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ODOUR PROFILING FROM DECOMPOSITION OF LOCAL FOOD WASTE

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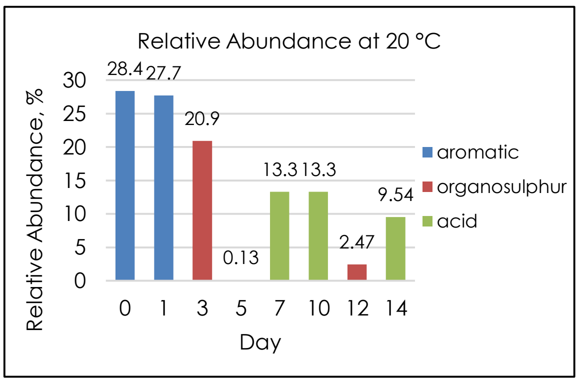
Graphical abstract



Abstract

The aim of this study is to investigate odour emission profiles from storage of local food waste and to assess the potential health risk caused by exposure to volatile compounds. Food waste decomposition process was conducted for 14 days and kept at 20°C and 30°C in self-made bioreactor. VOCs emissions from both samples were collected at different stages of decomposition starting at day 0, day 1, day 3, day 5, day 7, day 10, day 12 and day 14. It was analyzed using TD-GC/MS. Findings showed that various VOCs were released during decomposition of food waste. Compounds produced were influenced by time, temperature and the physico-chemical characteristics of the compounds. The most abundant compound released was dimethyl disulfide. Potential health risk of exposure to this compound is represented by hazard ratio, HR, calculated at 1.6×10^{11}. Since HR equal to or less than 1.0 is considered negligible risk, this indicates that the compound posed a potential risk to human health.

Keywords: Odour, volatile organic compounds (VOCS), decomposition, local food waste

1.0 INTRODUCTION

In Malaysia, approximately 50% of total amount of municipal solid waste is a food waste and mainly been disposal in landfill sites. However, the disposal of food waste has created another issues to the environment during degradation process such as odour and water pollution. In addition, it is difficult to find new landfill sites for disposal purpose because of limited land available. Due to these problem, the government of Malaysia recently made a new obligation to householder and premises for separation of food waste and other waste at generation point prior collection.

There are several elements in solid waste management. This includes waste generation, storage, collection, transportation, transfer and disposal on landfill. The collection by municipal council occurs at 2 to 3 days intervals not including delays that may occur due to technical problems (eg; compactor breakdown). Therefore, storage prior to collection becomes important. Improper waste storage may cause odour nuisance and attract pests and rodents such as flies and vermin, especially for organic waste.

According to studies conducted by Ting [1], VOCs emitted from food waste degradation process are dominated by compounds from the group of aromatic, alcohol, esters, acetic acid, ketones, terpenes and organosulphur. Their origin might be due to food flavors, growth of microorganisms and the oxidation of lipids or even endogeneous enzymatic decomposition [2]. Previous studies confirmed that both absolute and relative patterns of odorant emissions during the decaying process are affected greatly by food types [3-5]. However, there is no information on odour profiling released from decomposition of local food waste. Therefore, this study aims to investigate the profiles of Volatile Organic Compounds (VOCs) emitted during decomposition process and the potential health risk to human health.

2.0 METHODOLOGY

2.1 Experimental Set Up

The study was performed to collect gas emitted from food waste. Wastes that were collected are wastes that had been discarded within less than 24 hours from residential area. The volume of collection was made in quantities that are sufficient for experimental purposes. For laboratory simulation, self-made bioreactors with 40kg capacity were used. For the experiment, each reactor was loaded with approximately 15 kg shredded food wastes (incubated at 20^0C and 30^0C). Sampling was performed by collecting gas emitted by the food waste from headspace of bioreactor using low flow air sampling pump (LFS-113c, Gillian) with a flow rate of 50mL min^{-1} and trapped in carbotrap tube. The sampling was carried out for 40 minutes and the total gas collected was 4L. Gas sampled was collected in triplicate throughout experiment (day 0, day 1, day 3, day 5, day 7, day 10, day 12 and day 14).

2.2 Gas Chromatography/Mass Spectrometry (GCMS)

To analyze VOCs, a GC system (Thermo Quest Trace 2000, Perkin Elmer) fitted with a Thermo Quest Trace Finnigan MSD (ATD 400, Perkin Elmer Boston, Massachusetts) equipped with inert mass selective detector (MSD) was used. A thermal Desorption (TD) unit (Turbo Max 100, Perkin Elmer) concentrated the gas samples via cold trap and transferred to GC/MSD. Analytical separation was done on 30m x 0.25 mm (Elite MS) with 0.25 mm thickness. The temperature program started at 35^0C (initially for 4 min) and was raised 15^0C/min to a final temperature of 300^0C (held for 28 min). Mass range was 30 – 450 amu with Helium as carrier gas. Analysis identified a wide range of organic compound based on the library searching.

2.3 Data Analysis

Semi-quantitative analysis was used to determine the concentration of the VOC found from the GC/MS. The calculation of the VOC concentration was based on the formula developed by Nammari [6]. In the study, pure toluene standard was used as a reference substance. The formula developed can be used to calculate the compound concentration found in the GC/MS analysis from the peak height of the gas chromatograms.

2.4 Potential Health Risk

Potential health risk was calculated based on previous study conducted by Ertan [7]. The study measured health risks of VOCs emission in landfill environment. The potential adverse health effects of workers exposed to these compounds is characterized based on carcinogen and non-carcinogen adverse health effects. The exposure pathway is inhalation.

3.0 RESULTS AND DISCUSSION

3.1 Compounds Identification

Forty-one compounds were identified during food waste storage at different time length under different temperature (data not shown). Table 1(a) and (b) shows major compounds emitted from the food waste samples during 14 days simulation.

Table 1 (a) major VOCs emission from decomposition process in 20˚C

Day	20˚C	
	VOC	Group
0th	Toluene	Aromatic
1st	Toluene	Aromatic
3rd	Dimethyl disulfide	Organosulphur
5th	Dimethyl disulfide	Organosulphur
7th	Hexanoic acid	Acid
10th	Hexanoic acid	Acid
12th	Dimethyl disulfide	Organosulphur
14th	Benzenepropanoic acid	Acid

Table 1 (b) major VOCs emission for decomposition process in 30˚C

Day	30˚C	
	VOC	Group
0th	Dimethyl disulfide	Organosulphur
1st	Dimethyl disulfide	Organosulphur
3rd	Dimethyl disulfide	Organosulphur
5th	Hexanoic acid	Acid
7th	Benzenepropanoic acid	Acid
10th	Hexanoic acid, 4-tridecyl ester	Ester
12th	2-Piperidinone	Ketone
14th	Docosanoic acid, 1,2,3-propanetriyl ester	Ester

Throughout the process of food waste decomposition, various VOCs were released. The compounds found from the GC/MS analysis were classified based on the chemical groups. The compounds produced vary at different controlled temperature. Most commonly detected compounds were aromatic compound, organosulphur, acids, ketone and esters. Other compounds found were detected only in small percentages. Additionally, this finding supported the results from a study by Scaglia [8] who found similar compound groups released from the decomposition of food waste.

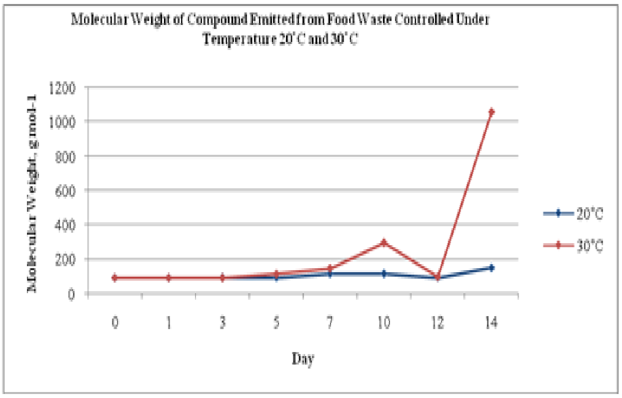


Figure 1 VOCs emission based on compound molecular weight

Based on the results analysed, there is a significant association between the chemical and physical characteristics of the compound and the length of waste decomposition process. As presented in Figure 1, the molecular mass of the compounds released increase proportionately as time progress. This proves that the VOCs emission from the food waste decomposition was influenced by its physico-chemical characteristics.

Generally, volatility of a certain compound is influenced by many factors, such as vapor pressure, molecular weight and boiling point. Volatile substances have high vapor pressures, which is affected by the weight of the substance. Chemicals with lower molecular weights can enter the gas phase and becomes volatile more easily. Temperature is also a factor that influences vapor pressure. Higher temperatures provide more energy, allowing molecules to move faster. As a result, more molecules escape as gas and become volatile. Therefore, compounds emitted from food waste stored in 30°C have higher molecular weight compared to the compounds emitted from food waste stored in 20°C. Previous study have shown similar scenario where temperature plays an important role in the volatilization of these compounds depending on their vapor pressure [9]. The intermolecular attractions or hydrogen-bonding are also able to determine vapor pressure. As a result, non-polar molecules such as hydrocarbons that have the weakest interactions are the easiest to become volatile. Due to these characteristics, the aromatics compounds are more volatile due to its low molecular weight, high vapour pressure and low boiling point as compared to other compounds

3.2 Relative Abundance and Concentration

The abundance of aromatics released during decomposition process was the highest at 20˚C (Figure 2 (a). At day 0 and day 1, toluene was released the most with 28.4% and 27.7% of the total 4L air collected, respectively. From day 5 to day 14, the abundance of compound in the air samples was replaced by other compounds such as Dimethyl disulfide (DMDS), acid, ester and ketone. In a previous study by Pinjing [9], aromatic compounds were also found in high concentration during the first stage of decomposition process (day 0 to day 4) and the aromatic compound concentration then decreases as the decomposition process continues. Meanwhile, organosulphur was the most abundant during incubation at 30⁰C (Figure 2 (b)).

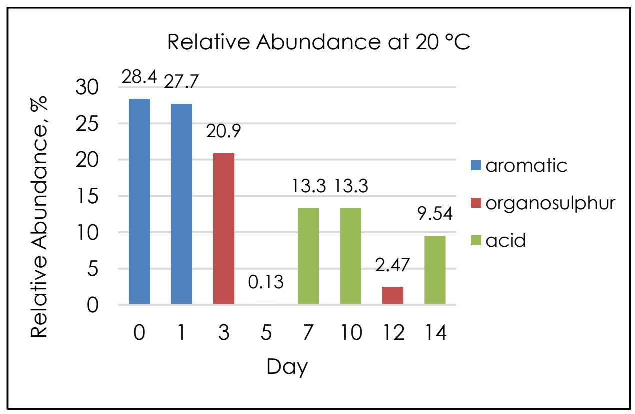


Figure 2 (a) Relative abundance compounds at 20⁰C

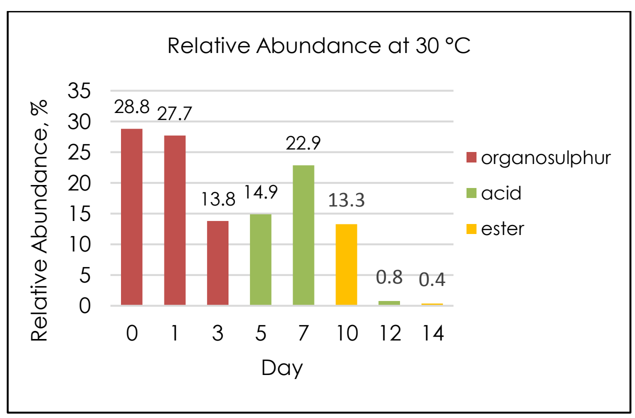


Figure 2 (b) Relative abundance compounds at 30⁰C

DMDS was found in high relative abundance at both 20°C and 30°C food waste decomposition. At 20°C, DMDS was released at day 3, 5 and 12, while at 30°C, DMDS was released at day 0, day 1 and day 3. Ting [1] found that VOSCs were released over 90% of the emissions during the first 10 days thus displaying its important role as odorant. Previous study also found that VOSCs were principally emitted at the early stage of waste decomposition [10-11]. The dominant release of organosulphur may be caused by its inherent presence in food or due to degradation of sulfur-containing amino acids and peptides in organic material [12].

As demonstrated in Figure 3, organosulphur is the main volatile compounds emitted during incubation in 30^{0}C while acid are the highest in 20^{0}C. Komilis [13] also revealed that organosulphur are among the most abundant VOC species (over 35%) during food waste degradation when compared with mixed paper and yard waste. Higher emission of organosulphur (mainly DMDS) in early stage of decomposition suggested that these compounds are probably present as a result of microbial activity. In fact, some organosulphur compounds were often used as a diagnostic marker of microbe's activity in degradation of organic material [14-15].

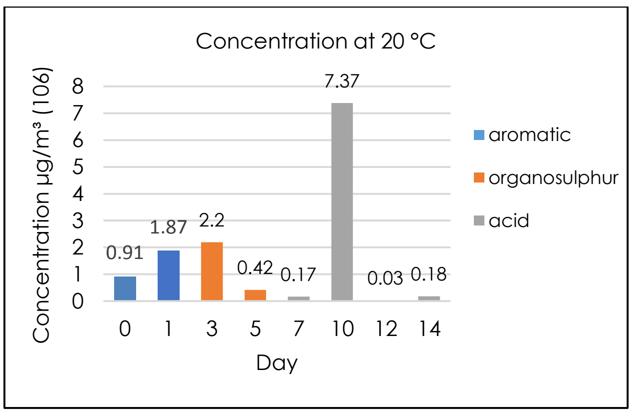


Figure 3 (a) Concentration of compounds at 20^{0}C

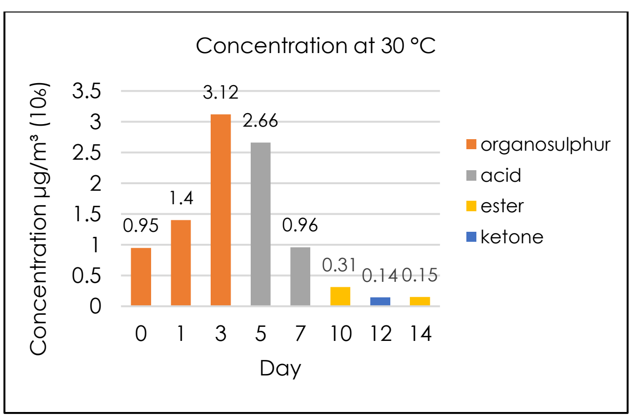


Figure 3 (b) Concentration compounds at 30^{0}C

3.3 Health Risk

DMDS was selected to be quantified for potential health risk due to its high emission rate over any other identified compounds. After calculation, the potential health risk of exposure to DMDS through inhalation was expressed as Hazard Ratio (HR). The HR of DMDS was 1.6 x 10^{11}

4.0 CONCLUSION

Results showed that food waste becomes a source of VOCs when it remained in storage for several days. The emission of VOCs from decomposition of food waste is influenced by physical and chemical properties as well as temperature. VOCs released vary according to their volatility. The chemical and microbiological reaction also influenced the emission of VOCs from the decomposition process. Most VOCs released from food waste decomposition fall within the compound group of aromatic, organosulphur, acid, ketone and esters. All of which may be the source of unpleasant odour. While the concentration of VOC emissions decreases as the decomposition process continues, should the waste be stored for longer periods, exposure to high levels of VOCs trapped within storage area will be inevitable. Apart from being an obvious source of unpleasant odour, acute inhalation of the compounds released from decomposing wastes may affect the health. This study provides early indications of level of VOCs produced during storage prior to collection. It is recommended to further investigation of VOCs in leachate during degradation process.

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