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# Simulation of Organic Fraction of Municipal Solid Waste in the Preparation of Synthetic Compost Recipe for Lab Scale In-Vessel Composting

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## 1. INTRODUCTION

Process modification is required for all kinds of physical, chemical and biological processes for improving their efficiency. This is achieved through experimentation by changing factors influencing the process. Composting is one of the processes to treat municipal solid waste (MSW). The parameter influencing composting process are C/N ratio, moisture content, aeration rate, pH, starting culture, substrate composition etc.

Unlike waste water or industrial sludge, municipal solid waste is not having a uniform characteristic. It changes from time to time and place to place. Many researchers do experiments in composting in the yard, which requires large amount of materials and they face difficulty in controlling and monitoring the process. Researchers have turned to lab-scale composting, where proper quality, process control and monitoring can be done. Tchobanoglous et. al., identified the decomposable fraction of MSW in the US, accounting approximately 40% for mixed paper waste, 19 % for yard waste and 9 % for food waste of the overall wet MSW after recycling (1). Komilis, D.P., and R.K. Ham in their laboratory study of composting normalized the 3 major organic components to 100 % by neglecting inorganic components and smaller organic component fractions. They set the % of the 3 components on wet basis as 59.3 % for mixed paper, 27.4 % for yard waste and 13.3 % for food waste (2). In lab-scale composting, to maintain proper quality control, simulated wastes are used. The advantage is repeatability and reproducibility of the experiment. If the simulated waste is to be used in lab-scale composting, it should be a true representation of the original composition of solid waste. In this study, the preparation of synthetic compost recipe by simulating the composition of organic fraction of municipal solid waste is done.

## 2. METHODOLOGY

In order to know the composition of a typical solid waste, Palakkad municipality in Kerala is selected. The municipality is collecting 40 tonnes of waste daily from houses, hotels, marriage and convention halls, markets, hospitals (except biomedical wastes), streets, etc. The waste collection is for 6 days in a week, except Sunday. Study was conducted for 1 week at the municipal dumping yard having the compost plant in it, to know the composition of waste. Sampling was done such that the total load from a waste collecting vehicle was divided into sixteen parts, and one among the sixteenth was chosen for the study. From this portion, a quantity of 250 Kg was weighed out. It was then separated into different categories and weighed separately (3). The mean observations were recorded as given in Table 1. The three major constituents identified in the study were food waste, mixed paper and yard waste. Hence, a more detailed study was done into the composition of these categories, by dividing them into subcategories and given in Table 2.

Food waste was found to be mainly of rotten vegetables, fruits, cooked food items as well as vegetable and fruit residues after consumption. Mixed paper mainly included cardboard, paper cups & plates, news paper, packing paper, book paper, office paper etc. Yard waste primarily composed of green leaves, dry leaves, grass clippings, plantain leaves, etc. In order to obtain a more precise data regarding the actual composition of food waste, a household field survey was done among 50 households in Palakkad Municipality through random sampling, in order to identify the various components of food wastes, and their percentages. The consolidated results of the survey are as shown in Table 3

After obtaining the percentage composition of food wastes generated among households, the items to be included in synthetic waste was fixed. Based on dominance, the items selected were: cooked food, pumpkin, ash gourd, plantain, spinach, potato, cabbage, onion, tomato, banana fruit, papaya, orange, low grade

paper, packing paper, printed paper, plantain leaves, other green leaves and dry leaves.

Once the components required for the composting process was finalized, the characteristics of each component is determined. The major parameters that influence the compost recipe are the weight, moisture, carbon and nitrogen content of the components. For each item to be included in the compost recipe, moisture (4), carbon (5) and nitrogen (6) content were determined as per the standard methods and results were consolidated as in Table 4.

The percentage composition of organic fraction of municipal solid waste were determined on wet basis for the field moisture content. Field moisture content is the moisture content present in the commingled waste during the study. The average moisture content was 60.74%. The moisture content present in various categories of wastes such as food wastes, paper wastes and yard wastes are different. Table 5 shows the various categories of wastes and their field moisture content (mixed wastes) and actual moisture content (unmixed waste).

In preparing synthetic waste, the actual moisture content of individual material should be considered. Therefore, the percentage composition on wet basis for actual moisture content of individual material in making compost recipe should be calculated, so as to keep the dry weight constant.

Dry weight of the material = Wet weight x (100-M)/100 (M is the moisture content)

The following equation is used to find the wet weight of the materials required for the compost recipe

Wet weight of the material required = Dry weight of the material x 100/ (100-M)

The required weight for each category of waste for the respective moisture content was calculated, and is shown in the Table 6.

This was done for the subcategory of food waste also as given in Table 7. Considering the mean values of the components, the final percentage composition of the synthetic waste is obtained as shown in Table 8.

Based on the above data, compost recipe can be prepared for a given quantity of synthetic waste by knowing carbon, nitrogen and moisture content of each component in it. The compost recipe should satisfy the following criteria.

The percentage composition of the material used in the recipe for synthetic MSW should agree with that of the organic fraction of MSW (OFMSW).

The final moisture content of the recipe should be in the range of 50 - 70% (7). This can be achieved by proper selection of the material and adjustment of weight. If this is not viable, add pure water when it is less and use a bulking agent (saw dust, coconut pith, fly ash etc.) if it is more.

The recipe should provide the required value of C/N ratio by adjusting the weights of components within the limits. Generally brown coloured materials have more carbon and green coloured materials have more nitrogen. A C/N ratio of 25-30 has been suggested for optimum composting (8).

The material size should be reduced to reduce the composting time.

Paper should be shredded.

Colour printed paper should be avoided in the recipe.

Fresh materials should be used.

Do not compost meat, bones, animal waste, dairy products or any other inorganic materials.

## Preparation of recipe for 10 kg waste

Use an electronic spread sheet. Enter the items to be included in the first column. Then enter the carbon, nitrogen and moisture content in the respective column. The weight of each category of material should be in proportion to the percentage composition as given in Table 8. The C/N ratio of substrate can be determined using the equation

C/N = {C1(1-M1)W1 + C2(1-M2)W2 + …..} / {N1(1-M1)W1 + N2(1-M2)W2 + …..}

Where C1, M1, W1 and N1 are respectively the percentage carbon content, moisture content, weight and nitrogen content of the one component of the recipe.

Results

Results are given in Tables 1 to 10.

**Table 1 Characteristics of the municipal solid waste at Palakkad**

| Sl No: | Item | % content |
|---|---|---|
| 1 | Food | 52.03 |
| 2 | Yard wastes | 17.14 |
| 3 | Mixed paper | 15.62 |
| 4 | Plastic | 4.13 |
| 5 | Textiles | 1.334 |
| 6 | Rubber & leather | 1.941 |
| 7 | Wood | 0.461 |
| 8 | Glass | 3.361 |
| 9 | Metal | 0.67 |
| 10 | Dust , dirt | 0.785 |
| 11 | Others | 2.528 |
| Total | | 100 |

**Table 2: Percentage composition of OFMSW in Palakkad municipality**

| Item | Average % | Std Dev |
|---|---|---|
| Food wastes | | |
| Fruits | 14.82 | 9.663 |
| Veg | 24.59 | 9.045 |
| C.F | 21.96 | 10.78 |
| Total food | 61.37 | 11.89 |
| Paper | | |
| Low grade paper | 3.53 | 1.547 |
| Cup,plate | 4.09 | 3.366 |
| Printed paper | 5.22 | 4.006 |
| packing paper | 4.27 | 3.899 |
| Book and notice paper | 1.31 | 1.158 |
| Total paper | 18.42 | 6.344 |
| Yard wastes | | |
| Palntain leaves | 10.68 | 5.61 |
| Other dry leaves | 8.01 | 8.201 |
| dry leaves | 1.52 | 1.128 |
| Total yard wastes | 20.21 | 11.45 |
| Total | 100 | |

**Table 3: % Content of components of food wastes in Palakkad Municipality from household survey**

| Item | Average % | Standard Deviation |
|---|---|---|
| Cooked food | 11.15 | 10.65 |
| Vegetables | | |
| Pumpkin | 8.62 | 7.99 |
| Cucumber | 8.31 | 8.01 |
| Plantain | 11.57 | 6.67 |
| Spinach | 3.85 | 4.74 |
| Potato | 1.66 | 2.76 |
| Cabbage | 2.66 | 3.26 |
| Onion | 2.16 | 1 |
| Tomato | 2.14 | 1.36 |
| Total Vegetables | 40.96 | 17.36 |
| Fruits | | |
| Banana | 13.64 | 5.88 |
| Papaya | 5.11 | 2.45 |
| Orange | 6.13 | 7.72 |
| Total Fruits | 24.88 | 7.89 |
| Fish | 13.33 | 14.57 |
| Total Food | 90.33 | 7.48 |
| Paper | 3.04 | 2.79 |
| Yard wastes | | |
| Green leaves | 4.15 | 4.87 |
| Dry leaves | 2.48 | 3.8 |
| Total Yard wastes | 6.63 | 6.59 |
| Total | 100 | |

**Table 4: C/N ratio and moisture content of the substrate components**

| Item | C/N ratio | C | N | Moisture (%) |
|---|---|---|---|---|
| Cooked Food (Rice) | 110.00 | 22.08 | 0.20 | 77.19 |
| Pumpkin | 50.00 | 48.98 | 0.98 | 92.21 |
| Ashgourd | 10.00 | 29.64 | 2.96 | 93.32 |
| Plantain | 20.00 | 33.28 | 1.66 | 78.00 |
| Spinach | 17.81 | 28.67 | 1.61 | 82.17 |
| Potato | 25.00 | 34.56 | 1.50 | 79.00 |
| Cabbage | 12.00 | 43.20 | 3.60 | 93.00 |
| Onion | 11.50 | 40.96 | 3.76 | 91.00 |
| Tomato | 12.00 | 39.60 | 3.30 | 94.00 |
| Banana (fruit) | 3.30 | 6.24 | 1.89 | 89.33 |
| Papaya | 4.00 | 8.11 | 2.03 | 91.86 |
| Orange | 400.00 | 11.23 | 0.03 | 92.34 |
| Low grade paper | 40.00 | 31.98 | 0.80 | 0.81 |
| Cup | | 31.04 | | 5.26 |
| Plate | | 9.98 | | 0.79 |
| Packing paper | 500.00 | 500.00 | 0.00 | 0.50 |
| Printed paper | 500.00 | 33.07 | 0.07 | 0.50 |
| Book, Notice paper | 110.00 | 35.00 | 0.50 | 11.50 |
| Plantain leaves | 5.82 | 40.71 | 7.00 | 85.00 |
| Other green leaves | 7.99 | 41.00 | 5.13 | 61.39 |
| Dry leaves | 50.00 | 48.36 | 0.97 | 0.10 |

**Table 5: Various categories of wastes and their field / actual moisture content (MC)**

| Sl. No | Category of wastes | % by weight of OFMSW | Field moisture content (%) | Actual Moisture content (%) |
|---|---|---|---|---|
| 1 | Food wastes | 61.37± 11.9 | 73.07± 8.5 | 86.96± 1.2 |
| 2 | Paper wastes | 18.42± 6.34 | 36.02± 5.5 | 5 ± 4.5 |
| 3 | Yard wastes | 20.21 ± 11.45 | 45.7 ± 11.3 | 48.7 ± 14.25 |

**Table 6: % wet weight required for compost recipe**

| Sl No | Category | % composition in field | Field moisture content (%) | Moisture content in unmixed waste (%) | Dry weight (%) | % wet weight required for compost recipe |
|---|---|---|---|---|---|---|
| 1 | Food waste | 61.37 + 11.9 | 73.07 + 8.5 | 86.96 + 1.2 | 16.52 + 9.44 | 78.95+ 4.52 |
| 2 | Paper | 18.42 + 6.34 | 36.02 + 5.5 | 5 + 4.5 | 11.78 + 5.42 | 7.72+ 1.25 |
| 3 | Yard waste | 20.21 + 11.45 | 45.7 + 11.3 | 48.7 + 14.25 | 10.97 + 7.8 | 13.33+ 5.76 |

**Table 7: Categorization of food waste**

| Sl No | Category | % composition | Moisture conten | Actual moisture | % wet weight required |
|---|---|---|---|---|---|
| | | | t (%) | content | |
| 1 | Fruits | 14.82 ± 9.66 | 73.2 ±5.5 | 91.18±2 .3 | 29.16 ± 5.3 |
| 2 | Vegetables | 24.59 ± 9.05 | 75.2 ±4.3 | 87.84±2 .5 | 31.4 ±6.5 |
| 3 | Cooked Food | 21.96 ± 10.8 | 70.6± 3.2 | 75.19±1 .2 | 18.39 ± 4.5 |

**Table 8: Percentage composition of the synthetic waste**

| Sl No | Category | % composition by weight |
|---|---|---|
| 1 | Fruits | 29.16 |
| 2 | Vegetables | 31.4 |
| 3 | Cooked food | 18.39 |
| 4 | Paper-mixed | 7.72 |
| 5 | Yard waste | 13.33 |

**Table 9: Compost recipe from spread sheet**

| **Item** | **C %** | **N %** | **C/N** | **M %** | **Dry wt.%** | **W (kg)** | **M x W** | **(100-M) W** | C x (100-M)W | Nx (100-M) x W |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 22 | 0.2 | 110 | 75.2 | 24.8 | 1.85 | 139 | 45.9 | 1010 | 9.18 |
| 2 | 29.1 | 2.96 | 9.8 | 93.3 | 6.68 | 0 | 0 | 0 | 0 | 0 |
| 3 | 49 | 0.98 | 50 | 92.2 | 7.79 | 0 | 0 | 0 | 0 | 0 |
| 4 | 42 | 1.3 | 32 | 79 | 21 | 0 | 0 | 0 | 0 | 0 |
| 5 | 33.3 | 1.66 | 20 | 74 | 26 | 1.2 | 88.8 | 31.2 | 1038 | 51.92 |
| 6 | 43.2 | 3.6 | 12 | 93 | 7 | 0.4 | 37.2 | 2.8 | 121 | 10.08 |
| 7 | 28.7 | 1.66 | 17 | 77.2 | 22.8 | 0.8 | 61.8 | 18.2 | 522.9 | 30.28 |
| 8 | 41 | 3.76 | 11 | 91 | 9 | 0.4 | 36.4 | 3.6 | 147.5 | 13.54 |
| 9 | 39.6 | 3.3 | 12 | 94 | 6 | 0.4 | 37.6 | 2.4 | 95.04 | 7.92 |
| 10 | 6.24 | 1.89 | 3.3 | 89.3 | 10.7 | 0.97 | 86.7 | 10.3 | 64.58 | 19.56 |
| 11 | 8.11 | 2.03 | 4 | 91.9 | 8.14 | 1.94 | 178 | 15.8 | 128.1 | 32.06 |
| 12 | 11.2 | 0.03 | 374 | 87.3 | 12.7 | 0 | 0 | 0 | 0 | 0 |
| 13 | 32 | 0.8 | 40 | 0.81 | 99.2 | 0.36 | 0.29 | 35.7 | 1142 | 28.5 |
| 14 | 33.1 | 0.07 | 500 | 4.5 | 95.5 | 0 | 0 | 0 | 0 | 0 |
| 15 | 35 | 0.5 | 70 | 11.5 | 88.5 | 0.36 | 4.14 | 31.9 | 1115 | 15.93 |
| 16 | 31 | 0 | | 5.26 | 94.7 | 0 | 0 | 0 | 0 | 0 |
| 17 | 9.98 | 0 | | 0.79 | 99.2 | 0 | 0 | 0 | 0 | 0 |
| 18 | 500 | 0 | | 0.5 | 99.5 | 0 | 0 | 0 | 0 | 0 |
| 19 | 40.7 | 7 | 5.8 | 85 | 15 | 0.33 | 28.1 | 4.95 | 201.5 | 34.65 |
| 20 | 48.4 | 0.97 | 50 | 0.1 | 99.9 | 0.99 | 0.1 | 98.9 | 4783 | 95.93 |
| 21 | 40.8 | 2.4 | 17 | 82.7 | 17.4 | 0 | 0 | 0 | 0 | 0 |
| 22 | 41 | 5.13 | 8 | 61.4 | 38.6 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | 10 | 698 | 302 | 10369 | 349.5 |
| | | | | | | | | | | 29.7 |

C: Carbon, N: Nitrogen, M: Moisture Content,
W: Weight of sample

**Table 10: Items of the Compost recipe in Table 9**

| Item No: | Item |
|---|---|
| 1 | Boiled rice |
| 2 | ash gourd |
| 3 | Pumpkin |
| 4 | Potato |
| 5 | green banana |
| 6 | cabbage |
| 7 | spinach |
| 8 | Onion |
| 9 | Tomato |
| 10 | banana fruit |
| 11 | Papaya |
| 12 | Orange |
| 13 | low grade paper |
| 14 | Newspaper |
| 15 | book,notice-paper |
| 16 | paper cup |
| 17 | paper plate |
| 18 | packing paper |
| 19 | Plantain leaves |
| 20 | Dry leaves |
| 21 | Grass clippings |
| 22 | Green leaves |

Fig 1: A typical synthetic compost recipe before mixing components


Fig 2: In-vessel reactor for lab-scale composting studies

The recipe identified here gives a moisture content of 69.83 and a C/N ratio of 29.66. This recipe (Fig. 1) was used for an experimental run in a lab-scale in-vessel composting reactor (Fig. 2). Once the carbon, nitrogen and moisture content of the components of substrates are known by choosing the right material and adjusting the weights, the compost recipe can be prepared for given value of total weight, C/N ratio and moisture content, for different experimental runs.

## 3. CONCLUSION

Use of synthetic waste in composting studies enables repeatability and reproducibility of the experiments. Simulated waste in experiments will give a true picture of the behaviour of the original waste. Carbon, nitrogen and moisture content of materials greatly influence the selection and the weight of material to be included for preparing compost recipe.

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