Evaluation of Biodegradable Waste Quality by Drying for Exploring the Possibilities of a Potential Renewable Energy Source in Yangon City, Myanmar

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Abstract—Biodegradable waste to fuel becomes a potential renewable energy source to gain environmental and economic benefits in the world. To explore the opportunities of a potential renewable energy source from the biodegradable wastes in Yangon city, the study collected 12 different waste samples from the four districts of Yangon and evaluated the composition of the collected wastes. Then, the study assessed their moisture contents by Halogen Moisture Analyzer and dried 23 prepared waste samples (100 grams, 300 grams and 500 grams in mass) by Binder Laboratory Heating and Drying Oven at 105°C. The study also analyzed the effect of moisture reduction in volume reduction, weight reduction and heating value increase of the biodegradable waste samples after drying. The results showed that about 50% of moisture reduction could contribute approximately 25% of volume reduction, 40% of weight reduction and 200% of heating value increase (initially approximately from 3 Mega joules per kilogram to 8 Mega joules per kilogram). Therefore, if drying could be conducted with a renewable source such as solar energy and a waste heat source from industrial sectors, the dried biodegradable wastes could be beneficial in the energy and environment sector of Yangon city. The objective of the study was to estimate the biodegradable waste quality of Yangon city by drying for a future potential renewable energy source.

Keywords: Biodegradable Wastes, Drying, Waste Quality, Energy Source, Biomass.

1. Introduction

Nowadays, waste generation in developing countries is increasing along with growing population, increasing per capita waste generation and economy growth. According to the World Bank 2012 Report [1], the amount of municipal solid wastes (MSW) in the world cities might reach 2.2 billion tonnes per year by 2025 and waste generation rates might double over the next two decades in developing countries. Currently, waste management is a serious problem in low-income and middle-income South East Asian countries due to the environmental pollution from the landfills [2] and open dumpsites. Therefore, the environmental pollution becomes an alerted global issue due to the large amount of wastes discharged by various sectors [3] including municipal sectors. The situation of MSW treatment and management is also correlated with the climate change impact [4]. Meanwhile, the climate change impact largely affects MSW treatment and management again. As an example, flooding during the rainy season and seasonal tropical storms are major problems to manage MSW efficiently [4, 5]. Therefore, the consequences of doing little or even nothing to address waste management can be very costly to society and to the economy overall [6].

With booming socio-economic development and improving educational level, the need for a green clean-living environment is increasing [3]. Nowadays, fossil fuels are depleting, and their consumptions raise the environmental problems, hence, the integration and cooperation of traditional and renewable energy sources are potentially meeting the need for sustainable development and sustainable environmental system [7-11]. In addition, energy infrastructure stands out as one of the key smart city components, especially to improve a city's goals of sustainability and provide a cleaner environment for its citizens [12]. Therefore, to meet the need for sustainable development by solving the issues related to dependency on fossil fuel, utilize renewable energy sources for energy and protect the environmental pollution, biomass sources including wastes become future potential renewable energy sources in the world. Biomass is available in large number and require small to no cost to obtain [13]. The energy content in waste can be utilized either by bio-logical conversion of organic matter to biogas or to biofuel like bio-ethanol, by combustion of waste, or by producing a solid fuel for usage in power plants or cement kilns [14]. The biogas or biofuel production from organic waste is also an economic process already in small and big plants [14]. It is observed that the heating values of the MSW in most developing countries could range approximately from 5 to 12 Mega joules per kilogram [15-18], depending on the composition of MSW.

Figure 1 shows the comparison of waste composition among the world countries during the year 2015. It was observed that municipal solid waste in low-income and lower-middle income countries was mainly composed of organic waste, with over 50% in 2015. Figure 2 presents the comparison of waste composition in Asian developing countries as per the World Bank 2012 report and International Monetary Fund (IMF) 2012 report. Due to the high organic fraction, high moisture content and low heating values in their MSW, thermal waste treatment such as waste incineration is not suitable in these countries [19, 20]. In addition, due to the costly waste-to-energy technologies and insufficient budget for waste management, the developing countries commonly use open dumping and landfilling for their major waste disposal method [1, 21] despite several severe impacts on the environment and public health [6, 22-24]. Further, annual increasing waste generation rates in some developing countries could potentially become a major issue about the insufficiency of the land use for open dumping and landfilling. Therefore, the most immediate energy, environmental and public health issues related to MSW are needed to be efficiently handled for the sustainable waste management in the developing countries.

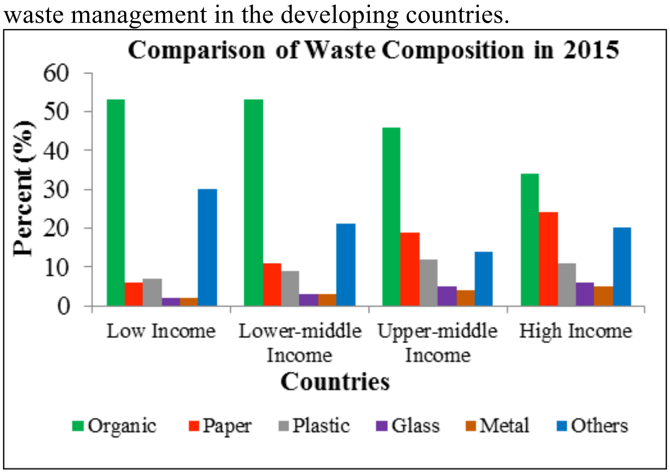

Fig. 1. Comparison of Waste Composition around the World in 2015 [6]

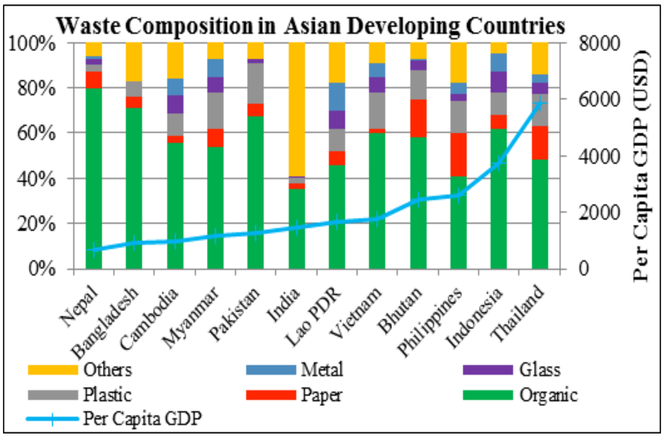

Fig. 2. Comparison of Waste Composition in Asian Developing Countries [1, 25]

2. Background of the Study

Yangon city is the largest and most densely populated city in Myanmar, with a population of over 5 million residents. It is located in the lower Myanmar and covers an area of about 598.75 square kilometers. The average population density is over 8,000 people per square kilometer [26] and the annual population growth rate accounts for approximately 2.6% [27]. There are 33 townships in 4 districts of Yangon. The four districts are divided into Eastern district, Western district, Southern district and Northern district. The total daily waste generation in 2015 amounted to 1981 tonnes per day, with 0.4 kg per capita per day, potentially trending around 3500 tonnes per day in 2025 [23]. Yangon city has four cleaning departments located in four districts to manage the solid wastes effectively (Figure 3).

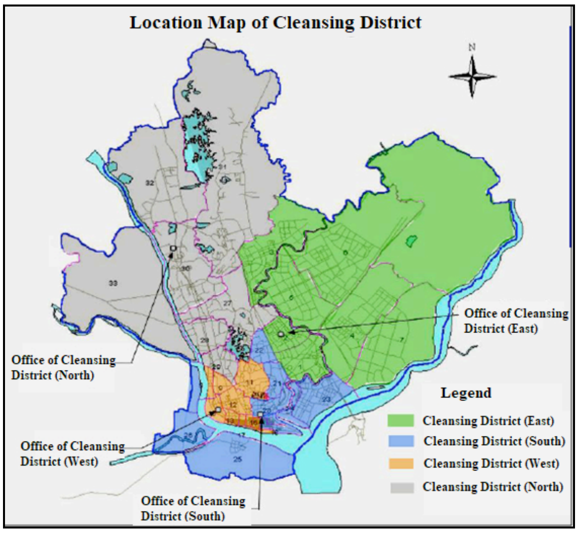

Fig. 3. Location of Cleansing Districts of Yangon City [28]

In Yangon city, waste is separately collected in two major groups—wet waste and dry waste [29, 30]. Wet waste is regarded as organic waste which includes food wastes and garden wastes while dry waste includes plastic, paper, glass, metal and others [23]. Collection efficiency has been recorded as 92% and only 5% of the generated wastes are reused and recycled [31]. One incineration plant for energy recovery has been built in Yangon city to generate 700kW of electrical power from 60 tonnes of wastes daily [32]. All the other collected wastes are transported and disposed at the open dumpsites.

Currently, there have been several possible methods for managing biodegradable wastes to gain a fuel source for waste to energy and a resource for agricultural purposes [33]. These methods include composting, anaerobic digestion, bio-drying and bio-stabilization and landfilling with gas-recovery systems [33]. Moreover, waste incineration for waste-to-energy of biodegradable wastes might also be a possibility if the waste quality could be improved for a high heating value and low moisture content of the wastes [33]. Thus, drying of biodegradable wastes might become a possible method to improve the waste quality for waste incineration by reducing moisture content inside the wastes and to reduce the weight and volume of the bulky wastes for transportation. Further, biodegradable waste to fuel could be a potential to solve several issues related to the energy, environment and public health.

In Yangon city, drying of biodegradable wastes for a future renewable energy source appears to be more suitable due to the following reasons: (a) separation work has been done between wet wastes and dry wastes in Yangon city; the separated wet waste could be easily dried for a potential fuel source while dry wastes could be potentially used for recyclable materials (b) Yangon has approximately 17 Mega joules per square meter of daily solar radiation [34], which is good enough for drying of biodegradable wastes. Drying can also be conducted by waste heat from international combustion engines, gas power plants, etc. However, there are some drawbacks such as the costly designs of the dryer and land use for drying and storage. These drawbacks could be overcome if local governments would cooperate with local technological universities and research institutions for the sustainable waste management solutions.

Nowadays, various dryers such as bio-drying equipment, solar dryer, green house dryer and thermal dryers are being used for the pretreatment of biodegradable wastes to improve the waste quality. Most studies [35-42] evaluated the waste quality by different drying methods and studied a relationship between moisture reduction and heating value increases of solid wastes. In this paper, the study evaluated the quality of the biodegradable wastes of Yangon city by drying and highlighted a relationship between moisture reduction and weight reduction, moisture reduction and volume reduction, and moisture reduction and heating value increase of the biodegradable wastes of Yangon city. The study aimed at estimating the biodegradable waste quality by drying in order to explore the possibilities of a future potential renewable energy source from biodegradable wastes of Yangon city.

3. Material and Methods

3.1 Collection of the Samples

Yangon region has 33 townships. They are categorized into four districts – North, South, East and West. Waste samples were collected from the twelve collection points in the twelve selected townships in the four districts of Yangon on January 28, 2017. The selected townships in the four districts were described as follows: (a) Eastern district: North Dagon, South Dagon and South Okkalapa; (b) Southern district: Yinkin, Tamwe and Thaketa; (c) Western district: Pabetan, Latha and Lanmadaw; (d) Northern district: Kamayut, Hlaing and Mayangone. Samples covered the different kinds of social activities and different geographic locations. A digital scale (Model: SF-400A, Capacity: 10kg) and a plastic basket (Capacity: 450 mm length x 300 mm width x 150 mm height) were used for measuring the samples. The collected waste was sorted according to the different items such as food waste, plastic, paper, etc., to determine waste composition. The survey data was partly described in the author's previous paper [43]. Exclusively from the previous paper, the collected data is presented in Table 1.

Table 1 Solid Waste Composition of 12 Samples in 4 Districts of Yangon

District	Sample No.	Food Waste	Plastics	Paper	Green Leaves	Textile	Glass	Metal	Leather and Rubber	Other	Mixed Wastes
		Avg. Mass (kg)	Avg. Mass (kg)	Avg. Mass (kg)	Avg. Mass (kg)	Avg. Mass (kg)	Avg. Mass *(kg)	Avg. Mass (kg)	Avg. Mass (kg)	Avg. Mass (kg)	Avg. Bulk Density (kg/L)
Eastern	(1,2,3)	0.118	0.048	0.022	0.027	0.001	0.000	0.001	0.000	0.085	0.302
Western	(4,5,6)	0.060	0.019	0.019	0.030	0.001	0.000	0.011	0.038	0.010	0.188
Southern	(7,8,9)	0.139	0.041	0.012	0.010	0.001	0.012	0.001	0.000	0.001	0.217
Northern	(10,11,12)	0.106	0.042	0.018	0.005	0.000	0.019	0.013	0.000	0.038	0.241
Yangon	Average	0.106	0.038	0.018	0.018	0.001	0.008	0.007	0.010	0.034	0.240

**Avg. = Average*

Figure 4 shows the waste composition in four districts of Yangon city. The average composition of the waste samples in Yangon was found to be 44% food wastes, 16% plastic wastes, 8% paper, 8% green leaves, 5% leather and rubber, 4% glass, 3% metal, 2% textile and 1% glue and 9% others. Waste composition may change with time of the day, season, public consumption pattern, living standards and economic development.

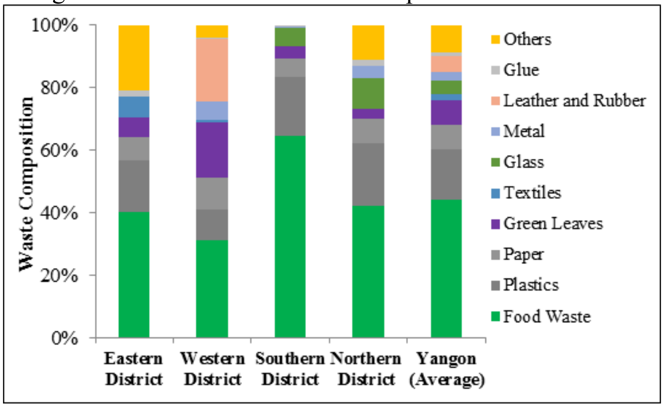

Fig. 4. Waste Composition in 4 Districts of Yangon

In Yangon, wet wastes and dry wastes are daily collected separately. Wet wastes in Yangon account for organic wastes, being composted of food wastes and green leaves while dry wastes include plastics, papers, glass, metals and others. Out of them, wet wastes (majorly, food wastes and green leaves) were considered for drying for optimization of the biodegradable waste quality in this study. The biodegradable samples were prepared to amount to 100 grams (g), 300 g and 500 g for each district and Yangon, as per their composition (based on 100%) as described in Figure 4 above.

3.2 Methods

(a) Assessment of moisture contents of the samples

The moisture contents of the samples were assessed by Mettler Toledo HG63 Halogen Moisture Analyzer (Type: HG63; SNR: 1125170452; SW: 2.01). Standard drying was used to dry the samples, with switch off criterion of one milligram per 50 seconds and drying temperature of 105 °C.

(b) Assessment of moisture reduction, weight reduction, volume reduction and heating value increase of the samples

The samples were dried by Binder Laboratory Heating and Drying Oven (BINDER: FED 400; Multifunctional heating oven with forced convection and timer; Interior dimensions (1000mm Width × 800mm Height × 500mm Depth)) at drying temperature of 105°C in a drying period of 5 hours. The moisture reduction, weight reduction and volume reduction of the samples were recorded with different time. The initial lower heating values [44] and final lower heating values of the samples were approximately estimated based on the following equations:

[illegible] (1)

[illegible] (2)

Where $LHV_{initial}$ and LHV_{final} are the initial lower heating values and final lower heating values of the samples (Megajoules per kilogram (MJ per kg)) respectively; D_{avg} is the average dry mass of the biodegradable wastes (kg) (assumed as 0.2 kg, based on the fact that the total weight and moisture content of the biodegradable wastes account for 1 kg and 80% respectively [44]); W_i is the initial weight of a waste component i in the total initial weight of waste composition in mass (kg); W_j is the final weight of a waste component j in the total final waste composition in mass (kg); MC_i and MC_j are the initial and final moisture content of the waste component i and j (%); E_i is the energy content of a waste component i (MJ per kg); n is the total number of the wastes in the total waste composition. The energy contents of food wastes and green leaves were assumed to be 3.489 and 2.326 MJ per kg respectively [44]. The weight of the biodegardable waste samples are approximately calculated based on 1 kg and the average energy content of the biodegradable waste samples was considered as 3 MJ per kg for ease of estimation.

(c) Statistical analysis

Statistical data analysis was performed to evaluate the effect of moisture reduction in weight reduction, volume reduction and heating value increase for four districts and Yangon city. By using the statistical data analysis, a relationship of moisture reduction, weight reduction, volume reduction and heating value increase was also illustrated.

Table 2 presents the biodegradable waste samples of four districts and Yangon for evaluating their quality by drying.

Table 2 The Properties of Biodegradable Waste Samples

District/ City	Sample No.	Properties					
		Food Wastes (g)	Green Leaves/ Garden Wastes (g)	Total Biodegradable Wastes (g)	Density (kg/L)	Moisture (%)	LHV (MJ/kg)
Eastern District	1	86	14	100	0.250	82.00	2.70
	2	86	14	100	0.250	68.84	4.67
	3	86	14	100	0.330	68.38	4.74
	4	258	42	300	0.323	79.55	3.07
	5	430	70	500	0.200	85.00	2.25
Western District	1	63	37	100	0.200	62.00	5.70
	2	63	37	100	0.250	81.20	2.82
	3	63	37	100	0.200	72.64	4.10
	4	190	110	300	0.178	81.59	2.76
	5	316	184	500	0.156	76.00	3.60
Southern District	1	94	6	100	0.330	84.00	2.40
	2	94	6	100	0.330	76.51	3.52
	3	94	6	100	0.330	84.13	2.38
	4	283	17	300	0.457	81.00	2.85
	5	471	29	500	0.294	75.00	3.75
Northern District	1	93	7	100	0.250	82.00	2.70
	2	93	7	100	0.250	72.86	4.07
	3	93	7	100	0.286	78.74	3.19
	4	280	20	300	0.439	82.00	2.70
	5	467	33	500	0.286	81.00	2.85
Yangon (Average)	1	84	16	100	0.250	78.00	3.30
	2	253	47	300	0.303	81.00	2.85
	3	421	79	500	0.219	79.00	3.15
Total Number of Samples	23						

4. Results and Discussion

4.1 Comparison of the weight and moisture content of the different biodegradable waste samples during the drying process

Figure 5 illustrates a comparison of the weight of the different biodegradable waste samples from 4 districts and Yangon during the drying process at 105 °C. It was observed that the initial weight of 100-gram waste samples in Yangon was reduced to 23 grams as the total final dry weight after a drying period of 5 hours. Meanwhile, 300-gram and 500-gram waste samples were reduced in average to approximately 70 and 130 grams, respectively.

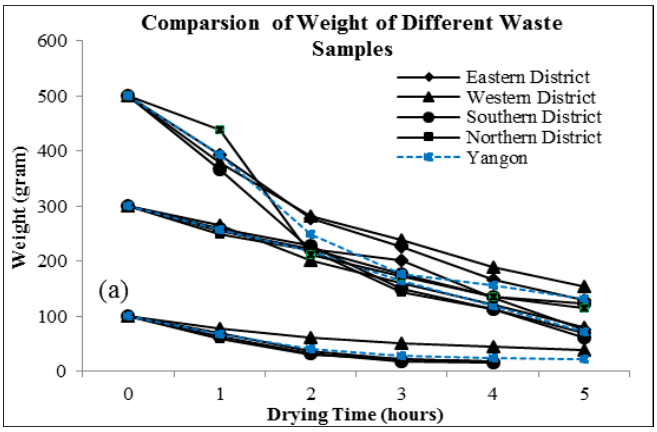

Fig. 5. Comparison of the Weight of (a) 100-gram waste samples (b) 300-gram waste samples and (c) 500-gram waste samples in 4 districts and Yangon at 105°C during a drying period of 5 hours

Figure 6 presents the comparison of the moisture content of the different waste samples in 4 districts and Yangon during the drying process at 105°C. It was observed that the drying rates could vary depending on the amount and thickness of the waste samples. Therefore, by using a convective drying oven (Han Baek HB- 502L) at the drying temperature of 100°C, Nzioka et al. [45] gained approximately 40% of moisture reduction of 100-gram mixed waste sample in 30 minutes. In addition to the weight of the samples, the sizes and thickness of the samples, air flow rates, air flow directions, drying temperature, turning effects of waste samples and bulking agents would also affect the drying rates [33, 37, 40, 42, 46]. Table 3 shows the results of biodegradable waste samples from four districts and Yangon city at 105 °C during a drying period of 5 hours.

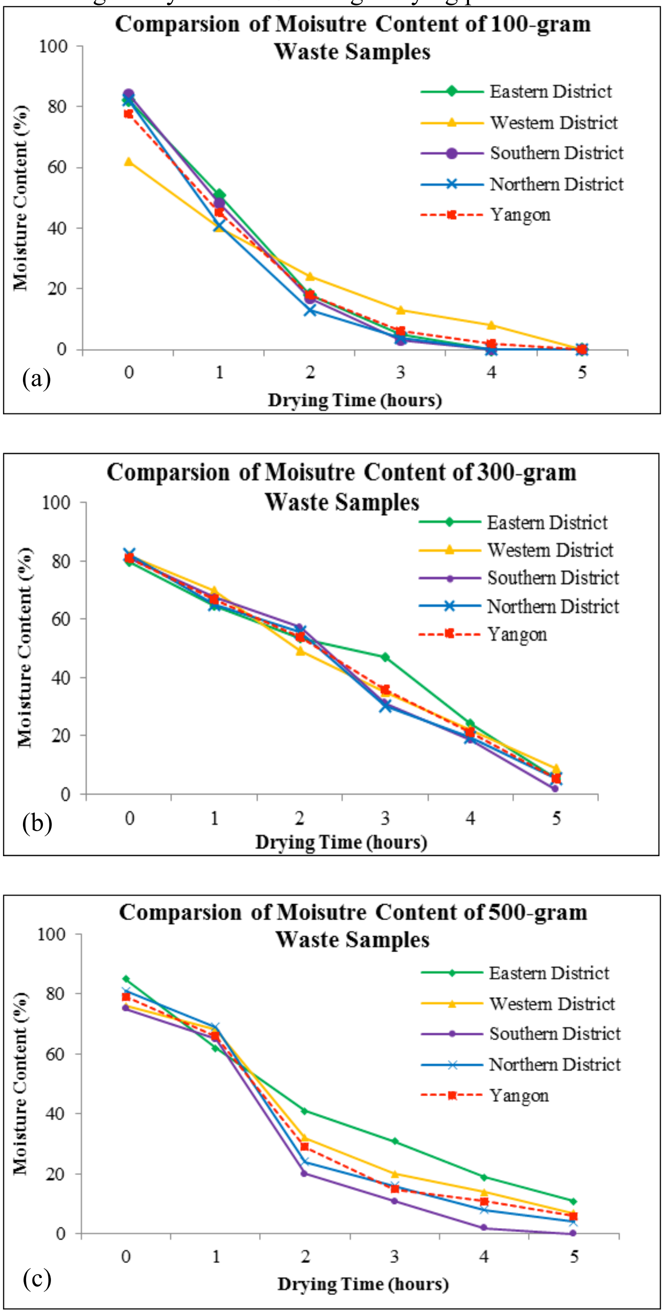

Fig.6. Comparison of moisture content of (a) 100-gram waste samples (b) 300-gram waste samples and (c) 500-gram waste samples in 4 districts and Yangon at 105°C during a drying period of 5 hours .

Table 3 Results of biodegradable waste samples before and after drying at 105 °C in 5 hours

District/ City	Sample No.	Biodegradable Waste Properties							
		Initial Mass (g)	Final Mass (g)	Initial Volume (mL)	Final Volume (mL)	Initial Moisture (%)	Final Moisture (%)	Initial LHV (MJ/kg)	Final LHV (MJ/kg)
Eastern District	1	100	18	400	200	82.00	0	2.70	15.00
	2	100	37	400	250	68.84	5.84	4.67	14.12
	3	100	32	300	200	68.38	0.00	4.74	15.00
	4	300	77	930	450	79.55	5.22	3.07	14.22
	5	500	129	2500	1500	85.00	11.00	2.25	13.35
Western District	1	100	38	500	400	62.00	0.00	5.70	15.00
	2	100	28	400	350	81.20	9.20	2.82	13.62
	3	100	37	500	400	72.64	9.64	4.10	13.55
	4	300	81	1686	1060	81.59	8.59	2.76	13.71
	5	500	155	3200	2020	76.00	7.00	3.60	13.95
Southern District	1	100	16	300	200	84.00	0.00	2.40	15.00
	2	100	30	300	250	76.51	6.51	3.52	14.02
	3	100	29	300	250	84.13	13.13	2.38	13.03
	4	300	62	657	400	81.00	1.67	2.85	14.75
	5	500	124	1700	980	75.00	0.00	3.75	15.00
Northern District	1	100	18	400	225	82.00	0.00	2.70	15.00
	2	100	39	400	250	72.86	11.86	4.07	13.22
	3	100	25	350	200	78.74	3.74	3.19	14.44
	4	300	70	684	450	82.00	5.33	2.70	14.20
	5	500	115	1750	1000	81.00	4.00	2.85	14.40
Yangon (Average)	1	100	23	400	200	78.00	0.00	3.30	15.00
	2	300	72	990	590	81.00	5.20	2.85	14.22
	3	500	131	2288	1375	79.00	6.00	3.15	14.10
Total Number of the Samples	23								

4.2 A relationship between the variables related to the moisture reduction of the Biodegradable Wastes in Yangon City

Statistical data analysis was performed on the variables related to moisture reduction of the biodegradable waste samples. To examine the strength and direction of linear relationship between the variables, Pearson correlation was calculated for each pair of the variables. Pearson correlation coefficient can range in value from -1 to 1. Absolute value of -1 or 1 indicates perfect linear relationship, while values close to 0 indicate no linear relationship between the variables. The significance of correlation coefficient was determined by comparison of the p-value to significance level 0.05. Since the p-value was below the significance level of 0.05, correlations were observed to be significant in the following pairs of variables: r = 0.99134 for moisture reduction and weight reduction; r = 0.88524 for moisture reduction and volume reduction; r = 0.92798 for moisture reduction and heating value increase. A relationship between moisture reduction and weight reduction, moisture reduction and volume reduction, and moisture reduction and heating value increase of the biodegradable waste samples is shown in Figure 7 (a), Figure 7 (b) and Figure 7 (c) respectively.

In Figure 7 (a), Figure 7 (b) and Figure 7 (c), it was observed that moisture reduction significantly affected weight reduction, volume reduction and heating value increase of the biodegradable waste samples in Yangon city. As a result, about 50% of moisture reduction from the total initial weight of the biodegradable wastes could provide approximately 40% of weight reduction from the total initial weight, 25% of volume reduction from the total initial volume and 200% of heating value increase from the total initial heating values of the biodegradable wastes respectively. Regarding the attainable different percentages of moisture reduction of the biodegradable wastes by drying, much or less improvement of the biodegradable waste quality could be improved.

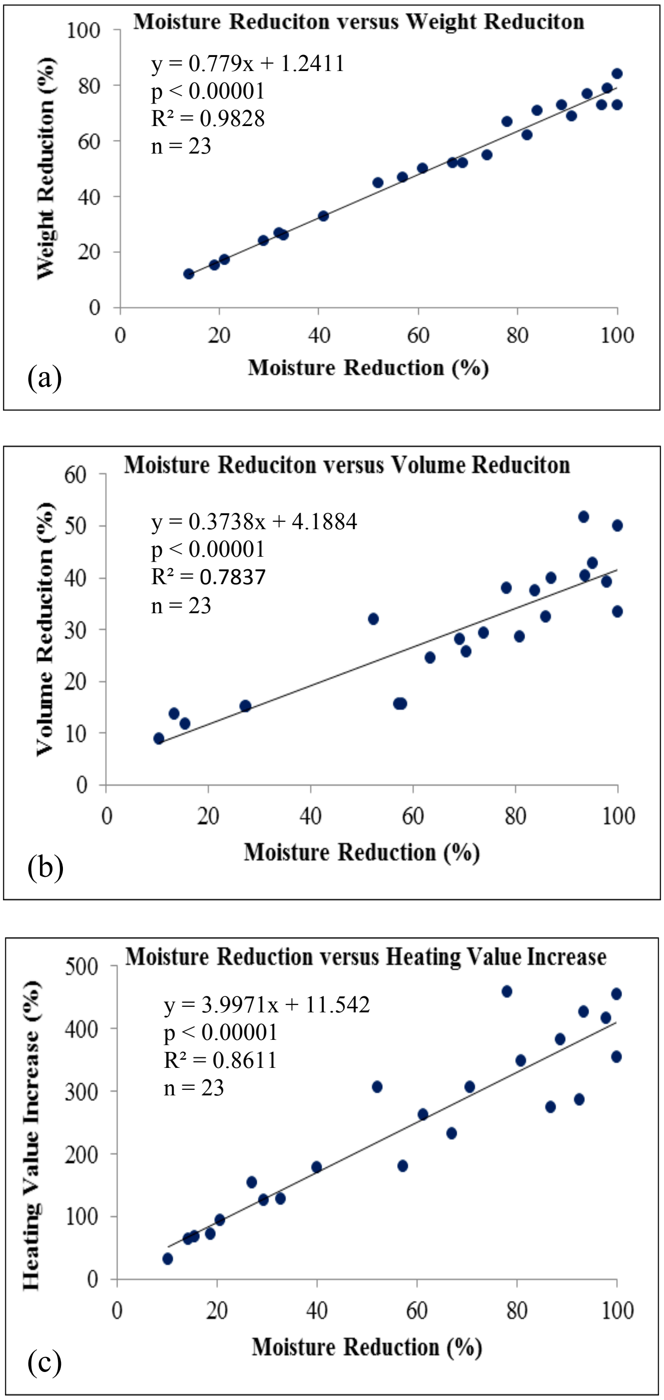

Fig. 7. Effect of (a) moisture reduction in weight reduction (b) moisture reduction in volume reduction (c) moisture reduction in heating value increase for Yangon city.

4.3 A relationship of moisture reduction, weight reduction, volume reduction and heating value increase of the biodegradable wastes in Yangon city

Figure 8 illustrates a relationship of moisture reduction, weight reduction, volume reduction and heating value increase of the biodegradable wastes in Yangon city.

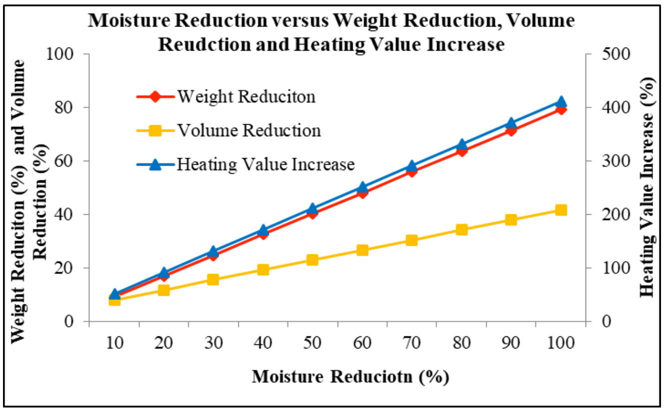

Fig. 8. A Relationship of Moisture Reduction, Weight Reduction, Volume Reduction and Heating Value Increase of the Biodegradable Wastes in Yangon city.

It was observed that 100% of moisture reduction from the total initial weight of biodegradable waste samples could largely affect the weight of the biodegradable wastes, with over 75 % of weight reduction. Meanwhile, it could also affect the volume of the biodegradable wastes, with around 45 % of volume reduction. The reduction of the weight and volume of the biodegradable wastes could benefit waste transportation sector for waste disposal at the final disposal sites such as waste-to-energy plants and landfills. It was worth notetaking that about 50% and 100% of moisture reduction from the total initial weight of the biodegradable wastes could contribute the comparatively higher heating values of the waste samples, with over 200% and 400% of heating value increase respectively. In other words, a biodegradable wastes sample with 2.5 MJ per kg of initial heating values and 82% of initial moisture content could yield approximately 8.85 and 15 MJ per kg of the final heating values respectively after 50% and 100% of moisture reduction by drying. As stated by the scholars [44], if the energy content of the waste is higher than 2.5 MJ per kg, waste incineration could be applicable. But, additional fuel supply for complete combustion might be needed depending on the lower or higher energy content of the wastes. In fact, the higher energy content and lower moisture content of the wastes could yield the higher efficiency of waste incineration plants for energy recovery. It could, then, be more efficient for combustion of wastes to have a waste fuel with over 10 MJ per kg of energy content. It would be acheived if the percentage of initial moisture content of the biodegradable wastes could be reduced to more than 50%. As a result, after improving their quality up to over 50% of moisture reduction and 10 MJ per kg of heating values by drying, there could be a possibility of a potential renewable energy source from biodegradable wastes in Yangon city. This status could also probably apply to the other cities of Myanmar and other Asian developing countries if the similar conditions such as separation of wet waste and dry waste and the waste quality improvement by drying could be implemented.

5. Conclusion

The study evaluated the biodegradable waste quality by drying for a future potential renewable energy source and waste heat source from internal combustion engines, gas power plants, etc. in Yangon city. The study collected and dried the different samples at a drying temperature of 105°C in 5 hours. The results showed that about 50% and 100% of moisture reduction could contribute 200% and 400% of heating value increase, respectively. Hence, the moisture reduction from the total initial weight of the biodegradable wastes by drying could be beneficial in waste combustion for energy recovery, leading the waste to a potential renewable energy source. Besides, the reduction of the volume and weight of the biodegradable wastes along with moisture reduction could also benefit waste transportation and safer disposal at landfills. Therefore, there could be a potential of renewable energy source from the biodegradable wastes for the sustainable energy system in the future of Yangon and other cities of Myanmar.

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