

VFA AND AMMONIA EMISSION DURING SEPARATE COLLECTION OF RESIDENTIAL WASTE AS A MEASURE OF ODOUR POTENTIAL

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SUMMARY: Research was conducted to determine suitable chemical parameters as indicators of odour from decomposing food wastes. The feedstock was prepared food scraps and stored in 18 L plastic buckets (2 kg wet weight each) at 20°C and 8°C to imitate high and low conditions, respectively. After 1, 3, 7, 10 and 14 days of storage, the smell from the buckets were marked to an intensity scale of 0 (no odour) to 5 (intense) and the corresponding leachate analysed for volatile fatty acids, ammonia and total organic carbon. A linear relationship between odour intensity and the measured parameter indicates a suitable odour indicator with the latter. This research found that odour intensified with longer storage period and warmer surroundings. Ammonia was the most promising odour indicator due to its close representation of the measured odour level, followed by isovaleric acid. To prevent offensive smell from food wastes, it is suggested that ammonia and isovaleric acid content be kept below 361 mg/l and 941 mg/l, respectively.

1. INTRODUCTION

The separate collection and transportation of food residues from residential waste, saves landfill capacity, but presents with it the issue of malodour (Qamaruz-Zaman and Milke, 2008). The coexistence of the waste treatment facilities (e.g. composting or anaerobic digestion plant) with near neighbours, particularly in urban areas, can hardly be avoided due to the consideration of transportation costs and available land, thus exacerbates the odour problem.

The use of indicators as a simple and cost effective tool to quantify the intensity of odour emission provides an alternative to the more sophisticated and expensive olfactometry measurements. Odour indicator is the use of the measurement of concentrations of one or more key compounds which reflect the degradation of the main waste constituents, to monitor odour development and/or the determination of odour intensity (Spoelstra, 1980). It has been suggested that for indicators (Spoelstra, 1980); (i) the components must be products of protein (or possibly carbohydrate) degradation, (ii) the formation of the components must reflect kinetics of degradation, (iii) the components must respond in a representative way to environmental changes

e.g. aeration, methane formation, and (v) the concentrations must be suitably large for easy measurements; trace components are not suitable. The selection of indicators also depends on speed of analysis and the availability of equipment (Williams, 1984).

Residential food waste because of its wet nature, high organic content, and mixture of chemical substances, quickly produces odours as it begins to decompose. Volatile fatty acids (VFAs) and ammonia have been identified to be potentially significant odorants resulting from the decomposition of organic matter containing carbohydrates and protein elements. Ammonia is produced from either anaerobic or anaerobic decomposition of proteins and amino acids, whereas VFAs particularly are a huge concern with the anaerobic degradation. Carbohydrates are degraded to a limited number of compounds (mainly acetic, propionic and butyric acids), while proteins are broken down to straight chain carboxylic acids, and fats and oils are broken down to long chain fatty acids. The longer chained acids can be hydrolyzed to lower molecular weight, volatile fatty acids such as acetic, propionic and isovaleric.

This research was conducted to investigate the use of odour indicators to quantify odour emission from food waste kept at two different temperature conditions. Three indicators; volatile fatty acids (VFAs), total organic carbon (TOC) and ammonia (NH_3) will be analysed to demonstrate their reliability in odour quantification. With odour indicators, results can be obtained where no odour panel is available and retrospective analysis of appropriate data can indicate the effectiveness of treatments that were designed for other purposes (Williams, 1984).

2. METHODOLOGY

2.1 Experimental procedure

Experiments were performed in the Environmental Engineering Laboratory situated in the Department of Civil and Natural Resources Engineering, University of Canterbury, New Zealand. To minimise the effect of feedstock variation to odour production, a standard food waste mixture was used throughout the study consisting of vegetables (34% wet weight basis), fruit (19%), meat (12%) and small amounts of coffee grounds, filters, teabags, rice, leftover spaghetti, eggshells and bread (Qamaruz-Zaman and Milke, 2008). The waste (2 kg wet weight) was discarded into 18 L buckets and stored for 14 days in temperature controlled rooms of 20°C and 8°C, to imitate ambient temperature for autumn or spring, and winter, respectively.

2.2 Data collection

Buckets were taken out from the temperature controlled rooms after 1, 3, 7, 10 and 14 days for evaluation. First, buckets were weighed, then smelled, followed by leachate analysis and finally pictures of the decomposed wastes were taken (Canon PowerShot S40 digital camera with 4.0 mega pixel output resolution). As pointed out earlier, three parameters; volatile fatty acids (VFAs), total organic carbon (TOC) and ammonia nitrogen ($\text{NH}_3\text{-N}$) will be used to quantify odour emission. Odour was categorized based on the procedure of Qamaruz-Zaman and Milke (2008) using an intensity scale of 0 (no odour) to 5 (intense odour). Relationships will be established between the parameters and the marked odour intensity level, to identify whether they have the potential to indicate odour intensity.

2.3 Leachate analysis

Using the leachate extraction technique introduced by Qamaruz-Zaman and Milke (2007), samples were analysed for ammonia ($\text{NH}_3\text{-N}$) on a Hach Spectrophotometer and total organic

carbon (TOC) on a Teledyne Tekmar (USA) Apollo 9000 Analyzer. Volatile fatty acid (VFA) were determined on a HP6980 Gas Chromatograph, with, only acetic, propionic, butyric and isovaleric acids being reported and summed as total VFA (TVFA). This is because no other VFAs were present in concentrations above 500 mg/l. pH of the extracted leachate was taken using an EDT RE357 Microprocessor pH meter.

3. RESULTS AND DISCUSSION

3.1 Mechanism of odour production

In general, odour intensity increased linearly with increasing storage time for food wastes stored at ambient (20°C) and lower temperature (8°C) conditions (refer Figure 1). Odour from the higher temperature was always more intense than the lower temperature emissions. For wastes stored at the higher temperature, a very intense smell (scale of 5) was evident after 7 days, compared to storing at the lower temperature which emitted only a light odour (scale of 2). Offensive smell (scale of 5) has never occurred with the latter.

Ammonia roughly increased 13 times to 1370 mg/l for the higher temperature after 14 days storage while tripled to 360 mg/l at low temperature from the initial ammonia content of 100 mg/l. Correspondingly, the odour intensity for the elevated temperature was very intense (scale of 5) whereas it was only moderate (scale of 3) for the lower temperature.

With volatile fatty acids, an inverse relationship was observed between acetic acid and odour whereby the former decreased at rising odour intensity. Where the difference between odour intensity was large, the drop in acetic acid was small, implying the weakness of acetic acid to portray the different scales of food waste odour intensity. The significantly mismatching pattern between odour intensity and individual VFA concentrations was also seen with butyric and propionic acid, indicating their unsuitability as food waste odour indicators. As a result, no correlation was found with TVFA, which may have been indirectly influenced by the same non-correlative response of the major individual acids, namely, propionic, acetic and butyric acids.

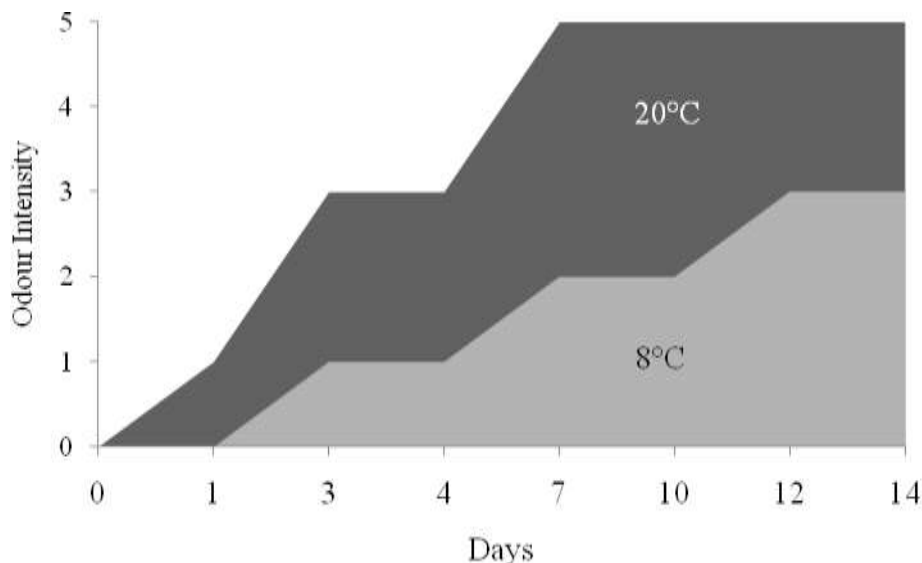


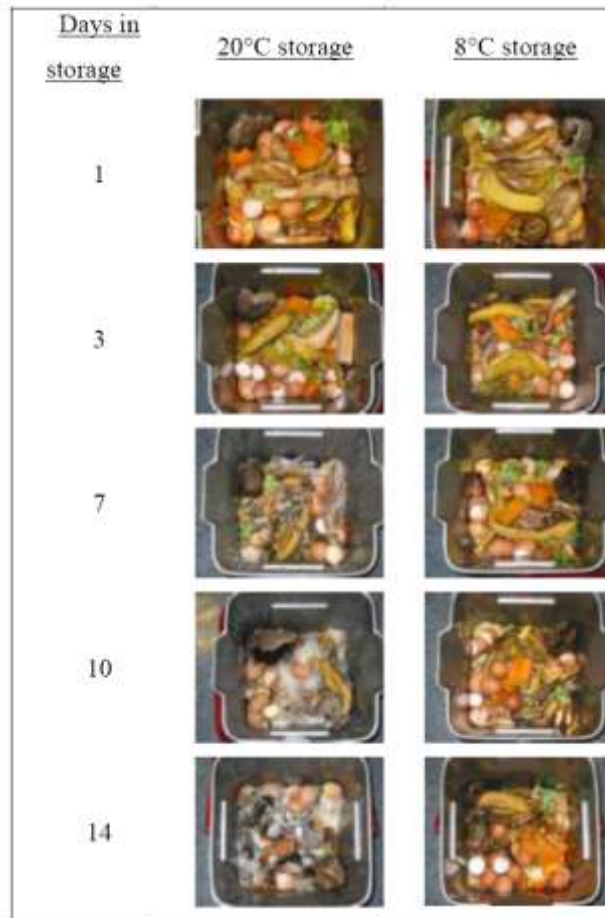
Figure 1. Odour intensity of food waste stored at different temperatures

Isovaleric acid is the only VFA measured that shows potential as a food waste odour indicator. When the presence of odour was minimal or even none, correspondingly, no isovaleric acid was present in the leachate. Likewise, the highest concentration of 1240 mg/l recorded at the higher temperature after twelve days saw an odour intensity of 5. Isovaleric acid increased with time and was always higher at the elevated temperature.

Unlike ammonia and isovaleric acid, no relationship was observed between odour intensity and the measured total organic carbon (TOC). Despite the rise in odour intensity level for both temperature conditions, the same pattern was not observed with the TOC measurements. The TOC content fluctuated where they rise and drop unexpectedly without any regard to a particular storage period, temperature let alone the odour emission.

It is thought that substrate decomposition and pH could have influenced the formation of odour. The increasing pH from 5.3 to 6.9 and 6.5 after 14 days for high and low temperatures respectively, saw a subsequent rise in ammonia from 100 mg/l to 1370 mg/l to 360 mg/l. According to Nakasaki et al. (2000), the increased in pH value is a result of both the production of NH₃ associated with protein degradation and the decomposition of the organic acids. As illustrated by Table 1, the waste was more decomposed in 20°C storage compared when stored at 8°C. About 10% of the initial weight was lost in the decomposition process, where understandably, weight loss was higher for the warmer condition.

Table 1. The decomposition of food wastes at high and low temperature



3.2 Identification of indicator threshold value

Following the identification of ammonia and isovaleric acid as suitable indicators, Table 2 shows their respective threshold values and the corresponding odour intensities. Odour was not detected when ammonia and isovaleric acid was below 170 mg/l and 530 mg/l, respectively. However, odour was very strong when the ammonia concentration rose to between 841 – 1400 mg/l and isovaleric acid between 1061 – 1240 mg/l.

Increases in ammonia are likely to be reflective of organic nitrogen reduction to a more suitable nitrogen form for bacterial incorporation (Powers et al., 1999). This is important as these bacteria work to degrade protein in food wastes, hence fulfilling the criteria proposed by Spoelstra (1980) that odour indicators must be products of protein degradation.

Isovaleric acid stood out as a promising odour indicator, even though it was present in the least amount compared to the other VFAs. Similarly, an experiment by Zhu et. al. (1997) found that some products reduced swine manure odour threshold without significantly reducing the total amount of VFAs, signifying a poor correlation. Their study suggested that the products may have reduced the concentrations of long chain and branching fatty acids, and since these acids did not necessarily exist in high concentrations, they were unlikely to have made a significant difference on the total VFA. This confirms our findings with isovaleric and the other individual acids as well as the total VFAs.

Table 2 Suggested threshold ammonia and isovaleric acid values for varying odour intensities

Odour intensity	Ammonia (mg/l)	Isovaleric Acid (mg/l)	Description of odour
0	100 - 170	≤ 530	No odour: <i>undetectable, unnoticeable</i>
1	171 - 240	531 – 670	Faint: <i>slight occasional wafts, undistinguishable smell</i>
2	241 - 300	671 – 700	Light: <i>slight and constant, distinguishable smell</i>
3	301 - 360	701 - 940	Moderate: <i>Distinguishable smell and soemtimes irritating</i>
4	361 - 840	941 - 1060	Strong: <i>Unbearable smell but causes no physiological effects</i>
5	841 - 1400	1061 - 1240	Intense: <i>Intolerable smell for any length of time and can produce physiological effects</i>

4. CONCLUSIONS

This research has shown that ammonia and isovaleric acid has the potential as an odour indicator for about two weeks stored food wastes. It was not the intention to try identify the smell volatilized from the bucket and use it as an indicator. Rather, to utilise universally known odour compounds, which are common end products of anaerobic and aerobic decomposition of organic wastes.

Nonetheless, it is not advised that treatment regimes be designed to specifically target at

reducing the concentrations of these indicators, as it cannot be guaranteed that by diminishing completely the ammonia and VFAs in the leachate, food waste would not smell, or smell less. Instead, odour indicators would be useful as a guide for waste managers of when the food waste odour would become intolerable, by setting acceptable and unacceptable limits of odour concentrations. In this regard, it has to be concluded that even though instrumental methods could help indicate the intensity of odour emission, it is still very far from being competitively as sensitive as the human nose.

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