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Appendices

Appendix A: Physicochemical characteristics of various biomasses reported previously published literature

S. No.	Biomass feedstock	MC	VM	FC	Ash	C	H	N	O	S	Hemi	Cell	Lig	References
1	Sal sawdust	8.88	76.03	14.09	1.14	49.83	6.01	0.58	43.56	-	14.59	52.36	11.18	[7]
2	Areca nut husk	7.43	74.05	15.55	2.48	48.80	5.79	1.95	43.45	0.1	16.81	48.98	13.27	[7]
3	Pine sawdust	6.09	78.03	13.96	2.07	50.03	6.0	0.69	42.99	-	15.35	55.92	10.55	[7]
4	Mango sawdust	7.06	73.38	15.09	4.47	38.98	5.06	0.08	44.34	-	25	46.25	23.75	[175]
5	*Cascabela thevetia*	4.97	78.05	14.78	2.19	54.93	9.99	3.33	31.07	0.66	21.01	36.00	15.23	[8]
6	Delonix regia	6.85	76.27	14.10	2.78	53.5	6.93	6.99	32.55	-	27.22	48.16	14.06	[8]
7	Pine wood	12.9	71.5	15.3	0.3	41.9	4.5	0.2	40.2	-	15.4	52.1	27.5	[176]
8	Pine cone	9.6	77.8	-	0.9	42.6	5.6	0.8	51.0	0.1	37.6	32.7	24.9	[177]
9	Samanea saman	6.19	76.00	14.74	3.06	48.46	6.75	7.30	37.47	-	26.55	30.81	10.59	[63]
10	Banana leaves	8.4	73.05	11.29	7.26	43.28	6.83	1.28	48.31	0.3	34.34	43.34	15	[142]
11	Poplar wood sawdust (Raw)	9.6	75.54	11.15	3.7	45.5	6.26	1.04	47.2	-	16.73	44.75	30.72	[178]
12	*Phyllanthus emblica*	6.56	75.20	15.55	2.69	48.76	5.91	2.01	43.31	-	21.98	48.11	5.48	[95]
13	Eucalyptus sawdust	6.12	74.38	18.79	0.81	49.75	5.77	0.17	44.26	0.03	24.74	33.89	20.77	[179]
14	Holm oak	9.5	80.8	7.4	2.3	48.0	5.9	0.5	45.6	0.02	25.9	37.9	27.8	[180]

15	Mallee bark	-	69.5	24.1	6.4	48.5	5.5	0.3	45.4	0.1	18.6	26.3	24.7	[181]
16	Sapodilla	8.07	77.02	13.73	1.19	52.67	6.74	1.46	38.78	0.34	26.55	34.03	7.61	[100]
17	Bamboo sawdust	10.13	74.9	9.2	5.8	46.73	5.91	0.0	47.36	-	-	-	-	[182]
18	Bambusa Multiplex	9.49	73.56	14.51	2.44	46.75	6.17	0.48	36.49	0.01	-	-	-	[183]
19	Black bamboo	8.49	75.31	13.53	2.67	42.39	5.71	0.55	39.52	0.01	-	-	-	[183]
20	*Dalbergia sissoo* wood	10.09	81.49	15.7	2.81	44.55	6.10	0.22	46.0	0.31	27	33.1	34.5	[184]
21	Birch	11.4	74.4	13.5	0.8	44.4	3.5	0.3	36.7	-	24.8	56.5	12.2	[176]
22	Cardoon leaves	-	59.5	10.9	29.6	34.1	4.9	1.4	29.8	0.20	-	-	-	[147]
23	Cardoon stems	-	77.7	14.7	7.6	41.6	6.1	0.8	43.8	0.05	-	-	-	[147]
24	Eucalyptus leaves	4.26	77.73	12.12	5.89	47.71	4.85	3.49	43.37	0.45	11.28	17.93	9.25	[179]
25	Eucalyptus bark	10.89	69.89	14.85	4.37	41.82	5.01	0.28	52.76	0.07	12.90	27.48	32.09	[179]
26	Pyrenean oak	11.1	80.5	6.0	2.4	48.5	5.9	0.5	45.1	0.01	25.5	33.9	31.2	[180]
27	Alfalfa stems (at early bud)	5.3	69.6	16.9	8.3	39.9	5.5	2.3	38.8	0.2	-	-	-	[185]
28	Silver fir	14.4	78.7	6.5	0.4	51.2	6.4	0.2	42.2	-	15.0	52.1	29.9	[180]
29	Softwood	13.5	-	-	0.5	48.8	5.6	0.0	45.6	-	9.2	51.6	30.6	[186]
30	Stone pine	9.8	82.1	7.4	0.7	50.4	6.0	0.3	43.3	0.01	21.0	41.0	31.2	[180]
31	Bamboo	5.26	77.12	15.44	2.18	45.05	5.57	0.56	39.42	0.03	-	-	-	[187]
32	Wheat straw	4.1	81	8.13	6.77	42.4	6.01	0.5	41.1	0.25	30	42	16.14	[188]

33	Apple pomace	8.87	81.32	6.41	3.40	47.98	6.65	0.78	37.44	-	27.77	47.49	24.72	[189]
34	Coffee husk briquettes	9.06	77.06	19.36	3.55	46.41	6.33	2.66	44.51	0.09	27.14	47.29		[98]
35	Coffee ground	1.3	77.5	19.8	1.4	54.6	6.6	3.9	34.8	0	-	-	33.3	[190]
36	*Shorea Robusta*	5.23	60.46	16.78	17.53	41.42	5.03	0.78	52.6	0.17	47	22	24.7	[191]
37	Cotton stalks	6.0	73.0	16.0	5.0	46.3	5.1	1.5	42.5	0.1	22.5	32	39.8	[192]
38	Defective coffee beans	6.5	69.18	21.16	3.14	45.95	6.62	2.38	45.02	-	6.05	28.83	3.41	[193]
39	Empty palm fruit bunches	7.4	76.4	11.6	4.6	51.8	7.0	0.7	40.3	0.2	22.1	59.7	18.2	[194]
40	Exhausted coffee residue	11.5	79.5	8.2	0.7	6.9	3.5	34.8	0.1	-	39.4	47.2	52.5	[195]
41	Groundnut shell	8.0	64.63	29.45	5.91	42.02	5.8	1.88	50.28	0.0	-	-	-	[196]
42	Jatropha seed shell cake	2.7	79.8	14.1	3.4	50.5	6.2	2.3	39.4	-	4.8	36.6	39.6	[194]
43	Palm fiber	6.6	75.9	12.4	5.3	50.3	7.1	0.4	36.3	0.6	-	-	-	[197]
44	Palm kernel shell	5.9	71.3	17.8	4.9	44.6	6.5	2.9	40.2	<0.1	30.6	30.6	20.4	[194]
45	Palm mesocarp fibers	5.7	82.0	10.2	2.1	54.5	7.0	0.8	35.5	-	34.6	37.5	27.9	[198]
46	Peach pulp	9.3	70.2	18.0	2.4	45.6	6.9	0.9	46.5	-	-	-	-	[199]
47	Tobacco waste	16.2	65.4	1.4	17.0	40.91	6.38	2.49	49.96	0.26	13.0	30.3	20.4	[200]
48	Finger millet straw	8.91	65.55	18.67	6.87	47.23	5.14	0.77	46.87	-	36.28	32.88	14.64	[167]
49	Aspens	8.2	80.4	11.0	0.4	45.8	5.2	0.4	39.9	0.01	19.1	60.7	14.8	[176]

50	Arhar stalk	4.67	77.33	16.33	1.67	36.19	3.64	0.42	59.35	-	18.0	24.0	19.0	[201]
51	Banana peels	8.53	66.79	20.55	4.13	45.43	5.67	2.31	36.40	0.35	-	-	-	[202]
52	Banana trunk	6.67	74.33	7.33	11.67	33.09	2.94	0.94	63.03	-	25.0	25.0	15.0	[201]
53	Barley straw	6.9	80.3	4.8	9.8	41.4	6.2	0.6	51.7	0.01	-	-	-	[203]
54	Cashew nut shell	10.4	69.3	19.3	1.0	48.7	6.9	0.4	42.9	-	18.6	41.3	40.1	[204]
55	Cherry seed shells	6.1	76.1	17.0	0.8	48.9	6.3	3.1	41.6	0.1	31.9	27.2	36.9	[205]
56	Cherry stones	4.78	75.64	19.16	0.42	51.11	7.18	3.08	38.62	-	26.88	26.96	42.16	[206]
57	Chestnut shells	10.17	65.55	23.08	1.20	48.14	5.47	0.6	45.79	-	22.64	31.61	42.69	[206]
58	Corn cob	8.1	77.1	12.9	1.9	46.4	5.4	1.0	45.2	-	46.0	41.0	-	[207]
59	Corn straw	9.2	75.0	9.7	6.1	42.7	5.6	1.5	49.2	<0.1	24.4	4.8	9.0	[208]
60	Flax straw	7.9	80.3	8.8	3.0	45.2	6.3	1.0	-	1.2	-	-	-	[209]
61	Grape bagasse	6.2	68.4	20.7	4.7	46.6	6.3	1.7	45.5	-	-	28.6	41.9	[210]
62	Hazelnut bagasse	-	68.2	15.3	6.7	43.8	6.3	7.9	41.9	-	-	-	-	[211]
63	Hazelnut shell	10.94	68.98	19.36	0.711	56.37	5.62	5.96	32.05	-	25.48	47.13	23.46	[212]
64	Legume straw	9.8	73.7	14.8	1.6	43.3	5.6	0.6	50.4	0.1	34.1	28.1	34.0	[213]
65	Laurel extraction residues	9.9	69.2	10.3	10.5	48.9	6.4	3.0	41.6	-	44.0	22.8	27.6	[214]
66	Litchi peels	5.75	75.53	15.42	3.30	47.39	6.32	0.81	36.81	0.019	-	-	-	[215]
67	Maize cob	1.88	77.85	17.46	2.81	45.27	5.97	1.09	47.67	-	-	-	-	[163]

68	Maize stalk	7.6	71.9	12.1	8.3	49.1	6.1	0.7	43.7	-	-	-	-	[216]
69	Mango peels	-	78.78	18.54	2.82	47.31	5.77	< 0.1	35.78	< 0.1	-	-	-	[107]
70	Musa balbisiana	-	74.48	21.87	2.16	47.37	6.41	2.87	42.09	1.04	-	-	-	[217]
71	Oat straw	6.7	75.9	0.1	17.3	48.5	6.0	0.4	45.1	-	49.6	31.6	16.6	[218]
72	Olive bagasse	6.8	67.2	21.6	4.4	53.4	7.5	1.7	37.4	-	-	-	-	[211]
73	Olive husk	-	64.8	15.9	7.2	47.2	5.6	0.8	35.4	0.2	24.6	25.0	50.4	[219]
74	Orange peels	-	79.02	17.54	3.43	46.04	5.54	0.65	36.89	< 0.1	-	-	-	[107]
75	Palm shell	5.7	73.7	18.4	2.2	53.8	7.2	0.0	36.3	0.5	-	-	-	[197]
76	Parinari fruit shell	2.7	78.2	14.5	4.7	48.0	5.8	2.1	43.5	0.1	6.4	45.4	30.1	[208]
77	Parthenium bagasse	3.1	79.1	14.8	3.2	53.5	6.2	0.6	33.4	0.2	25.8	23.0	30.0	[220]
78	Pea waste	6.45	71.6	20.9	7.5	40.15	5.60	2.90	48.65	< 0.1	-	-	-	[103]
79	Peanut crust	5.8	72.4	13.2	8.5	43.8	5.7	1.8	34.0	0.4	13.1	36.5	24.7	[221]
80	Pearl millet	3.61	61.29	0.59	34.51	43.66	6.30	0.45	49.54	0.06	3.16	48.93	15.75	[170]
81	Pineapple peels	-	75.38	19.61	5.21	45.79	5.31	< 0.1	33.58	< 0.1	-	-	-	[107]
82	Potato starch	11.95	81.52	6.35	0.18	39.07	5.54	0.18	42.92	0.16	-	-	-	[222]
83	Quinoa biomass	7.2	71.8	-	14.08	43.80	5.26	0.58	44.15	0.06	35.86	38.70	18.51	[223]
84	Quinoa husk	7.0	73.3	-	6.79	41.10	5.39	2.16	39.43	0.26	32.60	31.69	21.52	[223]
85	Rape straw	5.08	72.50	17.28	5.14	44.39	6.47	0.54	48.24	0.36	24.08	17.24	27.64	[224]
86	Rice	-	80.42	16.72	2.86	44.28	7.85	1.24	42.99	0.78	-	-	-	[225]

87	Rice hull	5.92	58.55	-	12.78	39.65	5.21	1.02	53.92	0.02	18.12	36.23	24.65	[226]
88	Rice husk	12.1	60.6	15.0	12.4	45.5	4.5	0.5	36.1	0.1	31.6	43.8	24.6	[227]
89	Rice straw	7.2	62.4	14.9	15.4	44.8	5.1	0.9	49.2	0.6	20.4	60.3	14.1	[208]
90	Soaked rice husk	2.0	70.5	14.3	13.2	41.3	5.1	0.4	38.0	0.02	-	-	-	[227]
91	Sorghum bagasse	7.6	81.0	1.9	9.5	68.33	8.64	0.08	22.81	0.14	24.0	41.0	10.0	[200]
92	Sugarcane bagasse	16.1	79.6	8.1	4.3	58.1	6.1	0.7	34.5	0.2	33.1	42.7	24.2	[219]
93	Sugarcane leaves	5.67	77.33	10.67	3.38	76.83	8.19	0.59	14.39	0.0	42.00	44.00	17.00	[108]
94	Sunflower stalks	12.4	-	-	14.4	49.9	6.3	0.9	42.9	-	18.0	33.0	23.0	[186]
95	Sunflower-extracted bagasse	5.0	78.4	10.5	6.1	53.2	7.1	8.0	31.7	-	-	-	-	[228]
96	Tobacco stalk	8.5	65.5	16.0	9.9	39.6	4.9	3.2	52.3	0.1	32.9	21.3	30.2	[229]
97	Tomato peel	4.67	78.12	12.34	4.87	55.0	7.9	2.8	34.0	0.3	-	-	-	[230]
98	Vine shoots	-	-	-	-	48.2	6.9	1.0	-	0.07	72.5	14.2	13.3	[231]
99	Walnut shells	6.98	76.45	15.99	0.58	47.52	6.71	0.21	45.56	-	26.20	32.19	36.89	[206]
100	Wheat bran	7.78	64.66	23.87	3.69	42.20	7.89	3.64	45.42	0.85	38.56	20.36	20.24	[224]
101	Wheat straw	7.41	80.98	7.52	4.09	48.24	5.64	0.56	45.55	-	36.0	35	18.0	[201]
102	Wheat straw	5.9	74.2	13.0	6.9	52.9	6.3	0.4	40.4	-	45.2	31.2	18.1	[218]
103	Black cumin seed cake	-	70.9	19.2	4.8	51.2	7.9	5.3	35.1	0.5	10.4	37.1	26.7	[232]
104	Cherry seed (kernel + shell)	5.5	77.6	15.7	1.2	52.5	7.6	4.5	35.3	0.1	28.6	32.1	29.1	[205]

105	Cotton seed cake	5.8	79.3	9.7	5.2	52.0	5.9	1.3	40.8	-	-	27.6	-	[233]
106	Date palm seed	4.9	76.6	7.7	10.8	45.3	5.6	1.0	47.2	0.8	55	20	23	[234]
107	Grape seeds	7.67	67.31	22.47	2.55	51.51	6.39	1.77	40.33	-	18.71	13.83	49.23	[206]
108	Guarana seed residue	-	78.34	16.06	5.59	41.55	6.44	1.51	44.91	-	59.37	7.82	13.49	[235]
109	Jatropha cake	10.0	72.5	10.9	6.5	44.4	6.2	4.3	44.5	0.5	-	-	-	[208]
110	Jatropha seed cake	8.1	43.6	4.4	-	49.3	6.1	3.4	-	-	-	-	-	[236]
111	Linseed seed	6.7	77.0	10.7	5.6	61.0	8.5	2.3	28.2	-	-	14.1	-	[237]
113	Moringa cakes	10.4	75.1	8.3	6.3	45.6	6.5	6.5	41.5	-	1.9	17.9	24.9	[208]
114	Neem seed	16.0	71.0	8.1	4.9	38.4	8.3	7.5	45.1	0.7				[238]
115	Pomegranate seed	5.4	78.7	14.1	1.8	49.7	7.5	4.0	38.1	0.7	25.5	26.9	39.7	[239]
116	Rapeseed residue	4.9	81.7	7.9	5.5	62.1	9.1	3.9	24.9	-	-	-	-	[240]
117	Safflower seed	5.7	80.8	11.3	2.2	60.5	9.1	3.1	27.4	-	18.6	27.2	28.9	[241]
118	Safflower seed cake	6.0	83.0	14.0	3.0	49.5	6.9	3.0	40.6	-	16.0	40.0	26.7	[242]
119	Canola residue	6.88	81.85	13.32	4.82	50.22	5.41	3.18	41.19	-	-	-	-	[202]
120	Castor residue	11.16	74.30	9.16	5.40	43.59	5.56	4.69	46.16	-	22.40	38.42	20.20	[243]
121	Cocoa pod	10.3	68.5	10.4	10.8	43.9	4.9	2.2	47.3	0.8	-	-	-	[208]
122	Corn cob	6.3	80.7	7.6	2.1	42.9	6.4	0.6	45.5	0.3	31.7	31.7	3.4	[208]
123	Empty fruit bunch	2.88	75.61	16.42	5.36	46.83	6.28	0.66	45.99	0.24	26.9	26.6	25.4	[244]
124	Olive kernel	-	73.1	19.8	7.1	49	6.7	2.0	34.8	0.3	-	-	-	[245]

125	Olive residue/waste	10.6	70.4	15.3	3.7	44.8	5.1	0.9	49.2	-	-	56.0	-	[246]
126	Olive stone	-	-	-	-	49.9	6.1	0.51	-	-	50.5	25.7	23.8	[231]
127	Palm empty fruit bunch	8.8	79.7	8.7	3.0	48.8	7.3	0	40.2	-	-	-	-	[194]
128	Acacia nilotica	6.46	79.08	13.68	0.78	43.69	7.54	0.47	48.30	-	28.64	41.66	24.20	[247]
129	Peach stones	6.88	72.42	19.84	0.86	49.28	6.65	0.34	43.73	-	25.10	29.50	39.26	[248]
130	E. rigida	3.02	75.05	15.21	6.72	54.17	5.70	1.30	38.30	-	29.50	19.17	37.92	[212]
131	Soybean straw	1.8	75.5	19.8	4.7	47.8	6.9	1.0	44.3	0.1	-	-	-	[104]
132	Miscanthus	5.7	72.9	25.0	2.0	46.0	6.0	0.5	47.5	-	29.6	40.8	21.9	[249]
133	Para grass	7.23	79.45	-	9.32	44.73	6.88	0.98	46.84	0.24	-	-	-	[250]
134	Reed canary grass	5.7	74.9	15.8	3.6	44.9	6.1	<0.04	39.1	-	28.3	42.9	9.4	[251]
135	*Saccharum munja*	4.5	80.7	10.91	3.89	63.29	7.84	2.34	27.19	-	38.90	35.10	17.70	[69]
136	Switchgrass	7.9	72.6	16.4	3.1	44.8	5.7	0.2	38.2	-	31.9	39.0	10.2	[251]
137	Timothy grass	5.0	77.9	16.0	1.1	42.4	6.0	1.0	50.4	0.2	33.1	38.0	28.9	[203]
138	C. humicola	3.42	55.6	14.18	26.8	33.16	5.58	4.8	27.54	2.42	-	-	-	[252]
139	C. pilulifera	10.5	32.2	18.4	38.6	-	-	-	-	-	-	-	-	[253]
140	Microalgae chlorella	6.8	72.2	15.1	5.9	6.7	38.6	-	-		47.5	9.5	7.1	[254]
141	*Polysiphonia elongata*	11.55	48.2	12.8	27.45	35.81	5.93	6.86	51.40	-	-	-	-	[255]
142	Reeds	5.89	72.12	13.52	8.47	42.78	5.17	1.33	50.51	0.21	30.68	43.05	20.34	[256]
143	*Wolffia arrhiza*	4.76	72.6	-	10.4	35.55	6.36	5.25	35.87	1.16	-	-	-	[257]

144	Cattle manure	24.6	53.1	4.6	42.3	21.9	3.6	2.3	20.8	1.1	24.5	32.7	42.8	[219]
145	Horse manure	8.2	70.4	11.0	10.5	43.3	5.9	0.9	49.2	0.8	23.8	6.3	56.0	[258]
146	Rice	-	80.42	16.72	2.86	44.28	7.85	1.24	42.99	0.78	-	-	-	[225]
147	Corrugated cardboard	-	-	13.1	4.0	43.24	5.8	0.12	-	-	-	-	13.2	[259]
148	Incense sticks	6.08	65.98	13.12	14.82	35.63	4.51	0.32	38.62	0.023	-	-	-	[260]
149	Kitchen garbage	-	63.5	8.8	27.8	-	4.4	2.3	5.3	0.6	-	-	-	[261]
150	Paper (waste pulps)	-	-	-	-	-	-	-	-	-	17.1	74.3	8.6	[219]

Note: VM- Volatile matter, FC- Fixed carbon, MC-moisture content, CL-Cellulose content, HEL- Hemicellulose content, LIG-Lignin, C-Carbon, H-Hydrogen, N-Nitrogen, S-Sulfur, O-Oxygen

Appendix B: Kinetic analysis data of different type of biomasses using various kinetic models

S.No	Biomass	Temperature range	Heating rate	Average activation energy (kJ/mol)	Kinetic models used	Calorific value (MJ/ kg)	References
1	*Cascabela thevetia*	30 to 900°C	10, 20, 30, and 40°C/min	166.28, 177.05, 185.22, 199.74, and 102.28	KAS, OFW, FM, DAEM, and VZK	21.12	[8]
2	Castor residue	Ambient to 900°C	5, 10, 15, 20, 30 and 40°C/min	165.86, and 167.10	KAS, and FWO	14.43	[243]
3	Switch grass	Ambient to 900°C	10, 20, 30, 40,and 50°C/min	126.03, 137.54, 130.33, and 134.26	KAS, FWO, DAEM, and VZK	18.21	[262]
4	Corrugated cardboard	30 to 900°C	5,10,15, 20 and 25°C/min		-	18±0.9	[259]
5	*Cynodon dactylon* grass	Ambient to 900°C	10, 30, and 50°C/min	208.89, 220.43, 211.90, 213.66, 214.28, and 192.30	KAS, FWO, FM, ST, DAEM, and VZK	17.96	[45]
6	Tomato peel	Ambient to 1000°C	5, 10, 15,20 and 25°C/min	112.7, 113.85, and 234.27	Kissinger, KAS, and FWO	22.50	[230]
7	*Vachellia nilotica* weed	Ambient to 900°C	5, 10, and 20°C/min	152.36, 150.10, and 166.21	FWO, KAS, and FM	18.92	[169]
8	*Samanea saman* seed	Ambient to 900°C	10, 20, 30, and 40°C/min	118.24, 168.7, 97.87,	Kissinger, DAEM, and MMI	17.68	[63]
9	Litchi peels	Room to 800°C	10, 20, 25, and 30°C/min	176.4	FWO, and KAS	19.12	[215]
10	Bamboo sawdust	30 to 900°C	5, 10, and 20°C/min	265, 265, and 353	KAS, FWO, and FM	17.04	[182]
11	Cherry seed	25 to 1000°C	5, 10, 20, and 40°C /min	274.6, 268.5, 266.6, and 272.2	FM, FWO, VZK, and DAEM	-	[105]
12	Straw, Sawdust, Cellulose	Room to 800°C	20, 30, 40, and 50°C/min	193.3 , 141.05, and 145.65	FWO, KAS, ST, and DAEM	-	[263]

13	Pineapple peels, Orange peels, Mango peels, Rice husk, Pine wood	Room to 700°C	5, 10, and 20°C/min	185, 275, 250, 170, and 180	KAS, FWO, ST, VZK, FM, and DAEM	19.02, 18.57, 18.36, 15.30, and 20.37	[107]
14	Sewage sludge	25 to 800°C	5, 10, and 20°C/min	-	Coats-Redfern	11.5	[264]
15	Potato starch, Lignite coal	Ambient to 950°C	10,20, and 40°C/min	183, and 253	KAS	15.92 18.79	[222]
16	Banana peel	Ambient to 800°C	10, 20, 30, and 40°C/min	94±17, 94± 11, and 94±2	FM, KAS, FWO	18.87	[265]
17	Solid leather wastes	30 to 800°C	5, 10, 15, and 20°C/min	391.79, 348.77, and 174.09	FWO, KAS, Kissinger	14.15	[266]
18	Horse manure	Room to 900°C	1, 2, 5, and 10°C/min	199.3, 200.2, 194.6, and 149	FWO,KAS, FM, and Kissinger	-	[258]
19	*Pistachio* shell	Room to 900°C	10, 20, 30, and 40°C/min	182.09, 182.15, 182.13, and 181.42	FWO, KAS, ST, and FM	16.85	[158]
20	Sugarcane leaves (*Saccharum officinarum* L)	30 to 1000°C	5, 10, 15, 20, 30, and 40°C/min	215.11, 214.89, 239.58, 226.97, 226.75, 226.94, and 226.91	VZK, V.AIC, FM, FWO, KAS, ST, and TM	18.08	[108]
21	Maize cob	Ambient to 900°C	5, 10 and 20°C/min	197.63, 186.06, 185.39, and 185.80	FM, FWO, KAS, and ST	15.27	[163]
22	*Chlorella vulgaris*, Kitchen waste	Room to 900°C	20, 30, 40, and 50°C/min	206.67, 198.94, and 237.00, 230.92	FWO, and KAS	22.82±0.044, and 18.74±0.040	[267]
23	*Melia azedarach* sawdust	Ambient to 900°C	10, 20, and 30°C/min	161.18, 162.68, and 161.41	FWO, KAS, and ST	15.43	[268]
24	*Wolffia* arrhiza	50 to 800°C	10, 30, and 50°C/min	168.35, and 170.37	KAS, and FWO	17.77	[257]
25	Empty fruit bunch	40 to 600°C	10°C/min	-	Coats-Redfern	19.64	[244]
26	Guarana seed residue	25±2 to	5, 10, and 15°C/min	Inert atm. 161.98±8.29 O_2 atm.- 142.70±7.31	VZK	17.58±0.03	[235]

		899.15± 0.36 ºC					
27	Melon seed husk	Room to 800ºC	5, 10, and 20ºC/min	161.26, and 192.96	Kissinger, and FWO	21.78	[269]
28	Groundnut shell	383 to 1223 K	10, 20 and 30 K/min	-	Single reaction, Series reaction, DAEM	20.2	[196]
29	*Musa balbisiana*	35 to 900ºC	5, 10, and 20ºC/min	137.94, 136.76, and 133.36	KAS, FWO, and FM	16.35	[217]
30	Coffee ground residues	Room to 500ºC	5, 10, 15, 25, 50, and 100ºC/min	Cellulose -214, Hemi cellulose -241 lignin -266	KAS, and FWO	23.4	[270]
31	Pea waste	Room to 800ºC	10, 20, 30 and, 40 ºC/min	212.71, 211.55, 212.94, and 212.93	KAS, FWO, ST, VZK	18.42	[103]
32	Pine sawdust, Sal sawdust, and Areca nut husk	25 to 900ºC	5, 10, 15, 20, and 25ºC/min	171.66, 179.29, 168.58, 206.62, and 148.44, 156.58, 181.53, 171.63, and 171.24, 179.47, 184.61, 160.45,	KAS, FWO, FM, and DAEM,	18.44±09, 18.20±09, and 18.21±09	[7]
33	Olive kernel, Municipal solid waste, and Sewage sludge	40 to 850ºC	5, 10, 20, 30, and 40ºC/min	-	Modified IPR	20.6 , 15.6 and 14.8	[245]
34	Chestnut, shells, Cherrystones, and Grape seeds	25 to 1000ºC	5, 10, 20, and 40ºC/min	170.3, 175.2, 175.9, 175.5, and 274.6, 272.2, 268.5, 272.2, and 184.2, 186.6, 187.3, 186.9	FM, KAS, FWO, and ST	-	[206]
35	Rape straw, and Wheat bran	Room to 1073K	10, 20, and 30 K/min	98.93, and 96.85	ST	-	[224]
36	*Typha latifolia*	Ambient to 1275K	10, 30, and 50 K/min	184.58, and 182.67	FWO, and KAS	18.32	[151]

37	Cattle manure	Room to 800°C	10, 20, 30, 40 ,60, 80°C/min	195.49, 182.05, 181.45, and 181.22	FM, FWO, KAS, and ST	-	[109]
38	Soybean straw	Room to 1173K	5, 10, 20, and 30 K/min	154.15, and 156.22	KAS, and FWO	-	[104]
39	Pine wood	-	-	21.305	Single step first order	20.58±0.12	[271]
40	Agricultural residue (cotton, wheat, rice, corn)	Room to 700°C	10, 20, and 30°C/min	221.7	CK-TPR	-	[272]
41	Para grass (*Urochloa mutica*)	Room to 1000°C	10, 30, and 50°C/min	163, and 175	KAS, and FWO	15.04	[250]
42	Rice straw	298 to 973K	5, 10, and 15 K/min	192.66, 193.60, and 172.62	FWO, KAS, and Kissinger	-	[273]
43	Empty fruit bunch, and Palm kernel shell	30 to 900°C	10, 20, 30, and 40°C/min	77.475 84.475	Coats-Redfern	_	[274]
44	Cotton stalk, and Corn straw	Ambient to 1173K	20 K/min	83.45, and 54.5	Two dimensional diffusion model	-	[192]
45	Eucalyptus leaves, Eucalyptus bark, and Eucalyptus sawdust	Room to 800°C	10 and 40°C/min	141.15, 215.65, 149.21, 264.76 175.79, 150.66	Continuous DAEM, and Modified discrete DAEM	-	[179]
46	*Ulva prolifera*	Ambient to 1000°C	5, 10, and 20°C/min	141.34±8.71	DAEM	16.54	[275]
47	Pigeon pea stalk	Ambient to 1000°C	10, 20, and 30°C/min	95.97, 100.74, 96.24, and 96.64	KAS, FWO, ST, and FM	18.57	[168]
48	*Chlorella sp., T. suecica*	Ambient to 600°C	5, 10, and 15°C/min	298.42, 301.70, and 99.69, 94.77	FWO, and KAS	-	[276]
49	Pinyon pine	20 to 900°C	5, 10, 15, and 20°C/min	102.1	Differential method	18.94	[277]
50	Finger millet straw	Room to 800°C	10, 25, 30, and 40°C/min	177.8, and 172.12	FM, and ST	18.61	[167]
51	Corn cob, Tree root, and Bagasse	Room to 850°C	20°C/min	164.475 , 181.6, and 174,75	DAEM	-	[278]

52	Palm fiber	30 to 800ºC	5, 10, 15 and 20 ºC/min	440.85	Differential method	18.08	[198]
53	*Sagarssum sp.*	30 to 800ºC	5, 10, 15, and 20ºC/min	344.55	Lumped kinetic model	10.10	[279]
54	*Sargassum thunbergii*,	Ambient to 800ºC	10, 30, and 50ºC/min	185.4, 185.6, 196.8	FWO, KAS, and Popescu	-	[280]
55	*Potamogeton crispus*	Ambient to 800ºC	10, 30, and 50ºC/min	145.3, 143.2, 131.7	FWO, KAS, and Popescu	-	[280]
56	Banana leaves biomass	Ambient to 900ºC	10, 20, and 30 ºC/min	84.02, 79.36, 92.12, 73.89, and 70.75	FWO, KAS, ST, TM, FM, Kissinger	17.8	[142]
57	*Saccharina japonica*	30 to 800ºC	10, 15, and 20ºC/min	181.66	Lumped kinetic model	12.11	[281]
58	Corn cobs, and Sugarcane bagasse	Room to 700ºC	10, 20, 30, 40, and 50ºC/min	102.5, and 197.5	FM	17.2, and 17.5	[282]
59	Mustard oil residue	Ambient to 900ºC	10, 20, and 30ºC/min	155.64, 152.94, 152.153.29, 153.52, 163.53, and 159.01	FWO, KAS, ST, TM, VZK, FM, and V.AIC	19.4	[283]
60	Cardoon leaves, and Cardoon stems	25 to 850ºC	5, 10, 20, and 30ºC/min	350.07, 242.01, and 224.51, 229.70	KAS, and FWO	17.9, and 21.5	[147]
61	Rice straw	Ambient to 900ºC	5, 10, 15, and 20 ºC/min	174.91, 174.77, 172.79, and 174.88	KAS, FWO, ST, and TM	17.4	[284]
62	Milk dust powder	Ambient to 950 ºC	10, 20, 30, and 40ºC/min	228.29, and 232.46	ST, and FM	17.5	[285]

Note: KAS = Kissinger Akahira Sunose, OFW = Ozawa Flynn Wall, TM = Tang, ST = Starink, VZK = Vyazovkin, V.AIC = Vyazovkin advanced isoconversional

Appendix C: Different operating parameters of biomass pyrolysis

Biomass	Reactor	Operating condition of pyrolysis	Optimum condition of temperature (°C)	Optimum product yield (wt. %)	References
Teak saw dust	Fixed bed reactor	Temperature (400–700°C), sweeping gas flow rate (150–250 ml/min), bed height (2–8 cm), and particle size (0.18–0.60 mm)	Temperature of 600 °C, a N_2 flow rate of 150 mL/min, a packed bed height of 8 cm, and particle size of 0.18–0.25 mm	48.8	[66]
Peanut shell	Fixed bed reactor	Temperature (400–650°C), sweeping gas flow rate (50–150 ml/min), and heating rate (10–20 °C/min)	Temperature = 650°C, N_2 flow rate = 100 ml/min and heating rate = 20°C/min	Liquid yield of 43.24 wt. %	[68]
Samanea saman seed	Fixed bed reactor	Temperature range of 450–600°C, heating rate of 50-120 °C/min, particle size of 0.5-1.5 mm, and N_2 flow rate of 100 ml/min	550°C temperature, 80°C/min heating rate, 0.5 mm particle size	Liquid yield 44.2 wt. %	[63]
Cascabela thevetia	Fixed bed reactor	Temperature range of 400–600°C, heating rate of 50-100°C/min, and N_2 flow rate of 100 ml/min	500°C temperature, and 80°C/min heating rate,	Liquid yield 64.23 wt. %	[71]
Madhuca longifolia	Fixed bed reactor	Temperature range of 400–600°C, heating rate of 50-120°C/min, and N_2 flow rate of 100 ml/min	500°C temperature, and 120°C/min heating rate,	Liquid yield 51.2 wt. %	[65]
Babool (*Acacia nilotica*) seed	Fixed bed reactor	Temperature range of 400–700°C, and N_2 flow rate of 100 –400 ml/min, particle size 0.4 – 1 mm	500°C temperature, particle size 0.4 mm, 100 ml/min N_2 flow rate	Liquid yield 38.7 wt. %	[286]
Cassia siamea seed	Fixed bed reactor	Temperature range of 450°C and 575°C at a heating rate of 50°C min^{-1}.using N_2 flow rate of 40 ml/min	550	50.21%	[287]
Mesuaferrea seed cover (MFSC) and	Fixed bed reactor	Temperature range of 350 –650°C	550 at heating rate of 40°C/min	28.5 wt. % and 29.6 wt. % for PGSC and	[127]

Pongamia glabra seed cover (PGSC)				MFSC respectively	
Corn cob, Wheat straw, Rice straw and Rice husk	Fixed bed reactor	Temperatures 300, 350, 400 and 450^{o}C	450, 400, 400 and 450	Liquid yield 47.3, 36.7, 28.4, and 38.1 wt. %	[67]
Saccharum munja	Fixed bed tubular reactor	Temperature range of 450 –600^{o}C, residence time of 30 – 60 min	525°C temperature, 60 min residence time	Liquid yield 46 wt. %	[69]
Manilkara zapota seed	Fixed bed reactor	Temperature range of 400–600^{o}C, heating rate of 50-120^{o}C/min, particle size of 0.5-2 mm, and N_2 flow rate of 100 ml/min	500°C temperature, 80°C/min heating rate, 0.5 mm particle size	Liquid yield 45.22 wt. %	[62]
Neem seed (*Azadirachta indica*)	Fixed bed reactor	Temperature range of 450–650^{o}C, heating rate of 50-120 ^{o}C/min, particle size of 0.5-1.5 mm, and N_2 flow rate of 80 ml/min	500°C temperature, 80°C/min heating rate, 0.5 mm particle size	Liquid yield 49.53 wt. %	[61]

Appendix D: GCMS analysis of LS bio-oil

Retention time (R.T)	**Compound**	**Area %**
5.739	Tricosane, 2-methyl-	3.99
6.270	Docosane	16.02
7.317	Oxalic acid, dineopentyl ester	3.49
11.544	3-Octen-2-ol, (E)-	3.39
12.702	3-Hexanone, 2,2-dimethyl-	2.70
16.927	Pentadecane	2.66
17.143	Sulfurous acid, 2-ethyl hexyl pentyl ester	0.24
18.001	Octane, 1-iodo-	1.52
18.300	2-Pyridine ethanamine, N-methyl-N-[2-(4-pyridinyl)ethyl]-	3.35
21.946	(S)-4-iodo-1,2-epoxybutane	13.97
30.666	1,2-Benzenedicarboxylic acid, diisooctyl ester	10.53
40.180	1,3-Dioxolane-4-methanol, 2-pentadecyl	9.44
41.699	5.alpha.-Cholest-8-en-3-one, 14-methyl-	28.70

Appendix E: GCMS analysis of MS bio-oil

Retention time (R.T)	Compound	Area %
4.160	4-tert-Butylcyclohexyl acetate	22.77
4.664	N-Isobutyl-isobutanamide	2.08
4.760	Acetaldehyde, (acetyloxy)-, 1-oxime, (E)	0.16
4.773	Imidazole-1,4,5-D3	0.20
5.223	Bicyclo[7.2.0]undec-4-ene, 4,11,11-trimethyl-8-methylene-, [1R-(1R*,4E,9S*)]	13.56
5.696	Oxalic acid, dineopentyl ester	4.24
6.263	Docosane	16.30
6.453	Disulfide, dioctyl	4.98
6.596	2-Methyl-1-octen-3-ol	0.07
6.945	Methyl 3-methyl-5-oxy-2-phenoxyhexanedithioate	0.32
7.236	Oxalic acid, allyl isobutyl ester	0.79
7.329	Acetyl valeryl	6.94
8.119	Propanoic acid, 2-propenyl ester	0.53
9.050	2-Pyridineethanamine, N-methyl-N-[2-(4-pyridinyl)ethyl]	0.83
9.184	[1,1'-Bibicyclo[2.2.2]octane]-4-carboxylic acid	0.22
9.382	Acetic acid, cyano-	0.23
9.471	Furazan	0.13
10.694	4-T-butyl-1-trifluoromethylcyclohexanol	0.14
10.815	Acetic acid, oxo-, butyl ester	0.34
10.837	2-Hexen-1-ol, (E)-	0.49
10.946	3-Buten-2-one, 4-(2,2,6-trimethyl-7-oxabicyclo[4.1.0]hept-1-yl)-	0.22
10.967	Acetonitrile	0.10
11.473	Butanoic acid, 3-methyl-, anhydride	1.88
11.551	2-Pentanol, 3-methylene-	7.55
11.702	3-Hexanone, 2,2-dimethyl-	3.39
12.702	Butanoic acid, 1,1-dimethylethyl ester	2.59
16.927	Hexadecane	3.54

17.011	1-Isopropyl-2-nonynylacetate	0.25
17.054	(R)-tetrahydro-4,4-dimethyl-2-oxofuranyl 2-diazo-3-oxobutanoate	0.42
17.121	Propanoic acid, anhydride	0.24
17.151	Butane, 1-bromo-2-methyl-	0.29
18.009	4-Heptanone, 2,6-dimethyl	1.84
18.399	2,3-Butanedione, dioxime	0.19
18.446	Propene-1,1-D2	0.12
18.469	1(2H)-napthalenone, 2-(3,3-dimethyl-2-phenyl-2-aziridinyl)-3,4-dihydro-	0.24
18.546	Propane, 2-nitro-	0.20
18.569	(1.Alpha.,2.alpha.,4A.alpha.)-octahydro-2-acetoxy-4A-(methoxycarbonyl)-napthalen-1-ol	0.12
21.928	Oxalic acid, butyl propyl ester	0.32
21.976	(R)-(-)-2-(N-undecyl)tetrahydrofuran	0.11
21.993	Cyclopentaneacetonitrile, .alpha.-methoxy	0.28
22.101	Carbonic acid, di-2-propenyl ester	0.39
26.473	(R)-Tetrahydro-4,4-dimethyl-2-oxofuranyl 2-diazo-3-oxobutanoate	0.40

Appendix F: GCMS analysis of SB bio-oil

Retention time (R.T)	Compound	Area %
4.177	Heptane, 1-iodo-	1.62
4.677	Hutanoic acid, anhydride	1.26
5.236	5-(Benzyloxy)-7,7-dimethyl-1,3,8-nonatriene	0.12
5.707	Oxalic acid, dineopentyl ester	4.24
6.188	2-Propenoic acid, methyl ester	2.75
6.260	Docosane	16.76
6.447	Butane, 2,2-dimethyl-	4.91
6.608	3-Hexanone, 2,2-dimethyl-	2.87
6.748	Acetonitrile	0.56
6.943	4-Fluoro-2-trifluoromethylbenzoic acid, neopentyl ester	4.39
7.332	Pentadecane	5.31
9.204	Butane, 2,2,3,3-tetramethyl-	5.56
10.230	Propane, 2-[(fluoromethyl)sulfonyl]-2-methyl	0.58
10.696	2-Hexen-1-ol, (E)-	0.48
10.823	4-H-Pyrazol-4-one, 3,5-dimethyl-, 1,2-dioxide	1.41
11.464	2-Pentanol, 3-methylene-	1.89
11.547	Acetyl valeryl	8.01
11.704	Butanoic acid, 1,1-dimethylethyl ester	2.41
12.707	3-Hexanone, 2,5-dimethyl-	2.53
16.186	Propane, 2-methyl-2-nitro-	0.47
16.391	2-Methyl-1,3-digerma-2-silapropane	0.17
16.934	3-Octen-2-ol	1.69
17.130	Borane, trimethyl-	0.07
17.149	Oxirane, propyl-	0.19
17.182	Oxalic acid, allyl isobutyl ester	0.40
17.998	Butane, 1-bromo-2-methyl-	3.67
18.317	Phthalic acid, 4-bromophenyl heptyl ester	9.69
18.921	Trans-1-(phenylthio)-6-oxo-4-oxahept-1-ene	0.68

19.212	Propane, 2-nitro-	0.25
21.724	Propanoic acid, ethenyl ester	0.19
21.970	2-Propenamide	8.41
22.716	1,3-Oxathiol-1-ium, 4-hydroxy-2-[(1-methylethyl)thio]-5-(trifluoroacetyl)-, hydroxide, inner salt	1.23
26.471	Nonane, 4-methyl	5.23

List of Publications

1. **Ahmad Nawaz** and Pradeep Kumar, Pyrolysis of mustard straw: Evaluation of optimum process parameters, kinetic and thermodynamic study **(Bioresource Technology)** 340 (2021) 125722.

2. **Ahmad Nawaz**, Bineeta Singh and Pradeep Kumar, H3PO4-modified Lagerstroemia speciosa seed hull biochar for toxic Cr(VI) removal: isotherm, kinetics, and thermodynamic study **(Biomass Conversion and Biorefinery)** 11 (2021) 1780.

3. **Ahmad Nawaz**, Ranjeet Kumar Mishra, Shivesh Sabbarwal and Pradeep Kumar, Studies of physicochemical characterization and pyrolysis behavior of low-value waste biomass using Thermogravimetric analyzer: evaluation of kinetic and thermodynamic parameters **(Bioresource Technology Reports)** 16 (2021) 100858.

4. **Ahmad Nawaz**, Bineeta Singh and Pradeep Kumar, Efficient removal of Cr (VI) using raw and phosphoric acid modified *Sterculia Alata* nutshell **(Indian Journal of Chemical Technology)** 28 (2021) 684 - 692.

5. **Ahmad Nawaz** and Pradeep Kumar, Elucidating the bioenergy potential of raw, hydrothermally carbonized and torrefied waste *Arundo donax* biomass in terms of physicochemical characterization, kinetic and thermodynamic parameters **(Renewable Energy)** 187 (2022) 844 - 856.

6. **Ahmad Nawaz** and Pradeep Kumar, Optimization of process parameters of *Lagerstroemia speciosa* seed hull pyrolysis using a combined approach of Response Surface Methodology (RSM) and ANN for renewable fuel production **(Bioresource Technology Reports)** 18 (2022) 101110.