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Enhancement of calorific value of municipal organics with suitable additives for RDF

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ABSTRACT

The increasing amount of municipal solid waste (MSW) in developing countries, especially in municipal area, currently is a severe problem and needs proper management. Source reduction and reuse are the most desirable solid waste management since they are the most effective way to reduce the quantity of waste and resource consumption, followed by recycling/composting. Combustion can reduce the quantity of waste being sent to landfill by 90% and hence saves landfill space. In this regard, RDF is one form of energy recovery from waste. Since MSW has low calorific value it is difficult to use raw MSW as a fuel. RDF presents several advantages as a fuel over raw MSW. The main objective of the present study was to produce RDF with high calorific value using biomaterials like coconut coir, saw dust, *Pongamia* seeds and ground nut shell. In the present study it was revealed that addition of biomaterials can enhance the calorific value of RDF. Among the four biomaterials used RDF prepared using MSW and the *Pongamia* seed showed higher calorific value of 4090 kcal/kg. Hence *Pongamia* seeds can be used in RDF preparation but in regard to the availability of the biomaterial saw dust and ground nut shell can form a more suitable biomaterial to increase the calorific value of MSW RDF.

KEYWORDS

Refuse derived fuel;
Biomaterials;
Calorific value;
Municipal solid waste management;
Pongamia seeds;
Coconut coir;
Sawdust.

INTRODUCTION

Municipal Solid Waste Management (MSWM) is a challenging problem in all the developing countries. A typical waste management system in India includes waste generation and storage, segregation, reuse, and recycling at the household level, primary waste collection and transport to a transfer station or community bin, street sweeping and cleaning of public places, management of the transfer station or community bin, secondary collection and transport to the waste disposal site and waste disposal in landfills[1].

With an increase in per capita generation of municipal solid waste along with population explosion, dumping of the MSW in open dumpsite will lead to land degradation along with release of many green house gases[2]. Moreover, as the waste generation increases the need for vacant land for dumping also becomes a challenge. Hence, conversion of municipal solid waste to value added products has become the focus of many developing countries. One of the focuses is combustion with energy recovery which can reduce the quantity of waste being sent to dumpsite and hence save land space for dumpsite. In this regard, conversion of MSW to energy blocks called refuse derived fuel can address the existing challenges in MSWM and also in energy crisis.

Energy can be recovered from MSW in the form of recovery of Biogas and utilizing its energy content and usage of MSW as fuel, either as-discarded basis or processed (Refuse derived fuel or RDF), for generation of steam through boilers. MSW has a very good calorific value which makes it a good source of energy[3]. MSW composition is varied from different sources, seasons and living behaviors. Raw MSW has high moisture content, low calorific value, wide range of particle size distribution and high ash content. These reasons make using raw MSW as fuel difficult and unattractive. Refuse derived fuel (RDF) is the component of MSW that has higher calorific value like paper, plastics and textile. RDF is combustible or, in other word, high calorific fraction recovered from MSW. RDF presents several advantages as a fuel over raw MSW. The main advantages are higher calorific value which also remains fairly constant, more uniformity of physical and chemical composition, ease of storage, handling and transportation, lower pollutant emissions and reduction of excess air requirement during combustion[4].

In developing countries like India, urban solid waste (SW) generation is increasing enormously and most of the MSW are disposed by land filling in low-lying areas, resulting in the generation of large quantities of green house gas methane, land degradation and water pollution. Other than serious environmental issue like land depletion, transportation of MSW into landfill area are also the major issues. Recent investigations on reclamation and hazard potential of the sites indicate the need for rehabilitation of the sites. Hence, a proper waste management system where the solid waste can be converted to value added product was implemented in many metropolitan cities in India. One such option is conversion of MSW into RDF. To the variability in the composition of MSW and presence of noncombustible materials will reduce the calorific value of MSW RDF. Hence, to increase the calorific value of RDF certain additives should be added along with MSW during RDF preparation. The present study was carried out to find out a suitable biomaterial which can enhance the calorific value of the RDF prepared from MSW.

EXPERIMENTAL

Collection and segregation of municipal solid waste

Municipal solid was collected from Zone 10 Adyar area of Chennai Corporation. The collected MSW was air dries and segregated to organic and inorganic materials like glass, plastic, other inert materials respectively. The organic part of the MSW was processed and used for the production RDF. MSW was also characterized for its physioc chemical properties like organic carbon content[5], total nitrogen[6], total phosphorus[7] and potassium[8].

Biomaterials for RDF preparation

RDF was prepared by mixing MSW with certain additives like waste biomaterials having high calorific value for increasing the quality of RDF. In this study waste biomaterials such as coconut coir, coconut shell, groundnut shell, sawdust and *Pongamia* seeds were used for making RDF blocks.

Processing of municipal solid waste and additive material

Municipal solid wastes were collected from Zone-13 Canal Bank Road, Adayar. The collected MSW were air dried (moisture content 20 - 25%) and were shredded to 0.5 to 1mm. Additive materials *Pongamia* seeds, groundnut shell, coconut coir, sawdust were collected and air dried. The air dried seeds were powdered to 0.5 to 1mm.

Preparation of RDF mixture

The air dried MSW and additive materials were mixed in the proportion of 7:3, 6:4, 5:5 (TABLE 1). The RDF mixture was filled in a cylindrical mould of size: height 6cm and diameter 7.5 cm. The filled cylindrical mould with RDF mixture was then subjected to compression at 300-350 Kg/cm^2 and at 1000 Kg/cm^2

Quality testing of RDF

The quality of the developed RDF was tested in terms of density, moisture content and compressive strength (by exposing to axial pressure) by using ton tensile tester and calorific value (Bomb Calorimeter). Ash content was also analyzed.

RESULTS AND DISCUSSION

Collection and segregation of municipal solid waste

Municipal solid waste was collected from Zone 13 Adyar area of Chennai Corporation. The collected MSW was segregated and was found to have plastics, paper, organic decomposable waste, cardboards, thermocoal and glass bottle, fabric waste, dry leaves and coconut leaves (TABLE 2).

TABLE 1 : Composition of RDF mixture

Preparation of RDF Mixture		MSW (kg)	Additive Material(Kg)
MSW+CC	7:3	150	45 (CC)
MSW+ GS	7:3	150	45 (GS)
MSW+ SD	7:3	150	75 (SD)
MSW+ PS	7:3	250	75 (PS)
MSW+CC	6:4	200	80 (CC)
MSW+ GS	6:4	200	80 (GS)
MSW+ SD	6:4	200	80 (SD)
MSW+ PS	6:4	185	78 (PS)
MSW+CC	5:5	250	75(CC)
MSW+ GS	5:5	150	45(GS)
MSW+ SD	5:5	150	45(SD)
MSW+ PS	5:5	150	45(PS)

TABLE 2 : Components of collected MSW

Parameters	Weight in Kilogram
Plastics	2.7
Paper	1.65
Kitchen & Vegetable waste (Organic decomposable waste)	16.25
Cardboards	0.65
Thermocoal & Glass Bottle	1.5
Fabric waste	1.4
Dry Leaves and Coconut Leaves	1.15
Total	30

Physicochemical characteristics of municipal solid waste

Physicochemical characteristics of the municipal solid waste are given in table 3Physicochemical characteristics of the municipal solid waste was in the usual reported range with a pH of the MSW was 7.2, moisture content 53%, organic carbon 24%, total nitrogen 1.2%,phosphorus was 137 mg/Kg and potassium was 688 mg/Kg.

Quality testing of RDF blocks

RDF blocks prepared using MSW and biomaterials (Figure 1) were tested qualitatively. The quality was assessed in terms of moisture content, density, compressive strength, calorific value and ash content.

Figure 1 : RDF Blocks

Moisture content and compressive strength of RDF blocks

Moisture content and tensile strength of the RDF blocks was represented in the Figure 2 & Figure 3. The moisture contents in various RDF mixtures were found in the range of 7.1% and 19.8%. In the present study the RDF with equal proportion of MSW and additive *Pongamia* seeds was able to withstand a higher compressive strength of 10.4 kgf/cm^2 with a moisture content of 7.1%. RDF blocks with high moisture content had a less compressive strength.

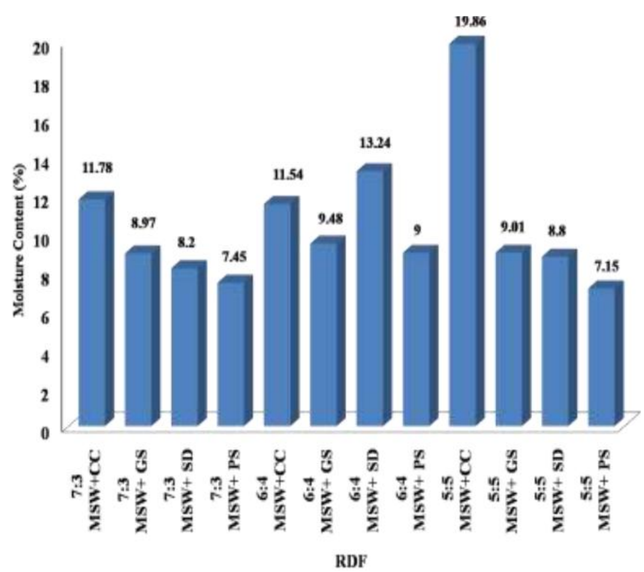

Figure 2 : Moisture content of RDF

The importance of reasonable moisture content in achieving stability of RDF with high compressive strength is clearly evident from this study. Moisture content is one of the important parameter which determines the quality of RDF. Berker (1997)[9] reported that moisture content of RDF is inversely related to calorific value. In this study also similar relation was observed. Moreover, when the moisture content is very high, the vaporization of surplus water tears the RDF to pieces[10]. Hence, maintaining an optimum moisture content which does not affect the quality of RDF is important. In the present study also the moisture content was maintained in the prescribed standard for RDF.

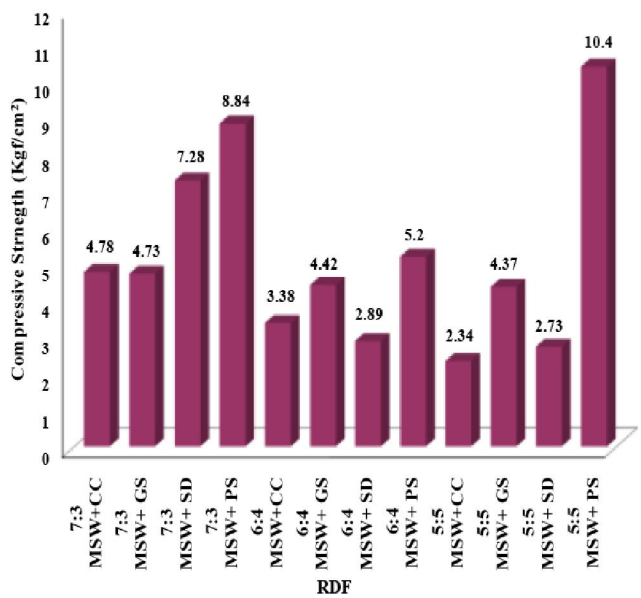

Figure 3 : Compressive strength of RDF calorific value of RDF blocks

Density of RDF block

Density of the RDF blocks is represented in the Figure 4. Density of the blocks varied from 0.4 to 0.7 g/cm^3. RDF block MSW/PS (5:5) had higher density of 0.7 g/cm^3. Kirzan, 2011[11] also reported the density of RDF prepared from MSW in the same range. Variation in the density of RDF blocks may be due to variation in density of the biomaterial used for the preparation of the RDF blocks. According to EU Standards, RDF have very good quality if density is from 1 to 14 kg/dm3. In the present study also the density of the RDF blocks was within the range.

Density is an important parameter. Higher the density, higher is the energy volume ratio. Hence, high-density products are desirable in terms of transportation, storage and handling[12]. The density of biowaste RDF depends on the density of the original biowaste, the briquetting pressure and to a certain extent, on the briquetting temperature and time.

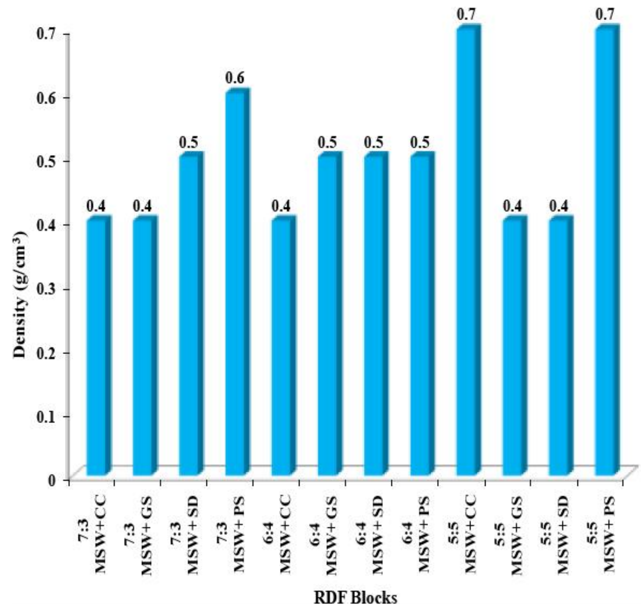

Figure 4 : Density of the RDF

Effect of compaction pressure on quality RDF

RDF quality was slightly changed when it was compacted at high pressure. An increase in the calorific value of RDF was observed in all the RDFs except the one with *Pongamia* seeds as the biomaterial. The calorific value ranged from 3564 to 4083 kcal/Kg (Figure 7). Normally a decrease in the ash content was observed in two RDFs with coconut coir, sawdust and ash content varied from 8% to 14% (Figure 7).

According to Kers, (2010)[13] quality of RDF depends on compaction pressure. In the present study also an increase in the compaction pressure had resulted in an increase in the calorific value and a decrease in ash content in general. Heterogenous nature of MSW might have resulted in slight decrease in the calorific value (PS) and ash content of RDF (PS and SD).

Calorific value of RDF blocks

Calorific value of the RDF blocks is represented in the Figure 5. It varied from 2858 kcal/kg to 4090 kcal/kg. Calorific value of RDF block MSW/PS (5:5) was maximum of 4090 kcal/kg followed by MSW/PS (6:4) of 4066 kcal/kg, MSW/PS (7:3) of 3830 kcal/kg, MSW/G.S (6:4) of 3858 kcal/kg, MSW/SD (5:5) of 3610 kcal/kg, MSW/SD (6:4) of 3376 kcal/kg, MSW/CC of 3331 kcal/kg, MSW/CC of 3090 kcal/kg, MSW/SD (7:3) of 2882 kcal/kg, MSW/GS of 2875 kcal/kg and MSW/CC of 2858 kcal/kg. Among the various biomaterials used, *Pongamia* seeds was found to be the best biomaterial giving a calorific value of 4090 kcal/kg which was followed by saw dust, coconut coir and groundnut shell. The calorific value was proportional to the density of RDF blocks. Denser RDF blocks showed higher calorific value and compressive strength in almost all the RDF blocks.

RDF blocks prepared using *Pongamia* seeds could meet the European standard in terms of calorific value (>3500 kcal/kg) in all the proportions. The RDF prepared using other materials such as sawdust, groundnut shell and coconut could also meet the European standard for calorific value in the equal proportion of MSW and biomaterial. In general, the biomaterial increased the calorific value of RDF prepared from MSW to a maximum of 1090 kcal/kg. Conversion of MSW to RDF with additives enhanced the calorific value by 3090 kcal/kg. Calorific value of MSW normally ranges from 800 to 1000 kcal/kg[14].

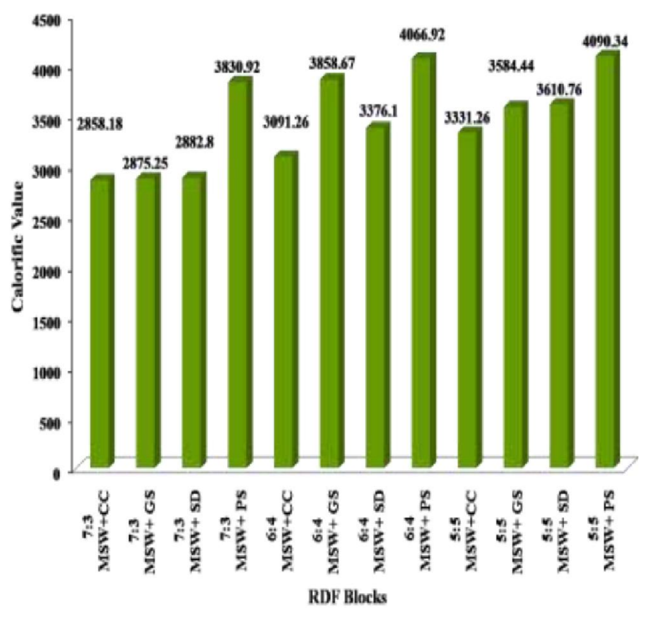

Figure 5 : Calorific value of RDF blocks

Pawan[15] reported a calorific value of 3500 kcal/Kg for RDF prepared from MSW. In the present study a maximum calorific value of 4090 kcal/Kg (MSW:PS-5:5) was obtained which is high in comparison with RDF prepared MSW without additives as reported above. Calorific value of RDF produced from MSW also depends on the composition of MSW. Hence, Calorific value of the RDF varies with places. Dinesh and Roomela, 2011[16] reported a higher calorific value of 5000 kcal/Kg for RDF prepared from MSW of Mauritius, which had a higher percentage (45% yard waste) waste with high calorific value. But the MSW used for the RDF preparation in this study had less percentage of yard waste (4%) which results in low calorific value RDF. A calorific value of 4090 kcal/Kg achieved in this study is mainly due to the biomaterials used as additives.

Ash content of RDF blocks

Ash content of the RDF blocks is represented in the Figure 6. Ash content in almost all the RDF blocks was within the range of 20%. It varied from 7.3% to 41.34%. RDF block MSW/SD (5:5) produced less ash content of 7.3%. followed by MSW/PS (5:5) of 8.3%, MSW/PS (7:3) of 12.95%, MSW/G.S (6:4) of 14.24 %, MSW/SD (6:4) of 3 14.4%, MSW/GS (5:5) of 17.62%, MSW/SD (7:3) of 18.34%, MSW/CC (5:5) of 19.67%, MSW/PS of 25.26%, MSW/CC (7:3) of 25.51%, MSW/CC of 27.59% and MSW/GS of 41.34%.

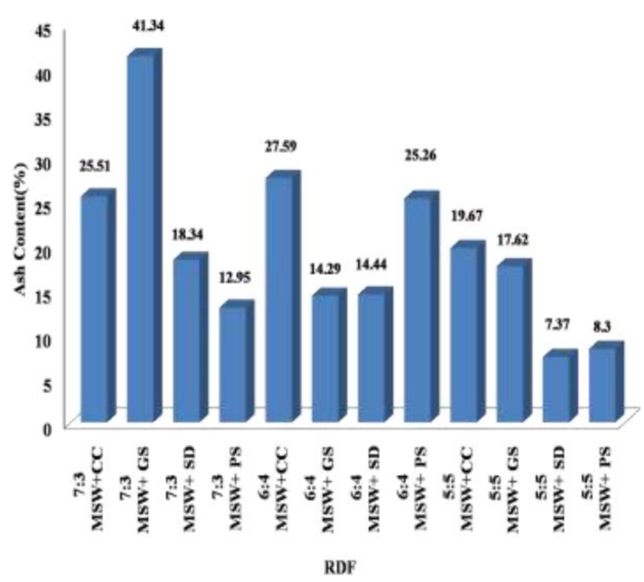

Figure 6 : Ash content of RDF blocks

High ash content in some of the RDF blocks may be due to the variation in the components of MSW used in the present study. As per the EU standards, the recommended ash content of the RDF should be less than 20. According Singh[17] and Grover[18] the ash content of the RDF should be less than 20%. In the present study also all the biomaterials used was having the ash content less than 20% So the chance of increase in the ash content due to additives which are used in the study is less. The heterogeneous nature of the MSW used in the study might have resulted in the increase in the ash content of some RDF mixture.

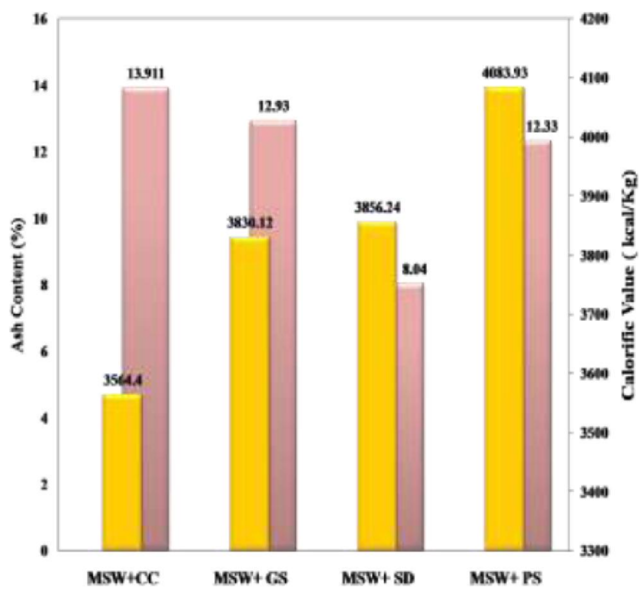

Figure 7 : Quality of RDF (5:5) at high compaction pressure

TABLE 4 : Energy yield by different RDF blocks

RDF	Energy Yield From MSW RDF Blocks with additives (kcal/Kg)	Net gain in energy without biomaterial comparing with MSW (kcal/Kg)	Net gain in energy with biomaterial comparing with MSW RDF (kcal/Kg)
MSW+CC7:3	2858	1858	NIL
MSW+GS7:3	2875	1875	NIL
MSW+SD7:3	2882	1882	NIL
MSW+PS7:3	3830	2830	830
MSW+CC6:4	3091	2091	91
MSW+GS6:4	3858	2858	858
MSW+SD6:4	3376	1276	376
MSW+PS6:4	4066	3066	1066
MSW+CC5:5	3331	2331	331
MSW+GS5:5	3584	2584	584
MSW+SD5:5	3610.7	2610	610
MSW+PS5:5	4090	3090	1090

Energy yield from the RDF

Comparing with the energy yield while burning MSW as such conversion of MSW into RDF blocks had an energy gain of 2000 Cal/g, and MSW RDF blocks had an energy gain of 3090 kcal/Kg. Hence *Pongamia* seeds can be used as an additive in preparation MSW RDF blocks (TABLE 4). Generally a net gain in energy of about 1000 kcal/Kg was obtained in the prepared RDF with biomaterials comparing with RDF without biomaterials. The study thus reveals that addition of biomaterials with high calorific value can enhance the net energy produced during the combustion and thus increase the quality of RDF.

CONCLUSION

Combustion with energy recovery is one of the effective ways to reduce the quantity of waste and resource consumption. RDF is one such form of energy recovery from waste by which 90% of waste being sent to land fill can be reduced. Low Calorific value of raw MSW limits its usage as a fuel due to the presence of inert material and other material with low caloric value. In this regard, conversion of MSW to RDF which is enriched with organic materials with no inert material will be effective. The present investigation was conducted to enhance the Calorific value of RDF by using biomaterial as additives. The study revealed that the biomaterial can enhance the Calorific value of RDF. Among, the four biomaterials used (Coconut coir, saw dust, ground nut shell and *Pongamia* seeds) *Pongamia* seeds showed a higher increase in Calorific value of RDF. Hence, *Pongamia* seeds can be used in RDF preparation but, in regard to the availability of biomaterial, coconut coir and saw dust can form a more suitable biomaterial for enhancing the calorific value of RDF.

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