ISERME 2024 Proceedings
2nd September 2024 – Sapporo, Japan
https://doi.org/10.31705/ISERME.2024.16

Distillery Spent Wash as an Alternative Fuel in Boilers and Potash Recovery from that Ash Remaining in Boilers

Warnakulasooriya[1] GAPKGG, *Amarasinghe[1] AMPC, Lankathilake[1] LJMU and Wijesekara[1] ERJMDDP
[1]*Department of Biosystems Technology, Faculty of Technology, Sabaragamuwa University of Sri Lanka*
*Corresponding author – Email: prasad@tech.sab.ac.lk

Abstract

Waste management stands as a critical global environmental challenge, with a growing emphasis on waste avoidance and the generation of revenue through byproduct recovery. Pollution prevention strategies aim to minimize waste generation, while waste minimization efforts focus on reducing waste volume or toxicity, often through water recycling, process modification, and byproduct recovery. In this context, the utilization of distillery effluent in agriculture presents an opportunity to save on fertilizer costs, enhance agricultural output, and mitigate pollution. However, molasses-based distilleries, along with their primary product, alcohol, generate significant volumes of wastewater known as spent wash. Improper disposal of spent wash into water bodies or land leads to a host of environmental issues. Consequently, recent efforts have shifted towards waste minimization and revenue generation through byproduct recovery. This study focuses an approach to address the challenge of distillery spent wash management by drying the spent wash and utilizing the resulting dried solids as an alternative fuel for boilers. The distillery spent wash contains approximately 14.6% solid content, and the dried solids have a gross calorific value of 13840 J/g. Furthermore, the dried solids possess an ash content of 2.26%, with the ash containing a notable 36.7% potassium oxide content. By transforming distillery spent wash into a valuable resource for boiler fuel, this research not only addresses waste management concerns but also offers a sustainable solution for revenue generation. The utilization of dried solids as an alternative fuel for boilers contributes to reducing environmental pollution associated with improper spent wash disposal while offering a viable source of renewable energy. This study underscores the potential of waste-to-energy initiatives in fostering sustainable waste management practices and enhancing economic viability in the distillery sector.

Keywords: Alternative fuel; Byproduct recovery; Calorific value; Distillery effluent; Spent wash

1. Introduction

Sugar production is a vital agricultural industry on a worldwide scale, supplying a key component for a wide array of consumer products. Countries worldwide, from the tropical plantations of Brazil and Thailand to the vast fields in India and the United States, are heavily involved in the cultivation and processing of sugarcane and sugar beets. Predominantly, sugar is extracted from sugarcane, which accounts for approximately 80% of global production, mainly in tropical regions, while sugar beet contributes around 20%, primarily in temperate climates such as the United States and Europe [1]. Sugarcane (*Saccharum officinarum L.)* is a significant cash crop, generating various byproducts that are integral to supporting numerous related industries [2]. Sri Lanka stands as a notable sugar producer, relying on sugarcane as its main raw material. Sugarcane serves as the exclusive crop cultivated in Sri Lanka exclusively for sugar manufacturing.[3] Currently, operational sugar factories in

Pelwatta, Higurana, Ethimale, and Sevanagala contribute to this effort. Sugar industry is one of the sustainable industries that can strength the economy of a country.

1.1 Sugarcane Industry Wastes into Commercial Products

The by-products and waste produced from the sugar industry are converted to obtain value-added products will decrease environmental pollution and also makes a huge economic benefits [4].(Figure 1)

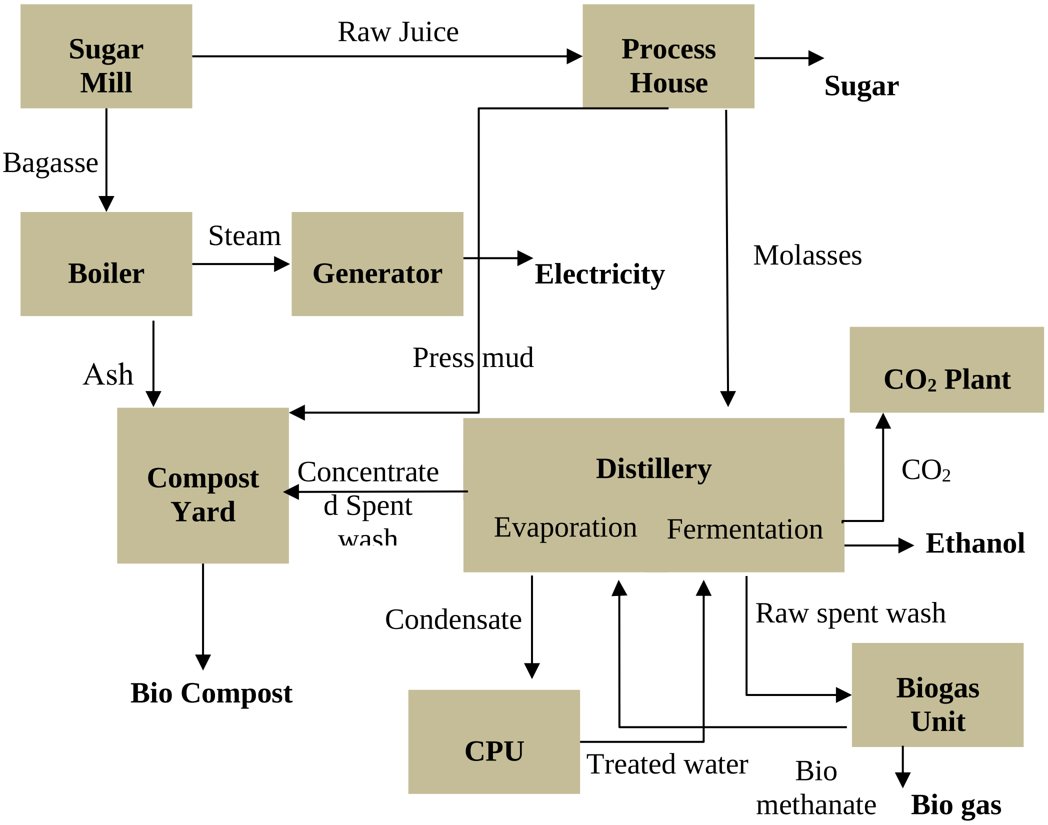

Figure 111 Sugar Industry waste to Valuable By-products

1.1.1 Distillery Spent Wash

Distillery Spent Wash (DSW) is a thick, viscous liquid residue that remains when fermented sugarcane juice is distilled with alcohol. It is sometimes referred to as vinasse or stillage. DSW comprises a large number of both organic and inorganic materials and is usually 12 to 15 times the volume of the alcohol produced. Its acidic pH, high organic content, and dark color are its major defining characteristics. The disposal of DSW presents notable environmental problems because of its huge volume, extremely high Biological Oxygen Demand/Chemical Oxygen Demand (BOD/COD) ratio (40,000–65,000 mg/lit), COD (80,000–140,000 mg/lit), and BOD/COD ratio [5], [6]. The strong bad odor and coloration of DSW further complicate its disposal by disrupting oxygenation and self-purification processes in water bodies. However, when applied in optimized doses, DSW can enhance and maintain the soil enzymatic and microbial activities, increase organic carbon levels, improve nutrient uptake, enhance soil porosity and water holding capacity, increase aggregate stability, and promote antioxidant activities, thereby enhancing photosynthetic efficiency, growth, and yields [7]. Although there are these benefits in spent wash, limited of DSW characteristics and proper agricultural application methods understanding causes concerns about groundwater pollution and environmental quality. DSW's production rate and properties depend largely on the feedstock which use, fermentation practices, and unit operations involved in molasses and ethanol processing. [8]. According to the Indian statical reports, 246 distilleries produce approximately 15,000 million liters of spent wash yearly, highlighting the significant scale of the issue. Spent wash classified as high-strength industrial wastewater and 'red' category waste.

These statistics underscore the significant contribution of the distillery industry to the generation of spent wash worldwide, emphasizing the need for effective waste management strategies and innovative treatment technologies. [9]. Numerous technologies have been investigated to mitigate the pollution load of DSW. Common methods for treating spent wash are biological treatments (aerobic treatments and anaerobic treatments) and also some other technologies such as incineration, fertilizer production, Electro coagulation, absorbent method and Membrane Technique. Moreover, spent wash can be utilized as a potential source of renewable energy through processes such as anaerobic digestion or combustion to generate biogas or bioenergy.

However, the ongoing development of innovative, effective, and commercially feasible treatment solutions is required due to the intricacy of DSW and the constantly changing laws. In order to manage DSW sustainably and minimize its environmental impact while satisfying the increasing demand for efficient treatment options, research and development must continue. [9, 16, 17, 18, 19]. DSW is an important agricultural resource because to its high organic content. It's safe for use in agriculture because it comes from plants and doesn't contain any harmful metals. DSW provides significant advantages to crop output and soil quality since it is rich in macronutrients (Table 1).

Table 1 Plant nutrients contains in DSW

Plant Nutrient	**Value (mg L^{-1})**
Nitrogen	1660–4200
Phosphorous	225–3038
Potassium	9600–17,475
Calcium	2050–7000
Magnesium	1715–2100
Sodium	492–670
Sulphate	3240–3425
Zinc	3.5–10.4
Copper	0.4–2.1
Manganese	4.6–5.1
Sodium	492–670
Iron	6.3–7.5

However, less understanding of DSW characteristics and appropriate agricultural application methods increases problems about potential ground water pollution and environmental impact [10].

There is a method is to precipitate potassium from distillery waste using hexafluorosilicic acid as a precipitant. However, the use of hexafluorosilicic acid can be cause fluoride contamination of the wastewater stream, requiring further measures for environmental management of the waste.

The other method for potash recovery from distillery spent wash involves number of several steps. Firstly, the spent wash is neutralized. Then concentrated and incinerated to produce "spent wash coke," which, upon combustion, yields ash. This ash undergoes leaching with water. After neutralizing with sulfuric acid and crystallizing, the resultant leachate produces a solid combination of potassium chloride and potassium sulfate. But because this mixed salt has about 5% sodium salts in it, it might not be up to current fertilizer regulations. Additionally, because of the increased risk of organic fouling and slag formation, extended operation may impair the efficiency of evaporation and incineration.

Another method involves selectively precipitating potassium from aqueous solutions, such as schoenite end liquor, using tartaric acid as a precipitant. However, due to interactions among solutes, especially organics, the direct application of this process leads to reduced potassium recovery and the production of highly colored and impure potash salt [11]

In this research study, the focus was on using DSW in a sustainable way and introduce a good waste management technique. If we can use DSW as a boiler fuel and make energy it is very useful. Furthermore, if there is an ability to use the ash comes out from boilers after combustion of DSW to extract Potash, it is very good sustainable solution for DSW. This study sought to conduct laboratory level tests to check the feasibility of using DSW as a boiler fuel and in addition, a computational calculation of potash extraction capability and how much potash can be extracted from the ash remaining after DSW combustion is carried out. Samples of raw spent wash was sourced from the Ethimale Plantation (Pvt) Ltd sugar factory, situated in Siyambalanduwa, Sri Lanka. This factory produces 150 m3 of spent wash daily alongside 12 m3 of ethanol.

2. Material and Methods

2.1 Calorific Value of DSW – by Bomb Calorimeter

In this method, the bomb calorimeter was employed to determine the Calorific Value (CV) value of DSW. First, by evaporating 1 liter of raw distillery spent wash using a rotary evaporator, 250 ml of evaporated spent wash was prepared. This was done by evaporating 500 ml of raw spent wash at 90°C and 700 mbar over a period of three hours, and then repeating the same procedure to collect a total of 250 ml of evaporated spent wash. Then, a 50 ml sample of the evaporated spent wash was oven-dried over 24 hours to produce solid DSW. Finally, the calorific value of the solid DSW was measured by using a bomb calorimeter. 0.5 grams of the solid DSW was utilized for this measurement. This method ensures the accurate determination of the calorific value, providing essential data for evaluating the potential of DSW as a boiler fuel.

Figure 2 Evaporating DSW using Rotary Evaporator

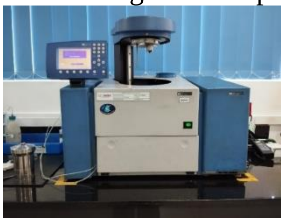

Figure 312 Bomb Calorimeter

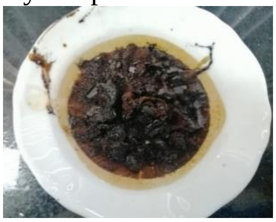

Figure 4 DSW Solid Sample

2.2 Available Potash Percentage in DSW – by X-Ray Fluorescence (XRF) Analyzer

To determine the available potash percentage in DSW, an XRF analyzer was utilized following a comprehensive preparatory procedure. Initially, 250 ml of evaporated spent wash was prepared by evaporating 1 liter of raw distillery spent wash using a rotary evaporator. This was done by evaporating 500 ml of raw spent wash at 90°C and 700 mbar over a period of three hours, and then repeating the same procedure to collect a total of 250 ml of evaporated spent wash. A 50 ml sample of the evaporated spent wash was then oven-dried over 24 hours to produce solid DSW. The solid DSW sample was subsequently crushed using a pestle and mortar. The crushed solid DSW sample was combusted in a muffle furnace for two hours to produce DSW ash. A portion of this ash, specifically 1.5 grams, was mixed with 7.5 grams of spectro melt (lithium tetraborate). Then the mixture was placed in a platinum crucible. 4-5 drops of lithium bromide were added to the mixture to facilitate melting, which was then heated in a muffle furnace at 1150°C for 20 minutes. The melted mixture was poured into a mold and allowed to solidify into a melt tablet. This DSW ash melt tablet was analyzed using an XRF analyzer to determine the elemental composition of the DSW ash. Then the results from the XRF analysis were used to calculate the potash percentage in the DSW ash. It provides valuable data for assessing the potential for potash extraction from DSW.

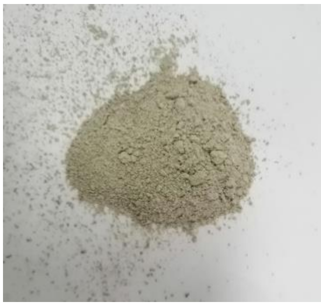

Figure 513 DSW ash sample

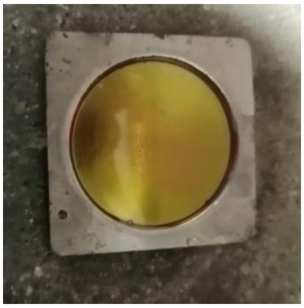

Figure 614 DSW ash melt Tablet making

3. Results and Discussion

3.1 Calorific Value of DSW

In this study, it mainly focused to provide a sustainable waste management solution for DSW. In order to evaluate the feasibility of using DSW as an alternative fuel for boilers, the CV value of DSW was measured using Bomb calorimeter.

Table 2 Gross Calorific Value (GCV) value of DSW

GCV of DSW (J/g)		Average GCV of DSW (J/g)
1st Experiment	**2nd Experiment**	
13896	13785	13840.5

According to the results obtained from the experiments that conducted to measure the calorific value of distillery spent wash the average CV value of DSW is 13840.5 J/g.

According to the references, considering the CV values of the materials currently used as boiler fuel, they are as shown in Table 3 [12].

When comparing the CV of DSW to CV of fuels already used in boilers, the approximately closeness suggests that the tested fuel can be considered suitable for use as a boiler fuel. Fuels with similar CV provide comparable energy output when burned. If the calorific value of the DSW is close to those already used in boilers, it implies that it can generate similar levels of heat energy when combusted.

Table 3 Calorific Values of Boiler Fuels

Biomass	**Calorific Value (J/g)**
Dry Bagasse	19605
Dry Rice Husk	16546
Dry Rice Straw	16345

Utilizing fuels with comparable calorific values can offer economic advantages. Due to the characteristics of DSW such as readily available and cost-effective, switching to it as a boiler fuel can lead to potential savings in fuel procurement and operational costs without sacrificing performance or reliability as well as it suggests a sustainable waste management solution.

If consider these things, when the calorific values of a tested fuel closely align with those of fuels already used in boilers, it suggests that the tested fuel possesses characteristics suitable for boiler applications, including efficient combustion, compatibility with existing systems, and potentially favorable economic implications.

3.2 Available Potash Percentage in DSW

3.2.1 Ash Percentage in DSW

DSW contains various organic and inorganic compounds along with a significant amount of water. During the combustion process, the organic components of the spent wash, such as sugars, proteins, and other organic compounds, are oxidized and converted into gases such as carbon dioxide and water vapor, as well as solids in the form of ash. Table 4 shows the results of experiments that conducted to measure the solid and ash percentages in DSW.

Table 48 Ash percentage in DSW

DSW (ml)	**Evaporated DSW (ml)**	**Spent wash Solid (g)**	**Spent wash Solid %**	**Spent wash Ash (g)**	**Spent wash Ash %**
1000	250	146	14.6	22.6	2.26

Distillery spent wash contains a high proportion of water and the solid content in DSW is 14.6%. after combustion it generates 2.26% of DSW ash which consists with plant nutrients as oxide forms. Proper testing and analysis of the spent wash ash is necessary to ensure its effective use as a fertilizer.

3.2.2 Potash percentage in DSW Ash

In a spent wash ash sample, Potassium included as a form of potassium oxide (K_2O). Potassium content is often expressed as K_2O because it represents the amount of potassium in a sample based on its equivalent weight. When we using spent wash ash to produce a fertilizer, understanding the potassium content in terms of K_2O can help in determining its potential fertilization value. Therefore, knowing the potassium content/percentage in spent wash ash, expressed as K2O, can be valuable information for agricultural applications. Accordingly, table 5 presents the average values of the results obtained in the XRF test conducted to find the amount of K_2O contained in DSW.

Figure 7 provides a graphical representation for enhanced clarity of this results. According to the results of XRF analysis, the most content of DSW ash is potassium oxide (K_2O) and its weight percentage is 36.75%. These data prove that, 1 liter of DSW can be burned and 22.6 g of DSW ash can be obtained, and the amount of potassium oxide (K_2O) contained in that amount of ash is 8.31 g. Table 6 shows the amount of spent wash generated in sugar factories in Sri Lanka per day according to the data obtained from the distilleries in sugar mills and the capacity of K2O producing using DSW per day.

Table 59 Average Concentrations of Plant nutrient elements in DSW Ash

Element	**Experiment 01 Concentration (%)**	**Experiment 02 Concentration (%)**	**Average Concentration (%)**
Na_2O	2.73	2.31	2.52
K_2O	37.09	36.4	36.75
MgO	5.89	5.55	5.72
CaO	11.29	11.19	11.24
Fe_2O_3	1.02	0.39	0.71
Al_2O_3	1.76	1.43	1.60
SiO_2	8.54	8.37	8.46

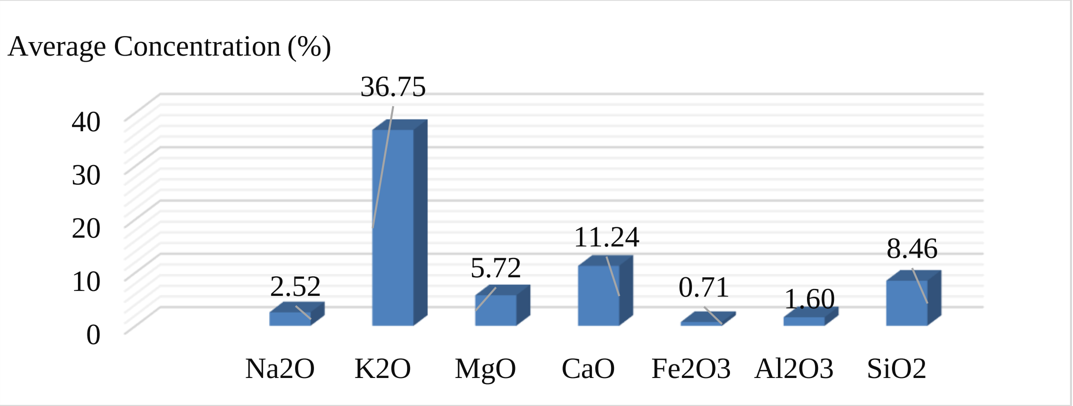

Figure 715 Average Concentrations of Plant nutrient elements in DSW Ash

Table 6 The amount of spent wash generated in sugar factories in Sri Lanka per day

Factory	**Generated DSW amount per day (L)**	**DSW Solid amount per day (kg)**	**DSW Ash amount per day (kg)**	**K2O Amount per day (kg)**
Pelwaththa Sugar Factory	300,000	43800	6780	2491.65
Sewanagala Sugar Factory	280,000	40880	6328	2325.54
Higurana Sugar Factory	300,000	43800	6780	2491.65
Ethimale Sugar Factory	150,000	21900	3390	1245.83
Total	1,030,000	150,380	23,278	8,555.00

According to these data and calculations, 8555 kg of potash can be produced in a day by the spent wash produced from the slags associated with the CINI factories in Sri Lanka and it is approximately 3122.58 tons annually. Based on data from the fertilizer calculation file of the Sri Lanka Department of Agriculture, the current import of Muriate of Potash (MOP) stands at 100,000 tons to fulfill Sri Lanka's potassium needs. 60% of the MOP contains potassium, resulting in an annual requirement of 60,000 tons of potash. So that, the utilization of this DSW ash can potentially meet around 5% of Sri Lanka's annual potash requirement.

4. Conclusion

The study shows the potential of utilizing DSW ash as a sustainable solution for waste management while addressing a portion of Sri Lanka's potash requirements. Through the analysis, it was found that DSW ash contains significant amounts of potassium oxide (K2O) which is a valuable nutrient for plants. This finding underscores the feasibility of repurposing DSW ash as a fertilizer. So then, it can be reducing the reliance on imported potassium sources. Moreover, the calorific value analysis showed that DSW could use as a suitable alternative fuel for boilers, offering comparable energy output to conventional fuels. These benefits of waste management and energy generation highlights the potential economic and environmental advantages of integrating DSW utilization into industrial processes.By harnessing the high potassium content of DSW ash and its energy generation capabilities, Sri Lanka can reduce its dependence on imported potash while addressing waste disposal challenges and promoting sustainable practices within the distillery industry. However, further research and implementation efforts are needed to optimize the extraction and application of potassium from DSW ash and to ensure its safe and effective use as fertilizer.

References

[1] "Sugar Producing Countries 2023," Wisevoter. Accessed: Feb. 05, 2024.

[2] A. M, "A Perspective Review on Sugar Industry Wastes, Uses and Treatment Techniques," Open Access J. Waste Manag. Xenobiotics, vol. 6, no. 3, pp. 1–10, Jul. 2023, doi: 10.23880/oajwx-16000186.

[3] "5.Sugar-Production-Process-in-Sri-Lanka-.pdf."

[4] S. P. Singh et al., "Sugarcane wastes into commercial products: Processing methods, production optimization and challenges," J. Clean. Prod., vol. 328, p. 129453, Dec. 2021, doi: 10.1016/j.jclepro.2021.129453.

[5] Y. S. Khandekar and D. N. P. Shinkar, "Treatment Methods of Distillary Spent Wash: A Review".

[6] M. Umair Hassan et al., "Sugarcane Distillery Spent Wash (DSW) as a Bio-Nutrient Supplement: A Win-Win Option for Sustainable Crop Production," Agronomy, vol. 11, no. 1, Art. no. 1, Jan. 2021, doi: 10.3390/agronomy11010183.

[7] P. Rath, G. Pradhan, and M. K. Misra, "Effect of Distillery Spent Wash (Dsw) and Fertilizer on Growth and Chlorophyll Content of Sugarcane (Saccharum Officinarum L.) Plant," 2011.

[8] M. Umair Hassan et al., "Sugarcane Distillery Spent Wash (DSW) as a Bio-Nutrient Supplement: A Win-Win Option for Sustainable Crop Production," Agronomy, vol. 11, no. 1, p. 183, Jan. 2021, doi: 10.3390/agronomy11010183.

[9] R. Jain and S. Srivastava, "Nutrient composition of spent wash and its impact on sugarcane growth and biochemical attributes," Physiol. Mol. Biol. Plants Int. J. Funct. Plant Biol., vol. 18, no. 1, pp. 95–99, Jan. 2012, doi: 10.1007/s12298-011-0087-1.

[10] M. Umair Hassan et al., "Sugarcane Distillery Spent Wash (DSW) as a Bio-Nutrient Supplement: A Win-Win Option for Sustainable Crop Production," Agronomy, vol. 11, no. 1, Art. no. 1, Jan. 2021, doi: 10.3390/agronomy11010183.

[11] P. Maiti et al., "Process for potash recovery from biomethanated spent wash with concomitant environmental remediation of effluent," WO2017042832A1, Mar. 16, 2017 Accessed: Feb. 23, 2024.

[12] I. Gravalos, P. Xyradakis, D. Kateris, T. Gialamas, D. Bartzialis, and K. Giannoulis, "An Experimental Determination of Gross Calorific Value of Different Agroforestry Species and Bio-Based Industry Residues," Nat. Resour., vol. 7, no. 1, Art. no. 1, Jan. 2016, doi: 10.4236/nr.2016.71006.