Potential of organic waste from Caringin Central Market as raw material for biogas and compost

E S Butar-Butar1*, Mutiara2, E A Priantoro1, T Sembiring1

1 Research Unit for Clean Technology, Indonesian Institute of Sciences (LIPI), Komplek LIPI Bandung, Jalan Sangkuriang, Gedung 50, Bandung 40135, Indonesia
2 Department of Chemistry, Faculty of Mathematics and Natural Sciences, Indonesian University of Education, Bandung, Indonesia

*E-mail: erni004@lipi.go.id

Abstract. Caringin Central Market is a traditional market in Bandung which is managed by the private party. This market produces approximately 84 tons of waste per day. The waste management system used is the 3P system (Pengumpulan, Pengangkutan, dan Pembuangan) including Collection, Transport, and Disposal of waste. The operational cost for this system is relatively high, which is IDR 55,440,000 per day. Therefore a study to investigate the potential utilization of organic waste from Caringin Central Market as raw material for biogas and compost is necessarily needed to be conducted. The research method used for this study is a field survey to collect primary and secondary data. The methodology is based on the National Standard of Indonesia (SNI 19-3964-1995) for waste sampling to study the waste characteristics and generation. This study is conducted in a temporary disposal site in Caringin Central Market. The results showed that the utilization of organic waste from the Caringin Central Market as raw material could potentially produce 6,272 m³ of biogas and 4.2 tons of mature compost.

Keywords: Caringin Central Market; biogas production; mature compost; organic waste

1. Introduction

According to SNI 19-2454-2002 [1], garbage is solid waste consisting of organic and inorganic materials that should be well managed in order to avoid the harmful effects to the environment and to protect development investment. Based on the chemical content, garbage is divided into organic waste and inorganic waste. Organic waste is biodegradable materials that come from either plants or animals leftover. Organic waste can be decomposed by microorganisms over time and may also be referred to as wet waste. Meanwhile, inorganic waste, or also known as non-biodegradable waste, are chemical substances of mineral origin. Inorganic waste is also including waste material such as sand, salt, iron, calcium, and other mineral materials that are only slightly affected by the action of organisms.

Population growth, lifestyle changes, consumption pattern changes have altered the waste volume and waste characteristics or composition. Lack of effective and efficient methods in solid waste management can endanger environmental health and can potentially extend beyond the geographical boundaries of cities [2].

One of the biggest waste producers is the traditional or central market, which mainly produces organic waste such as vegetables and fruit in large quantities. One of the traditional markets that
gained the local government attention due to its waste problems is Pasar Induk Caringin (Caringin Central Market), Bandung. Caringin Central Market is one of the largest markets in Bandung with an area of 11 hectares and a total of 2,100 traders. The types of goods sold are vegetables, fruits, fish, cosmetics, clothing, plastics, and grocery stores [3]. To solve the waste problem in Caringin Central Market effectively, it is important to know the total waste generated, composition, and characteristics of waste produced.

The importance of knowing wastes composition and characteristics is related to the potential use of those wastes. As convenient and environmentally friendly ways to utilize the wastes are anaerobic digestion to produce biogas and composting. Abundant vegetable and fruit waste have great potential as raw material for biogas and compost. Biogas is an alternative energy source that is growing rapidly in the decade. This biogas technology intends to produce methane from vegetable and fruit waste by anaerobic fermentation processes [4]. Scientifically, biogas is an easily generated gas produced from organic wastes by the presence of anaerobic bacteria. Only good organic material and also liquid waste are suitable for simple biogas systems. When organic waste decays, methane (CH₄) and carbon dioxide (CO₂) will be produced as the main gases in biogas [5]. Furthermore, only CH₄ will be used as fuel. Other than that, the production of biogas and compost from vegetables and fruits also has economic value. Therefore it is necessary to study the composition and characteristics of waste in Caringin Central Market to know the potency of biogas and compost that can be produced.

2. Method
The data were collected from waste sampling in the Caringin Central Market and the composition and characteristics of wastes were determined in the laboratory. Meanwhile, the waste generation entering the temporary waste collection point (TPS) of Caringin Central Market for 24 hours was obtained from secondary data. Sampling was carried out for one day by randomly picking up the waste and around 113.9 kg of waste was obtained.

Determination of the composition of waste is done by sorting the wastes that have been put into an open tank. Waste sorting is done by separating the types of organic and inorganic waste, then the percentage of composition of organic and inorganic waste is obtained.

The chemical composition or characteristics of waste were determined based on the moisture content, ash, and total solid using the Gravimetric method. C-Organic was determined by the difference of total solid to the ash content, and N-Total levels were obtained by using the Kjehdahl method.

3. Results and Discussions

3.1. Waste generation and composition
Based on the measurements of domestic and non-domestic waste obtained from secondary data, the average waste generated that enters the Caringin Central Market Bandung TPS is 84 tons/day. The operational cost for this system is relatively high, IDR 55,440,000 per day. Figure 1 shows that the composition of solid waste in Caringin Central Market TPS Bandung is dominated by organic waste which is 97.7 % and inorganic waste 2.3 %, respectively. The high level of organic waste is due to the continuous supply of vegetables and fruits to Caringin Central Market which finally ended with an accumulation. Most of the organic wastes in Caringin Central Market were originated from oranges, watermelon, cauliflower, garlic, onion, lettuce, cabbage, water spinach, spinach, fish leftovers, chicken, etc. Those organic waste containing high moisture content, nutrition, and vitamins besides the organic polymers which mainly carbohydrates and proteins.
3.2. Chemical characteristics

Chemical characteristics of organic waste from the Caringin Central Market are shown in Table 1. The determination of chemical precursors of organic waste samples from Caringin Central Market Bandung for moisture content was 92.42%. It is figured out that vegetables and fruits are the major fractions contained in organic waste although the fish and chicken leftovers and others are found. The moisture content in the waste can be used as a parameter to choose the right waste treatment process, either by composting or by anaerobic fermentation to produce compost or biogas, respectively. Water content for anaerobic processes must be higher than 60% so that the pores of the sample in the reactor will be filled more by the water than air, to finally creating an anaerobic atmosphere [6]. Based on the measurement, the wastewater content in TPS Caringin Central Market Bandung has fulfilled the requirements for the anaerobic process which is more than 60%.

Measurement of organic carbon is carried out to determine the content of organic compounds in the sample. The carbon content is very influential on the activity of microorganisms. The determination of waste carbon content is done by burning dry waste (total solid) at 550 °C to finally become ash. Ignition loss calculates carbon content. Meanwhile, the determination of total N was found around 0.61%. Nitrogen will be used by microbes as a protein precursor of the cell both in aerobic and anaerobic processes. Nitrogen needed for aerobic metabolism from microbes is more than anaerobic metabolism. Anaerobic biodeterioration of organic waste requires only about 0.3% of the total Nitrogen from the substrate [7].

| No.  | Parameter                        | Amount (%)       |
|------|----------------------------------|------------------|
| 1.   | Moisture content                | 92.42            |
| 2.   | Total solid                     | 7.58 – 12.2      |
| 3.   | Carbonaceous (by difference)    | 6.77 - 10.17     |
| 4.   | Nitrogen                        | 0.61             |
| 5.   | Ash                             | 0.82             |
3.3. Potential as raw material for biogas and compost.

Shredded and ground organic material from marked waste can be used as a direct raw material or substrate for composting using the aerobic process or biomethane/biogas generation using a dry anaerobic process. Due to the nature of shredded and ground organic material, during dry fermentation, the material will be deteriorated by the hydrolysis process of microorganisms and fungi, where the hydrolyzed liquid contains soluble protein, fatty acids, carbohydrates, vitamins, and minerals. This compound in aerobic fermentation or composting will inhibit the process because the liquid will create the anaerobic zone. Therefore, the hydrolyzate must be dried in the process, or by turning the process onto compost media. The addition of porous lignocellulosic material, such as sawdust, rice husks, etc will be beneficial where valuable hydrolyzate will be absorbed and used as nutrition in the composting of the lignocellulose additive.

Composting will be the best whenever the C/N ratio is around 30/1. Mixing wet grated organic waste with dry organic material such as sawdust in 1:1 will approach the ideal ratio. The fast composting process can take between 14 to 21 days. The reversal process plays an important role in the composting process. If the pile changes every day, fast composting will occur; if set longer, the compost will take longer to mature. Fast decomposition can be detected by the following indicators; pleasant odor, by the generation of heat, white fungi growth in decaying organic matter, volume reduction, and discoloration of the material to dark brown. The compost is then mature and ready to use. Compost yields around 15-25% of the original weight associated with the total compost material solids and moisture content.

Organic waste from Caringin Market is obtained around 84 tons, which means that composting from all organic waste will produce around (0.15 - 0.25) 84 tons of mature compost or in the range of 12.4 to 21 tons. On the other hand, if organic waste from Caringin is grinded and mixed to separate fibers and organic solutions, the compost portion will be lower. From the experiments, about 20% of
the waste sample is attached to the fiber, which is equivalent to 16.8 tons. The amount of organic waste will be composted to a maximum of 4.2 tons of mature compost.

Biogas production from organic market waste which mostly contains cellulose will be hydrolyzed under anaerobic conditions into sugar with the following equation

\[(C_6H_{10}O_5)n + n H_2O \rightarrow n C_6H_{12}O_6 + n H_2 \] (1)

As shown in equation (1) cellulose hydrolysis \((C_6H_{10}O_5)\) through the addition of water \((H_2O)\) to form glucose \(\((C_6H_{12}O_6)\) as the main product and hydrogen \((H_2)\) evolved into space. Glucose is then converted to acetate [8] at the acidogenic and acetogenic stages by acidogenic and acetogenic bacteria as shown in equation (2)

\[C_6H_{12}O_6 \rightarrow 3 CH_3COOH \] (2)

The methane will be generated by methanogenic bacteria through the conversion of acetate. Acetate-consuming methanogenic bacteria such as Methanosarcina barkteri, M. stadmanae, M. Mazei, and Methanothrix sochngenii are some of the important bacteria in the process.

\[CH_3COOH \rightarrow CH_4 + CO_2 \] (3)

Hydrogen, Carbon dioxide and formic acid were also converted to methane by methanogenic bacteria such as Methanobacterium formicicum, M. thermoautotrophicus, and M. bryantii. However in methane generation; it should be taken into account that there is a wide variety of inhibitory substances such as ammonia, heavy metals, and sulfides. The majority of about 70 % of methane is produced from acetic acid due to the fact that acetic acid is the main acid product in the anaerobic degradation of biomass [9] which means that the remaining 30 % will come from carbon dioxide and hydrogen and also from formic acid.

Theoretically, according to the (1) (2) and (3) from 1 mole of glucose obtained from biomass digestion will be metabolized into 3 moles of methane and 3 moles of carbon dioxide. Carbon dioxide generated in the equation (3) will be metabolized to form methane by the consuming hydrogen generated in the equation (1). Therefore, the concentration of methane in the biogas would be higher than carbon dioxide. The carbonaceous in the organic solid waste from the Caringin market is about 10 % of the weight. If it is assumed that all the carbonaceous is cellulose so that it will be equal to the same amount of glucose, which is 10 % of 84 tons of biomass is equivalent to 8.4 tons. This amount is equal to 46,667 moles of glucose. The biogas produced from glucose is around 6,272 m^3 with a concentration of methane is above the carbon dioxide.

4. Conclusion
Waste generation generated by Caringin Central Market TPS Bandung is 84 tons/day. The waste transported to the temporary landfill site. The operational cost for this system is relatively high, which is IDR 55,440,000 per day. The conversion of the organic materials to compost by aerobic composting could be achieved in rapid time. The yield of compost potentially harvested would be around 12.4 to 21 tons. Meanwhile, the conversion to the biogas would be beneficial with 6,272 m^3 of biogas.

Acknowledgments
The research was financed by research Mandiri of LPTB – LIPI.

Author Contributions
Erni Saurmalinda Butar-Butar, T Sembiring, and EA Priantoro contributed equally as the main contributor to this work. Mutiara contributed as a supporting contributor. All authors read and approved the final paper.
References

[1] Standar Nasional Indonesia Nomor SNI -19-2454-2002 tentang Tata Cara Teknik Operasional Pengelolaan Sampah Perkotaan, Badan Standar Nasional (BSN).

[2] Seik, F. (1997). Recycling of domestic wastes: Early experiences in Singapore. Habitat International, 21(3), 277–89.

[4] Bayuseno, A. (2009). Penerapan dan Pengujian Model Teknologi Anaerob Digester Untuk Pengolahan Sampah Buah-Buahan dari Pasar Tradisional, 11, 1-12.

[5] Mujahidah, Mappiratu, Rismawaty Sikanna. (2013) “Kajian teknologi Produksi Biogas Dari Sampah Basah Rumah Tangga, Online Jurnal of Natural Science, Vol. 2 (1): 25-34.

[6] Brinkmann, A. J. F. (1997). Biological Treatment of Household Biowaste: The Triangle of Collection – Technology – Market. Tobin Environmental Services: Dublin.

[7] Hermawan B, Lailatul Q, Candrarini P, Sinly Evan P,(2007). Pemanfaatan Sampah Organik sebagai Sumber Biogas Untuk Mengatasi Krisis Energi Dalam Negeri. Karya Tulis Ilmiah Mahasiswa Universitas Lampung. Bandar Lampung.

[8] Sriwuryandari L, Sembiring T (2014) Biomethane and biohydrogen from Biowaste/Wastewater , Journal of Indonesian Technology 37: 123 – 35.

[9] Sembiring T, Ekoputranto A, Sriwuryandari L, Nilawati D, Gallert C, Winter J (2012) Propionic Acid Metabolism During Anaerobic Biowaste Slurry Digestion Journal of Teknologi Indonesia 35 : 24–32.