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Data Article

Data on optimization of bioconversion of fruit rind of *Telfairia occidentalis* (Fluted pumpkin) and poultry manure for biogas generation

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A R T I C L E I N F O

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A B S T R A C T

The data described in this article was obtained in an experiment designed for generation of biogas from the anaerobic co-digestion of Fluted pumpkin fruit rind and poultry manure in three phases namely A, B and C. This paper is directly related to a published article "Dahunsi SO, Oranusi S, Efeovbokhan VE, Zahedi S, Ojediran JO, Olayanju A, Oluyori AP, Adekanye TA, Izebere JO, Enyinnaya M (2018). Biochemical conversion of fruit rind of *Telfairia occidentalis* (Fluted pumpkin) and Poultry manure. *Energy Sources (Part A) Utilization and Environmental Effects*, 40(23): 2799–2811". This paper presents the data on optimization of important process parameters (temperature, pH, retention time, total solids and volatile solids) for standardization during the production of biogas. The response surface methodology (RSM) and artificial neural networks (ANNs) were both used for the modeling and optimization in this study and the optimal conditions for this process were statistically predicted as temperature of 30.02°C, pH of 7.90, retention time of 20.03 days, total solids of 5.94 g/kg and volatile solids of 4.01 g/kg. The predicted biogas yield under the above set conditions was 2614.1, 2289.9 and 1003.3 10^{-3} m^3/kg VS for digestions 'A', 'B' and 'C' respectively.

Specifications table

Subject area	*Environmental biotechnology, chemical engineering, environmental engineering.*
Compounds	*Nil.*
Data category	*Computational optimizations/simulations, physicochemical.*
Data acquisition format	*Design-Expert software version 9.0.3.1 (Stat-Ease Inc., Minneapolis, USA), elemental analysis.*
Data type	*Analyzed*
Procedure	*Anaerobic co-digestion of pretreated and non-pretreated fruit rind of Telfairia occidentalis (Fluted pumpkin) and poultry manure was carried out. The RSM and ANNs were both used to model and optimize the process parameters.*
Data accessibility	*Data is available within this article.*

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1. Rationale

The rationale behind this data article was the need to document the optimization of the thermo-alkaline pretreatment of the fruit rind of *Telfairia occidentalis* (Fluted pumpkin). The necessity arose to pretreat the biomass in order to enhance biogas generation potentials of the biomass. Besides, there was need to document the most suitable modeling tool for the process after which the optimal condition for the pretreatment in terms of the values of the most important process parameter i.e. temperature, pH, retention time, total solids (TS) and volatile solids (VS) were all properly documented. After this, there was need to validate the biogas generation process based on the optimal values obtained from the modeling study and this helped in making recommendation on the suitability of the models for usage in further studies.

2. Procedure

The data presented here was obtained from the experimental design used for the thermo-alkaline pretreatment procedure of fruit rind of *Telfairia occidentalis.* The optimal condition for the treatment was: temperature of 80 °C, thermal treatment duration of 60 min, alkali (NaOH and KOH) concentration of 3 g/100 g TS and alkaline treatment for 24 h as shown in Table 1. Table 2 shows the experimental design matrix by the Central Composite Design (CCD) for the five-level-five-factor response surface study for biogas generation. The table reveals the experimentally observed and predicted yields as well as the residual values. Table 3 shows the results of test of significance and that of the second-order response surface model's fit as ANOVA for every regression coefficient. The relationship/interaction between the biogas yields (Y) and the coded values of the five variables i.e. temperature (T_1), pH (T_2), retention time (T_3), total solids (T_4) and volatile solids (T_5) was described by a regression model Eq. (3) below:

$$\begin{aligned} Y = {} & 1770.17 + 13.16T_1 - 2.51T_2 - 13.62T_3 + 50.41T_4 + 3.64T_5 + 15.19T_1T_2 \\ & + 71.23T_1T_3 + 52.31T_1T_4 + 14.24T_1T_5 - 9.47T_2T_3 - 26.60T_2T_4 - 25.73T_2T_5 + 0.23T_3T_4 \\ & + 17.33T_3T_5 - 1.79T_4T_5 + 21.42{T_1}^2 + 16.89{T_2}^2 - 20.48 \quad {T_3}^2 - 55.72{T_4}^2 + 7.04{T_5}^2 \end{aligned} \tag{1}$$

where Y = Biogas yield (m^3/kg VS).

When the above equation was represented in figure forms, the three-dimensional (3D) plots formed are shown in Fig. 1(a–j). Fig. 2 shows the importance level of each independent variable as shown by the ANNs' architecture (Experiment 'A').

Prior to choosing the suitable temperature, duration of thermal treatment and quantity of alkali to be used, the Central Composite Design (CCD) was used for the experimental design according standard method [1–12]. In the design, a four-factor model was used i.e. (i) Temperature for thermal pre-treatment (ii) Time/duration of thermal pre-treatment (iii) Quantity of alkali for alkaline pre-treatment (iv) Time/duration for alkaline pre-treatment. The pre-treatment temperature was varied between 70 and 200°C while a pre-treatment time between 50 and 80 min was considered. For the quantity of alkali, a variation of 2 g/100 g TS to 5 g/100 g TS was used while a time variation of between 18 and 36 h was used for the alkaline pre-treatment.

Table 1
Experimental design of *Telfairia occidentalis* fruit rind's pretreatment prior to digestion.

Sample	Pretreatment temperature (°C)	Pretreatment time(min)	Quantity of alkali for pretreatment (g/100 g TS)	Time/duration for pretreatment (h)	Biogas produced from mono-digestion of *Telfairia occidentalis* fruit rind (10^{-3} m^3/kg VS) [1]	Biogas produced from co-digestion of *Telfairia occidentalis* fruit rind and poultry manure (10^{-3} m^3/kg VS)
UTO	0	0	0	0	1003.30	2134.06
$TO_{70,70}$	70	70	2	24	1166.22	2237.31
$TO_{80,60}$	80	60	3	24	1659.90	2614.14
$TO_{90,60}$	90	70	3	28	1622.17	2600.20
$TO_{100,60}$	100	60	5	32	1592.12	2543.12
$TO_{110,60}$	110	70	3.5	30	1561.13	2403.31
$TO_{120,60}$	120	60	2.5	26	1432.36	2231.11
$TO_{130,50}$	130	50	4	24	1575.23	2163.05
$TO_{140,70}$	140	70	4.5	24	1483.26	2231.91
$TO_{150,50}$	150	50	5	28	1323.24	2521.51
$TO_{160,70}$	160	70	4	34	1149.24	2145.55
$TO1_{70,50}$	170	50	3	36	1509.21	2311.11
$TO_{180,50}$	180	50	3.5	28	1199.21	2401.11
$TO_{190,60}$	190	60	2.5	36	1581.70	2090.00
$TO_{200,50}$	200	50	3	30	1600.03	2311.04

Note: TO = *Telfairia occidentalis*; UTO = untreated *Telfairia occidentalis*.

Table 2
Experimental design for biogas generation from the co-digestion of *Telfairia occidentalis* fruit rind and poultry manure with five independent variables for RSM and ANNs using actual values.

Independent factors						Digestion A			Digestion B			Digestion C		
Run	T_1	T_2	T_3	T_4	T_5	Actual biogas yield (10^{-3} m^3/kg VS)	RSM predicted biogas yield (10^{-3} m^3/kg VS)	ANNs predicted biogas yield (10^{-3} m^3/kg VS)	Actual biogas yield (10^{-3} m^3/kg VS)	RSM predicted biogas yield (10^{-3} m^3/kg VS)	ANNs predicted biogas yield (10^{-3} m^3/kg VS)	Actual biogas yield (10^{-3} m^3/kg VS)	RSM predicted biogas yield (10^{-3} m^3/kg VS)	ANNs predicted biogas yield (10^{-3} m^3/kg VS)
1	30.02	7.90	20.03	5.94	4.01	2539.2	2614.1	2540.3	2239.2	2289.9	2249.5	0995.5	1003.3	0997.4
2	39.98	7.90	29.88	11.45	11.83	2480.9	2462.5	2484.3	2260.9	2290.9	2221.2	0990.6	1008.3	0921.5
3	30.43	7.99	20.05	6.64	4.11	2365.1	2408.1	2368.5	2265.1	2201.6	2203.4	0988.7	1001.6	0979.8
4	39.85	6.59	25.46	11.79	11.60	2473.3	2540.8	2459.6	2203.9	2220.8	2203.6	1000.5	1007.5	0977.2
5	39.98	6.53	29.57	11.98	7.08	2600.1	2612.1	2597.0	2200.1	2211.6	2200.5	0950.6	0978.3	0967.2
6	39.52	6.52	25.39	10.86	11.51	2523.1	2606.2	2523.5	2280.1	2211.3	2285.6	0986.5	1001.0	0985.4
7	40.00	7.72	29.99	11.03	10.89	2484.2	2486.2	2484.4	2241.2	2200.2	2240.3	0964.6	0979.9	0980.5
8	39.93	7.08	29.23	11.89	9.23	2435.9	2481.8	2435.9	2225.9	2201.9	2226.3	0945.3	0979.5	0952.6
9	39.68	6.68	29.68	9.99	11.24	2563.3	2572.9	2560.2	2263.3	2283.9	2263.1	0943.6	1007.4	0952.4
10	39.56	7.41	29.89	11.42	11.77	2851.1	2872.6	2836.2	2251.1	2201.7	2251.2	0958.8	1002.4	0929.5
11	39.77	6.74	29.92	8.40	11.45	2907.1	3065.6	2588.3	2207.1	2252.9	2207.1	0937.4	0920.3	0904.5
12	30.22	7.92	20.09	7.46	4.05	2681.0	2664.9	2588.2	2221.0	2252.5	2219.5	1002.4	1002.2	0978.2
13	39.17	6.68	26.24	10.69	11.97	2591.6	2608.6	2591.5	2291.6	2206.4	2290.2	1001.2	0997.2	0951.5
14	39.96	6.63	25.40	11.30	11.62	2551.1	2557.3	2553.7	2209.1	2216.6	2266.5	1002.1	0959.5	0937.8
15	39.97	6.99	29.35	11.91	9.24	2501.2	2556.3	2503.3	2221.2	2208.1	2221.6	0941.1	0967.5	0950.1
16	39.96	6.55	27.00	11.29	10.30	2511.9	2555.9	2509.9	2204.9	2226.5	2266.5	0984.5	1001.7	0976.1
17	39.21	6.74	27.19	11.70	11.23	1002.5	1054.9	1002.5	2228.0	2209.2	2266.5	0938.3	1001.7	0949.4
18	39.97	7.74	29.72	10.86	11.42	2732.0	2749.8	2731.6	2232.0	2201.6	2266.5	0996.3	1004.7	0952.2
19	40.00	7.70	29.65	11.89	11.58	2727.3	2749.4	2734.6	2277.3	2201.4	2277.1	0977.6	1000.9	0957.3
20	39.99	7.19	29.94	11.53	9.40	2700.9	2743.7	2700.4	2203.9	2204.7	2201.5	0990.4	0964.1	0971.2
21	39.95	7.42	29.84	10.21	10.96	2700.1	2733.3	2705.6	2291.1	2202.9	2285.4	0931.5	0982.5	0919.9
22	40.00	7.75	30.00	10.57	9.57	2597.2	2610.9	2600.5	2297.2	2202.9	2294.9	0907.9	0992.8	0940.7
23	40.00	8.00	28.83	10.84	4.00	2556.1	2504.6	2555.7	2256.1	2287.9	2255.8	0955.6	0998.3	0990.1
24	40.00	8.00	29.55	10.73	4.00	2642.1	2701.3	2643.5	2242.1	2287.6	2242.1	0942.8	0971.3	0984.7
25	30.00	8.00	20.00	7.95	5.56	2398.1	2377.9	2397.5	2288.1	2207.8	2289.3	0968.1	0983.1	0959.7
26	40.00	8.00	29.82	11.05	4.01	2350.1	2476.6	2588.2	2250.0	2287.4	2250.0	0901.7	0977.6	0951.4
27	40.00	8.00	29.53	11.26	5.38	2569.0	2673.6	2567.5	2269.0	2385.5	2281.5	0966.7	1005.1	0950.1
28	40.00	8.00	29.18	9.85	5.07	2410.0	2473.3	2404.4	2210.0	2383.6	2210.3	0950.6	1000.4	0978.7
29	30.00	7.53	20.00	6.58	4.00	2400.0	2457.9	2588.2	2250.0	2383.1	2250.7	0940.8	1003.1	0951.6
30	40.00	8.00	26.91	10.30	4.45	3456.0	3429.5	3456.3	2276.0	2382.9	2276.3	0979.3	1002.6	0955.8
31	38.00	7.82	28.99	10.03	10.19	2681.02	2540.8	2836.1	2201.1	2332.2	2221.3	0948.1	1003.1	0959.3
32	37.93	7.08	29.23	11.89	9.03	2691.62	2612.1	2588.3	2307.1	2316.3	2214.3	0904.6	1006.1	0950.7
33	38.68	6.58	28.68	9.29	10.24	2551.14	2606.2	2588.2	2351.0	2398.9	2243.2	0941.9	1001.2	0963.2
34	38.56	7.41	29.89	10.42	10.17	2601.25	2486.7	2591.5	2292.6	2301.2	2289.4	0977.3	1001.3	0975.8
35	37.77	6.74	29.92	8.40	11.45	2531.97	2581.8	2553.8	2310.1	2322.3	2203.8	0941.5	1002.1	0956.6
36	36.22	7.62	20.09	7.46	4.05	1902.58	2572.9	2503.3	2211.2	2323.9	2221.1	0901.3	0983.3	1001.6
37	39.17	6.58	26.24	10.69	10.97	2742.63	2872.6	2509.9	2234.9	2343.2	2240.0	0984.5	1003.6	1004.8
38	38.96	6.63	25.40	11.30	10.62	1037.32	1265.6	1002.5	2223.0	2300.1	2254.6	0913.7	1000.4	0964.4
39	38.97	6.69	29.65	10.91	9.24	2700.91	2964.9	2731.5	2262.0	2301.3	2269.7	0989.9	1001.2	0959.7
40	37.96	6.55	27.00	10.29	10.30	2710.14	2618.6	2735.6	2207.3	2312.9	2209.0	0904.6	1002.4	0969.3
41	39.21	6.75	27.19	11.70	10.23	2457.25	2657.3	2730.4	2211.9	2343.3	2224.8	0981.9	1002.3	0929.4
42	39.97	7.74	29.42	10.86	11.42	2456.13	2506.3	2705.6	2231.1	2376.3	2242.2	0981.7	1006.4	0950.7
43	40.00	7.71	29.45	11.89	10.58	2652.12	2585.9	2600.6	2297.2	2302.3	2299.9	1007.8	1002.3	0947.1
44	39.99	7.19	29.94	11.53	9.40	2693.31	2554.9	2535.8	2259.1	2311.2	2263.2	1005.8	1006.8	0926.2
45	38.95	7.45	29.64	10.21	10.96	2450.58	2749.8	2643.5	2242.1	2393.2	2256.6	0949.1	1003.8	0956.6
46	40.00	7.55	30.00	10.57	8.57	2569.34	2749.4	2497.5	2288.1	2301.2	2296.6	0999.6	1005.6	1006.2
47	38.00	8.00	29.08	9.85	6.07	2410.33	2743.6	2588.2	2250.0	2362.2	2258.8	0987.0	1002.5	1008.7
48	30.00	7.53	20.00	6.58	4.00	2400.62	2733.3	2567.4	2229.0	2325.3	2231.1	0929.7	1005.6	1001.6
49	37.00	8.00	26.91	10.30	5.45	3245.92	2620.9	2504.3	2220.0	2316.5	2219.6	0907.7	1001.6	1002.2
50	38.00	7.52	27.59	10.03	10.89	3215.42	2534.6	2553.8	2251.4	2361.6	2259.4	0958.5	1001.2	0968.2

T_1 = temperature; T_2 = pH; T_3 = retention time; T_4 = total solids: T_5 = volatile solids.

Table 3
Test of significance and analysis of variance (ANOVA) for all regression coefficient terms for biogas generation from *Telfairia occidentalis* fruit rind and poultry manure.

Source	df	Digestion A				Digestion B				Digestion C			
		SS	MS	*F*-value	*P*-value	SS	MS	*F*-value	*P*-value	SS	MS	*F*-value	*P*-value
Model	20	3.65	183.68	4.03	0.018	3.84	158.4	4.11	0.015	3.91	187.15	4.08	0.019
T_1		4159	4159	0.92	0.363	5183	5.83	0.06	0.038	4946	4946	0.045	0.281
T_2		151.3	151.3	0.033	0.859	1.508	1.558	1.33	0.574	5408	5408	1.29	0.706
T_3		4452	4452	0.98	0.347	7.362	5.362	7.69	0.069	6.033	6.033	6.64	0.061
T_4		6099	6099	13.47	0.005	8215	8.151	0.78	0.516	8.371	8.371	0.91	0.396
T_5		317.5	317.5	0.070	0.797	6468	6768	0.65	0.447	7267	7267	0.71	0.034
T_1T_2		3691	3691	0.82	0.390	4.006	4506	6.02	0.236	5.405	5.405	4.09	0.037
T_1T_3		8118	8118	17.93	0.002	5.229	5.229	4.98	0.016	6181	6181	5.63	0.015
T_1T_4		4379	4379	9.67	0.013	7442	7.442	5.66	0.115	6.289	6.289	0.055	0.526
T_1T_5		3243	3243	0.72	0.419	3657	3657	3.07	0.173	4189	4189	0.42	0.716
T_2T_3		1435	1435	0.32	0.587	2968	2.068	1.24	0.766	3.594	3.594	0.40	0.573
T_2T_4		1132	1132	2.50	0.014	5.049	5.049	5.10	0.025	6.104	6.104	3.96	0.041
T_2T_5		1059	1059	2.34	0.160	5.498	5.498	7.78	0.020	4.966	4.966	6.02	0.011
T_3T_4		0.85	0.85	1.869	0.989	2.015	2.015	2.90	0.119	1.033	1.033	1.84	0.199
T_3T_5		4805	4805	1.06	0.029	1.589	1.589	5.87	0.063	1095	1095	10.01	0.031
T_4T_5		51.05	51.05	0.011	0.918	1.013	1.013	9.93	0.015	1.161	1.161	8.96	0.133
T_1^2		1224	1224	2.70	0.135	1651	1.651	3.13	0.555	1657	1657	0.19	0.500
T_2^2		7603	7603	1.68	0.027	5.733	5733	4.72	0.108	3.899	3.899	6.06	0.044
T_3^2		1118	1118	2.47	0.151	3158	3158	4.23	0.655	3.258	3.258	0.23	0.534
T_4^2		8281	8281	18.29	0.002	1156	1.156	1.63	0.625	1188	1188	0.012	0.813
T_5^2		1322	1322	0.29	0.602	82.93	8.293	9.05	0.660	80.93	80.93	7.028	0.581
Residual	9	407.9	453.00			413.9	460.00			404.2	460.03		
Lack of fit	6	355.1	591.19	3.36	0.174	405.1	651.8	3.52	0.169	353.1	583.13	3.44	0.176
Pure error	3	27.87	157.62			28.37	149.07			24.57	161.60		
R-squared		0.8996				0.9067				0.8993			
Adequate precision		8.009				9.017				8.006			

df = degree of freedom; SS = sum of square; MS = mean square.

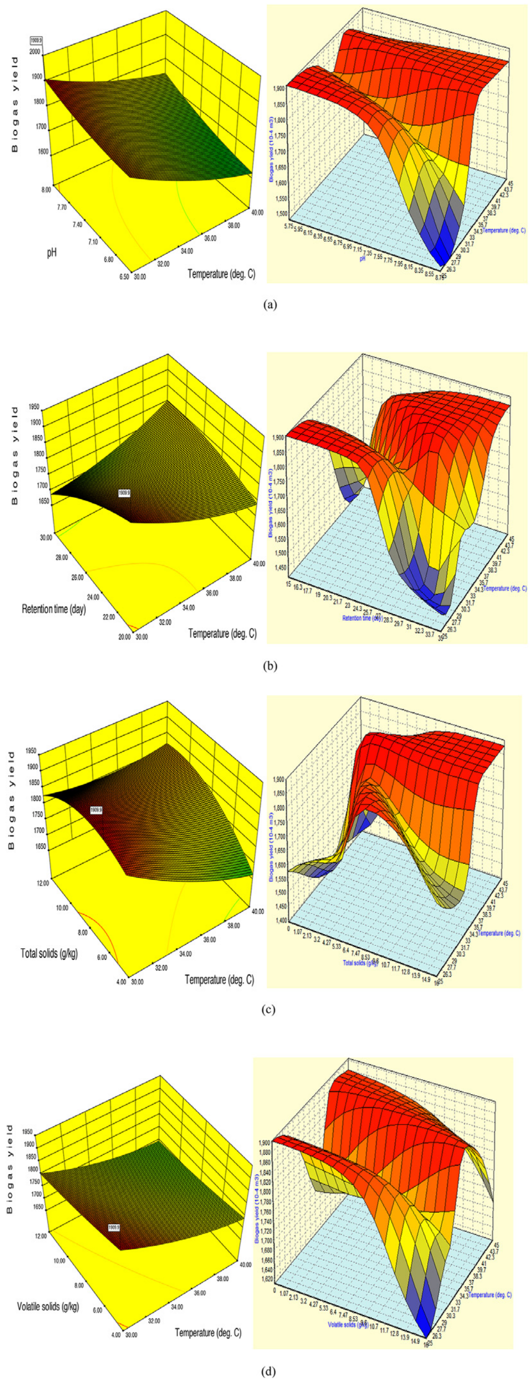
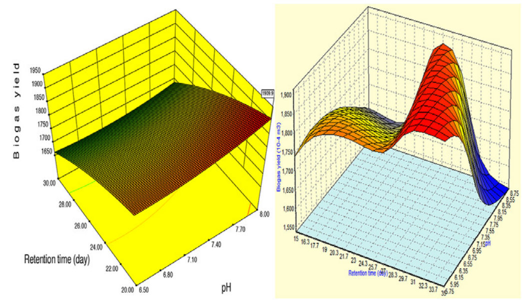


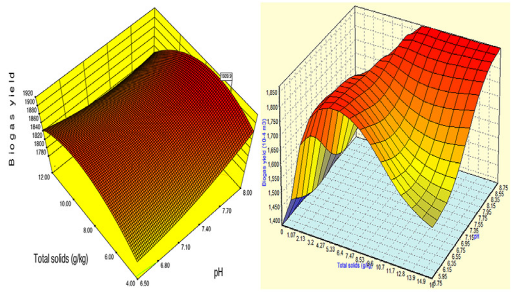
Fig. 1. (a–j): 3D Curvatures' plots of RSM (left) and ANNs (right) optimization of biogas generation from *Telfairia occidentalis* fruit rind and poultry manure (digestion 'A').

2.1. Experimental design

The CCD used in designing the pre-treatment procedures was also employed in the experimental design of the anaerobic digestion of all the pre-treated and untreated samples of *Telfairia occidentalis* fruit rind and poultry manure due to the reported high efficiency of the model in product optimization [13–20]. A total of 50 experimental runs were generated using the five-level-five-factors design. Five importance process parameters: "Temperature (°C), pH, Retention time (days),



(e)



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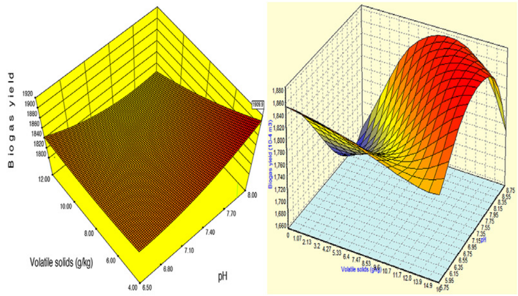
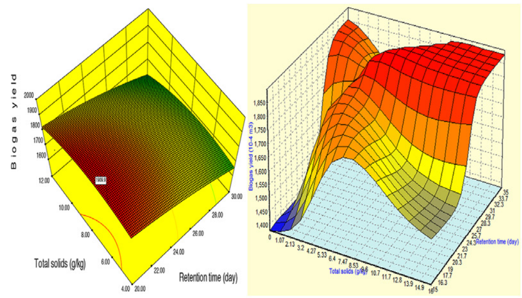


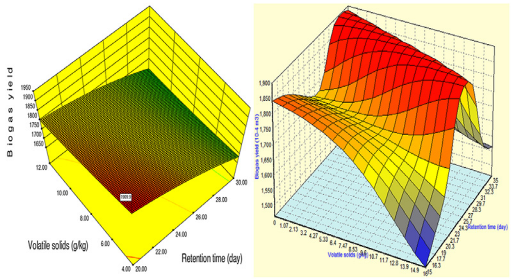
(g)



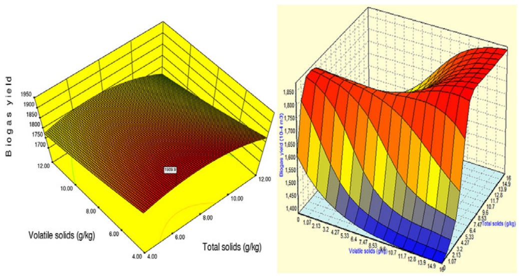
(h)

Fig. 1. Continued

Total solids (g/kg) and Volatile solids (g/kg)" were selected for the modeling and optimization and each was designated as T_1, T_2 T_3 T_4 and T_5 respectively. The artificial neural networks (ANNs) via the Neural Power version 2.5 (CPC-X software) was also used to analyze data obtained from the CCD. In totality, 50 experimental data were obtained and further divided into 32 in training set and 9 each in the validation and test sets respectively. Both the Tanh and linear transfer functions at hidden and output layers were used respectively. Also, the mean square error (MSE) approach was used to determine the optimum ANN structure and the higher coefficient of determination (R^2).



(i)



(j)

Fig. 1. Continued

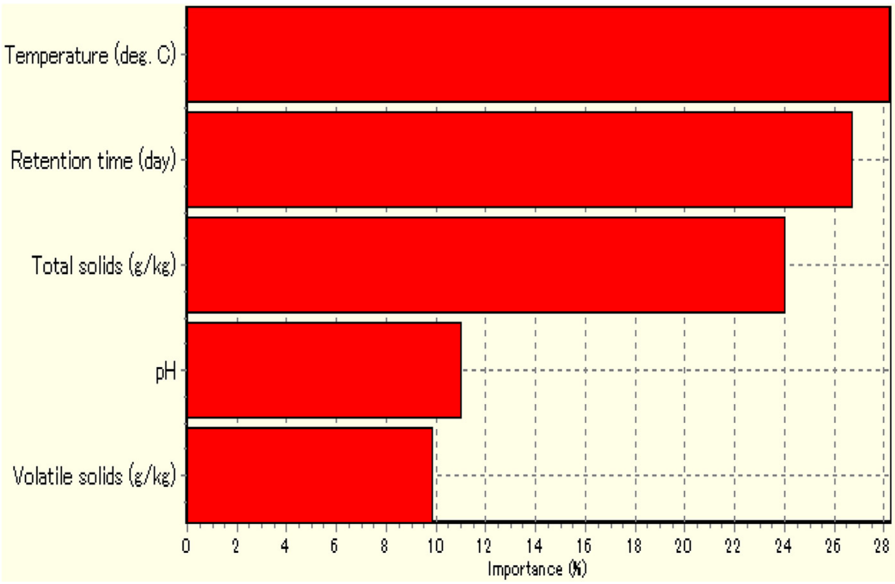


Fig. 2. ANNs' importance level of each independent variable employed in the optimization.

2.2. Statistical data analysis

The RSM was used to statistically analyze all data obtained from each of the three experiments using the Design-Expert software version 9.0.3.1 (Stat-Ease Inc., Minneapolis, USA) while using multiple regressions to fit the coefficient of the polynomial model of the responses.

3. Data

3.1. Values of the data

- The data presented in this article shows the modeling and optimization of biogas generation from the anaerobic co-digestion of fruit rind of *Telfairia occidentalis* (Fluted pumpkin) and poultry manure.
- The data will serve as a benchmark for further researches on the possibility of biogas generation from the substrates used in this study as well as improving over the report of this paper.
- The data presented here will serve as an eye opener on the possibilities of turning other waste materials and biomass to useful biofuels and other bioproducts. This will further drive the search for environmental protection and sustainability.
- Further researches can use more robust statistical tools in order to better explore the generated data presented in this study

3.2. Validation

The prediction and estimation abilities of both RSM and ANN were critically examined so as to know which model gives the best result. RSM and ANN were used to stimulate responses, which were then compared with actual values. The roots mean squared error (RSME), coefficient of determination (R^2) and the predicted value were used to compare the RSM and ANN. From the results in digestion 'A', it was noticed that the RSME of biogas for RSM (157.52) is higher than that of ANN (14.042). The R^2 for RSM (0.8996 i.e. 89.96%) is lower compare to that of ANN (0.9929 i.e. 99.29%). The most desirable RSM predicted value was 1659.50 while that of ANNs was 1639.50 m^3/kg VS. In digestion 'B', the RSME of biogas for RSM (141.07) is higher than that of ANN (21.129). The R^2 for RSM (0.9067 i.e. 90.67%) is lower compare to that of ANN (0.9988 i.e. 99.88%). The most desirable RSM predicted value was 1542.30 while that of ANNs was 1528.60 m^3/kg VS. In digestions 'C', the RSME of biogas for RSM (161.60) is higher than that of ANN (24.061). The R^2 for RSM (0.8993 i.e. 89.93%) is lower compare to that of ANN (0.9994 i.e. 99.94%). The most desirable RSM predicted value was 1003.30 while that of ANNs was 0997.40 m^3 kg/VS. In all the three digestion regimes, though RSM predicted higher biogas yields than ANNs, the latter gives higher accuracy and efficiency than the former for the generation of biogas from *Telfairia occidentalis* fruit peels with digestion 'A' being the highest in all values.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.cdc.2019.100192.

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