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Data on Emission Factors of Gaseous Emissions from Combustion of Woody Biomasses as Potential Fuels for Firing Thermal Power Plants in Nigeria

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This article contributes to:

7 AFFORDABLE AND CLEAN ENERGY
SUSTAINABLE DEVELOPMENT GOALS

Highlights

- The data showed the gaseous emissions from combustion of woody biomasses are minimal compared to those from others solid fuels like coal species.
- The data furnished us with reliable information as regards the availability of numerous woody biomasses in southwest, Nigeria.
- The data examined the emission factors of CO_2, SO_2, and NO_2 emissions from combustion of woody biomasses as potential fuels for firing thermal power plants in Nigeria.
- The data give us the hint on the reduction of fossil fuels for firing thermal plants in Nigeria and the propagation of woody biomasses to replace fossils.
- The data will serve as guide on selecting the best woody biomasses for mass planting and in taking emission inventory from thermal plants in Nigeria.

Abstract

This work generated data on the emission factors of air emissions from combustion of woody biomasses collected from southwest, Nigeria. This was with a view to finding their potentials as sustainable and environmentally friendly fuels for firing thermal power plants compared to coals. The data on heating values and elemental contents (carbon, sulphur and nitrogen) responsible for gaseous emissions in the 100 woody biomasses were collected from the previous results of this work to determine the gaseous emission factors on the expected condition of complete combustion. The current results showed that the CO_2 emission factors ranged from 0.0147 kg/(MJ/kg) for *Ficus mucuso* to 0.1499 kg/(MJ/kg) for *Spondias mombin*, SO_2 emission factors ranged from 0.0000000 kg/(MJ/kg) for *Pterygota macrocarpa, Irvingia grandifolia,* and fifteen others, to 0.0011341kg/(MJ/kg) for *Khaya ivorensis*, while NO_2 emission factors ranged from 0.0000000 kg/(MJ/kg) for *Citrus medica* to 0.0035824 kg/(MJ/kg) for *Ficus carica*. Considering the minimal emissions from biomasses compared to coal species, serious political will is needed on the part of the Nigerian government to propagate these biomasses for fuels in firing the thermal plants in the country.

Keywords: Renewable energy sources; Woody biomasses; Thermal power plant; Air emissions; Environment

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1. Specifications Table

Subject area	Mechanical Engineering, Chemical Engineering
More specific subject area	Environmental Pollution
Type of data	Tables, Figures
How data was acquired	Experimental and mathematical modelling
Data format	Raw, analyzed

Parameters for data collection	The gaseous emissions are associated with firing of thermal plants due to fuel used. The amounts of emissions released depend on the heating value of fuel consumed. The potential fuels here are woody biomasses which are renewable and in abundance in southwest, Nigeria.
Description of data collection	The data (**Table 1**) were obtained from the mathematical modelling analysis of CO_2, SO_2, and NO_2 emissions from combustion of woody biomasses in southwest, Nigeria (**Table 2**) by combining Equations 1, 2, 3, and 4 as shown in **Table 1** as potential fuels for firing a typical thermal plant (**Figure 1**) in Nigeria. The raw data (**Table 2**) used in the modelling were obtained from the previous results of this work Sources were appropriately cited and referenced.
Data source location	Nigeria
Data accessibility	Information on data are available within this article.
Related research article	Assessment of sawdust of different wood species in Southwestern Nigeria as source of energy [1], and Comparative Study of Non-Metallic Contents of Sawdust of Different Wood Species and Coal Species in Nigeria [2].

2. Rationale

The data obtained from this research come from the mathematical modelling analysis of CO_2, SO_2, and NO_2 emission factors from combustion of 100 woody biomasses collected from southwest, Nigeria. This was with a view to finding their potentials as sustainable and environmentally friendly fuels for firing thermal power plants (**Figure 1**) compared to the corresponding emissions from coal species. **Table 1** showed the estimated emission factors of CO_2, SO_2 and NO_2 form the 100 woody biomasses identified and selected. The data showed that the CO_2 emission factors ranged from 0.0147 kg/(MJ/kg) for *Ficus mucuso* to 0.1499 kg/(MJ/kg) for *Spondias mombin*, SO_2 emission factors ranged from 0.0000000 kg/(MJ/kg) for *Pterygota macrocarpa, Irvingia grandifolia,* and fifteen others, to 0.0011341kg/(MJ/kg) for *Khaya ivorensis*, while NO_2 emission factors ranged from 0.0000000 kg/(MJ/kg) for *Citrus medica* to 0.0035824 kg/(MJ/kg) for *Ficus carica*. The estimated emission factors for CO_2, SO_2, and NO_2 emissions from coal species ranged from 0.0903 to 0.1041 kg/(MJ/kg) for CO_2, 0.0003445 to 0.00127234 kg/(MJ/kg) for SO2, 0.0013727 to 0.0018728 kg/(MJ/kg).

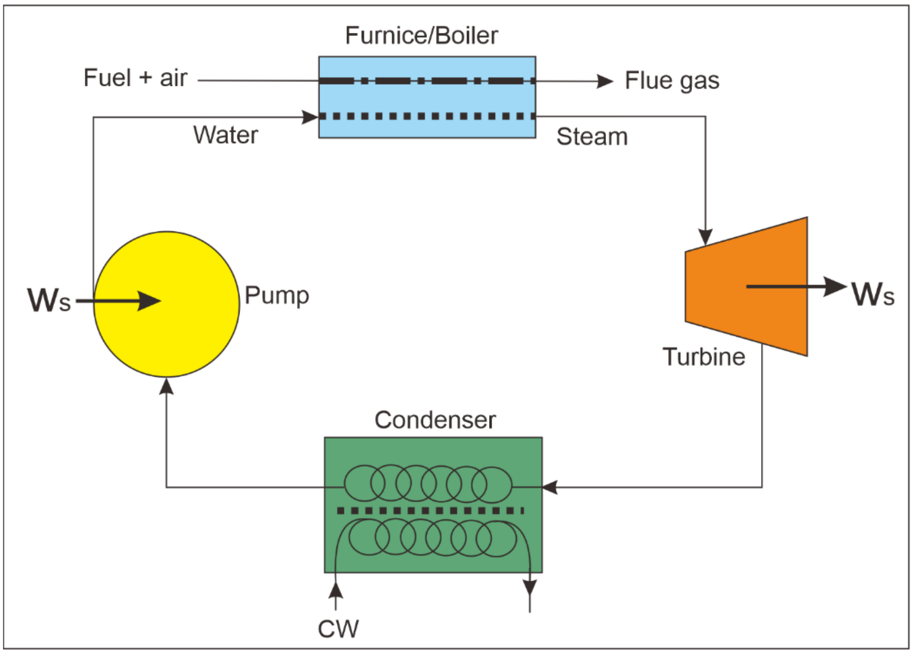

Figure 1. A typical thermal power plant [3]

Table 1. Emission factors of Air emissions from the identified woody biomasses

S/N	Botanical Name	CO_2 [kg/(MJ/kg)]	SO_2 [kg/(MJ/kg)]	NO_2 [kg/(MJ/kg)]
1.	*Albizia gummifera*	0.1322	0.0000141	0.0006014
2.	*Pterygota macrocarpa*	0.1082	0.0000000	0.0002307
3.	*Irvingia grandifolia*	0.1406	0.0000000	0.0006700
4.	*Crassocephalum biafrae*	0.1117	0.0000500	0.0001527
5.	*Daniella oliveri*	0.1110	0.0000119	0.0000392
6.	*Parkia biglobosa*	0.1100	0.0000337	0.0001477
7.	*Daniella ogen*	0.1071	0.0000113	0.0019534
8.	*Cola acuminata*	0.1132	0.0000124	0.0002804
9.	*Bambusa vulgaris*	0.1409	0.0000159	0.0009728
10.	*Entada gigas*	0.1345	0.0000298	0.0000980
11.	*Ficus thionningii*	0.1225	0.0000000	0.0010941
12.	*Uapaca heudelotii*	0.0761	0.0000568	0.0002026
13.	*Symphonia globulifera*	0.0940	0.0000213	0.0007198
14.	*Cola millenii*	0.0821	0.0000090	0.0016209
15.	*Prunus dulcis*	0.1020	0.0000540	0.0014219
16.	*Entandrophragma cylindricum*	0.1112	0.0000108	0.0000177
17.	*Irvingia excelsa*	0.1347	0.0000117	0.0002302
18.	*Milicia excels*	0.1175	0.0000719	0.0012063
19.	*Delonix regia*	0.0900	0.0000000	0.0025353
20.	*Ficus carica*	0.1145	0.0000109	0.0035824
21.	*Astonia boonei*	0.0976	0.0000108	0.0007102
22.	*Newbouldia laevis*	0.1023	0.0000324	0.0010475
23.	*Cassia fistula*	0.0882	0.0000098	0.0005669
24.	*Brachystegia leonensis*	0.1108	0.0000224	0.0007906
25.	*Musanga cecropiodes*	0.0988	0.0000108	0.0000177
26.	*Asteromyrtus symphyocarpa*	0.0911	0.0000000	0.0015480
27.	*Poga oleosa*	0.0997	0.0000215	0.0023303
28.	*Tectona grandis*	0.1046	0.0000119	0.0000782
29.	*Pycananthus angolensis*	0.1144	0.0000969	0.0000398
30.	*Gmelina arborea*	0.0929	0.0000109	0.0003408
31.	*Parkia biglobasa*	0.1195	0.0000122	0.0013662
32.	*Anthocleista vogelii*	0.0976	0.0000237	0.0011523
33.	*Afromosia elata*	0.0884	0.0000000	0.0006369
34.	*Isoberlina doka*	0.1062	0.0000830	0.0002145
35.	*Mitragyna ciliata*	0.1217	0.0000127	0.0000209
36.	*Blighia sapida*	0.1166	0.0000103	0.0000169
37.	*Nauclea diderrichii*	0.0850	0.0000077	0.0009328
38.	*Cissus adenopoda*	0.1186	0.0000000	0.0020476
39.	*Antrocaryon micraster*	0.1087	0.0000470	0.0009866
40.	*Garcinia kola*	0.1257	0.0000122	0.0000201
41.	*Lecaniodiscus cupanioides*	0.1103	0.0000131	0.0034412
42.	*Nesorgodonia paparivera*	0.1174	0.0000000	0.0006810
43.	*Erythrophylium sp.*	0.1002	0.0000102	0.0002180
44.	*Khaya ivorensis*	0.1061	0.0011341	0.0031715
45.	*Ficus mucuso*	0.0147	0.0000610	0.0015558
46.	*Anogeissus leiocarpus*	0.0917	0.0000196	0.0008288
47.	*Chrysophyllum africanum*	0.0969	0.0001023	0.0000505
48.	*Pterocarpus erinaceus*	0.1018	0.0000779	0.0010433
49.	*Adansonia digitata*	0.1135	0.0000000	0.0005183
50.	*Vitellaria paradoxa*	0.1033	0.0000245	0.0020344
51.	*Mangifera indica*	0.0990	0.0000093	0.0004733
52.	*Cylicodiscus gabunensis*	0.0947	0.0000110	0.0018015
53.	*Antiaris Africana*	0.0989	0.0000104	0.0013648
54.	*Triplochoton scleroxylon*	0.0949	0.0000000	0.0003540
55.	*Hildegardia barteri*	0.1390	0.0000000	0.0010142
56.	*Hymenocardia acida*	0.1221	0.0000385	0.0001898
57.	*Gliricidia sepium*	0.0895	0.0000000	0.0001365
58.	*Diospyros crassiflora*	0.1134	0.0000121	0.0007763
59.	*Terminalia ivorensis*	0.0939	0.0000099	0.0011585
60.	*Spondias mombin*	0.1499	0.0001267	0.0009031
61.	*Pterocarpus osun*	0.1212	0.0000256	0.0000211
62.	*Bombax buonopozense*	0.1314	0.0000000	0.0014669
63.	*Chasmanthera dependens*	0.1168	0.0000116	0.0005512
64.	*Mansonia altissima*	0.1026	0.0000000	0.0002544
65.	*Napoleona vogelii*	0.1186	0.0000220	0.0002718

S/N	Botanical Name	CO_2 [kg/(MJ/kg)]	SO_2 [kg/(MJ/kg)]	NO_2 [kg/(MJ/kg)]
66.	*Pinus ponderosa*	0.1237	0.0000255	0.0020357
67.	*Citrus limon*	0.1409	0.0000152	0.0020227
68.	*Funtumia elastic*	0.1134	0.0000242	0.0020517
69.	*Quecus robur*	0.1043	0.0000116	0.0017350
70.	*Terminalia glaucescens*	0.1053	0.0000127	0.0033511
71.	*Swieteni sp.*	0.1350	0.0000000	0.0014367
72.	*Citrus aurantifolia*	0.1036	0.0000000	0.0020513
73.	*Bytraria marginata*	0.1064	0.0000678	0.0007995
74.	*Azadirachta indica*	0.1036	0.0000692	0.0004365
75.	*Macaranga barteri*	0.1220	0.0000320	0.0010718
76.	*Sterculia rhinopetala*	0.1312	0.0000116	0.0011215
77.	*Berlinia grandifolia*	0.1120	0.0000127	0.0014457
78.	*Bombax ceiba*	0.1158	0.0000000	0.0006287
79.	*Theobroma cacao*	0.1090	0.0000000	0.0031910
80.	*Terminalia superb*	0.1254	0.0000231	0.0015039
81.	*Lovoa trichlioides*	0.1233	0.0000264	0.0026251
82.	*Citrus medica*	0.1311	0.0000000	0.0000000
83.	*Percuguaria daemia*	0.1314	0.0000132	0.0000871
84.	*Zanthozylum leprieuril*	0.1099	0.0000000	0.0000210
85.	*Elaeis guinensis*	0.1063	0.0000000	0.0001997
86.	*Citrus paradise*	0.1252	0.0001239	0.0013047
87.	*Ricinodendron heudelotti*	0.1244	0.0000000	0.0018132
88.	*Raphia Africana*	0.1284	0.0000130	0.0019630
89.	*Phoenix dactylifera*	0.1049	0.0000247	0.0008735
90.	*Hevea brasiliensis*	0.1146	0.0000000	0.0015058
91.	*Cocos nucifera*	0.1314	0.0000126	0.0010125
92.	*Strychnos spinosa*	0.1195	0.0000199	0.0015365
93.	*Ceiba pentandra*	0.1083	0.0000114	0.0019253
94.	*Piptadeniasrum africanum*	0.1135	0.0000101	0.0000167
95.	*Cordia milleni*	0.1204	0.0000000	0.0000124
96.	*Cola nitida*	0.1130	0.0000099	0.0021594
97.	*Cleistopholis patens*	0.1187	0.0000216	0.0000533
98.	*Strombosia pustulata*	0.1146	0.0000000	0.0015229
99.	*Artocarpus altilis*	0.1260	0.0000265	0.0015454
100.	*Anacardium occidentale*	0.1173	0.0000228	0.0010123

3. Experimental Design, Materials, and Methods

3.1. Study area

The study area is southwest region of Nigeria which comprises Osun, Oyo, Ekiti, Ondo, Ogun, and Lagos States as shown in **Figure 2**. It falls between Latitudes 6^0 21^1, 8^0 37^1 N and Longitudes 2^0 31^1, 6^0 00^1 East. Y approximation, the area is about 77,818 km^2 with 85 reserves of forests covering 842,499 of hectares as reported by Faleyimu [4]. The climate of the region is characterized by dry and wet seasons with temperature ranging from 21degree centigrade to 34 degrees centigrade while the annual rainfall ranging from 150 cm to 300 cm [5]. From the work of Ajayi [6] and Agbetuyi [7], the vegetation in southwest, Nigeria is freshwater swamp and mangrove forest at the belts, derived and southern savannah exist towards the northern boundary.

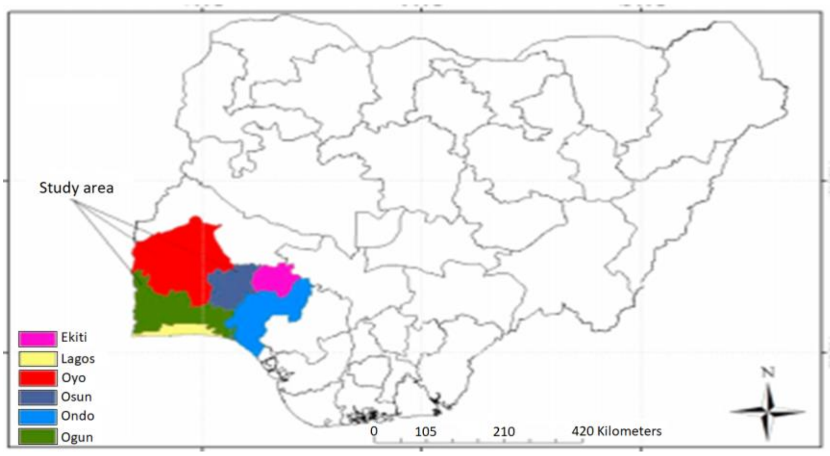

Figure 2. Map of Nigeria showing southwest [8]

3.2. Raw materials (data) used

The data on heating values and elemental contents responsible for gaseous emissions in the 100 woody biomasses were collected from the previous results of this work [1], [2] as shown in **Table 2**. The data on heating values (23.968 to 29.8650 MJ/kg) and elemental contents (59 to 84.7% for carbon, 1.1 to 1.9% for sulphur, 1.0 to 1.17% for nitrogen) responsible for gaseous emissions from coal species were collected from Wang [9] and Morvay [10], respectively.

Table 2. Means of heating values and elemental contents responsible for air emissions in identified woody biomasses

S/N	Botanical Name	HHV(MJ/kg)	%C	%H	%S	%N	%O
1.	*Albizia gummifera*	14.2225	51.25	5.73	0.01	0.26	42.75
2.	*Pterygota macrocarpa*	17.1115	50.44	5.60	0.00	0.12	43.84
3.	*Irvingia grandifolia*	11.2945	48.07	6.19	0.00	0.23	45.51
4.	*Crassocephalum biafrae*	17.2375	52.46	5.97	0.05	0.08	41.44
5.	*Daniella oliveri*	16.8060	50.97	4.99	0.01	0.02	44.01
6.	*Parkia biglobosa*	17.8200	53.43	7.07	0.03	0.08	39.39
7.	*Daniella ogen*	17.6850	51.63	5.95	0.01	1.05	41.36
8.	*Cola acuminata*	16.1410	49.78	6.02	0.01	0.21	43.98
9.	*Bambusa vulgaris*	12.5130	48.04	5.62	0.01	0.37	45.96
10.	*Entada gigas*	13.4310	49.21	4.35	0.02	0.04	46.38
11.	*Ficus thionningii*	16.3105	54.43	7.03	0.00	0.55	37.99
12.	*Uapaca heudelotii*	21.1140	43.78	5.42	0.06	0.13	50.61
13.	*Symphonia globulifera*	18.7400	48.00	6.72	0.02	0.41	44.85
14.	*Cola millenii*	22.3275	49.93	7.02	0.01	1.10	41.94
15.	*Prunus dulcis*	18.5105	51.43	5.40	0.05	0.80	42.32
16.	*Entandrophragma cylindricum*	18.5410	56.17	4.90	0.01	0.10	38.82
17.	*Irvingia excelsa*	17.1490	62.95	4.99	0.01	0.12	31.93
18.	*Milicia excels*	13.9090	44.55	6.12	0.05	0.51	48.77
19.	*Delonix regia*	21.1520	51.88	5.99	0.00	1.63	40.50
20.	*Ficus carica*	18.3675	57.29	6.21	0.01	0.20	36.29
21.	*Astonia boonei*	18.5310	49.29	6.06	0.01	0.40	44.24
22.	*Newbouldia laevis*	18.5310	51.63	4.89	0.03	0.59	42.86
23.	*Cassia fistula*	20.3125	48.82	7.06	0.01	0.35	43.76
24.	*Brachystegia leonensis*	17.8950	54.02	5.49	0.02	0.43	40.04
25.	*Musanga ecropiodes*	18.5600	49.99	5.00	0.01	0.01	44.99
26.	*Asteromyrtus symphyocarpa*	20.6150	51.17	6.29	0.00	0.97	41.57
27.	*Poga oleosa*	18.6360	50.64	5.27	0.02	1.32	42.75
28.	*Tectona grandis*	16.8200	47.96	5.73	0.01	0.04	46.26
29.	*Pycananthus angolensis*	16.5130	51.46	6.06	0.08	0.02	42.36
30.	*Gmelina arborea*	18.3435	46.45	5.31	0.01	0.19	48.04
31.	*Parkia biglobasa*	17.8200	58.04	5.89	0.01	0.74	35.32
32.	*Anthocleista vogelii*	16.8450	44.79	5.68	0.02	0.59	48.92
33.	*Afromosia elata*	21.1780	51.03	5.79	0.00	0.41	42.77
34.	*Isoberlina doka*	16.8740	48.84	6.04	0.07	0.11	44.94
35.	*Mitragyna ciliata*	15.7435	52.24	5.10	0.01	0.10	42.55
36.	*Blighia sapida*	16.4610	61.84	6.11	0.01	0.00	32.04
37.	*Nauclea diderrichii*	26.0995	60.47	7.07	0.01	0.74	31.71
38.	*Cissus adenopoda*	16.0675	51.94	6.18	0.00	1.31	40.57
39.	*Antrocaryon micraster*	17.0070	50.38	5.32	0.04	0.51	43.75
40.	*Garcinia kola*	16.3710	56.07	4.39	0.01	0.01	39.52
41.	*Lecaniodiscus cupanioides*	15.2840	45.95	4.90	0.01	1.60	47.54
42.	*Nesorgodonia paparivera*	15.6570	50.10	5.14	0.00	0.08	44.68
43.	*Erythrophylium sp.*	19.6190	53.56	6.85	0.01	0.13	39.45
44.	*Khaya ivorensis*	17.6350	50.98	5.62	0.01	1.70	41.69
45.	*Ficus mucuso*	19.6660	47.97	5.79	0.06	0.93	45.25
46.	*Anogeissus leiocarpus*	20.2440	50.58	5.28	0.02	0.51	43.61
47.	*Chrysophyllum africanum*	19.5420	51.59	6.19	0.01	0.03	42.18
48.	*Pterocarpus erinaceus*	17.9750	49.87	5.39	0.07	0.57	44.10
49.	*Adansonia digitata*	16.5030	51.04	5.53	0.00	0.26	43.17
50.	*Vitellaria paradoxa*	16.3335	45.96	5.92	0.02	1.01	47.09
51.	*Mangifera indica*	21.5495	58.11	6.39	0.01	0.31	35.18
52.	*Cylicodiscus gabunensis*	18.2625	47.10	5.85	0.01	1.00	46.04
53.	*Antiaris Africana*	19.2850	51.99	5.40	0.01	0.80	41.80
54.	*Triplochoton scleroxylon*	18.5860	48.05	6.46	0.00	0.20	45.29
55.	*Hildegardia barteri*	16.2190	61.41	5.87	0.00	0.50	32.22
56.	*Hymenocardia cida*	15.6045	51.92	5.54	0.03	0.09	42.42

S/N	Botanical Name	HHV(MJ/kg)	%C	%H	%S	%N	%O
57.	*Gliricidia epium*	19.2750	47.03	5.40	0.00	0.08	47.49
58.	*Diospyros rassiflora*	16.5275	51.09	6.02	0.01	0.39	42.49
59.	*Terminalia vorensis*	20.1630	51.57	4.91	0.01	0.71	42.80
60.	*Spondias mombin*	14.2070	58.03	6.04	0.09	0.39	35.45
61.	*Pterocarpus osun*	15.6210	51.58	5.63	0.02	0.01	42.76
62.	*Bombax buonopozense*	14.1300	50.58	5.91	0.00	0.63	43.29
63.	*Chasmanthera dependens*	17.3100	55.07	5.79	0.01	0.29	38.84
64.	*Mansonia ltissima*	16.8100	47.01	5.86	0.00	0.13	47.00
65.	*Napoleona ogelii*	18.1580	58.70	6.03	0.01	0.15	35.11
66.	*Pinus ponderosa*	15.6770	52.83	5.52	0.02	0.97	40.66
67.	*Citrus imon*	13.1750	50.58	5.80	0.01	0.81	42.80
68.	*Funtumia elastic*	16.5165	51.02	6.07	0.02	1.03	41.86
69.	*Quecus robur*	17.2560	49.04	5.77	0.01	0.91	44.27
70.	*Terminalia glaucescens*	15.7085	45.06	5.61	0.01	1.60	47.72
71.	*Swieteni p.*	16.0290	58.96	6.00	0.00	0.70	34.34
72.	*Citrus urantifolia*	16.5195	46.65	5.40	0.00	1.03	41.86
73.	*Bytraria marginata*	17.6950	51.30	4.92	0.06	0.43	43.29
74.	*Azadirachta ndica*	17.3340	48.92	6.10	0.01	0.23	44.74
75.	*Macaranga barteri*	18.7240	62.26	7.02	0.03	0.61	30.08
76.	*Sterculia rhinopetala*	17.3085	61.87	5.39	0.01	0.59	32.14
77.	*Berlinia grandifolia*	15.7020	47.90	5.64	0.01	0.69	45.76
78.	*Bombax eiba*	16.2230	51.19	6.22	0.00	0.31	42.28
79.	*Theobroma acao*	17.1150	50.83	5.88	0.00	1.66	41.63
80.	*Terminalia uperb*	17.2820	59.03	6.03	0.02	0.79	34.13
81.	*Lovoa trichlioides*	15.1645	50.93	5.50	0.02	1.21	42.34
82.	*Citrus medica*	16.7150	59.73	5.49	0.00	0.00	34.78
83.	*Percuguaria daemia*	15.1050	54.07	5.30	0.01	0.04	40.58
84.	*Zanthozylum eprieuril*	15.6650	46.92	4.98	0.00	0.01	48.00
85.	*Elaeis guinensis*	21.4180	62.06	5.83	0.00	0.13	31.98
86.	*Citrus paradise*	16.1385	55.04	5.29	0.10	0.64	38.93
87.	*Ricinodendron heudelotti*	18.1450	61.50	5.70	0.00	1.00	31.80
88.	*Raphia fricana*	15.4190	53.96	5.90	0.01	0.92	39.21
89.	*Phoenix dactylifera*	16.1965	46.30	7.02	0.02	0.43	46.23
90.	*Hevea brasiliensis*	19.2275	60.05	6.250	0.00	0.88	32.82
91.	*Cocos nucifera*	15.9220	57.02	5.65	0.01	0.49	36.83
92.	*Strychnos pinosa*	20.1270	65.54	5.36	0.02	0.94	33.14
93.	*Ceiba pentandra*	17.6010	51.95	6.21	0.01	1.03	40.80
94.	*Piptadeniasrum fricanum*	19.7065	60.98	5.81	0.01	0.01	33.19
95.	*Cordia milleni*	18.5960	61.03	5.40	0.00	0.07	33.50
96.	*Cola nitida*	20.1115	61.94	6.15	0.01	1.32	30.58
97.	*Cleistopholis patens*	18.5280	59.91	5.90	0.02	0.03	34.14
98.	*Strombosia pustulata*	19.2275	60.04	5.83	0.00	0.89	33.24
99.	*Artocarpus ltilis*	15.1150	51.91	5.90	0.02	0.71	41.46
100.	*Anacardium occidentale*	17.5510	56.08	5.81	0.02	0.54	37.55

Source: [1] and [2]

3.3. Modelling procedure

A mathematical model for estimating an emission factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant was used. The general modelling equation (Equation 1) for emission estimation as found in Okedere's study [11] is:

$$E = A\,x\,EF\,x\,(1 - ER/100) \qquad (1)$$

Where, E is emissions (the amount of air emission from an element responsible for the emission), A = activity rate (HHV of woody biomass), EF = emission factor, ER = overall emission reduction efficiency, % = 0 in this study. ER is further defined as the product of the control device destruction or removal efficiency and the capture efficiency of the control system.

Assumptions:

(i) complete combustion of fuel (woody biomass) in the furnace;

(ii) air emissions are released and properly dispersed into the air without removal from the flue gas generated by the power thermal plant; and

(iii) thermal NO_x not considered.

The stoichiometric equations (Equations 2, 3 and 4) used for the complete combustion equations of the targeted elemental contents of the biomasses are:
For carbon contents

$$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)} \quad (2)$$
$$12 \quad + \ 32 \quad \rightarrow 44$$

i.e. 12 kg of carbon requires 16 kg of oxygen to form 44 kg of carbon dioxide, therefore 1 kg of carbon requires 32/12 kg (12.67 kg) of oxygen to produce 44/12 ton (3.67 kg) of carbon dioxide.

For sulphur contents

$$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)} \quad (3)$$
$$32 \quad + \ 32 \quad \rightarrow 64$$

i.e. 32 kg of sulphur requires 32 kg of oxygen to form 64 kg of sulphur dioxide, therefore 1 kg of sulphur requires 32/32 kg (1 kg) of oxygen to form 64/32 ton (2 kg) of sulphur dioxide.

For nitrogen contents

$$N_{2(g)} + 2O_{2(g)} \rightarrow 2NO_{2(g)} \quad (4)$$
$$28 \quad + \ 64 \quad \rightarrow 92$$

i.e. 28 kg of nitrogen requires 64 ton of oxygen to form 92 kg of nitrogen dioxide, therefore 1 kg of nitrogen requires 64/28 kg (2.29 kg) of oxygen to form 92/28 kg (3.29 kg) of nitrogen dioxide.

Taking the carbon content of the first woody biomass, *Albizia gummifera* for instance, the emission factor of CO_2 emission is calculated as follows:
From **Table 1** and Equation 2:
Carbon content = 51.25% of every 1 kg of the biomass = 0.5125 kg.
1 kg of carbon produces 3.67 kg of CO_2.
Therefore:
0.5125 kg of carbon produces (0.5125 x 3.67) kg = 1.8809 kg of CO_2.
Therefore:
E_{CO_2} = 1.8809 kg
A = 14.2225 MJ/kg
ER = 0
EF = 0.1322 kg/(MJ/kg)

4. Contribution to the SDGs

The research contributes to the SDGs in the following categories:

- 100 renewable and environmentally friendly woody biomasses were discovered to replace fossils like coals that not environmentally friendly in firing thermal power plants, and
- The propagation of these biomasses can serve as source of employment for teaming population in the southwest Nigeria if harnessed.

Authors' Declaration

Authors' contributions and responsibilities
The authors contributed resources to the research in the following capacities:

- Sourcing for the samples of the woody biomasses in the southwest sub-region in Nigeria
- Preparation of the collected samples for analyses
- Payments for the analyses in the analytical laboratories
- Writing of the manuscript
- Vetting of the manuscript
- Approval of the manuscript for publication

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Availability of data and materials - All data are available from the authors. Transparency data associated with this article can be found in the online version at Ref [12] and [2].

Competing interests - The authors declare no competing interest.

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