

Supplementary material

β -Galactosidase-producing isolates in Mucoromycota: screening, enzyme production, and applications for functional oligosaccharide synthesis

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List of supplementary data

Table S1. Mucoromycota strains included in the β -galactosidase production screening assays and their activity on X-gal contained medium. The intensity of the blue color is proportional with the enzyme activity.

Figure S1. SDS-PAGE analysis of the crude β -galactosidases. Lane 1 and Lane 2 are *L. ramosa* and *R. pusillus* partially purified β -galactosidases, respectively, obtained after filtration through a Bio-Gel P-6 desalting cartridge (Bio-Rad, Hercules, USA). Lane M: SeeBlue Plus2 SDS-PAGE molecular weight standard (Invitrogen, Carlsbad, USA).

Table S1. Mucoromycota strains included in the β -galactosidase production screening assays and their activity on X-gal contained medium. The intensity of the blue color is proportional with the enzyme activity.

Fungal strains	Code ²	β-Galactosidase activity ¹					
		t(incubation)/day					
		1	2	4	6	8	10
<i>Lichtheimia</i> group							
<i>Lichtheimia brasiliensis</i>	SZMC 23766	NC	NC	NC	NC	NC	NC
<i>Lichtheimia corymbifera</i>	SZMC 11361	++	++++	++++	+++++	+++++	+++++
<i>Lichtheimia corymbifera</i>	SZMC 11367	NC	+	+	++	++	+++
<i>Lichtheimia corymbifera</i>	SZMC 23760	+	+++	++++	++++	++++	+++++
<i>Lichtheimia corymbifera</i>	SZMC 23761	+	+++	++++	+++++	+++++	+++++
<i>Lichtheimia hyalospora</i>	SZMC 11363	+	+++	++++	++++	+++++	+++++
<i>Lichtheimia hyalospora</i>	SZMC 11364	++	++++	++++	+++++	+++++	+++++
<i>Lichtheimia hyalospora</i>	SZMC 23765	NC	++	++	+++	+++	++++
<i>Lichtheimia ornata</i>	SZMC 11370	++	++++	++++	++++	++++	+++++
<i>Lichtheimia ornata</i>	SZMC 11368	+	+++	+++	++++	+++++	+++++
<i>Lichtheimia ornata</i>	SZMC 23764	+	+++	++++	+++++	+++++	+++++
<i>Lichtheimia ramosa</i>	SZMC 11369	++	++	++++	++++	++++	++++
<i>Lichtheimia ramosa</i>	SZMC 11360	+++	+++++	+++++	+++++	+++++	+++++
<i>Lichtheimia ramosa</i>	SZMC 11362	++	++++	++++	+++++	+++++	+++++
<i>Lichtheimia ramosa</i>	SZMC 23762	+	+++	+++	++++	++++	+++++
<i>Lichtheimia ramosa</i>	SZMC 23763	+	++	+++	+++	++++	++++
<i>Lichtheimia sphaerocystis</i>	SZMC 11371	+	+++	+++	++++	+++++	+++++
<i>Lichtheimia sphaerocystis</i>	SZMC 23768	+	+++	++++	++++	++++	+++++

Fungal strains	Code ²	β-Galactosidase activity ¹					
		t(incubation)/day					
		1	2	4	6	8	10
Mortierella group							
Mortierella alpina	SZMC 11213	NC	NC	NC	NC	NC	NC
Mortierella gamsii	SZMC 11215	NC	NC	NC	+	++	++
Mortierella antarctica	SZMC 11217	NC	NC	NC	NC	NC	NC
Mortierella echinosphaera	SZMC 11251	+	+	+++	++++	++++	+++++
Mortierella exigua	SZMC 11257	NC	NC	+	++	++	++
Mortierella turficola	SZMC 11207	NC	NC	+	++	++	+++
Mortierella gemmifera	SZMC 11201	+	+	++	+++	+++	+++
Mortierella globulifera	SZMC 11209	+	++	+++	+++	++++	+++++
Mortierella indohii	SZMC 11253	NC	+	++	+++	+++	++++
Mortierella capitata	SZMC 11256	NC	NC	NC	NC	NC	NC
Mortierella paraensis	SZMC 11272	NC	NC	NC	NC	NC	NC
Mortierella parvispora	SZMC 11266	NC	+	+	++	+++	+++
Mortierella rishiksha	SZMC 11273	NC	NC	+	++	+++	++++
Mortierella wolfii	SZMC 11243	+	++	+++	+++	+++	++++
Mortierella zychae	SZMC 11212	NC	+	++	++	++	+++
Mortierella epicladia	SZMC 11247	NC	NC	NC	+	+	++
Mucor group							
Mucor amphibiorum	SZMC 12014	NC	NC	NC	NC	NC	NC
Mucor circinelloides	SZMC 20680	NC	NC	NC	NC	NC	NC
Mucor circinelloides	SZMC 12028	+	++	++	+++	+++	++++
Mucor corticolus	SZMC 12031	NC	NC	NC	+	+++	+++

Fungal strains	Code ²	β -Galactosidase activity ¹					
		<i>t</i> (incubation)/day					
		1	2	4	6	8	10
<i>Mucor corticolus</i>	SZMC 12058	NC	NC	NC	NC	NC	NC
<i>Mucor fragilis</i>	SZMC 0482	NC	NC	NC	NC	NC	NC
<i>Mucor guillermundii</i>	SZMC 12011	NC	NC	NC	NC	NC	NC
<i>Mucor hiemalis</i> f. <i>hiemalis</i>	SZMC 12056	+	++	++	++	++	+++
<i>Mucor mucedo</i>	SZMC 0485	NC	NC	NC	NC	NC	NC
<i>Mucor piriformis</i>	SZMC 12077	NC	NC	NC	NC	NC	NC
<i>Mucor plumbeus</i>	SZMC 12070	NC	NC	NC	NC	NC	NC
<i>Mucor plumbeus</i>	SZMC 12635	NC	NC	NC	NC	NC	NC
<i>Mucor plumbeus</i>	SZMC 12023	++	++++	++++	++++	++++	+++++
<i>Mucor racemosus</i>	SZMC 0472	NC	NC	NC	NC	NC	NC
<i>Mucor irregularis</i>	SZMC 23820	NC	NC	NC	NC	NC	NC
<i>Mucor irregularis</i>	SZMC 23821	NC	NC	NC	NC	NC	NC
<i>Mucor racemosus</i> f. <i>chibinensis</i>	SZMC 12005	NC	NC	NC	NC	NC	NC
<i>Rhizomucor</i> group							
<i>Rhizomucor miehei</i>	SZMC 11005	++	+++	++++	++++	++++	+++++
<i>Rhizomucor miehei</i>	SZMC 11008	NC	NC	NC	NC	NC	NC
<i>Rhizomucor miehei</i>	SZMC 11014	++	++++	+++++	+++++	+++++	+++++
<i>Rhizomucor miehei</i>	SZMC 11007	NC	+	++	+++	++++	+++++
<i>Rhizomucor miehei</i>	SZMC 11009	NC	NC	NC	+	+	++
<i>Rhizomucor miehei</i>	SZMC 11028	+	+++	++++	++++	++++	+++++
<i>Rhizomucor pusillus</i>	SZMC 11025	+	+++	+++	++++	++++	+++++

Fungal strains	Code ²	β -Galactosidase activity ¹					
		t (incubation)/day					
		1	2	4	6	8	10
<i>Rhizomucor pusillus</i>	SZMC 11024	NC	NC	+++	++++	++++	++++
<i>Rhizomucor pusillus</i>	SZMC 11022	+	+++	++++	++++	++++	+++++
<i>Rhizomucor pusillus</i>	SZMC 11023	NC	NC	NC	NC	NC	NC
<i>Rhizomucor pusillus</i>	SZMC 11021	NC	+	++	++	+++	+++
<i>Rhizopus</i> group							
<i>Rhizopus arrhizus</i>	SZMC 21290	NC	NC	NC	NC	NC	NC
<i>Rhizopus arrhizus</i>	SZMC 21291	+	+	+	+	+	+
<i>Rhizopus homotallicus</i>	SZMC 13623	NC	NC	NC	NC	NC	NC
<i>Rhizopus microsporus</i>	SZMC 21297	NC	NC	++	+++	++++	++++
<i>Rhizopus microsporus</i>	SZMC 21298	+	++	++	+++	+++	+++
<i>Rhizopus microsporus</i> var. <i>oligosporus</i>	SZMC 13622	NC	NC	++	+++	+++	+++
<i>Rhizopus microsporus</i> var. <i>oligosporus</i>	SZMC 13619	NC	+	+++	++++	++++	+++++
<i>Rhizopus microsporus</i> var. <i>rhizopodiformis</i>	SZMC 13645	++	+++	+++	++++	++++	++++
<i>Rhizopus niveus</i>	SZMC 13625	NC	NC	NC	NC	NC	NC
<i>Rhizopus oryzae</i>	SZMC 0497	NC	NC	NC	NC	NC	NC
<i>Rhizopus oryzae</i>	SZMC 13618	NC	NC	NC	NC	NC	NC
<i>Rhizopus oryzae</i>	SZMC 13635	NC	NC	NC	NC	++	+++
<i>Rhizopus oryzae</i>	SZMC 13643	NC	NC	NC	NC	NC	NC
<i>Rhizopus oryzae</i>	SZMC 0495	NC	NC	NC	NC	NC	NC
<i>Rhizopus oryzae</i>	SZMC 13616	NC	NC	NC	NC	NC	NC

Fungal strains	Code ²	β -Galactosidase activity ¹					
		<i>t</i> (incubation)/day					
		1	2	4	6	8	10
<i>Rhizopus oryzae</i>	SZMC 13611	NC	NC	NC	NC	NC	NC
<i>Rhizopus oryzae</i>	SZMC 13617	NC	NC	NC	NC	NC	NC
<i>Rhizopus oryzae</i>	SZMC 13634	NC	NC	NC	NC	NC	NC
<i>Rhizopus schipperae</i>	SZMC 21304	NC	NC	NC	NC	NC	NC
<i>Rhizopus stolonifer</i>	SZMC 21295	NC	NC	NC	NC	NC	NC
<i>Umbelopsis</i> group							
<i>Umbelopsis angularis</i>	SZMC 11252	+	++	+++	+++	++++	+++++
<i>Umbelopsis autotrophica</i>	SZMC 11276	+	++	+++	++++	++++	++++
<i>Umbelopsis isabellina</i>	SZMC 11076	+	+	+++	++++	++++	+++++
<i>Umbelopsis isabellina</i>	SZMC 11335	+	+	+++	+++	++++	++++
<i>Umbelopsis isabellina</i>	SZMC 11325	+	++	+++	++++	+++++	+++++
<i>Umbelopsis isabellina</i>	SZMC 11290	+	++	++	++++	++++	+++++
<i>Umbelopsis isabellina</i>	SZMC 11319	+	+	+++	++++	++++	+++++
<i>Umbelopsis isabellina</i>	SZMC 11323	+	++	++	+++	+++	+++
<i>Umbelopsis longicollis</i>	SZMC 11208	+	+++	++++	+++++	+++++	+++++
<i>Umbelopsis ovata</i>	SZMC 22674	+	++	++++	+++++	+++++	+++++
<i>Umbelopsis dimorpha</i>	SZMC 22797	+	+	+	++	+++	+++
<i>Umbelopsis ramanniana</i>	SZMC 11078	+	++	+++	+++++	+++++	+++++
<i>Umbelopsis ramanniana</i> var. <i>angulispora</i>	SZMC 11234	+	+++	+++++	+++++	+++++	+++++
<i>Umbelopsis versiformis</i>	SZMC 21866	NC	+	++	++	+++	+++
<i>Umbelopsis versiformis</i>	SZMC 23387	+	+++	++++	+++++	+++++	+++++

Fungal strains	Code ²	β -Galactosidase activity ¹					
		<i>t</i> (incubation)/day					
		1	2	4	6	8	10
<i>Umbelopsis vinacea</i>	SZMC 11316	++	++	+++	+++	+++	++++
<i>Umbelopsis ovata</i>	SZMC 22674	+	+	+	++	+++	+++

¹ light blue color (+), darker blue color (++), blue color (+++); dark blue color (++++), deep dark blue color (+++++), NC: no blue color. ² SZMC=Szeged Microbiological Collection.

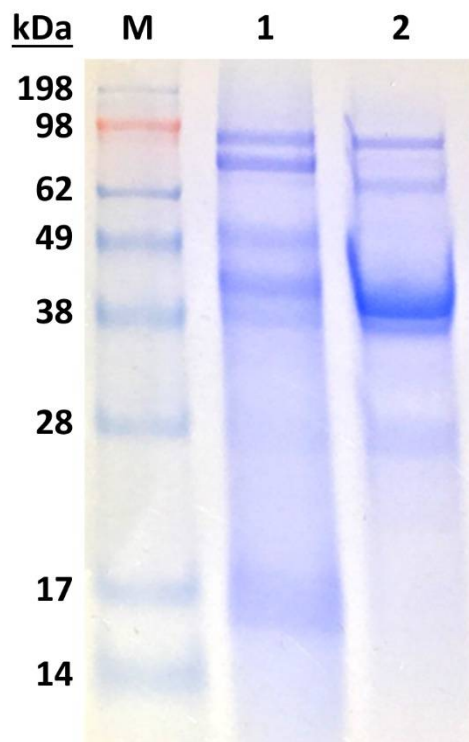


Figure S1. SDS-PAGE analysis of the crude β -galactosidases. Lane 1 and Lane 2 are *L. ramosa* and *R. pusillus* partially purified β -galactosidases, respectively, obtained after filtration through a Bio-Gel P-6 desalting cartridge (Bio-Rad, Hercules, USA). Lane M: SeeBlue Plus2 SDS-PAGE molecular weight standard (Invitrogen, Carlsbad, USA).