

Supplementary Material

A review of pesticides sorption in biochar from maize, rice, and wheat residues: current status and challenges for soil application

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Figure SM1 - World's leading countries on maize, rice, and wheat crop production (Adapted from FAO, 2019).

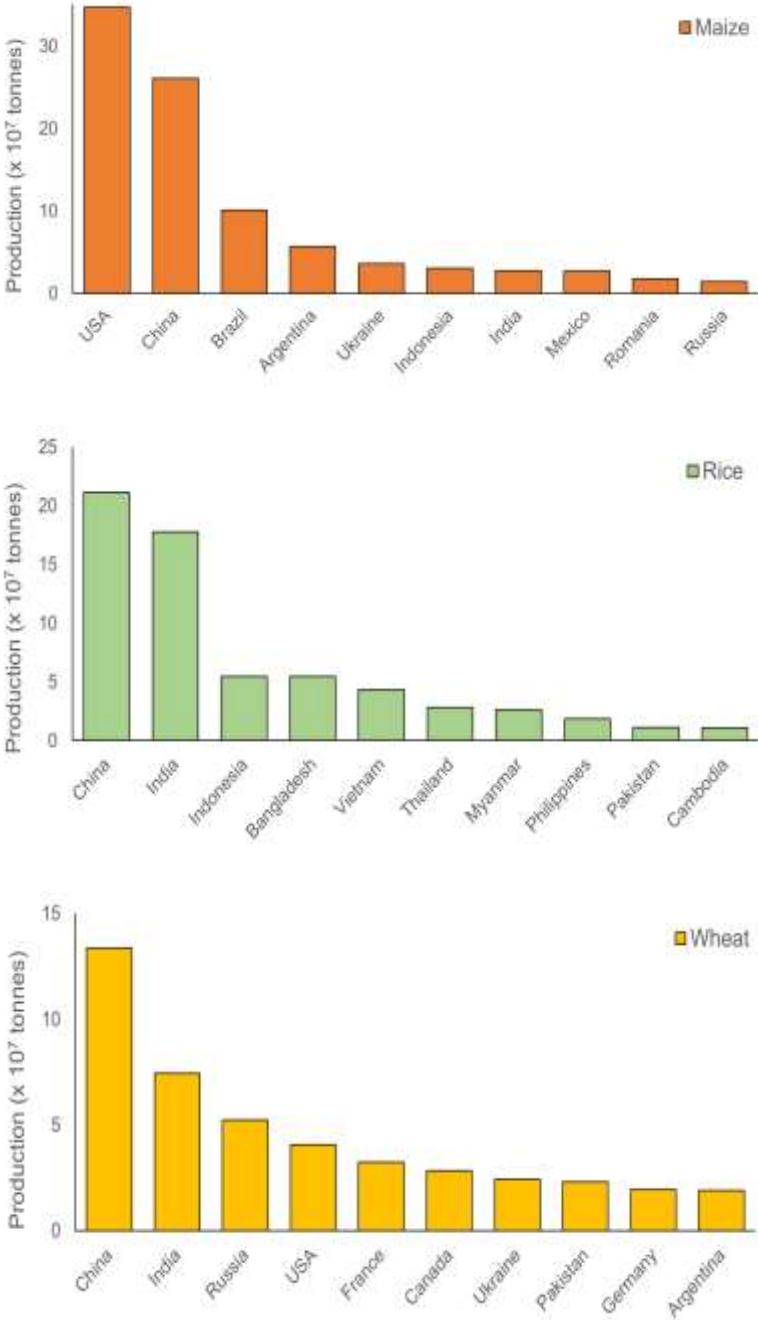


Table SM1 – Systematic review summary: studies from final selection on pesticide sorption into maize residues biochar (part 1).

Feedstock	Pyrolysis conditions and treatment	pH	Cation Exchange Capacity (cmol _c kg ⁻¹)	Specific Surface Area (m ² g ⁻¹)	Particle sizes (mm)	Pore volume (cm ³ g ⁻¹)	Ash (%)	C (%)	N (%)	H (%)	Pesticide	Reference
Corn straw	500°C	-	-	3	0.02 (median)	-	32	50	1.4	1.9	1,3-D	Graber et al. (2011)
Maize stover	850°C, 4h, air-dried	> 9.5	468	196	< 2	-	-	-	-	-	Atrazine, 2,4-D	Clay et al. (2016)
Maize stover	850°C, 4h, water-cooled	> 9.5	459	176	-	-	-	-	-	-		
Corn straw, dipped in 5% (w/w) ADP solution at a solid to solution ratio (g/mL) of 1:10 for 24 h	400°C, 4h	-	-	341.05	-	0.22	-	71.07	6.01	3.6	Atrazine	Ouyang et al. (2016a)
Corn cob	200°C (1h) + 450°C (4h), demineralized with 0.1 M HCl for 24h	-	-	1.506	< 0.154	0.00321	3.01	82.45	0.54	3.25	Atrazine	Ouyang et al. (2016b)
Corn cob, dipped in 5% ammonium dihydrogen phosphate at solid and solution ratio of 1:10 for 24 h	200°C (1h) + 450°C (4h), demineralized with 0.1 M HCl for 24h	-	-	356.01	< 0.154	0.221	11.47	67.07	7.48	3.32		
Corn stalk	200°C (1h) + 450°C (4h), demineralized with 0.1 M HCl for 24h	-	-	44.966	< 0.154	0.0345	9.03	75.17	0.98	3.25		
Maize straw	350°C, 2h	7.9	-	6.71	0.75-0.038	-	15.4	58.9	1	3.36	Carbaryl	Ren et al. (2016)
Maize straw	700°C, 2h	10.6	-	265	0.75-0.038	-	21.9	43.8	1.27	1.47		
Maize straw	300°C, 4h	7.08	-	6.33	0.075-0.425	-	14.24	61.59	1.5	4.21	Thiacloprid	Zhang et al. (2018)
Maize straw	500°C, 4h	8.6	-	12.49	0.075-0.425	-	23.42	66.73	1.44	2.57		
Maize straw	700°C, 4h	9.06	-	151.22	0.075-0.425	-	29.01	64.69	1.13	1.29		

Table SM1 – Systematic review summary: studies from final selection on pesticide sorption into maize residues biochar (part 2).

Feedstock	Pyrolysis conditions and treatment	pH	Cation Exchange Capacity (cmol _c kg ⁻¹)	Specific Surface Area (m ² g ⁻¹)	Particle sizes (mm)	Pore volume (cm ³ g ⁻¹)	Ash (%)	C (%)	N (%)	H (%)	Pesticide	Reference
Corn straw	550-600°C, 6-8h	-	-	62.11	0.15 (median)	0.031	-	45.44	-	-	Atrazine	Qin et al. (2019)
Maize straw	300°C, 1h	-	-	2.063	< 0.2	-	-	-	-	-	Topramezone	Uwamungu et al. (2019)
Maize straw	400°C, 1h	-	-	20.286	< 0.2	-	-	-	-	-		
Maize straw	500°C, 1h	-	-	20.897	< 0.2	-	-	-	-	-		
Maize straw	300°C, 2h	6.83	-	1.68	< 2	0.01	23.75	43.36	1.27	4.37	Oxyfluorfen	Wu et al. (2019)
Maize stalk	500°C	9.38	37.6	13.2	< 0.2	-	19.7	61.9	1.17	-	Flubendiamide	Das and Mukherjee (2020)
Corn stalk	250°C, 2h	-	-	212.28	-	0.22	-	-	-	-	Atrazine	Tao et al. (2020)
Corn stalk	550°C, 2h	-	-	272.59	-	0.28	-	-	-	-		
Corn stalk	850°C, 2h	-	-	386.07	-	0.36	-	-	-	-		
Maize straw	300°C, 4h	7.14	-	6.33	0.075-0.425	-	14.2	61.6	1.5	4.21	Imidacloprid, Clothianidin	Zhang et al. (2020)
Maize straw	500°C, 4h	9.43	-	12.5	0.075-0.425	-	23.4	66.7	1.44	2.57		
Maize straw	700°C, 4h	10.1	-	151	0.075-0.425	-	29	64.7	1.13	1.29		

Table SM2 – Systematic review summary: studies from final selection on pesticide sorption into rice residues biochar (part 1).

Feedstock	Pyrolysis conditions and treatment	pH	Cation Exchange Capacity (cmolc kg ⁻¹)	Specific Surface Area (m ² g ⁻¹)	Particle sizes (mm)	Pore volume (cm ³ g ⁻¹)	Ash (%)	C (%)	N (%)	H (%)	Pesticide	Reference
Rice straw	350°C, 6h, washed four times with 1 M hydrochloric acid solution, then washed with distilled water and oven-dried at 70 °C	-	-	20.6	-	-	31	46.9	2.08	12.3	2,4-D, Acetochlor	Lü et al. (2012)
Rice hull	600°C, 3h	9.57	-	10.66	0.1-0.4	0.049	38	-	-	-	Fomesafen	Khorrām et al. (2015)
Rice straw	400 °C, 1h	9.8	86.5	13.53	< 0.154	-	-	43.26	1.15	-	Pyrazosulfuron-ethyl	Manna and Singh (2015)
Rice straw	600°C, 1h	11.1	45.3	12.6	< 0.154	-	-	46.07	0.94	-		
Rice straw	350°C, 2h	7.8	-	9.01	0.75-0.038	-	29.1	44.5	1.64	2.69	Carbaryl	Ren et al. (2016)
Rice straw	700°C, 2h	10.6	-	188	0.75-0.038	-	38.2	56.7	0.1	2.39		
Rice husk	300 °C, 3h	6.32	70.73	1.99	< 0.200	0.006898	22.24	48.26	-	2.3	Imazapic, Imazapyr	Yavari et al. (2016)
Rice husk	700 °C, 3h	9.24	43.02	202.11	< 0.200	0.113707	34.79	57.47	-	1.07		
Rice hull	600°C, 3h	9.57	-	10.662	0.1-0.4	0.039	38.012	-	-	-	Fomesafen	Khorrām et al. (2017)
Rice husk	300°C, 3h	6.32	70.73	1.99	-	0.006898	-	48.26	0.11	2.3	Imazapic, Imazapyr	Yavari et al. (2017a)
Rice husk	700°C, 3h	-	44.001	202.115	-	0.113707	-	-	-	-	Imazapic	Yavari et al. (2017b)
Rice straw	500°C	9.72	-	63.1	0.6-2	0.065	29.61	-	-	-	Fomesafen	Khorrām et al. (2018)
Rice hull	500°C, 4h	7.34	-	54.95	< 2	0.04	-	23.4	0.4	4.03	Acetochlor	Li et al. (2018)

Table SM2 – Systematic review summary: studies from final selection on pesticide sorption into rice residues biochar (part 2).

Feedstock	Pyrolysis conditions and treatment	pH	Cation Exchange Capacity (cmol _c kg ⁻¹)	Specific Surface Area (m ² g ⁻¹)	Particle sizes (mm)	Pore volume (cm ³ g ⁻¹)	Ash (%)	C (%)	N (%)	H (%)	Pesticide	Reference
Rice straw	400°C, 1h	9.8	86.5	13.53	< 0.154	-	-	43.26	1.15	-	Pyrazosulfuron-ethyl	Manna and Singh (2019)
Rice straw	600°C, 1h	11.1	45.3	12.6	< 0.154	-	-	46.07	0.94	-		
Rice hull	500°C, 4h	6.96	-	95.67	< 2	0.04	50.34	33.6	0.31	2.22	Oxyfluorfen	Wu et al. (2019)
Rice hull	500°C, 4h, mixed with 30% H ₂ O ₂ solution for 24 h, washed with deionized water and dried at 80 °C	6.72	-	79.28	< 2	0.04	49.21	33.36	0.31	1.97		
Rice straw	300°C, 4h	7.19	-	7.981	-	-	19.15	54.91	1.29	3.04	Atrazine	Zhao et al. (2019)
Rice straw	400°C, 4h	9.12	-	13.562	-	-	23.28	54.96	1.26	2.23		
Rice straw	500°C, 4h	10.2	-	22.445	-	-	25.19	57	1.08	1.72		
Rice straw	600°C, 4h	10.2	-	106.163	-	-	26.58	61.16	0.93	1.09		
Rice straw	700°C, 4h	10.33	-	141.124	-	-	27.65	63.35	1.12	0.95		
Rice husk	700°C	-	-	42	< 2	-	-	-	0.85	-	Atrazine, Diuron, Enrofloxacin, Oxytetracycline, Tetracycline	Aldana et al. (2020)
Rice husk	300°C, 1h	6.01	5	5.15	-	-	22.6	58.01	-	1.56	Imazapic, Imazapyr	Yavari et al. (2020)
Rice husk	300°C, 1h, modification with chitosan	8.88	35	2.01	-	-	9	51.37	-	2.28		

Table SM3 – Systematic review summary: studies from final selection on pesticide sorption into wheat residues biochar.

Feedstock	Pyrolysis conditions and treatment	pH	Cation Exchange Capacity (cmol _c kg ⁻¹)	Specific Surface Area (m ² g ⁻¹)	Particle sizes (mm)	Pore volume (cm ³ g ⁻¹)	Ash (%)	C (%)	N (%)	H (%)	Pesticide	Reference
Wheat straw	500°C, 1.5h	10.51	-	4.81	< 0.15	0.0051	-	48.53	0.46	-	Hexachlorobenzene	Song et al. (2012), Song et al. (2016)
Wheat straw, carbonized in a sand bath at 200°C	300°C, 6h	10.6	-	4.59	-	-	5.05	51.7	0.64	5.13	MCPA	Tatarkova et al. (2013)
Wheat straw	400°C, 1h	9.3	62	10.15	< 0.154	-	-	-	0.74	-	Pyrazosulfuron-ethyl	Manna and Singh (2015)
Wheat straw	600°C, 1h	10.4	62.6	62.6	<0.154	-	-	-	0.61	-		
Wheat midds	550°C	8.86	-	24.73	< 2	-	12.53	81.83	-	0.32	1,3-D	Wang et al. (2016)
Wheat straw	250°C, 1h	5.4	68.7	2.7	-	-	16.2	64.6	1	4.1	Simazine	Cheng et al. (2017)
Wheat straw	350°C, 1h	8.8	58.6	5.2	-	-	18.8	74.1	1.1	4.2		
Wheat straw	450°C, 1h	9.2	40.5	4.6	-	-	14.7	73.9	0.9	3.7		
Wheat straw	550°C, 1h	9.7	22	10.5	-	-	18.5	82.3	0.9	3		
Wheat straw	500°C, 100 - 110 min	7.89	85	4.83	< 0.200	0.0051	-	-	0.9	-	Chlorpyrifos	Humera Aziz et al. (2018)
Wheat straw	500°C, 4h	-	92	10.7	-	-	-	56.7	2.08	0.832	Atrazine	Ren et al. (2018)
Wheat straw	400°C, 1h	9.3	62	10.15	< 0.154	-	-	40.42	0.74	-	Pyrazosulfuron-ethyl	Manna and Singh (2019)
Wheat straw	600°C, 1h	10.4	62.6	20.38	< 0.154	-	-	42.98	0.61	-		

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