glucosidase β-xylosidase	[22]
	EG I	46.2	-	-	4	2-8	60	to 45	Endoglucanase Exoglucanase	[23]

									Cellobiohydrolase	
Anaerocellum thermophilum	CelA	0.372	-	-	5-6	-	85-95	-	Endoglucanase Exoglucanase	[26]
Bacillus amyoliquefaciens	Cellulase	22.5	-	-	7	4-9	50	40-80	Endoglucanase Exoglucanase Cellobiohydrolase β-glucosidase	[27]
Bacillus circulans	XylA	2039.5	4	2667	6-6.5	4-8	75-80	to 65	None	[141]
	XylB	6423	25	200000	6-6.5	4-8	65-70	to 65	None	[141]
Bacillus licheniformis	Xylanase	28.7	3.33	111	6-7.5	5-8	60	to 60	None	[142]
Bacillus stearothermophilus	Xylanase	122	3.8	-	7	5-11	60	to 60	None	[121]
Bacillus subtilis	Cellulase	980	-	-	6	6-7.5	50-60	to 50	Endoglucanase	[32]
Bacillus thermantarcticus	Xylanase	141	1.6	-	5.6	-	80	to 60	None	[122]
Caldibacillus cellulovorans	CMCase	4.56	-	-	6.5-7	-	80	to 70	Endoglucanase Exoglucanase	[33]
Cellulomonas fimi	Exg	37	-	-	6	5-9	-	60-75	Endoglucanase Cellobiohydrolase	[61]
Clostridium stercorarium	Avicelase II	0.340	-	-	5-6	4.5-7	75	65-80	Exoglucanase	[38]
Streptomyces lividans	Xylanase	364	0.78	850	6	5.5-7	60	0-37	None	[143]
Streptomyces rameus	Xylanase	4326	5.8	-	5.3	4.3-6.7	70	40-65	None	[144]
Streptomyces thermoviolaceus	STX-I	1460	-	-	7	5-9	70	to 50	None	[145]
	STX-II	1405	-	-	7	5-9	60	to 60	None	[145]
Thermatoga maritima	CelA	2.5	-	-	5	4-9	85-90	to 95	Endoglucanase Exoglucanase Cellobiohydrolase	[65]
	CelB	0.008	-	-	7	5-9	85-90	to 95	Endoglucanase Exoglucanase Cellobiohydrolase	[65]
Thermatoga neapolitana	CelB	37	-	-	6-6.6	-	106	to 106	Endoglucanase Exoglucanase Cellobiohydrolase	[21]

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