Study of C/N ratio of organic materials and its application in the production of natural fertilizer (bokashi)

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Abstract. Bokashi is an organic fertilizer made from organic materials through fermentation process. A high quality bokashi should have C/N ratio between 10-20, which normally produced from a mix raw organic material with has C/N ratio of 30. However, many studies have shown a composition of raw organic material without a calculation of C/N ratio. Therefore, the objectives of this study were to gather the initial C/N ratio of various raw material from previous published studies, calculate the C/N ratio, and examine the descriptive characteristic (colour, aroma, and texture) of bokashi made from three selected C/N ratios of raw material (30, 70, and 110) and various length of fermentation (10, 17, and 24 days). This research combined literature reviews and laboratory experimental. For laboratory experimental, Complete Randomise Design (CRD) was applied. The result showed that all bokashi produced from raw material mixture with the C/N ratio up to 110 was still acceptable to be directly applied as a fertilizer. Bokashi produced with longer fermentation time had better texture but lower aroma and colour quality.

1. Introduction
Bokashi is an organic fertilizer made from organic material through fermentation process. Currently, organic fertilizer is often used by farmers because it can improve the soil quality which needed by plants to increase the productivity [1]. Bokashi is produced with an addition of bio decomposers which is known as local microorganisms (MOL).

MOL is an activator in the fermentation which can accelerate the decomposition of complex organic matter [2]. During fermentation, the organic material will be decomposed into simpler compounds [1]. Vegetable and fruit waste is a good medium for the proliferation of decomposing microorganisms so that it can be used as a bio activator in the composting process [3]. The MOL solution contains micro and macro nutrients as well as lactic acid bacteria [4].

The availability of raw organic materials in the community is certainly a more concern for observers and agricultural experts. The use of organic materials in bokashi production by the
community or researcher in general is still carried out by adjusting the proportion of raw materials, without considering the C/N ratio of the raw materials used in detail.

The raw organic matter cannot be directly used by plants because the C/N ratio of the raw material does not match the one of the soil. Therefore, the objectives of this study were to gather initial C/N ratio of various raw material from previous published studies, calculate the C/N ratio of raw material mixture based on its individual proportion of organic matter, and examine the descriptive characteristic (colour, aroma, and texture) of bokashi produced from three selected C/N ratios of raw material mixtures (30, 70, and 100) and various length of fermentation (10, 17, and 24 days).

2. Materials and methods

2.1. Materials
The materials used in this study were cow manure, husk ash, bran, sawdust and MOL. The manure was obtained from cattle farm, the husk ash and the bran from rice mills, and the sawdust from a wood factory. All raw materials were collected in Aceh Besar District, Aceh Province, Indonesia.

2.2. Experimental design
This research combined literature reviews and laboratory experimental. The C and N numbers of organic materials data were collected from previous work published from 2013 to 2021 in Banda Aceh and Aceh Besar, Indonesia. The C/N ratio of raw materials was calculated using Formula 1 and the C/N ratio of bokashi was calculated using Formula 2.

\[
\text{C/N Ratio of Raw Materials} = \frac{\% C}{\% N}\quad (1)
\]

\[
\text{C/N Ratio of Bokashi} = \frac{\left(\% A_1 \times \frac{C}{N} \text{ of } A_1 \right) + \left(\% A_2 \times \frac{C}{N} \text{ of } A_2 \right) + \left(\% A_3 \times \frac{C}{N} \text{ of } A_3 \right) + \left(\% A_n \times \frac{C}{N} \text{ of } A_n \right)}{\left(\% A_1 + \% A_2 + \% A_3 + \% A_n \right)}\quad (2)
\]

A1, A2, A3, An: individual raw material

The obtained C/N data of individual raw material collection than used to estimate the C/N ratio of raw material mixture from various previous bokashi studies. Three C/N ratios of raw material mixture were then selected to be prepared as factor of this study, besides the length of fermentation process. The analyse was focused on the descriptive characteristics of produced bokashi. The research used a completely randomized design (CRD) with two factors. The first factor was C/N ratio of bokashi raw materials (R) consisted of 3 levels. The second factor was length of fermentation (L) also consisted of 3 levels. Each treatment was repeated twice so that totally there were 18 experimental units (Table 1).

| Table 1. Combination between treatments of bokashi production. |
|-----------------|-----------------|-----------------|
| C/N Ratio of Raw Material Mixture (R) | Length of Fermentation (Days; L) | Replicates (U) |
| 30 (R1) | 10 (L1) | R1L1U1, R1L1U2 |
| | 17 (L2) | R1L2U1, R1L2U2 |
| | 24 (L3) | R1L3U1, R1L3U2 |
| 70 (R2) | 10 (L1) | R2L1U1, R2L1U2 |
| | 17 (L2) | R2L2U1, R2L2U2 |
| | 24 (L3) | R2L3U1, R2L3U2 |
| 110 (R3) | 10 (L1) | R3L1U1, R3L1U2 |
| | 17 (L2) | R3L2U1, R3L2U2 |
| | 24 (L3) | R3L3U1, R3L3U2 |
2.3. Production of MOL [5]
MOL was made from fruit waste materials (California papaya (*Carica papaya* L.) and banana (*Musa balbisiana*). Fruit waste material was peeled, cut into small pieces, weighed as much as 750 grams each and crushed with a blender. Then, the first rinsed rice water (1500 ml) and sugar (60 grams) were added and stirred until homogeneous. The mixture was put into a jar container and tightly closed for 7 days fermentation at room temperature.

2.4. Production of bokashi [7]
The formulation for production of bokashi can be seen in Table 2. The raw materials were mixed with MOL (0.5% by weight of the total raw materials) and were stirred evenly. The mixture was fermented for 10 days, 17 days and 17 days. The quality of bokashi (texture, aroma, and colour) was analysed using a descriptive organoleptically test. The scale used for texture analysis: 1 describes very bad (very rough), 2 describes bad (rough), 3 describes ordinary (little loose), 4 describes good (loose), and 5 describes very good (loose and slightly moist). The scale for aroma analysis: 1 describes very bad (stink), 2 describes bad (raw material smell), 3 describes ordinary (slightly earthy), 4 describe good (scented earth), and 5 describes very good (very scented earth). The scale for colour analysis, 1 describes very bad (raw material colour), 2 describes bad (a bit like raw material), 3 describes ordinary (slightly brown), 4 describes good (brownish black), and 5 describes very good (black).

| C/N Ratio of Raw Material Mixture | Rice Bran (%) | Sawdust (%) | Husk Ash (%) | Cow Manure (%) |
|----------------------------------|---------------|-------------|--------------|---------------|
| 30                               | 5             | 5           | 5            | 85            |
| 70                               | 15            | 15          | 15           | 55            |
| 110                              | 25            | 25          | 25           | 25            |

2.5. Statistical analysis
The organoleptic data was analysed using ANOVA (Analysis of Variance). If a treatment test shows a significant effect between treatments for descriptive analysis, it is followed by a further test to determine the effect between level using Duncan's follow-up test (DMRT) using SPSS (IBM Software version 22).

3. Results and discussion

3.1. Brief overview of C/N ratio of raw organic materials
Organic waste is often obtained from by-product of a process, nature, or the result of human activities. The potential sources of organic waste in Banda Aceh, Aceh Province, Indonesia that are easy to get and can be applied in the production of bokashi can be seen in Table 3.

In the production of bokashi, in addition to paying attention to the C/N ratio of raw materials, the benefits of using organic waste as the main raw material must also be considered with the aim of accelerating the fermentation process and containing micro and macro nutrients needed by plants. The C content, N content and the calculated C/N ratio of organic materials can be seen in Table 4. While the estimated C/N ratio of four selected raw material mixtures of previous bokashi studies can be seen in Table 5.
Table 3. Potential sources of organic waste in Banda Aceh, Aceh Province, Indonesia.

| No | Waste Source             | Organic Materials                  |
|----|--------------------------|------------------------------------|
| 1  | Roadside sugarcane seller| Sugarcane bagasse                  |
| 2  | Chicken farm             | Chicken manure                     |
| 3  | Cow cattle farm          | Cow dung                           |
| 4  | USK waste bank           | Leaf litter                        |
| 5  | Wood mill                | Sawdust and tree bark              |
| 6  | Rice mill                | Bran, husk ash and rice husk       |
| 7  | Vegetable market         | Left over vegetables and fruits    |
| 8  | Fish market              | Fish bones and fish heads          |
| 9  | Goat farm                | Goat dung                          |
| 10 | Community plantation     | Dried grass, banana stalks, coconut husks and rice straw |
| 11 | Coffee shop              | Coffee dregs and tea dregs         |

Table 4. C, N, and the calculated C/N ratio of individual organic materials.

| No | Waste Name     | References | C (%) | N (%) | Calculated C/N Ratio of Raw Material* |
|----|----------------|------------|-------|-------|--------------------------------------|
| 1  | Chicken manure | [1]        | 17.2  | 1.31  | 13.57                                |
| 2  | Cow dung       | [1]        | 23.83 | 0.83  | 25.41                                |
| 3  | Cow manure     | [6]        | 10.56 | 0.81  | 13.03                                |
| 4  | Goat dung      | [1]        | 20.28 | 0.97  | 21.28                                |
| 5  | Sawdust        | [6]        | 39.71 | 0.14  | 283.34                               |
| 6  | Paper waste    | [7]        | 26.5  | 1.1   | 37.7                                 |
| 7  | Rice straw     | [8]        | 45.98 | 1.05  | 43.94                                |
| 8  | Rice bran      | [6]        | 35.45 | 1.51  | 23.48                                |
| 9  | Husk ash       | [6]        | 22.38 | 0.18  | 124.36                               |
| 10 | Coir           | [9]        | 42.1  | 3.92  | 10.77                                |
| 11 | Fish waste     | [10]       | 1.56  | 2.07  | 0.75                                 |
| 12 | Coffee grounds | [11]       | 28.16 | 1.10  | 25.6                                 |
| 13 | Chocolate fruit skin | [12] | 10.02 | 0.61  | 16.61                                |
| 14 | Corn skin      | [13]       | 1.75  | 0.08  | 15                                   |
| 15 | Coconut pulp   | [11]       | 26.78 | 1.05  | 25.51                                |
| 16 | Banana peel    | [14]       | 6.59  | 2.94  | 10.49                                |
| 17 | Sago dregs     | [15]       | 14.35 | 0.99  | 15.18                                |
| 18 | Coconut shell charcoal | [16] | 1.12  | 0.12  | 9.33                                 |
| 19 | Sweet potato skin | [17] | 33.59 | 0.51  | 66.49                                |
| 20 | Tofu dregs     | [9]        | 42.8  | 3.56  | 12.01                                |

*Based on Formula 1

Cow dung has a high nitrogen, potassium, and fibre content so it is good to be used as raw material for making bokashi. The benefits of using cow dung in making bokashi is it can improve nutrients in the soil, increase the population of soil microbes so that the soil texture remains loose and improve the basic state (pH) of the soil [18]. Bran is potential in the production of bokashi because it contains excellent nutrients for microorganisms [19]. The nutritional content of bran that utilizes fermented bacteria can stimulate the growth of microorganisms [20].

Sawdust is one of the raw materials that is often used in the manufacture of bokashi, sawdust contains chemical components such as cellulose, lignin and extractive substances [21]. The benefits of sawdust are that it can absorb large amounts of water and can store nutrients and have high porosity.
Giving rice husk ash to the soil can help aerate the soil so that it will facilitate the movement of air and water in the soil and greatly assist the plant root system [22].

According to [6], the optimal C/N value of raw material mixture in making bokashi is 30. However, many previous researches on making bokashi did not pay attention to the C/N ratio of raw materials, so that the initial C/N ratio of the raw material mixture base on the calculation which using the data of Table 4 could exceed 30 (Table 5). The most frequent used formula for raw material mixture is made by adding 55% cow dung, 15% sawdust, 15% bran and 15% husk ash.

| Raw Materials        | Reference Sources |
|----------------------|-------------------|
|                      | [1]   | [5]   | [7]   | [15]  |
| Cow dung             | 65%   | 20%   | 42%   | 25%   |
| Husk ash             | 10%   | -     | 11.5% | 15%   |
| Sawdust              | 10%   | -     | -     | 15%   |
| Ricew bran           | 15%   | 10%   | 11.5% | 15%   |
| Sago pulp            | -     | -     | -     | 15%   |
| Fish bone meal       | -     | -     | -     | 15%   |
| USK waste bank       | -     | 70%   | -     | -     |
| Paper waste          | -     | -     | 35%   | -     |
| Estimated C/N ratio of raw material mixture* | 61    | 49    | 41    | 73    |

* Based on Formula 2

### 3.2. Descriptive characteristics of bokashi

#### 3.2.1 Texture

Organoleptic (descriptive) testing of the texture of the bokashi at each treatment level was between 1 (very bad/rough) and 4 (good/loose) with an average of 3 (ordinary/slightly loose). The results of analysis of variance showed that the ratio of C/N (R) and fermentation time (L) had a very significant effect (P≤0.01) on the texture of the bokashi, while the interaction between two treatments had a significant effect (P≤0.05). The effect of the interaction between the two (RL) on the texture of the bokashi can be seen in Figure 1; the longer the fermentation process, the higher the value of the texture. This is in accordance with the results of [7].

![Figure 1](image_url)

**Figure 1.** The interaction effect of the C/N ratio of raw materials and fermentation time (RL) on the value of bokashi texture (values followed by unequal letters indicate a very significant difference (P≤ 0.01) DMRT=0.57, KK=9.02%. Descriptive scale of texture: 1 describes very bad (very rough), 2 describes bad (rough), 3 describes ordinary (little loose), 4 describes good (loose), and 5 describes very good (loose and slightly moist).
3.2.2 Aroma. Descriptive analysis on aroma of bokashi was from 1.5 (very bad/raw material smell) to 4 (good earth smell) with an average of 3 (ordinary/slightly earthy smell). The results of the analysis of variance showed that the treatment ratio of C/N (R) (Figure 2) and fermentation time (L) (Figure 3) had a significant effect (P≤0.05) on the aroma of bokashi.

**Figure 2.** The effect of the C/N ratio of raw materials on the aroma value of bokashi (values followed by unequal letters indicates a significant difference (P≤0.05) DMRT0.05 = 1.28, KK = 18.60%. Descriptive scale of aroma: 1 describes very not good (raw material), 2 describes not good (a little smell of raw material), 3 describes plain (slightly earthy), 4 describe good (scented earth), and 5 describes very good (very scented earth).

The higher the initial C/N ratio of the raw materials affected the produced aroma of bokashi which was less good (scented raw materials). A good bokashi is one that has a scent close to the smell of earth [23]. This is because the decomposition process of raw materials is not perfect because the C/N ratio used is too high. To improve the aroma with a high C/N ratio, a longer fermentation can be carried out. The higher the value of the C/N ratio used, the longer the fermentation process required.

**Figure 3.** The effect of fermentation time on the aroma value of bokashi (the value followed by the letter is not the same shows a significant difference (P≤0.05) DMRT 0.05 = 1.28, KK = 18.60%. Descriptive scale of aroma: 1 describes very not good (raw material), 2 describes not good (a little smell of raw material), 3 describes plain (slightly earthy), 4 describe good (scented earth), and 5 describes very good (very scented earth).
From Figure 3, we can see that the length of fermentation affects the aroma produced in the bokashi. After 10 days fermentation, the aroma of bokashi decreased. Some of aroma indicating good quality bokashi were disappeared or evaporated into the air.

3.2.3. Colour. Organoleptic test (descriptive) on the colour of each treatment level ranged from 2 (bad/ slightly like the raw material) to 5 (very good/black) with an average of 3 (ordinary/slightly brown). The results of the analysis of variance of the C/N ratio (R) have a significant effect (P≤0.01) on the colour of bokashi (Figure 4). It can be seen in Figure 4 that the colour of bokashi was affected by the C/N ratio of raw material mixture. The bokashi produced from the raw material with higher C/R ratio had lower colour quality. The C content in material with higher C/N ratio was also still high.

4. Conclusion
The result showed that the estimation (calculation) of C/N ratio of raw material mixture of previous studies was above 30 (41-73), and it could still produce good quality bokashi. The results of experimental research in this study showed that in general the C/N ratio of raw material mixture up to 110 also could produce good bokashi, however the higher C/N ratio of raw material mixture used, the lower aroma and colour quality of bokashi produced. Bokashi produced with longer fermentation time had better texture quality.

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