Chapter 6

Bio-Drying of Biodegradable Waste for Use as Solid Fuel: A Sustainable Approach for Green Waste Management

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.77957

Abstract

The potential for thermal recovery of waste is increasingly gaining impetus among researchers and industries across the globe especially in many developed countries. However, in processing waste for energy recovery, the type and nature of input waste materials particularly those with high moisture content have a significant impact in determining the quality, environmental profile of the waste as well as the thermal properties of the final product. Bio-drying, as a waste to energy conversion technology, tends to reduce moisture content of waste while maintaining the energy content of the processed waste. The current study investigates the effect of input materials (biogenic and non-biogenic materials) on the energy and biogenic contents of waste material by bio-drying process. The results indicated a positive correlation between biogenic and energy contents of the input materials with some variations observed. Further analysis showed that, high proportion of food waste in the waste mix indicated a slight difference in biogenic and energy contents. Conversely, the same proportion of paper in the waste mix showed similar biogenic content with slight variation in energy content.

Keywords: bio-drying, biogenic content, energy content, waste, fuel

1. Introduction

Waste is unavoidable as long as human continues to live and engaged in economic activities. Most of the waste generated are either recycled or dumped in landfills, where it decomposes over a period of decades or even centuries. More than 50% of the energy content of municipal solid waste (MSW) originates from biogenic matter both in developed and developing countries. However, the disposal of the organic fraction of waste in landfill has dire consequences on the environment including the generation of methane, which can pose a threat or contribute to the greenhouse effect. Some landfills have sought to collect methane, which may be used for fuel; nonetheless, the conversion to methane takes place on long time scales, wastes much of the internal energy of the waste, and is rather ineffective in recovering much of the available energy content of the waste.

The search for sustainable solutions for biodegradable waste management represents a challenge not only for the waste management sector but also for the agricultural and industrial sectors. The enormity of this problem intertwined with the aforementioned issues associated with landfilling led to the introduction of the Landfill Directive of 1999 by the European Union (EU). According to the Landfill European Directive 1999/31/EC, member states are required to only landfill wastes that have been preliminary subjected to treatment or require a phased reduction in the amount of biodegradable waste disposed of to landfill [1]. Biodegradable waste refers to any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard [2]. Similarly, the Energy Information Administration (EIA) of the Environmental Protection Agency (EPA) of the United States defines biodegradable/biogenic waste as any waste produced by biological processes of living organisms. Based on the definition by the EU and inter alia [3, 4], it is clearly that the concept of biodegradable waste is wide and regards not only the production of food waste at household level; however, it includes all agricultural waste. The UNEP estimates that the decay of organic proportion of municipal solid waste contributes about 5% of global Greenhouse Gas (GHG) emissions annually [5]. In curbing this menace, a number of technologies for waste treatment such as composting (organic fertilizer), landfilling, anaerobic digestion and thermal methods have been developed [6]. However, the implementation of some of these techniques has been hindered due to the high implementation costs and other related environmental concerns.

By virtue of these concerns and in line with the new European Union Landfill Directive (1999/31/EC), this has motivated research into the development of technologies to reduce the impact associated with landfilling of waste [7–9]. Consequently, composting has been identified as an alternative method for transforming the organic fraction of waste into a potentially safe, stable and sanitary product that can be used as a soil amendment or an organic fertilizer [10]. Nonetheless, high operational cost, low quality of final product and long residence time (30-50 days) associated with composting have hindered wider application of this technology as inept for waste treatment [11, 12].

Energy from the biogenic part of waste is considered as one of a number of options that either have the greatest potential to help in a cost effective and sustainable way in waste management. Although, energy recovery may not be the first option according to the waste hierarchy, this option becomes paramount when the material is generated and considered as waste [13]. The EU directive categorized waste incineration either as a disposal or energy recovery technology depending on the energy efficiency of the incineration plant [14]. Thus, the operation and design of the aforementioned process highly require the knowledge of its thermal properties or the biogenic fraction of the waste. The carbon stored in waste originated

http://dx.doi.org/10.5772/intechopen.77957

from biological sources is refers to as biogenic carbon. However, biodegradable waste with high moisture content is often difficult to utilize the full energy potential of the waste due to its limited lower heating value (3–6.7 MJ/kg) [15].

The carbon content of any waste depends on the waste components. The relative proportions of biogenic and fossil carbon also depend upon the waste components, as do other important factors such as the calorific value or energy content. The calorific value of waste is how much (chemical) energy is stored in the waste per tonne that could potentially be converted into useful electrical or heat energy when burned. The term calorific value is synonymous to the heating value. The higher the calorific value, the more energy can potentially be captured from the waste. Different waste components have different individual calorific values i.e. food waste tends to have a relatively low value due to its high water content while plastic has much higher energy content. The variation of different proportions of these wastes will therefore significantly impact on the overall calorific value. This brings to forth the composition of waste as it affects many of the overall properties of the waste including both the calorific value and the biogenic content of the fuel.

According to literature, a number of pre-treatment technologies such as Mechanical Sorting Plant, Mechanical Biological Treatment (MBT) and Mechanical Heat Treatment (MHT) have been research and developed. These treatment techniques apply mechanical sorting and processing techniques to remove recyclates, moisture, and shred and/or homogenize the waste to create some kind of refuse derived fuel (RDF) or solid recovered fuel (SRF). However, in this study, bio-dried material obtained from bio-drying process was used to ascertain the fuel properties of the final product. Bio-drying technology, as a waste to energy conversion technology, aims at removing water by microbial activities, is regarded as a good option in reducing the moisture content of wet organic wastes [16]. The essence of this technology is to reduce the volume of waste sent to landfills which in turn will benefit short time storage and transportation, and provides alternative energy source as fuels for industries.

Whereas some technologies can cope with a broad range of calorific values and water content of the waste fuel, others require much more specific levels to operate efficiently. Additionally, the biogenic content of waste also affects the technologies that are suitable to deliver environmental benefits. Thus, having a good understanding of composition in terms of calorific value and biogenic content is essential for planning and designing energy from waste solution. Hence, the main objective of this research is to characterize bio-dried material produced by bio-drying from biodegradable/biogenic and non-biodegradable/non-biogenic materials based on biogenic and energy content of the waste material.

2. Bio-drying process

Bio-drying, a concept similar to composting, aims at removing or reducing water from biodegradable waste with high water content and increasing the treatability and subsequent utilization value of the bio-dried material. In other words, it is the utilization of the heat released during the decomposition of biodegradable waste in order to reduce the moisture content and partially stabilize the waste. The removal or reduction of moisture contents in bio-drying process involves evaporation of liquid water through aerobic decomposition of the organic material or reduction of water vapor via aeration [17–21]. This mechanism is accomplished by relying on microorganisms, both bacteria and fungi to biologically degrade the organic component in order to reduce the moisture content while maintaining the energy content [22]. Therefore, metabolic heat production, air convection and molecular diffusion of oxygen and water vapor are the main mechanisms involved in water removal from wet wastes under bio-drying [23].

The importance of bio-drying process of waste includes:

- Pre-treatment
- Short residence time
- Partial biostabilization
- Increasing energy content
- High quality solid fuel production
- Reduce volume of waste to be landfilled
- Reduce green house emissions

Compared to traditional composting process, the essential distinguish feature of bio-drying is the application of a higher ventilation rate to reduce moisture content by using the heat generated during the aerobic degradation process as well as forced aeration [24]. Also, the output from composting is stabilized organic material whereas that of bio-drying is partially stabilized. Bio-drying also has added advantage of pre-treating the waste at the lowest possible retention time to produce a high quality solid fuel. Furthermore, bio-drying process tends to increase the energy content of the bio-dried material by reducing the moisture content in the waste matrix and preserving most of the calorific value or energy content of the organic matter present through minimal biodegradation [25]. Besides these benefits, bio-drying process also renders the output material more suitable for short-term storage and lessens the transportation cost by reducing its weight via moisture loss and partially biostabilizing it. In contrast, composting is used to stabilize the biodegradable organic material of waste prior to landfill disposal, minimizing leachate and landfill gas generation. It is also used to produce humus-like compost that can beneficially and safely apply to land. The difference between composting and bio-drying also depends on the control parameters including temperature, oxygen content, air flow rate, and moisture content. In order to ensure high degradation performance for the former, the temperature, oxygen concentration, and moisture content should be kept within an optimal range whereas for the latter, the process should be managed to accelerate drying and to reduce organic matter degradation.

2.1. Factors affecting bio-drying process

2.1.1. Moisture content

Moisture content of the waste is considered as a single critical parameter for evaluating the efficiency of bio-drying process. The moisture content influences microbial activity and

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biodegradation of the organic component during bio-drying process. Despite the fact this technology is considered as a zero leachate approach, it is likely that a limited amount of free water may seep through the waste matrix and collected at the bottom of the bioreactor as leachate [11]. Bio-drying has mostly been studied for MSW (municipal solid waste) [24, 26–29], pulp and paper [23, 30, 31] and, garbage residues and sewage sludge [32–34] with 50–70% as the optimal initial moisture content range for bio-drying process [12, 28, 34]. The initial moisture content is important because microbial activity is impeded due to high initial moisture content favoring anaerobic conditions because water rather than air fills pore space limiting oxygen transport within the matrix, whereas low moisture content slows down the activity of the microorganisms resulting in reduce bio-drying performance. Conversely, if initial moisture content is low, microbial activity is slowed due to insufficient moisture which could results in reduced drying performance. It is suggested that, in order to improve the water content reduction and accelerated biodegradation of MSW with high water content, supplemented a hydrolytic stage prior to aerobic degradation and inoculated the biomass with the bio-drying products as leachate [29]. However, the concept of bio-drying has not been fully understood with regards to bio-drying of organic waste of high moisture content including food waste [11, 25], leaving a research gap to be filled.

Most organic wastes like dewatered sewage sludge, food waste and garden waste contain abundant water with a typical moisture content around 80% or higher, and this excessive moisture affects particle aggregation, causes packing and reduces void space, which all prevents efficient air movement throughout the matrix and limits aerobic decomposition [35, 36].

2.1.2. Air-flow rate

According to literature, it has been established that air-flow rate is the main operational parameter used both in laboratory and commercial applications for process control in bio-drying process. The air-flow rate has a direct influence on the matrix temperature and drying efficiency. The effect of air-flow rate on bio-drying has recently been studied extensively by several researchers. On the one hand, a higher air flow rate leads to higher heat loss, resulting in a decrease in the matrix temperature, which is unfavorable for water evaporation. On the other hand, an increase in the airflow rate will also increase the amount of water carried, improving the water loss. Adani et al. [26] and Roy [37] established that high air-flow rate contributes to effective and fast drying, and high calorific value. In another study, the simultaneous effect of initial moisture content and airflow rate on bio-drying of sewage sludge was investigated, and the results revealed that initial moisture content has a stronger effect on bio-drying, affecting the temperature and improving the water removal [38].

Skourides et al. [39] investigated the agitated bio-drying of the organic fraction of municipal solid and the results showed maximum drying rate achieved for the highest aeration rates used (120 m^3/h), leading to lower final moisture content levels (20% w/w from an initial 40% w/w) with a short retention time of less than 7 days. In a similar study to investigate the effect of air-flow on the bio-drying of gardening wastes, it was found that higher air-flow rate corresponds to greater weight loss (40–57% weight loss) and leachate production at low air-flow. Even though higher air-flow rate causes higher water removal, it was further stressed that it is imperative to identify the optimal air-flow rate for bio-drying, since excessively high air-flow rate may induces physical drying [40]. It is shown that forced aeration during sewage sludge bio-drying controlled the matrix temperature and improved evaporation, establishing it as a vital parameter influencing water loss [18]. In effect, an increase in the air-flow rate increases the amount of water carried, improving the water loss and an output with high calorific value. Likewise, low air-flow rates result in decomposition without significant moisture removal.

2.1.3. Temperature

It is well established that the supplied of air during bio-drying in one direction contributes to the appearance of temperature gradients, resulting in a lack of homogeneity in the moisture and energy content of the final product [26, 41]. However, it was suggested in another study that daily inversion of airflow in bio-drying by means of reactors eliminates marked temperature differences and leads to a homogeneous final product [41]. An increase in air flow rate at the inlet had positive contribution to moisture loss from the waste but had no effect on temperature and calorific values [25].

Frei et al. [23] and Navaee-Ardeh et al. [31] indicated that high temperatures (>55°C) during bio-drying process enhance the conversion of moisture to vapor and also facilitate the vapor pressure of the air-flow passing through the matrix to carry more moisture out. Accordingly, the biodegradation potential of a bulking agent (BA) would significantly influence the bio-drying process by the biogenerated heat. Additionally, the physical structure and moisture content of the materials are influenced by the decay of bulking agents. A study to investigate the effect of BA particle and controlled temperature on sludge bio-drying concluded that small-particle-sized bulking agent coupled with high matrix temperature was more beneficial for volatile solid degradation whereas large-particle-sized bulking agent resulted in poor biodegradation [42].

2.1.4. Bulking agents

Additionally, the use of bulking agent (BA) plays a crucial role in bio-drying process. The use of BA adjusts the initial moisture content and facilitates air movement due to the increase in voids ratio. It effects on bio-drying has been demonstrated by some authors. A number of different materials as bulking agents have been used by different researches including bark to bio-dry sewage sludge [23], and sawdust and/or straw [43, 44]. Yang et al. [34] revealed that air-dried sludge possesses a more suitable biodegradation potential than shredded rubber and sawdust when used as BA due to its porous nature and high water holding capacity. In short, the smaller or finer the particles, the stronger the water holding capacity of the substrate. Moreover, BA is important for regulating the matrix porosity and enabling air flow to carry away the water vapor passing through the matrix. For effective bio-drying, it is important to consider the physical structure as well as biodegradability of the bulking agent. In another study, rice straw of different sizes as BA was used in sludge bio-drying and it was reported that small-particle size BA reduced the water content by 0.3% more compared to the large particle size BA [42]. It is revealed that straw has substantial biodegradation potential in bio-drying process while sawdust has poor capacity to be degraded [44]. In order to improve the efficiency of bio-drying, it is important to consider the physical structure as well as the biodegradability when selecting a material as BA. Colomer-Mendoza et al. [40] observed that adding 15% of BA

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Substrate	Residence time (days)	Weight loss (%)	Moisture loss (%)	Reference
Household waste + plant materials (straw, grass, branches, −shrubs)	10	na	50%	[25]
Agricultural harvest + gardening waste	12–30	<50%	na	[40]
Garden waste	20	<40–57%	<40–60%	[46]
MSW	14	41%	na	[24]
Sewage sludge + bio-dried + sawdust	20	<20%	>35.5%	[18]
MSW	13	49.16	32.65%	[27]
Food waste + pruning waste	7	36.7–56.8%	10.32–48.9%	[47]
Sludge + MSW + harvest waste	8-9	na	na	[26]

na, not available.

Table 1. Summary of bio-drying of different waste materials.

to gardening waste resulted in 25% moisture reduction. It is proposed that BA of small particle size is preferred due to its adequate porosity and internal homogeneous porous size distribution within the matrix. These features enhance effective waste absorption. However, it should be pointed out that, the use of small particle size BA can cause compaction during bio-drying which can have adverse effect on moisture removal [45]. **Table 1** shows a summary of waste materials used in bio-drying process and their effect on weight and moisture loss.

3. Materials and method

Different waste compositions obtained from bio-drying process (i.e. bio-dried material) consisting of biogenic and non-biogenic materials were used to assess the biogenic carbon and energy content of the bio-dried materials. The biogenic materials included food waste, paper and pruning waste, while plastic (light density polyethylene – LDPE) was considered as a non-biogenic material. These materials were varied at different proportions by weight in the bio-drying experiment and their impact on biogenic and calorific value was determined. **Tables 2** and **3** show the composition and physico-chemical properties of the different waste materials. The proportion of the waste components varied in the range of 30–90, 20–80, 5–50 and 30–60% for food waste, paper, plastic and pruning waste respectively. To further test more extreme conditions, two additional (T10 and T11) experiments were conducted with only biogenic and non-biogenic materials as the waste materials, respectively. Prior to mixing, the materials were separately shredded into 15×35, 2×14, 5×10 and 15 mm in diameter for food waste, paper, plastic and pruning waste respectively. The bio-drying experiments were carried out for a period of 7 days. A constant and uninterrupted air-flow rate (15 $m^3 h^{-1}$) was used in all the trials using a whirlpool pump connected to the bottom of the reactor with an air-flow meter. After the bio-drying process, bio-dried samples were analyzed for the moisture, biogenic and energy content. The moisture content of the substrate was analyzed following the

Mixture	Composition (%)	
	Biogenic mix	Non-biogenic mix
T1	85	15
T2	65	35
T3	50	50
T4	80	20
T5	75	25
T6	90	10
T7	80	20
T8	94	6
T9	84	16
T10	100	—
T11	—	100

Table 2. Composition of waste.

Parameter	Unit	Food waste	Paper	Plastic	Pruning waste
Moisture content	% (a.r)	91.48	5.40	0.94	8.43
Ash content	% (a.r)	25.33	18.64	2.05	6.36
Biogenic content	% (a.r)	72.73	72.34	—	92.31
Non-biogenic content	% (a.r)	1.94	9.02	96.44	1.33
Bulk density	kg/m^3 (a.r)	464.18	100.46	346.50	204.14
Calorific value	MJ/kg (a.r)	0.11	12.51	44.65	16.01

Table 3. Physico-chemical properties of raw material.

ASTM–D 3173 standard (105°C) using moisture analyzer (Precisa, XM 50), whereas the heat value of the bio-dried material was determined using IKA C-7000 model calorimeter (IKA Laboratory Equipment, Werke Staufen, Germany), in accordance with EN 15400 standard. It is worth mentioning that, due to the heterogeneous nature of the waste, the weighted average method was employed in determining the initial moisture content of the waste matrix, since it was impossible to get a typical sample from the heterogonous mixture of the waste, a similar procedure employed by Shuqing et al. [48]. Elemental analysis was analyzed with Thermo Scientific Flash 2000 Elemental Analyzer (Thermo Fisher Scientific Inc., Bremen, Germany).

Three different methods are employed for the determination of biogenic content of solid recovered fuels/bio-dried materials according to the technical specifications CEN/TS 15440:2006 (CEN, 2006). These include Selective Dissolution Method (SDM), Manual Sorting Method (MSM) and ^{14}C Method. In the present study, the biogenic and non-biogenic content of the waste matrix in different proportions was analyzed by SDM. The latter and former were determined based on Eqs. (1) and (2). The basic principle of this method is that the biogenic in bio-dried material selectively dissolves and oxidizes in H_2SO_4/H_2O_2, while the non-biogenic (fossil material) and the inert material remains in the residue. Furthermore, the relationship between the biogenic and energy content of the bio-dried were established.

$$X_B = \left[1 - \left\{\frac{m_{residue} - m_{residue-ash}}{m_S} + \frac{A_S}{100}\right\}\right] \times 100 \tag{1}$$

$$X_{NB} = 100 - X_B - A_S \tag{2}$$

where X_B = Biogenic content (%); X_{NB} = Non-biogenic content (%); $m_{residue}$ = Mass of residue (g); $m_{residue\text{-}ash}$ = Mass of residue and ash (g); A_S = Ash content of sample (%); m_S = Mass of dry sample (g).

4. Results and discussion

It is an established fact that combustible non-biogenic materials are characterized by higher heat content per unit weight than combustible biogenic materials. Consequently, the ratio of biogenic to non-biogenic material proportion can have a considerable effect on the heat content of a waste material intended for combustion purpose [40, 49]. **Figure 1** shows the relationship between moisture content and calorific value. The moisture content is a key parameter, as it affects both the biogenic carbon content and the effective heating value of the combustible waste. The moisture content of the bio-dried material varied between 8.59 and 50.93%, whereas that of the extreme conditions was 91.48 and 0.94% for biogenic (food waste) and non-biogenic materials, respectively (**Table 3**). It should be pointed out that the two extreme conditions were just raw materials without been subjected to bio-drying process. It can be seen that as the share of biogenic waste in the waste matrix gradually decrease, a corresponding trend in moisture content could be expected. Additionally, depending on the amount of food waste in the waste mix of the biogenic material, a decrease or increase in moisture content could be envisaged since the food waste contributes the highest initial moisture content to the biogenic waste mix.

The results revealed a positive correlation between moisture content and calorific value (R^2 = 0.85). As indicated earlier, the amount of biogenic waste had a significant impact on the former and latter. A discrepancy was observed in T3 and T5 in terms of moisture content and calorific value. Even though T3 had the lowest moisture content, T5 had the highest calorific value. The possibly reason was that the difference in food waste in both trials versus the other waste types in the biogenic mix was high enough to induce significant difference in the observed levels of calorific value, with approximately same non-biogenic mix. This suggest that, depending on the amount of food waste in the biogenic mix, the moisture content and calorific value of the bio-dried material could be significantly affected, regardless of the amount of non-biogenic waste in the waste matrix.

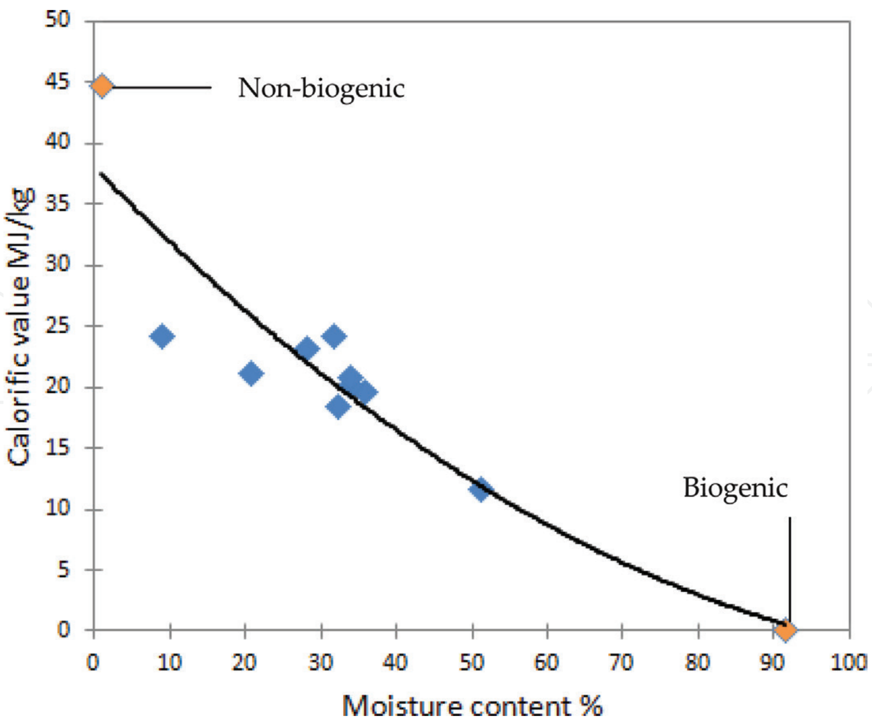

Figure 1. Calorific value as a function of moisture content of bio-dried materials.

However, a relatively slight deviation was observed in the trend for certain composition of waste particularly in instances where there is an absence of pruning waste and slightly decrease in food waste. This is probably attributed to the pruning waste having the highest proportion of biogenic carbon content of all the waste types, thus having a proportionally greater impact on biogenic carbon content of the waste matrix relative to its calorific value.

As shown in **Table 2**, a range of waste composition was developed to examine their impact on biogenic content and calorific value. The elemental analysis of carbon, hydrogen, oxygen, nitrogen and sulfur are presented in **Table 4**. The results indicated that carbon and oxygen were the most dominated elements in the raw materials, with biodegradable waste such as food waste, pruning waste and paper composed at 32.55, 37.14 and 64.72% of the total weight, respectively. The non-biogenic material (plastic) had the highest carbon content of 68.55%. Nitrogen was measured in high contents in food waste with paper as the lowest. The hydrogen content of the raw materials ranged from 5.17% to 12.90%, with plastic having the highest hydrogen content. Food

Parameter	Food waste	Paper	Plastic	Pruning waste
Carbon	32.55	64.72	68.55	37.14
Nitrogen	2.97	0.32	0.99	1.10
Hydrogen	5.17	5.49	12.90	8.09
Oxygen	33.85	10.79	15.46	47.30
Sulfur	0.07	0.04	0.05	0.01

Table 4. Elemental composition of raw materials.

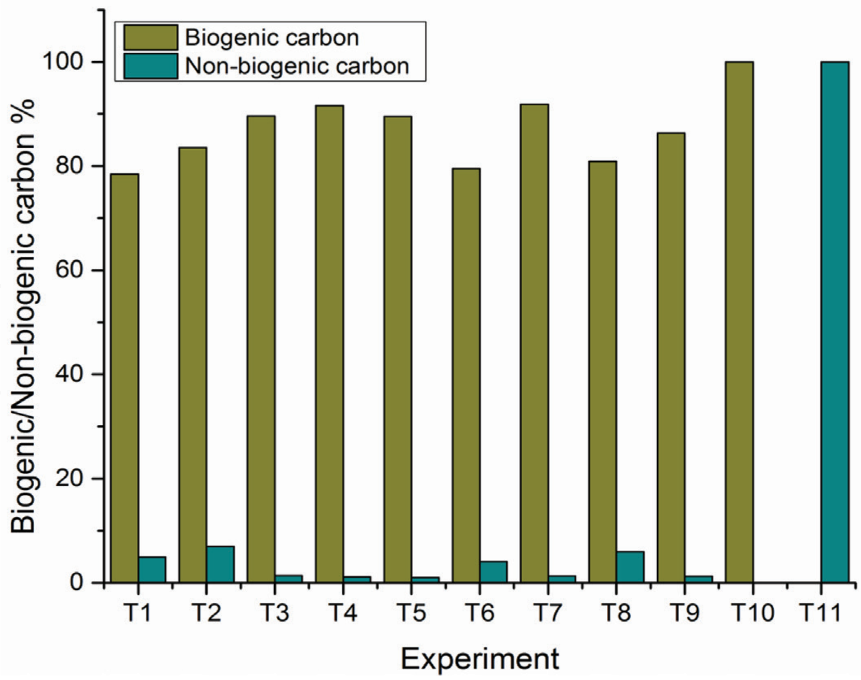

Figure 2. Biogenic and non-biogenic carbon content of bio-dried materials.

waste had the highest sulfur content relative to the other raw materials. Oxygen was dominant in pruning and food waste with lowest oxygen content recorded in paper (10.79%), indicating the presence of inorganic or low oxygen content organic molecules in papers. The results of the elemental analysis obtained in this study are consistent with those reported by Komilis et al. [49].

Figure 3 shows the relationship between calorific value and biogenic carbon content of the different composition of waste. The different compositions resulted in a wide range of biogenic carbon content and calorific value. The non-biogenic carbon content in the waste matrix ranged between 1 and 7%, with T2 having the highest non-biogenic content (**Figure 2**). This was attributed to the low contribution of paper and pruning waste to the waste matrix of the biogenic mix, which were the major contributors to the biogenic carbon content of the bio-dried materials. On the other hand, T7 had the highest biogenic carbon content of 91.84%. The reason was associated with the amount of food waste relative to the other the biogenic waste materials in the biogenic mix. Similarly, two extremes conditions of biogenic (T10) and non-biogenic (T110 waste were considered. It is evident that the proportion of the different waste components in the waste matrix had significant impact on the biogenic content and the calorific value as well. It can be seen that the former reduces as the amount of biogenic source in the waste mix reduces whiles the latter increases as the calorific value of non-biogenic source due to the high moisture content. The results revealed a very highly positive correlation between biogenic content and calorific value (R^2 = 0.87). It should be pointed out that the amount of food waste as a biogenic material in the waste mix impacted on the calorific value of the bio-dried materials due to its high initial moisture content. Additionally, it should also be emphasized that pruning waste and paper were the major contributors to the biogenic content of the bio-dried materials. For instance, it is clearly that T1 contained higher proportion of pruning waste and paper as compared to bio-dried material obtained in T9. The biogenic content herein refers to the non-fossil based carbon content. It is suggested that any material with a calorific value that

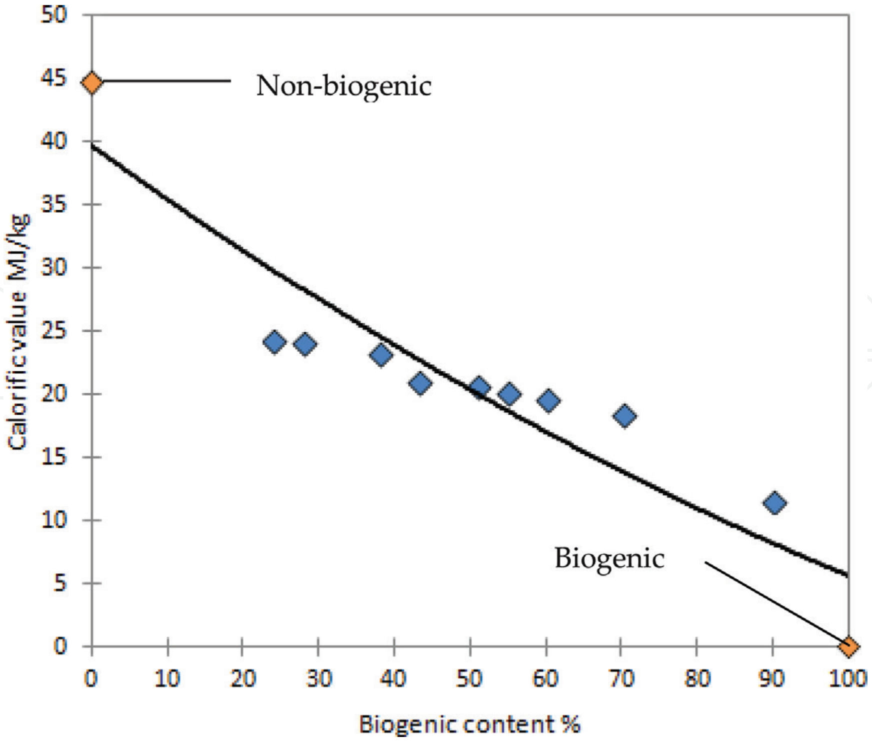

Figure 3. Calorific value as a function of biogenic carbon content of bio-dried materials.

exceeds the range of 1–6 MJ/kg could be considered for combustion purpose [50]. Accordingly, waste-to-energy technology can be applied to recover energy from the bio-dried material.

5. Conclusions

Biogenic materials have the potential to serve as an alternative energy source. In this study, bio-dried materials obtained from biogenic and non-biogenic sources by bio-drying process were analyzed to assess its potential for energy recovery. Bio-dried material obtained from different composition of waste materials were assessed with regards to biogenic carbon and energy content. The composition of biogenic source in the waste matrix was found to significantly impact on the nature of the bio-dried material produced due to its high moisture content, particularly food waste. Moreover, high amount of biogenic source in the waste mix corresponded to high moisture content and lower calorific value. Food waste significantly impacted on the biogenic carbon content of the bio-dried material, whereas paper and pruning waste were identified as the positive main contributors to the biogenic carbon content of the bio-dried material obtained. It was further revealed that, notwithstanding the amount of non-biogenic source in the waste matrix, the proportion of food waste could have an effect on the moisture content and calorific value of the final product. Based on the energy content of the bio-dried material obtained, the final product could be used as an energy source in combustion process which could lead to reduction in over reliance on fossil fuel. Additionally, optimization of the waste materials would enhance the biogenic and energy content of the bio-dried material. Bio-dried material obtained from waste would therefore be a better sustainable environmental solution than landfill provided the waste being used has the right biogenic content and a plant is efficient at turning that waste into useable energy. Finally, this technology will help mitigate environmental pollution from the disposal of biodegradable waste.

Acknowledgements

The authors would like to thank the Scientific and Research Unit (BAP) of University of Kocaeli for the financial support.

Conflict of interest

The authors declare no conflict of interest.

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