# RATIO MODELING FOR EFFICIENT BIODEGRADATION OFORGANIC SUBSTANCES IN LIGNOCELLULOSIC BIOMASS

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## Introduction

The organic waste in Malaysia can be grouped into domestic waste, agriculture residues, animal wastes and sewage sludge and wood chips. Agriculture residues accounted nearly 70% of total 70 million tons of organic waste discharged in Malaysia per year [1]. This follows by domestic waste 9.5%, and the rest make up the total percentage. Malaysia is enjoying the achievement as one of the world's largest palm oil producers, with total export volume of 18 million metric tons of crude palm oil per year [2]. However, the achievement comes at a price. Several studies pointed out that production of single ton of crude palm oil generate huge amount of by-products which include 1425 kg of empty fruit bunch (EFB), 300 kg of palm kernel shell (PKS), 150 kg of mesocarp fiber, 150 kg of decanter cake (DC), 300 kg palm kernel cake (PKC) and 3 ton of palm oil mill effluent (POME) with total solid content of 0.6% [3,4]. EFB make up the largest volume of organic material waste in term of weight over weight (w/w) basis (20.41 million tonnes/year). Ideally, EFB generated from palm oil production should be returned to the plantation to enrich the soil through the composting process. Nonetheless, long period for composting of EFB to reach maturity (up to 180 days) poses problems in the industrial scale composting due to high land area needed.

The composting process can be shortened to three to four weeks by co-composting with different organic materials. In co-composting, by combining the two or more organic materials, the benefits of each can be used to optimize the process and the product. The key for starting a successful matching ingredient for co-composting is to understand the physical and chemical characteristic of organic waste materials. Analysing organic waste materials for their physical and chemical characteristics helps in developing co-composting recipes.

## Ratio Modeling of Matching Ingredients for EFB and Other Organic Materials for Efficient Biodegradation

This ratio modeling aims to provide recipes for starting a successful composting process and making good compost. The ideal composting are C/N ratio of the composting material between 20/1 and 40/1 [5]. Excessive or insufficient quantities of carbon or nitrogen greatly affect the composting process. High initial C/N ratio will cause a slower beginning of the process and the required composting time to be longer than usual [6,7] while low initial C/N ratio results in high emission of $NH_3$ [7,8]. Maximum degradation efficiency is achieved through altering the C/N ratio. As mentioned, EFB is high in C/N ratio and require proper treatment for efficiency composting. Therefore, nitrogen source materials or co-composting substrates need to be added to the EFB compost pile to increase the compost efficiency. The nitrogen sources are important for microorganism to grow and reproduce. Carbon is the basic building block of life and is a source of energy. Given the proper C/N ratio, microorganisms are able to reproduce very quickly, thus, increase the composting rate. Based on the ratio of carbon to nitrogen, the organic waste materials can be separated into two groups; nitrogen source materials (C/N <30) and carbon source materials (C/N >30). In this section, a right ratio of EFB (C/N: 57.89) mixed with nitrogen source organic waste materials in co-composting was discussed. POMS (C/N: 8.05), decanter cake (C/N: 23.71), PKC (C/N: 18.44), coffee grounds (C/N: 27.29), cocoa shell (C/N: 25.9), chicken manure (C/N: 6.1) and sewage sludge (C/N: 11.05) which grouped as nitrogen were formulated with EFB using Eq. 1 to develop co-composting recipes with C/N ratio of 30.

$$\text{C/N ratio} = \frac{\text{Weight of Carbon in Material A} + \text{Weight of Carbon in Material B}}{\text{Weight of Nitrogen in Material A} + \text{Weight of Nitrogen in Material B}} \quad \text{Eq. 1}$$

To use the equation, carbon and nitrogen content of selected materials are required. C/N ratio of the mixture is calculated based on weight basis of carbon and nitrogen content of the materials. The calculation for C/N ratio is in dry weight basis.

Table 1 shows the mixing ratio for the selected organic waste materials. Theoretically, mixture I– VII are ideal mixing ratio for effective of co-composting of EFB with other organic materials. Results in Table 5 can be divided into two groups, mixture with EFB as major compost feedstock (ratio>50%) and EFB as minor major compost feedstock (ratio <50%). Mixtures having EFB ratio < 50% in the effective co-composting model (I, II and III) can be achieved by adding coffee grounds, cocoa shell and DC which are higher C/N ratio compared to other organic materials. Other nitrogen sources like POMS, sewage sludge, chicken manure and PKC with lower C/N ratio (< 20) lead to higher EFB (>50%) can be added in the compost pile. This will lead to more EFB able to be returned to the soil.

Adding single nitrogen source into the EFB compost will generate model with either little quantity of EFB (less than 10%) or huge amount of EFB (more than 70%). EFB with exceptionally low bulk density (66.98 kg/$m^3$) should be put into consideration. The bulk density indirectly provides a measure of the porosity. EFB with high porosity affects the water absorption in compost. If the water absorption too high, the composting temperature might not increase. Due to the physical characteristic of EFB, the percentage ratio of EFB in a co-compost pile should not be too high. Thus, other feedstock with higher bulk density should be added. In order to fully utilize the EFB, mixture with optimal EFB content should be considerate in the mixing ratio. Therefore, the ideal quantity of EFB in the co-composting should be in the ranged in 50 - 60%.

Table 1. The following mixing ratio is derived from the Eq.1 to achieve C/N ratio of 30.

| Mixture | EFB (%) | Coffee Grounds (%) | Cocoa Shell (%) | Poms (%) | Sewage Sludge (%) | DC (%) | Chicken Manure (%) | PKC (%) |
|---|---|---|---|---|---|---|---|---|
| I. | 7 | 93 | - | - | - | - | - | - |
| II. | 24 | - | 76 | - | - | - | - | - |
| III. | 37 | - | - | - | - | 63 | - | - |
| IV. | 57 | - | - | - | - | - | - | 43 |
| V. | 78 | - | 22 | - | - | - | - | - |
| VI. | 78 | - | - | - | 22 | - | - | - |
| VII. | 87 | - | - | - | - | - | 13 | - |

The new model for effective co-composting with two nitrogen sources and EFB presented in Table 2. EFB mixes with two nitrogen source create a practical mixing ratio with appropriate amount of EFB (50 – 60%) that achieve the favourable C/N ratio and bulk density. In this study, Mixtures IV - VIII in Table 6 are considered to be the most effective mixing ratio for EFB co-composting.

Table 2. Mixing ratio of EFB co-composting with two nitrogen source.

| Mixture | EFB (%) | Coffee Grounds (%) | Cocoa Shell (%) | Poms (%) | Sewage Sludge (%) | DC (%) | Chicken Manure (%) | PKC (%) |
|---|---|---|---|---|---|---|---|---|
| I. | 17 | 37 | 46 | - | - | - | - | - |
| II. | 30 | - | 37 | - | - | 33 | - | - |
| III. | 37 | 36 | - | - | - | - | - | 27 |
| IV. | 50 | 37 | - | 13 | - | - | - | - |
| V. | 50 | - | 37 | - | 13 | - | - | - |
| VI. | 52 | - | 37 | 11 | - | - | - | - |
| VII. | 52 | - | 37 | - | 11 | - | - | - |
| VIII. | 56 | 36 | - | - | - | - | 8 | - |
| IX. | 68 | - | - | 12 | - | - | - | 20 |

## Conclusion

The study on physical and chemical analysis of representative materials helps in selection of suitable organic materials for composting process. Most of the organic materials are not suitable to be composted alone due to impropriate C/N ratio. Organic waste materials with higher nitrogen content can mix with EFB in co-composting. The model presented here suggested that percentage of EFB ranged between 50- 60% considered as ideal mixing ratio in effective co-composting. The ratio modeling of matching ingredients for EFB and other organic materials co-composting determined here can as foundation and starting point for any real composting process.

Heaps of EFB prepared for composting


Materials were mixed according to the ratio and heap using a bulldozer

Temperature Monitoring

Co-composting - was prepared by mixing EFB with two nitrogen source (according to the ratio)

## References


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