Characterization of Torrefied Biomass from Sugarcane (*Saccharum officinarum*) Bagasse Blended with Semirara Coal

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Abstract. Utilizing and improving the quality of Philippine indigenous coal is getting more important in order to sustain the country's high dependence on coal over the next 10 years and to keep up with the country's growing energy demands. Also, environmental problems and negative impacts of agricultural wastes are drawing more and more attention since the quantity of agricultural wastes has been rising rapidly all over the world. In the Philippines, sugarcane (*Saccharum officinarum*) bagasse has been identified as one of the significant contributor to the country's biomass energy resource. Hence, in this study, coal blending technique has adopted as a proper approach to improve the quality of indigenous coal reserves while concurrently reducing and reusing agricultural wastes. This paper aimed to establish recommended blending ratios for Semirara coal, a sub-bituminous type of coal from Semirara Island in the province of Antique, Philippines and sugarcane (*S. officinarum*) bagasse. Proximate analysis, ultimate analysis, and calorific value were determined to characterize and understand the physical conditions and coal properties during combustion. Results showed that blending torrefied sugarcane (*S. officinarum*) bagasse with Semirara coal would generally improve its quality in terms of its combustion properties thereby making these combinations of coal and biomass advantageous.

1 Introduction

Coal is the largest source of energy in power generation industry worldwide that supports for the economy in both developed and developing countries. Currently, coal fuels 46% of the world's electricity and foreseen to continue to supply a strategic share over the next three decades [1]. The Asian Development Bank (ADB) said that the Philippines is expected to become the most coal-dependent country in Southeast Asia by 2030 [2]. In the Philippines, one coal resources is in Semirara Island located in Caluya, Antique, with an estimated total coal reserve of around 170 million metric tons [3]. However, Semirara coals are black in color, dull (not shiny), have higher moisture and volatile matter, and lower sulfur and fixed carbon content compared to other types of coal, referred to as sub-bituminous [4,5]. Moreover, it is classified as second lowest rank of coals due to their lower calorific value [6-8].

Considering that the Philippines is also an agricultural country wherein sugarcane (*Saccharum officinarum*) is the number one agricultural crop produced in the country in terms of tonnage, generating an enormous abundance of agricultural biomass (bagasse) resource of approximately 6 million metric tons yearly based on the data of Bureau of Agricultural Statistics, that may be used as energy fuel [9].

Utilizing and improving the quality of Philippine indigenous coal is getting more important in order to sustain the country's high dependence on coal and to ensure that the growing energy demand can also be addressed. Likewise, in recent years, the quantity of agricultural waste has been rising rapidly all over the world. As a result, the environmental problems and negative impacts of agricultural waste are drawing more and more attention. Therefore, there is a need to adopt proper approaches to reduce and reuse agricultural waste.

In order to simultaneous address these issues, one of the cost-effective methods to develop the indigenous coal reserves is via coal blending with biomass, essentially blending two dissimilar fuels, with one being the dominant fuel and the other its supplement. Typically coal is the dominant fuel, and the principles of blending apply, thereby making some combinations of biomass and coal advantageous. Through this technique, it ensures that the cleaned coal contains minimum ash, sulfur, and also maximum heating value on a timely basis.

Thus, the main purpose of this work is to establish recommended blending ratios for sugarcane (*S. officinarum*) bagasse and Semirara coal. Proximate

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analysis, ultimate analysis, and calorific value were determined to characterize and understand the physical conditions and coal properties during combustion process.

Furthermore, this study would give a valuable introduction on the combustion characterization of Philippine coal and its blends that will enrich the database on properties of Philippine coal and of Philippine coal blends, and would show the potentials and fuel flexibility of the Philippine coal.

2 Methodology

2.1 Preparation of Sugarcane (*Saccharum officinarum*) Bagasse

For this study, 3 kilograms of raw sugarcane (*Saccharum officinarum*) bagasse were collected from a sugarcane plantation in the Town of Calaca in the province of Batangas, Philippines. Representative sugarcane (*S. officinarum*) samples were taken to the Bureau of Plant Industry (BPI) for plant identification, species authentication, and certification.

The raw sugarcane (*S. officinarum*) bagasse was reduced in size in the range of 1.0 to 1.5 cm, and then dried using a Binder Drying Oven ED 53 at 105°C for 24 hours prior torrefaction. The weights of the raw and the oven-dried sugarcane (*S. officinarum*) bagasse were recorded, and then the percentage of moisture removed from drying was calculated.

2.2 Torrefaction of Sugarcane (*Saccharum officinarum*) Bagasse

Biomass torrefaction is a mild thermochemical process that generally performed in inert atmosphere in the temperature range of 200 to 300°C for several minutes or hours. This treatment gained interest as it promotes an increase in the energy content of biomass to levels equal to and sometimes above that of coal [10], making it a more attractive and competitive source within the primary energy matrix [11].

The oven-dried sugarcane (*Saccharum officinarum*) bagasse was torrefied using an electric Ney Vulcan 3-1750 Box Muffle Furnace equipped with thermocouple, slide out heating elements, combined fiber, and firebrick insulation for quick cooling and three-stage programmable system of temperature regulation. The 1,750 cubic inches inner volume capacity of the furnace was connected to the outer atmosphere through a tube that provides access of oxygen into the torrefaction zone and discharge of gaseous pyrolysis products.

For each run, approximately 200 grams of oven-dried sugarcane (*S. officinarum*) bagasse were placed into unsealed 110.45 cubic inches ceramic vessels to provide free access of oxygen. The oven-dried sugarcane (*S. officinarum*) bagasse was torrified at 300°C (heating rate of 5°C/min) for 30 minutes under normal atmospheric pressure. The torrefied sugarcane (*S. officinarum*) bagasse was grinded using a Wiley mill and then sifted using a stainless steel laboratory test sieve with mesh screen no. 60 equivalent to an approximate size of 250 μm to homogenize the particle size. Finally, the sifted sugarcane (*S. officinarum*) bagasse were collected in a clean, dry, and sealed bag, and stored in a dessicator until used for blending and characterization.

The weights of the oven-dried and the torrified sugarcane (*S. officinarum*) bagasse were recorded, and then the percentage recovery was calculated.

2.3 Proximate Analysis

The proximate analysis performed for the torrefied sugarcane (*Saccharum officinarum*) bagasse, Semirara coal, and its blends (% w/w) – 25, 50, and 75 was in accordance to ASTM D3172-13: Standard Practice for Proximate Analysis of Coal and Coke [12]. This practice covers the determination of moisture (MC), volatile matter (VM), and ash (AC) and the calculation of fixed carbon (FC).

All measurements performed in this study were carried out in three replicate runs and the mean values were reported.

2.4 Ultimate Analysis

The ultimate analysis for the torrefied sugarcane (*Saccharum officinarum*) bagasse, Semirara coal, and its blends (% w/w) – 25, 50, and 75 was performed using LECO CHN628 Series Elemental Determinator and CKIC 5E-S3200 Coulomb Sulfur Analyzer operated using S3200 application program to determine the carbon (C) / hydrogen (H) / nitrogen (N) and the total sulfur (S) content, respectively.

For C/H/N determination, a 0.10 mg of the torrified sugarcane (*S. officinarum*) bagasse was placed in a tin capsule, heated at 980°C with a constant flow of helium enriched with oxygen gas [13].

While for the total S, on average, a 50.45 mg of the torrified sugarcane (*S. officinarum*) bagasse is required, and then covered with a thin layer of tungsten trioxide (WO_3) after weighing in temperature rise period. The furnace was heated to 1,150°C for 30 minutes before analyzing the samples.

Also, average values of the triplicate runs were reported for all measurements done in this study.

2.5 Calorific Value (Experimental)

The experimental calorific value (CV) of the torrefied sugarcane (*Saccharum officinarum*) bagasse, Semirara coal, and its blends (% w/w) – 25, 50, and 75 was determined using an adiabatic CKIC 5E-AC/PL Calorimeter by completely combusting 1.00 gram of the samples under a pressurized O_2 atmosphere [10]. For all combustion experiments, the samples were charged with oxygen at a pressure of 2.80 to 3.00 MPa and a cylinder pressure of ≥ 5 MPa.

2.6 Calorific Value (Calculated)

The values obtained from the proximate and ultimate analyses were used to calculate the calorific value based on existing correlations taken from the literature which are applicable for both coal and biomass based on parameters for proximate and ultimate analyses as shown in Tables 1 and 2, respectively. Thus, it follows that the existing correlations presented are not specific for sugarcane (*Saccharum officinarum*) bagasse alone.

Table 1. Correlations for calorific value applicable for both coal and biomass based on proximate analysis.

Study	Correlation for Calorific Value, $MJ\cdot kg^{-1}$	Eq.
Kavšek et al. [14]	CV = 0.4108FC + 0.1934VM - 0.021AC	(1)
Kieseler et al. [15]	CV = 0.3536FC + 0.1559VM - 0.0078AC	(2)
Majumder et al. [16]	CV = -0.03AC - 0.11MC + 0.33VM + 0.35FC	(3)
Mesroghli et al. [17]	CV = 37.777 - 0.647MC - 0.387AC - 0.089VM	(4)
Parikh et al. [18]	CV = 0.3536FC + 0.1559VM - 0.0078AC	(5)

Table 2. Correlations for calorific value applicable for both coal and biomass based on ultimate analysis.

Study	Correlation for Calorific Value, $MJ\cdot kg^{-1}$	Eq.
Channiwala & Parihk [19]	CV = 0.3491C + 1.1783H + 0.1005S - 0.1034O - 0.0151N - 0.0211A	(6)
Friedl et al. [20]	$CV = 0.00355C^2 - 0.232C - 2.23H + 0.0512CH + 0.131N + 20.6$	(7)
Jenkins et al. [21]	CV = -0.763 + 0.301C + 0.525H + 0.064O	(8)
Sheng & Azevedo et al. [22][b]	CV = 0.3259C + 3.4597	(9)
Sheng & Azevedo et al. [22][c]	$CV = -1.3675 + 0.3137C + 0.7009H + 0.0318O^{*a}$	(10)
Tillman [23]	CV = 0.4373C -1.6701	(11)

[a] O^* is the sum of the contents of oxygen and other elements in the organic matter (O^* = 100-C-H-Ash).

3 Results and Discussion

The results for the proximate analysis, ultimate analysis, and calorific value for the torrefied sugarcane (*Saccharum officinarum*) bagasse, Semirara coal, and its blends (% w/w) – 25, 50, and 75 were summarized in Tables 3, 4, and 5, respectively.

Table 3. Results for the proximate analysis – moisture (MC), ash (AC), volatile matter (VM), and fixed carbon (FC) on the basis of concentration (% w/w) of sugarcane (*Saccharum officinarum*) bagasse.

Concentration (% w/w) of Biomass	MC (%)	AC (%)	VM (%)	FC (%)
0	13.04	36.03	24.19	26.74
25	9.64	39.04	29.20	22.12
50	7.36	40.86	33.13	18.65
75	5.64	43.73	36.67	13.96
100	2.89	45.24	42.22	9.65

Table 4. Results for the ultimate analysis – carbon (C), hydrogen (H), nitrogen (N), and sulfur (S) on the basis of concentration (% w/w) of sugarcane (*Saccharum officinarum*) bagasse.

Concentration (% w/w) of Biomass	C (%)	H (%)	N (%)	S (%)
0	40.22	4.61	9.80	0.77
25	45.57	4.17	9.85	0.80
50	52.00	3.81	9.66	0.60
75	57.08	3.53	9.65	0.56
100	61.48	3.19	9.78	0.38

Table 5. Results for calorific value and energy yield on the basis of concentration (% w/w) of sugarcane (*Saccharum officinarum*) bagasse.

Concentration (% w/w) of Biomass	Calorific Value ($MJ\cdot kg^{-1}$)	Energy Yield (%)
0	16.17	-
25	18.57	42.68
50	20.16	46.33
75	21.82	50.15
100	23.20	53.32

3.1 Proximate Analysis

Generally, any two coals cannot just be blended. To decide to blend or not, it is very important to understand the composition of the coals that are to be blended. The linear additive rule shown in Equation (12) is used to estimate the theoretical composite value of the coal blends to show the relationship of the coal properties and the amount of that coal in the blend, where M is the composite value of the parameter being estimated and x is the weight fraction of the components in the blend.

$$M = x_b M_b + (1 - x_b) M_a \quad (12)$$

A property can be considered additive when the physical property of the blend can be predicted by the relative amounts of component coals and their physical properties. The applicability of the additive property for coal blending was determined using the coefficient of determination, R^2 value of at least 0.9000 [24]. Based on Figure 1, comparing the experimental values from the calculated values for moisture (MC), ash (AC), volatile matter (VM), and fixed carbon (FC) based on the linear additive rule, it showed acceptable results with minimal deviations with overall R^2 value of 0.9602. Thus, it can be established that Semirara coal blended with sugarcane (*Saccharum officinarum*) bagasse were additive based on its proximate analysis parameters.

The proximate analysis involves the quantitative determination of moisture content (MC), ash content (AC), volatile matter (VM), and fixed carbon (FC). The results for the proximate analysis for the torrefied sugarcane (*S. officinarum*) bagasse, Semirara coal, and its blends (% w/w) – 25, 50, and 75 was shown in Table 3. The trends of these values were also illustrated in Figure 1 on the basis of increasing concentration (% w/w) of sugarcane (*S. officinarum*) bagasse.

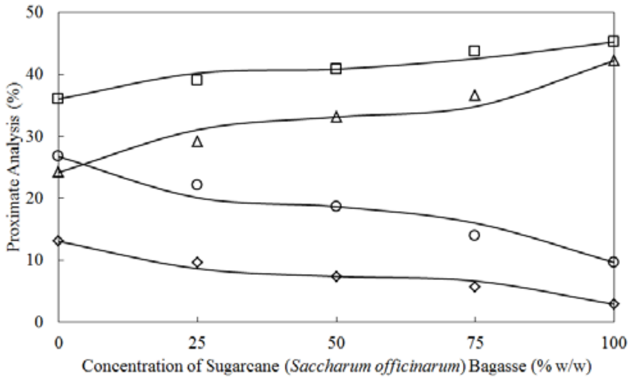

Fig. 1. Comparison of experimental values for proximate analysis parameters – moisture (◇), ash (□), volatile matter (△), and fixed carbon (○) versus calculated values (solid lines) based on linear additive rule.

It was observed that an increase in the concentration of torrefied sugarcane (*S. officinarum*) bagasse in the coal blend caused a decrease in the moisture content (MC) by as much as 77.84%. An increase in the moisture content of coal results in an increase in heat loss due to evaporation and superheating of vapor. Therefore, an increase in the concentration of torrefied sugarcane (*S. officinarum*) bagasse in the coal blend is a good indication that it averts the presence of fungi and decreases other biological activities upon storing. High moisture content can affect the overall energy conversion upon combustion because it influences the calorific value of the given fuel. The higher moisture content, the less energy per kilogram is released that causes lower calorific value [25]. This claim could be supported by the relationship of moisture content and calorific value shown in Table 5. A decrease in the moisture content in the coal blend corresponds to an increase in the calorific value.

Ash (AC) is the inorganic residue after combustion. One characteristic of a good fuel is having little amount of ash during combustion. Small amount of ash residues signifies the maximum utilization of the fuel used. High amount of ash affects combustion efficiency and boiler efficiency because it causes clinkering and slagging. Looking at Table 3, it can be observed that an increase in the amount of torrefied sugarcane (*S. officinarum*) bagasse in the coal blend also increases the amount of ash.

High volatile matter (VM) indicates that the fuel can be easily ignited and subsequently oxidized. High volatile matter also contributes to better efficiency for burning during combustion. It influences the secondary air requirement, distribution aspects, and secondary oil supports. An increase in the amount of torrefied sugarcane (*S. officinarum*) bagasse in the coal blend corresponds to an increase in volatile matter by 74.54%.

Fixed carbon (FC) is the solid combustible residue that remains after a biomass particle is heated and the volatile matter is expelled. The amount of fixed carbon and volatile combustible matter directly contribute to the heating value of coal. Fixed carbon acts as a main heat generator during burning. High fixed carbon in biomass increases the char formation [25]. An increase in the amount of torrefied sugarcane (*S. officinarum*) bagasse in the coal blend caused a decrease in the amount of fixed carbon by 63.91%.

Lastly, in terms of the coal blending ratios used in this study, the 75 % w/w Semirara coal blended with 25 % w/w torrefied sugarcane (*S. officinarum*) bagasse is considered to be the most favorable based on the results of the proximate analysis.

3.2 Ultimate Analysis

Shown in Figure 2 is the comparison of experimental values versus the calculated values based on the linear additive rule for ultimate analysis – carbon (C), hydrogen (H), nitrogen (N), and sulfur (S). Just like in proximate analysis, the values are within the allowable results with slight deviations with overall R^2 value of 0.9349. Thus, it follows that Semirara coal blended with sugarcane (*Saccharum officinarum*) bagasse were also additive based on its ultimate analysis parameters.

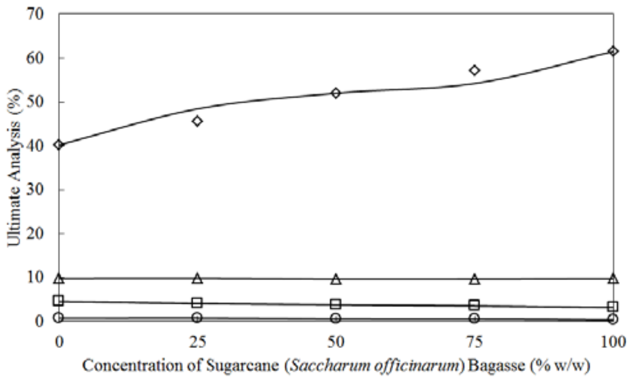

Fig. 2. Comparison of experimental values for ultimate analysis parameters – carbon (◇), hydrogen (□), nitrogen (△), and sulfur (○) versus calculated values (solid lines) based on linear additive rule.

The ultimate analysis determines the elemental composition of the coal including moisture, ash, carbon (C), hydrogen (H), nitrogen (N), sulfur (S), and oxygen (O) (by difference). It is valuable in determining the quality of air required for combustion and composition of combustion gases. The results for the ultimate analysis for the torrefied sugarcane (*S. officinarum*) bagasse, Semirara coal, and its blends (% w/w) – 25, 50, and 75 was shown in Table 4. The trends of these values were also illustrated in Figure 2 on the basis of increasing concentration (% w/w) of sugarcane (*S. officinarum*) bagasse.

Carbon content is a good indicative property of coal ranks. The highest rank coals have the highest carbon contents and the lowest oxygen contents. Ratios of these elements can indicate the rank of the coal and its coalification degree [26]. It is also important to measure the sulfur content in coal samples to evaluate the potential sulfur emissions from coal combustion. Increasing the amount of torrefied sugarcane (*S. officinarum*) bagasse in the coal blend increases the carbon content by 52.86%.

Meanwhile, the hydrogen content for all coal blends decreases by 45.12% with increasing amount of torrefied sugarcane (*S. officinarum*) bagasse. The increased content of hydrogen is normally more of a characteristic of low rank coals, while the decreased values are commonly more typical for higher-rank coals [27]. Based on this, it could be said that a decrease in hydrogen content indicates that the quality of Semirara coal blended torrefied sugarcane (*S. officinarum*) bagasse improved to higher rank.

Nitrogen content for all coal blends is approximately the same with 9.75% on average. Nitrogen is an inert and incombustible gas and it does not contribute any useful property to the combustion of coal. It is generally found in the organic fraction of the coal wherein upon combustion, it is emitted as nitrogen oxide (NO_x) in the flue gas.

Sulfur content for all coal blends decreases by 59.74% with increasing amount of torrefied sugarcane (*S. officinarum*) bagasse. Presence of sulfur in coal is harmful for use in metallurgy as it transfers to the metal and adversely affects the property of metal. Also, oxidation products of sulfur such as sulfur dioxide (SO_2) and sulfur trioxide (SO_3) have corrosive effect on the equipment and causes atmospheric pollution. Hence the presence of sulfur in coal is undesirable. A decrease in the sulfur content of Semirara coal upon coal blending with torrefied sugarcane (*S. officinarum*) bagasse is an indication that an environment-friendly approach have been taken.

Based on the results of the ultimate analysis, considering the coal blending ratios studied, the 25 % w/w Semirara coal blended with 75 % w/w torrefied sugarcane (*S. officinarum*) bagasse is considered to be the most favorable.

3.3 Calorific Value

The calorific value of a fuel is the number of heat units evolved when unit mass (or unit volume in the case of a gas) of a fuel is completely burned and the combustion products are cooled to 298 K. This definition of calorific value includes the provision that the products of combustion are cooled to 298 K which means the sensible heat and the latent heat of condensation of the water produced during combustion are included in the heat liberated. Therefore, the calorific value of the fuel is designated as ‘gross calorific value (GCV)’ or ‘high heating values (HHV)’ [28].

The energy analysis of torrefied sugarcane (*Saccharum officinarum*) bagasse, Semirara coal, and its blends (% w/w) – 25, 50, and 75 were studied by determining the calorific value experimentally and calculating the calorific value theoretically using existing correlations found in literature applicable for both coal and biomass based on proximate and ultimate analyses as summarized in Tables 6 and 7, respectively. Also presented in these tables are the average absolute deviations (AAD) to describe variation in a data set for experimental and calculated values, and the coefficient of determination, (R^2) to measure the goodness of fit of the experimental values to the model. Here, as shown in Equation (13), the AAD is evaluated as

$$\mathrm{AAD} = \frac{1}{n} \times \sum_{i=1}^{n} \left| \left(\varepsilon_{\mathrm{cald}} - \varepsilon_{\mathrm{expt}} \right) \right|_i , \tag{13}$$

where n is the number of data points and ($\varepsilon_{\mathrm{cald}}$ and $\varepsilon_{\mathrm{expt}}$) are calculated and experimental values, respectively.

The carbon content in ultimate analysis was a predictive basis of the calorific value. And evidently, calorific values and the amount of carbon content show a direct proportionality since the calorific value of blended torrefied sugarcane (*S. officinarum*) bagasse and Semirara coal increases with increasing biomass concentration from 16.17 MJ/kg to 23.20 MJ/kg or by 43.48%.

Table 6. Summary results of the calorific values (experimental) for torrefied sugarcane (*Saccharum officinarum*) bagasse, Semirara coal, and its blends (% w/w) – 25, 50, and 75 and calorific values (calculated) from literature correlations based on proximate analysis.

Concentration (% w/w) of Biomass	$CV_{exp.}$, $MJ \cdot kg^{-1}$	Literature Correlations $CV_{cald.}$, $MJ \cdot kg^{-1}$				
		[14]	[15]	[16]	[17]	[18]
0	16.17	14.91	12.95	14.83	13.24	12.95
25	18.57	13.91	12.07	15.15	13.83	12.07
50	20.16	13.21	11.44	15.43	14.25	11.44
75	21.82	11.91	10.31	15.05	13.94	10.31
100	23.20	11.18	9.64	15.64	14.64	9.64
OAAD (%)	-	32.92	41.88	22.77	29.18	41.88
R^2	-	0.983	0.984	0.587	0.803	0.984

Table 7. Summary results of the calorific values (experimental) for torrefied sugarcane (*Saccharum officinarum*) bagasse, Semirara coal, and its blends (% w/w) – 25, 50, and 75 and calorific values (calculated) from literature correlations based on ultimate analysis.

Concentration (% w/w) of Biomass	CV_{exp}, $MJ \cdot kg^{-1}$	Literature Correlations CV_{calc}, $MJ \cdot kg^{-1}$					
		[19]	[20]	[21]	[22][b]	[22][c]	[23]
0	16.17	14.03	17.51	16.62	16.57	15.09	15.92
25	18.57	15.83	19.12	17.68	18.31	16.21	18.26
50	20.16	18.19	21.05	19.06	20.41	17.72	21.07
75	21.82	20.06	22.63	20.14	22.06	18.87	23.29
100	23.20	21.55	23.96	21.03	23.50	19.84	25.22
AAD (%)	-	10.59	4.53	6.02	1.49	11.90	4.64
R^2	-	0.989	0.991	0.989	0.992	0.988	0.992

Considering the calorific values calculated from literature correlations based on for both proximate and ultimate analyses, the model presented by Sheng and Azevedo [22][b] has the lowest AAD value of 1.49% among the eleven correlations, at the same time the experimental values best fit with that same model, as shown in Figure 3, having an R^2 value of 0.992. The calorific value is the key parameter to evaluate the fuel quality of a special biomass material in energetic application [29]. Higher calorific value is desirable to achieve higher rank of coal. Blended biomass-coal can be predicted to be able to keep pace with pure coal in terms of calorific value.

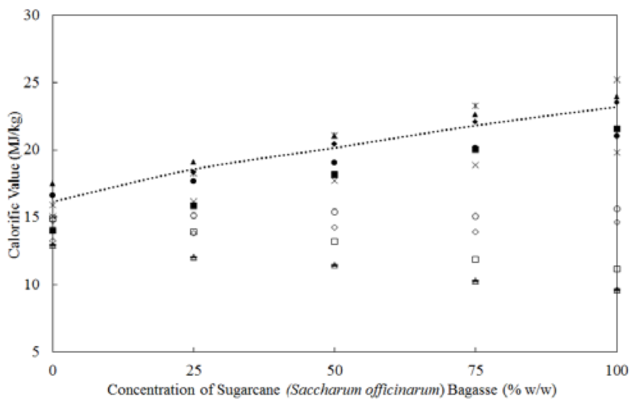

Fig. 3. Plot of experimental (dotted line) calorific values of blended Semirara coal and torrefied sugarcane (*Saccharum officinarum*) bagasse fitted to various correlations applicable for both coal and biomass based on: proximate analysis – Kavšek et al. (☐), Kieseler et al. (△), Majumder et al. (○), Mesroghli et al. (◇), Parikh et al. (─); and ultimate analysis – Channiwala & Parihk (■), Friedl et al. (▲), Jenkins et al. (●), Sheng & Azevedo[b] (◆), Sheng & Azevedo[c] (✕), Tillman (✱).

4 Conclusion

This paper aimed to establish recommended blending ratios for Semirara coal, a sub-bituminous type of coal from Semirara Island in the province of Antique, Philippines and torrified sugarcane (*Saccharum officinarum*) bagasse thru coal blending technique in order to improve the quality of indigenous coal reserves while concurrently reducing and reusing agricultural wastes. The torrefied sugarcane (*S. officinarum*) bagasse, Semirara coal, and its blends (% w/w) – 25, 50, and 75 were subjected to proximate and ultimate analyses tests, and calorific value determination to characterize and understand the physical conditions and coal properties during combustion.

Using the linear additive rule, it can be established that Semirara coal blended with sugarcane (*S. officinarum*) bagasse were additive based on its proximate and ultimate analyses parameters.

Blending torrefied sugarcane (*S. officinarum*) with Semirara coal would reduce the moisture content and fixed carbon by 77.84% and 63.91%, respectively, while increasing the volatile matter by 74.54% and the ash content by 25.56%. On the other hand, the carbon content increased by 52.86% which is a good indicative property of coal ranks; the hydrogen and sulfur content decreased by 45.12% and 59.74%, respectively which imply that the coal blend improved to higher rank and became environment-friendly. Remarkably, the calorific value was enhanced by 43.48%.

In terms of the coal blending ratios used in this study, the 75 % w/w Semirara coal blended with 25 % w/w torrefied sugarcane (*S. officinarum*) bagasse is considered to be the most favorable based on the results of the proximate analysis. Whereas for the ultimate analysis, it is the 25 % w/w Semirara coal blended with 75 % w/w torrefied sugarcane (*S. officinarum*) bagasse. Among the eleven correlations considered, the model presented by Sheng and Azevedo [22][b] best fit with the experimental values with R^2 value of 0.992 and AAD value of 1.49%.

Therefore, blending torrefied sugarcane (*S. officinarum*) bagasse with Semirara coal would generally improve its quality in terms of its combustion properties thereby making these combinations of coal and biomass advantageous.

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