



Preparation of Different Refused Derived Fuel Combinations with Domestic Sewage Sludge to Enhance Gross Calorific Value

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

The objective of the present study is to maximize the resource value. The need to minimize disposal has prompted efforts within sewage sludge management to utilize sewage sludge as a commodity. The present study describes the refused derive fuel preparations from sewage sludge for sustainable management of sewage sludge. For the production of energy, Proximate and ultimate analyses of domestic sewage sludge were conducted. Many parameters were analyzed for the energy production from domestic sewage sludge. These parameters included moisture content, volatile matter, Ash content, fix carbon content, gross calorific value (GCV). Different RDF combinations with sewage sludge were made and their gross calorific values were assessed. The highest GCV (6790 Btu/lb, 32.1±55.6) was obtained by RDF combination comprising sewage sludge, saw dust, oil and polythene, it was considered as best RDF combination with heating value equal to rice husk so it can be used as an alternative fuel in industry. It was concluded from this study that the environmental risks can be reduced by sustainable management of sludge and it has also a great potential as an alternative energy resource.

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1. INTRODUCTION

Sewage sludge (bio solids) is a product resulting from the municipal wastewater treatment. Basically treatment consists of the settling of solids and partial biological decomposition [1]. Sewage sludge can also be dumped into landfills, sea dumping, forests and soil recovery, appliance in to agricultural area and ignition into incinerators [2].

A worldwide energy crisis is threatening our energy security and economy as well as the security of the planet. This crisis is apparent in every country of the world. The sustainable energy challenge needs innovative solutions and new technologies as well as greatly amplified energy efficiency [3]. The depletion of fossil fuels, hikes in oil prices, growing demand for energy and the mounting apprehension of environmental problems which have confronted researchers to expand innovative technical procedures to attain sustainable and spotless energy primarily by the exploitation of renewable energy resources [4].

Universal utilization of bio energy could substitute a major component of current fossil energy use [5]. Bio energy is an essential energy source for around 2.7 billion people throughout the world and it acts as a crucial element to fulfill the regional power requirements in many progressing nations. Additionally bio energy generation can create services for local people as well it is a source of income and by this mean poverty is declined. Further significant advantages of sustainable bio energy generation comprise the wide diversity of agricultural markets, minimizing reliance on expensive, imported fuels, growing regional energy generation and even though also reducing greenhouse gas emission (GHGs) [6].

Energy production by urban refuse material is striking procedures in the field of replenishable energy utilization [7]. Sludge waste is considered as a powerful substitute which can be use as derived fuel in elevated power requiring industrial practices because of its calorific power such as in cement kilns [8].

Wastewater treatment produces huge amounts of sewage waste and its dumping causes various environmental concerns. Conversely there are various opportunities to usefully handle this waste like renovation into useful fuel. The

untreated sewage waste cannot be utilized as a power source because it have high moisture content so drying is necessary as it have significant quantities of hydrogen and carbon [9].

In recent years refuse derived fuel turn out to be waste management practice accepted by progressed countries of the world like America, Japan and Europe. ASTM classifies RDF in to seven main divisions and the significant type of refuse derived fuel is RDF-5, in which after a range of methodologies the end product is solid pellet shape fuel of sludge waste. The major features of RDF-5 are its elevated and continuous heating capacity 3000 to 6000 Kcal/Kg and it does not produce stinking odor and has low level of pollution. In addition after processing it condensed ten times as compare to its original volume then its handling and transportation is not a difficult task. This fuel is also easy to use and can be keep safe under room temperature for six to twelve months without putrefying. This fuel could also be used as a direct fire source in boilers or it can be blend with other materials [10].

Therefore sewage waste can be used as a biomass source for energy creation because it contains harmless organic materials. When sewage waste blends with other biomass it improves the procedure's effectiveness and the fuel characteristics. Additionally blending of sludge with biomass reduces the concentration of lethal and lifeless materials [11].

In arid country such as Pakistan these materials should be considered as precious resources for soil fertilization and agricultural irrigation. It restrains high percentage of organic matter and can be used as an important source of plant nutrient to alternate chemical fertilizer. However the toxic metals found in sewage sludge is considerably high and significant accumulation of these heavy metals in food crops may cause potential undesirable impacts on the human health and environment [12]. Large amounts of sewage sludge is produced in Pakistan annually, most of the rivers are now badly polluted because merely one percent of the wastewater produced is treated before discharge into streams or watercourses which results in the pollution of water bodies to the level that most of the water bodies are now badly contaminated. Every day approximately 2,000 million gallons of sludge is being discharged to surface

watercourses. Only the major cities of Pakistan like Karachi, Islamabad, Faisalabad and Peshawar are providing biological treatment to a part of the municipal sewage sludge produced. All the other cities discharge their untreated sewage waste into the water bodies as a result, heavily exhausting their oxygen resources and posing a serious threat to human health and environment [13].

The objectives of the present study are to assess energy from domestic sewage sludge to estimate the gross calorific value of sludge and to enhance the gross calorific value of domestic sewage sludge by adding different biomass.

2. MATERIALS AND METHODS

Samples of domestic sewage sludge were collected from Pakistan council of scientific and industrial research (PCSIR), near back gate sewage system and segregated. In segregation polythene bags, paper and stones were separated from sewage sludge samples. Samples were dried properly under sunlight and composite samples were prepared from collected domestic sewage sludge samples. Five different Refuse Derived Fuel (RDF) combinations were made in the process of energy production from domestic sewage sludge and then their energy was assessed.

Different parameters such as moisture content, ash, volatile matter, fix carbon, gross calorific value were included in proximate analysis.

Ultimate analysis included an assessment of level of carbon, nitrogen, hydrogen, sulphur.

2.1 Analytical Methods

Measurements of Inherent moisture content, ash, volatile matter, fix carbon were done by ASTM 2007 and the Gross calorific value (GCV) was measured by Bomb Calorimeter (Parr USA-6200 Calorimeter). The ultimate analysis of parameters was done by Vario Macro elemental CHNOS analyzer.

2.2 Statistical Analysis

The obtained data was tabulated and presented in forms of graphs. The results were statistically analyzed and presented. The standard deviation was applied using Minitab (version 15.0 INC., U. S. A.). The standard error was applied on graphs that statistically show the variation in data [14].

3. RESULTS AND DISCUSSION

Variations in the values of moisture content were observed in all of five combinations and it ranged from 1.3 to 3% (Fig. 1). The maximum moisture was found in A RDF combination which comprised of sewage sludge, rice husk and oil. In china according to the regulations moisture content of sewage sludge must be less than 80% before discharge from the waste water treatment plant. Usually sludge contains around 72 to 84% moisture and moisture content contributes negatively to the resulting heating value of domestic sewage sludge [15].

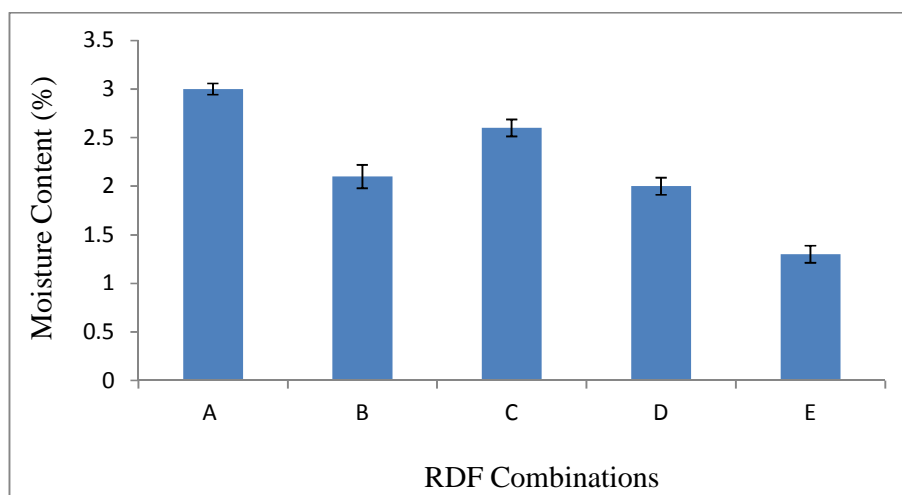


Fig. 1. Moisture content (%) in five RDF combinations of domestic sewage sludge samples
 A = Sewage sludge (50 g), rice husk (40 g) and oil (10 g), B = Sewage sludge (50 g), rice husk (40 g), oil (5 g) and polythene (5 g), C = Sewage sludge (50 g), saw dust (30 g), oil (10 g) and polythene (10 g), D = Sewage sludge (50 g), saw dust (30 g) and pet coke (20 g), E = Sewage sludge (60 g), pet coke (20 g) and oil (20 g)

In the case of volatile matter there were no significant variations in values of A, B and C RDF combinations were observed but sample D and E had less percentage of volatile matter as compared to other combinations. The combination B and C gave maximum values of volatile matter 50.9% and 50.5% (Fig. 3). Respectively this is because of the presence of polythene in both of these RDF combinations, which gave them the high volatility. The ash content of these two combinations were 45.95% and 44.45% (Fig. 2) respectively this showed that

there exists inverse relation in volatile matter and ash contents. The ash content of other RDF combinations A, D and E was 46.05%, 36.3% and 52.3% respectively. High percentage of ash indicates the presence of high percentage of minerals or commercial fiber additives especially in paper sludge. The high heating values are due to higher volatile matter and lower ash contents. So, volatile matter contributes positively to the resulting heating values, while ash contents have negative effects on heating values [16].

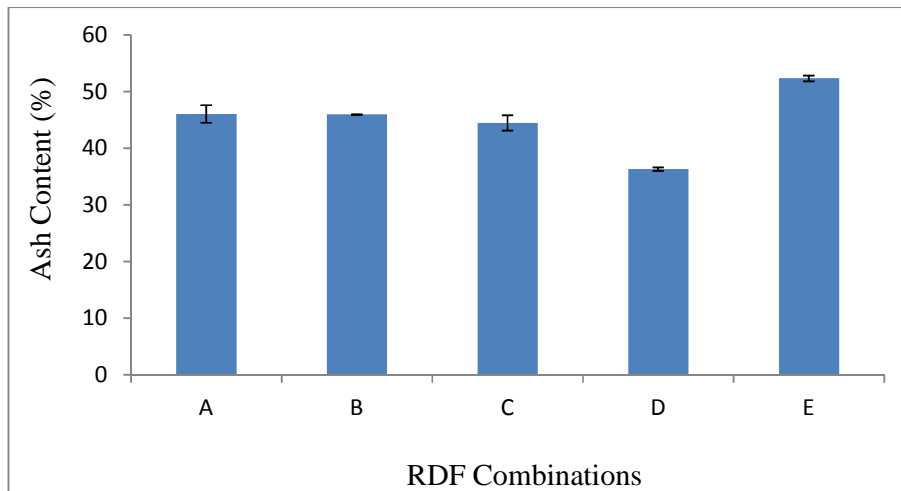


Fig. 2. Ash content (%) in five RDF combinations of domestic sewage sludge samples

A = Sewage sludge (50 g), rice husk (40 g) and oil (10 g), B = Sewage sludge (50 g), rice husk (40 g), oil (5 g) and polythene (5 g), C = Sewage sludge (50 g), saw dust (30 g), oil (10 g) and polythene (10 g), D = Sewage sludge (50 g), saw dust (30 g) and pet coke (20 g), E = Sewage sludge (60 g), pet coke (20 g) and oil (20 g)

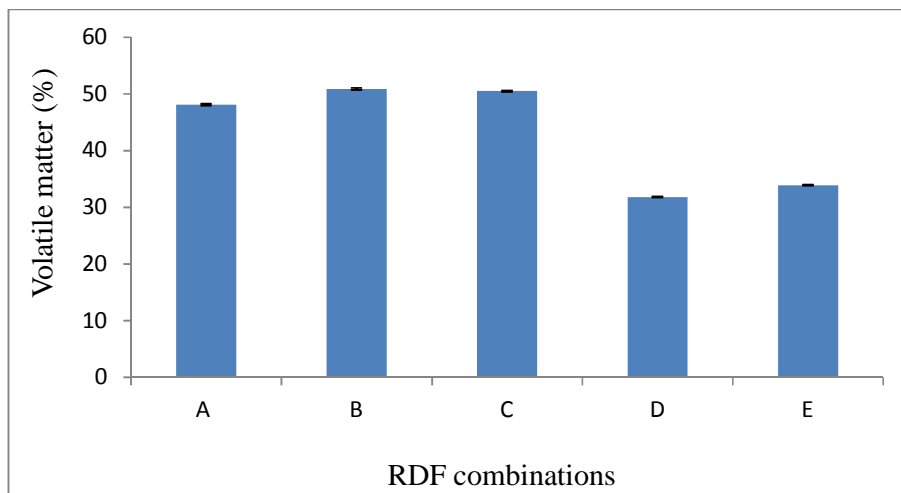


Fig. 3. Volatile matter (%) in five RDF combinations of domestic sewage sludge sample

A = Sewage sludge (50 g), rice husk (40 g) and oil (10 g), B = Sewage sludge (50 g), rice husk (40 g), oil (5 g) and polythene (5 g), C = Sewage sludge (50 g), saw dust (30 g), oil (10 g) and polythene (10 g), D = Sewage sludge (50 g), saw dust (30 g) and pet coke (20 g), E = Sewage sludge (60 g), pet coke (20 g) and oil (20 g)

The values of fix carbon were ranged between 2.6% to 29.8% in five different RDF combinations (Fig. 4). The highest value of fix carbon was (29.8%) found in D RDF combination it mainly contained sewage sludge, saw dust and pet coke. This highest value of DRDF combination is due to the presence of pet coke because coal has the fix carbon about 54.8%. The fix carbon also contributes positively to the heating value as like volatile matter [17].

The gross calorific values (GCV) of all RDF combinations of domestic sewage sludge

samples were also determined and it was ranged between 5402 Btu/lb to 6790 Btu/lb (Fig. 5). A comparison of results showed that the highest GCV was given by the C RDF combination, in which sewage sludge was blended with different materials and this combination mainly consists of sewage sludge, saw dust, oil and polythene. The highest GCV of C RDF combination is due to the presence of polythene which has high volatility and if 50% of waste plastic film is included in the mixture then it is possible to achieve a heating value of about 6000 kcal/kg for the RDF [18].

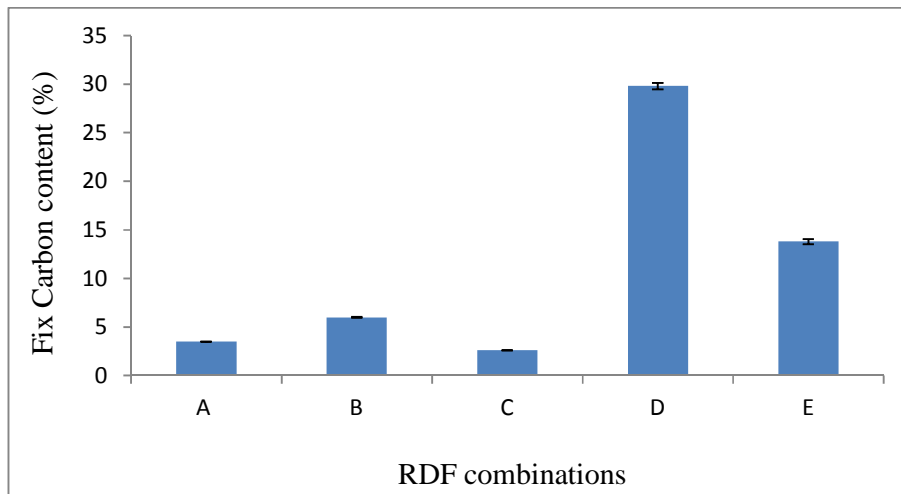


Fig. 4. Fix carbon content (%) in five RDF combinations of domestic sewage sludge sample
 A = Sewage sludge (50 g), rice husk (40 g) and oil (10 g), B = Sewage sludge (50 g), rice husk (40 g), oil (5 g) and polythene (5 g), C = Sewage sludge (50 g), saw dust (30 g), oil (10 g) and polythene (10 g), D = Sewage sludge (50 g), saw dust (30 g) and pet coke (20 g), E = Sewage sludge (60 g), pet coke (20 g) and oil (20 g)

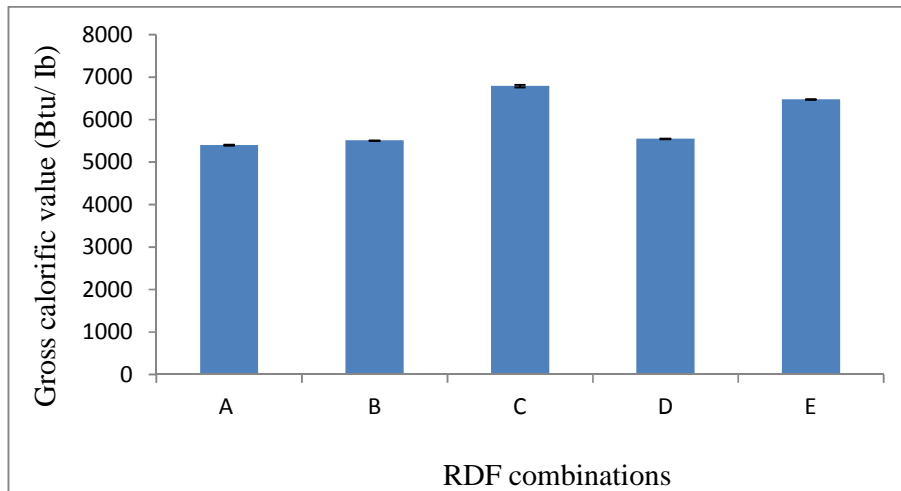


Fig. 5. Gross calorific value (Btu/lb) in five RDF combinations of domestic sewage sludge sample

A = Sewage sludge (50 g), rice husk (40 g) and oil (10 g), B = Sewage sludge (50 g), rice husk (40 g), oil (5 g) and polythene (5 g), C = Sewage sludge (50 g), saw dust (30 g), oil (10 g) and polythene (10 g), D = Sewage sludge (50 g), saw dust (30 g) and pet coke (20 g), E = Sewage sludge (60 g), pet coke (20 g) and oil (20 g)

All the RDF combinations of domestic sewage sludge were contained 2.1% to 3.98% hydrogen (Fig. 7) and 0.09% to 1.067% sulfur (Fig. 9) and usually sludge contain 2 to 6.3% hydrogen and 0.72 to 0.91% sulfur [19]. In domestic sewage sludge sulfur is essential nutrient for crop growth and it is increasingly more use as a constituent of fertilizer. When there is sulfur deficiency it reduce yield and have significant impacts on quality of harvested product. Sulfur also enhances the use efficiency of other crucial plant nutrient, predominantly nitrogen and phosphorous [20].

Carbon contents ranges from 26.40% to 33.52% (Fig. 6) in B and E RDF combination, the highest carbon contents were found in E combination because of the presence of pet coke and oil and the sludge may contain 30% to 40% of carbon [21]. Nitrogen content was in between 1.03% to 1.24% (Fig. 8). The highest nitrogen contents were found in C RDF combination which contains sewage sludge, saw dust, oil and polythene. Nitrogen was found in many important substances such as fertilizers, drugs and explosive materials etc. sludge usually contains 1.5% to 5% nitrogen [21].

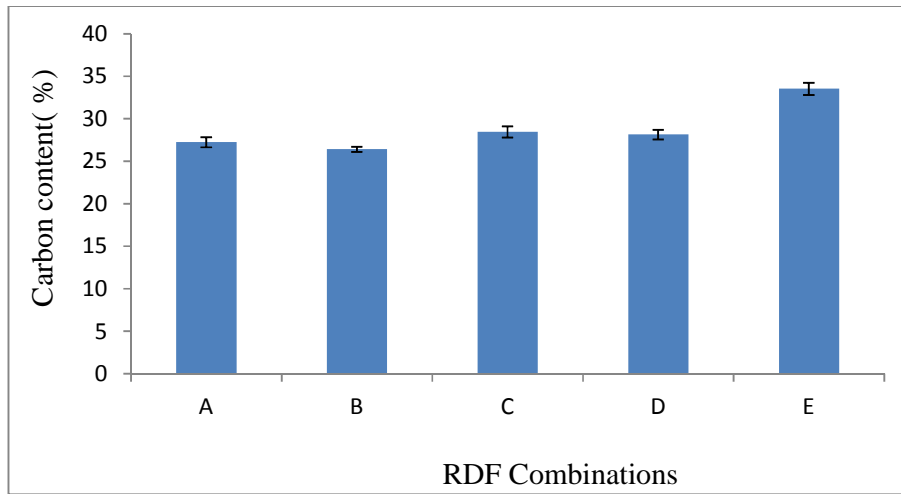


Fig. 6. Carbon content (%) in five RDF combinations of domestic sewage sludge sample
 A = Sewage sludge (50 g), rice husk (40 g) and oil (10 g), B = Sewage sludge (50 g), rice husk (40 g), oil (5 g) and polythene (5 g), C = Sewage sludge (50 g), saw dust (30 g), oil (10 g) and polythene (10 g), D = Sewage sludge (50 g), saw dust (30 g) and pet coke (20 g), E = Sewage sludge (60 g), pet coke (20 g) and oil (20 g)

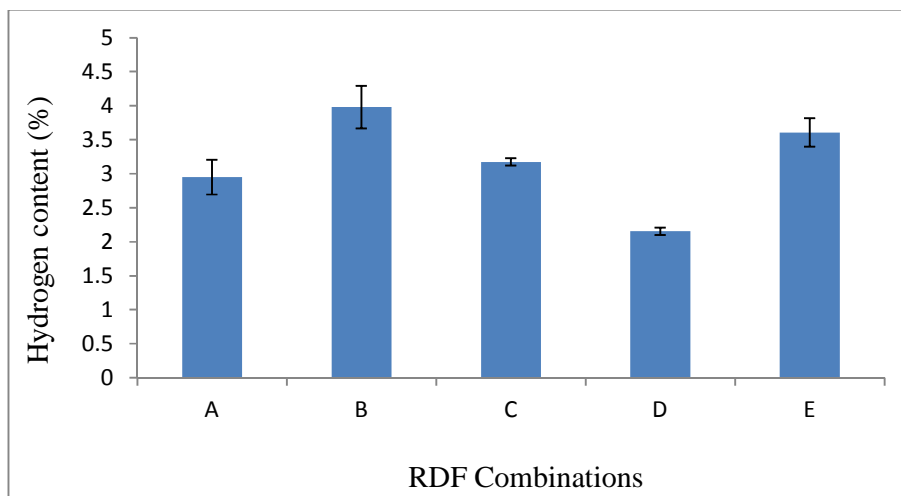


Fig. 7. Hydrogen content (%) in five RDF combinations of domestic sewage sludge sample
 A = Sewage sludge (50 g), rice husk (40 g) and oil (10 g), B = Sewage sludge (50 g), rice husk (40 g), oil (5 g) and polythene (5 g), C = Sewage sludge (50 g), saw dust (30 g), oil (10 g) and polythene (10 g), D = Sewage sludge (50 g), saw dust (30 g) and pet coke (20 g), E = Sewage sludge (60 g), pet coke (20 g) and oil (20 g)

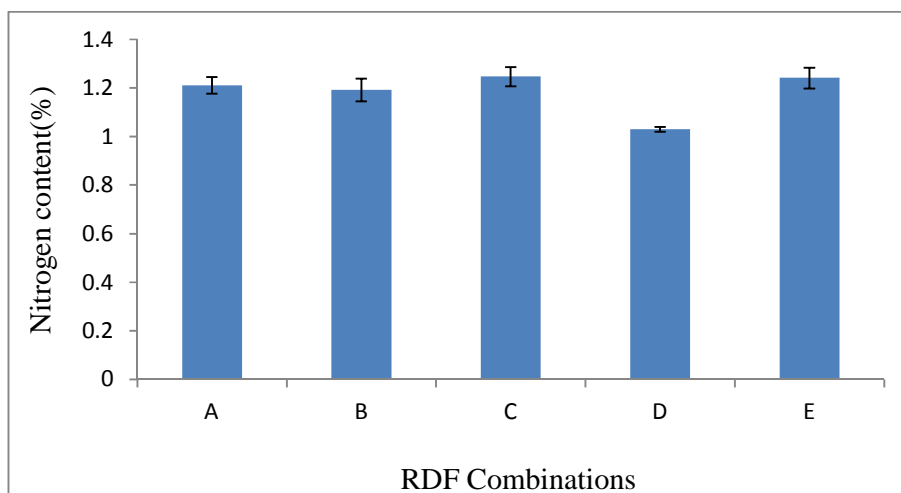


Fig. 8. Nitrogen content (%) in five RDF combinations of domestic sewage sludge sample
 A = Sewage sludge (50 g), rice husk (40 g) and oil (10 g), B = Sewage sludge (50 g), rice husk (40 g), oil (5 g) and polythene (5 g), C = Sewage sludge (50 g), saw dust (30 g), oil (10 g) and polythene (10 g), D = Sewage sludge (50 g), saw dust (30 g) and pet coke (20 g), E = Sewage sludge (60 g), pet coke (20 g) and oil (20 g)

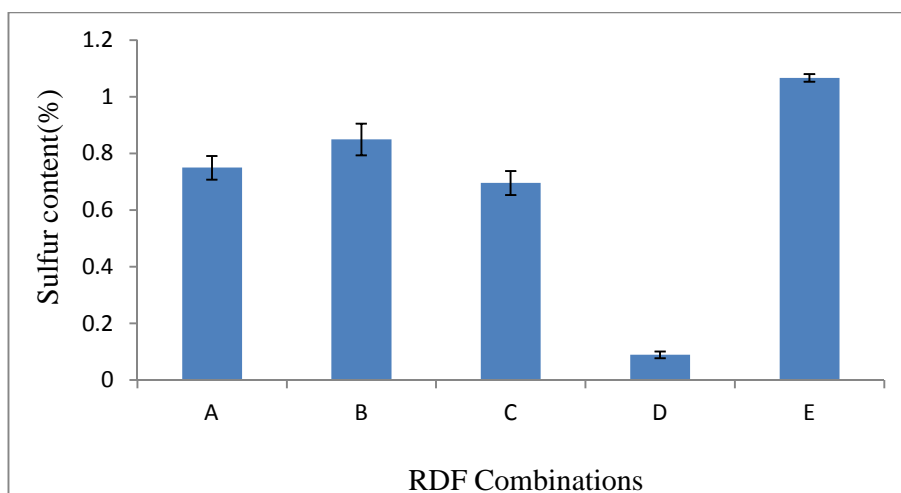


Fig. 9. Sulfur content (%) in five RDF combinations of domestic sewage sludge sample.
 A = Sewage sludge (50 g), rice husk (40 g) and oil (10 g), B = Sewage sludge (50 g), rice husk (40 g), oil (5 g) and polythene (5 g), C = Sewage sludge (50 g), saw dust (30 g), oil (10 g) and polythene (10 g), D = Sewage sludge (50 g), saw dust (30 g) and pet coke (20 g), E = Sewage sludge (60 g), pet coke (20 g) and oil (20 g)

4. CONCLUSION

Proximate and ultimate analysis of domestic sewage sludge were conducted by analyzing different parameters. These parameters included moisture content, volatile matter, Ash content, fix carbon content, gross calorific value (GCV). The largest GCV (6790 Btu/lb, 32.1±55.6) was obtained by RDF combination comprising of sewage sludge, saw dust, oil and polythene. This RDF combination was considered best with heating value equals to rice husk. It was concluded from this study that the risks of

environment can be reduced by using RDF combination for sewage sludge. It also serves as an alternate to energy resources.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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