

COMPOSTING OF RICE STRAW WITH EFFECTIVE MICROORGANISMS (EM) AND ITS INFLUENCE ON COMPOST QUALITY*

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Abstract

This study aimed to assess the effect of EM application on the composting of rice straw with cow dung and to evaluate the quality of compost. Four treatment piles were investigated in this study, in which two piles (rice straw and cow dung ratio of 1:1 and 2:1) were applied with EM and another two piles (rice straw and cow dung ratio of 1:1 and 2:1) were treated without EM as control. Changes in temperature, pH, total organic carbon, height of compost piles, moisture content and C/N ratio showed that decomposition of organic matter occurs during 90 days of composting in EM treatments and 120 days in control treatments. It was also found that the composts produced from rice straw and cow dung ratio of 2:1 possessed better characteristics and higher nutrient values than those produced from raw materials ratio of 1:1. The application of EM in composting increased the macro and micronutrient contents of compost. In the range of the matured level the studied parameters supported this conclusion: compost applied with EM has more N (1.52%), P (0.34%) and K (1.36%) content compared with compost without EM in which N (0.92%), P (0.18%) and K (0.91%). This study suggested that the application of EM shortened the composting process and increased the mineralization of compost.

Keywords: effective microorganisms, composting process, C/N ratio, macronutrient, micronutrient

Introduction

Rice is the most important staple food for a large part of the world's human population. It is the grain with the second highest worldwide production, after maize (corn). In Myanmar, rice is the main source of carbohydrate and grows in every part of the country. Besides producing rice seed, it also produces a large amount of waste by-product of which, one is rice straw residue. A major portion of the agricultural waste is disposed of by burning or is mulched in the rice fields. These wastes, if not properly handled, will cause many problems to farmers as well as to the environment. If rice straw is left in the field without proper management, it can cause the

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spreading of disease, such as stem disease and can also encourage the breeding of pests, especially rats. Burning is not the best way to deal with such waste, as it is harmful to the environment.

The rice straw can be converted to biofertilizer through the process of composting. Composting was the first concept for using effective microorganisms (EM) in environmental management. Crop residues and animal wastes have been effectively composted by EM to produce biofertilizers. However, composting of rice straw using effective microorganisms as an accelerator to speed up the composting process has not been well documented (Tiquia, S.M. *et al.* 2002, Bruchem, V. *et al.* 1998 and Shitani, M. 2000).

The aim of this study was to assess the effect of EM application on the composting process of rice straw with cow dung and also to evaluate the nutrients at the end of composting. This study was based on the hypothesis that the application of EM on rice straw would increase the microbial activity and thus, increased the composting rate. It also increases the mineralization process of compost through the enhanced microbial colonization and activity. To test these hypotheses, compost from rice straw residue was produced with application of EM and compared to non-EM treatment.

The objectives of the study were:

- (a) to produce compost from rice straw and cow dung by the application of Effective Microorganism (EM);
- (b) to assess the composting process by conducting with and without EM;
- (c) to evaluate the quality of compost which are produced by varying the amount of rice straw and cow dung ; and
- (d) to analyze the characteristics of compost samples such as nitrogen content, phosphorus content, potassium content, calcium, magnesium and sulfur contents, total organic carbon content, moisture content, pH, and C/N ratio.

Materials and Methods

Experimental Set up

The experiments were conducted at the Laboratory of Department of Industrial Chemistry, West Yangon University, during the year 2014, taking 4 months (from August 1 to November 30).

Four different treatment methods were studied:

- Treatment 1 (T₁) Composting of rice straw and cow dung (in the ratio of 1:1) with EM
- Treatment 2 (T₂) Composting of rice straw and cow dung (in the ratio of 2:1) with EM
- Treatment 3 (C₁) Composting of rice straw and cow dung (in the ratio of 1:1) without EM
- Treatment 4 (C₂) Composting of rice straw and cow dung (in the ratio of 2:1) without EM

Sources of Raw Materials

Rice straw and cow dung were collected from the rice field adjacent to the West Yangon University. EM culture was obtained from Vegetables and Fruits Research Development Center (VFRDC), Ministry of Agriculture and Irrigation, Ye-Mon, Yangon Region. Rice Rinse Water was collected from food shops of West Yangon University. Jaggery was bought from Insein Market in Insein Township, Yangon Region.

Preparation of Compost Piles

Rice straw was used as the main material for composting together with cow dung. The composting containers were placed in shaded area in the Laboratory. The rice straw was soaked in water for 24 hours and was shredded to get 3 cm length with knife to obtain easy decomposition. In this experiment, four different compost piles were prepared: compost piles with EM (T₁ and T₂) and compost piles without EM (C₁ and C₂) for control. The mixtures used for all piles were arranged with the ratio as follows: 50 % rice straw and 50 % cow dung, in which 7.5kg of rice straw was mixed with 7.5kg of cow dung for T₁ and C₁, and 66% rice straw and 33% cow dung in which 10kg of rice straw was mixed with 5kg of cow dung for T₂ and C₂.

In each compost pile, there were five alternate layers of rice straw and cow dung. For the treatments T₁ and C₁, the bottom, middle and top layers were filled with 2.5kg each of rice straw and the two rice straw layers were sandwiched with 3.75kg each of cow dung as shown in Figure 1 (a). For the treatments T₂ and C₂, the bottom, middle and top layers were filled with 3.3kg

each of rice straw and the two rice straw layers were sandwiched with 2.5kg each of cow dung as shown in Figure 1 (b).

2.5kg of Rice Straw	3.3kg of Rice Straw
3.75kg of Cow Dung	2.5kg of Cow Dung
2.5kg of Rice Straw	3.3kg of Rice Straw
3.75kg of Cow Dung	2.5kg of Cow Dung
2.5kg of Rice Straw	3.3kg of Rice Straw
(a) Compost Piles of T ₁ and C ₁	(b) Compost Piles of T ₂ and C ₂

Figure (1) Layers of Compost Piles

Preparation of Activated EM (EM-A) Solution

EM is a combination of useful regenerative microorganisms. It consists of 80 different kinds of microorganisms including mainly of lactic acid bacteria, photosynthetic bacteria, yeast, actinomycetes, and fermenting fungi (<http://en.wikipedia.org/wiki/EM>).

Activation of EM is a fermentation process occurred by using EM culture, jaggery (Myanmar name - Htanyat) and rice rinse water. City water could not be used in the activation process because city water is chlorinated and chlorine is killer of microorganisms. Jaggery is a traditional uncentrifuged sugar. It is a concentrated product of palm sap, and can vary from golden brown to dark brown in color. It contains up to 50% sucrose, up to 20% invert sugars, up to 20% moisture, and the remainder made up of other insoluble matter, such as wood ash and proteins (<http://en.wikipedia.org/wiki/Jaggery>).

EM-A was prepared by mixing 1 part of EM culture, 1 part of molasses (prepared by dissolving 400g of jaggery in 1 liter of non-chlorinated water) and 8 parts of rice rinse water (obtained by rinsing rice and water in the volume ratio of 1:3 for the first time). The solution was allowed to ferment in an air tight plastic bottle for 5-7 days at room temperature. The built up gas was released once daily starting from the third day of fermentation. EM-A was ready to use when pH value gave in the range 2.5-

4.0. EM-A has a shelf life of 4 weeks. The sweet and sour smell is a good indicator of perishability. If it has a rotten smell then it is no longer suitable for use.

Finally, the EM-A solution to use in composting was prepared by mixing 1 part of EM-A with 9 parts of non-chlorinated water.

Composting Process

Throughout the whole composting period by frequent checking, the moisture content of compost piles were maintained at 50-60% by the addition of EM-A solution in the treatments T₁ and T₂, and non-chlorinated water in the treatments C₁ and C₂. The compost piles were turned at 2 day interval to maintain porosity, to improve aeration, to speed up the microorganism activities and to ensure uniform decomposition. The temperature of compost piles were measured daily with a thermometer at random depths. The height of compost piles were also recorded daily.

Harvesting Process

The composts obtained from T₁ and T₂ were harvested after three months of composting period when the temperature of piles fall below ambient temperature. On the other hand, those obtained from C₁ and C₂ were harvested after four months of composting period. When the composts were ready to harvest, it was kept without applying EM-A solution or non-chlorinated water for five days to make the compost easy for shifting. The harvested composts were spread on the plastic sheets for 3 days to reduce moisture content to about 35%. The dried compost samples were weighed and screened to pass through a 60 mesh sieve and were stored in air tight plastic bags.

Physicochemical Analysis

The physical characteristics (such as moisture content and pH) of rice straw, cow dung and the compost samples were determined at the Laboratory of Department of Industrial Chemistry, West Yangon University. The chemical characteristics (such as carbon to nitrogen ratio, nitrogen content, phosphorous content, potassium content, calcium, magnesium and sulfur

contents, and total organic carbon content) of rice straw, cow dung and four compost samples were analyzed at the Laboratory of Department of Land Use Division, Myanmar Agriculture Service (MAS), Ministry of Agriculture and Irrigation, Yangon Region.

Results and Discussion

It was found that the complete conversion of all the rice straw into compost took 3 months (from August 1 to October 31, 2014) for the treatments with EM (T_1 and T_2). On the other hand, the composting process took 4 months (from August 1 to November 30, 2014) for the treatments without EM (C_1 and C_2). The matured composts were black, light in weight and free from bad odor.

Physicochemical Characteristics of Raw Feedstock

To promote the growth of microbial populations as a way to increase the decomposition of organic matter during composting, a favourable environment or condition must be provided. According to Dalzell, H.W.(1987), for efficient compost production the compost piles should have a carbon to nitrogen ratio (C/N ratio) in the range of 25-35. If it is higher, the composting process will take a long time and if it is lower, the process will give off ammonia. The simplest method of adjusting the C/N ratio is to mix together different materials of high and low carbon and nitrogen contents. Therefore, in this study rice straw which had a high C/N ratio was mixed with cow dung which had low C/N ratio. The physicochemical characteristics of raw feedstock are presented in Table (1). The results showed that the C/N ratio of rice straw and cow dung fall within the range of literature value.

Table (1) Physicochemical Characteristics of Raw Feedstock

Parameters	Rice Straw		Cow Dung	
	Experimental Values*	Literature Values	Experimental Values*	Literature Values**
C/N Ratio	91.1	30-100	27.9	11-30
Total Organic Carbon (%w/w)	43.7	47.8	39.7	44.1
Moisture Content (%w/w)	13.2	-	65.2	-

* The data were determined at the Laboratory of Department of Land Use Division, Myanmar Agriculture Service (MAS), Ministry of Agriculture and Irrigation.

** Aveyard, J. (1988) and Steinegger, D.H. *et al.* (1993)

Weight of Compost Products

With an input of 15 kg of raw feedstock in each treatment, 3.4kg, 3.7 kg, 3.2 kg and 3.3 kg of compost were produced as shown in Table (2). The results showed that the weight of compost produced from all the different treatment methods were almost the same. Since the average moisture content of raw materials (39% w/w) and that of compost (35 %w/w) were nearly the same, it can be assumed that 4 fold reductions in weight was achieved at the end of decomposition process.

Treatments	Weight of Raw Feedstock (kg)			Weight of Composts (kg)
	Rice Straw	Cow Dung	Total	
T ₁	7.5	7.5	15.0	3.4
T ₂	10.0	5.0	15.0	3.7
C ₁	7.5	7.5	15.0	3.2
C ₂	10.0	5.0	15.0	3.3

Table (2) Weight of Raw Feedstock and Compost Products

Treatments	Weight of Raw Feedstock (kg)			Weight of Composts (kg)
	Rice Straw	Cow Dung	Total	
T ₁	7.5	7.5	15.0	3.4
T ₂	10.0	5.0	15.0	3.7
C ₁	7.5	7.5	15.0	3.2
C ₂	10.0	5.0	15.0	3.3

T₁. Composting of rice straw and cow dung (1:1) with EM

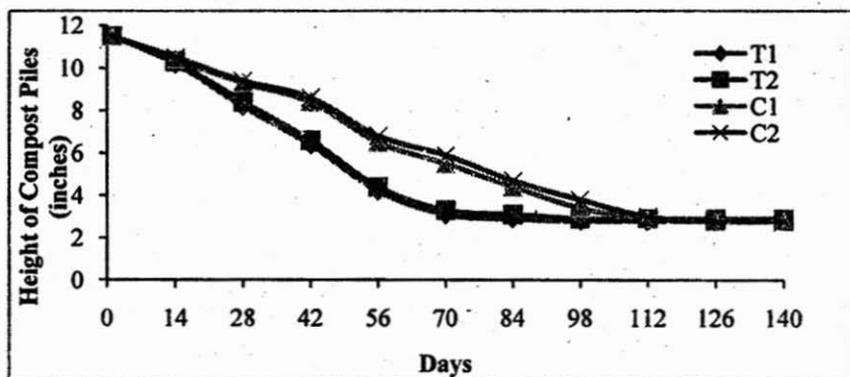
T₂. Composting of rice straw and cow dung (2:1) with EM

C₁. Composting of rice straw and cow dung (1:1) without EM

C₂. Composting of rice straw and cow dung (2:1) without EM

Changes in Height of Compost Piles

Changes in height of piles during the composting process (from 0 to 140 days) were recorded every two weeks and indicated in Figure (2). The changes in height of piles were very significant for the treatments with EM (T₁ and T₂) during 10 days and 70 days and the complete decompositions were achieved in 90 days. For the treatments without EM (C₁ and C₂), the gradual decrease in height of piles were noted up to 120 days and it took 4 months to get complete decomposition. The height of piles reached a minimum of 2.8 and 2.9 inches in T₁ and T₂ and 2.8 and 2.8 inches in C₁ and C₂.



Figure(2)Changes in Height of Compost Piles during Composting Process

Temperature Changes during Composting Process

The temperature pattern showed that there is a rapid progress from the initial mesophilic phase to the thermophilic phase for all different treatment methods. The temperature profiles of four different composting treatment methods are shown in Figure (3). All treatment methods showed an increase in temperature right after composting started.

On Day 14, the temperature rose from 28°C to 37°C for the treatments with EM (T_1 and T_2) and from 28°C to 34°C for the treatments without EM (C_1 and C_2). The piles treated with EM reached the highest peak values of 48°C on the 28th day and also the piles treated without EM reached the highest peak values of 42°C on the 28th day. These showed that all the composting treatments reached thermophilic temperature (>40°C). The increase in temperature was caused by the heat generated from the respiration and decomposition of sugar, starch and protein by the population of microorganisms. The increase in temperature was a good indicator that there was microbial activity in the compost pile.

The thermophilic phase lasted for 28 days for treatment T_1 and T_2 , whereas treatment C_1 and C_2 lasted for 42 days. As shown in Figure (3), the temperature gradually decreased afterwards and finally stabilized near the ambient temperature at 84-98 days for composting treatment T_1 and T_2 and 112-126 days for composting treatment C_1 and C_2 .

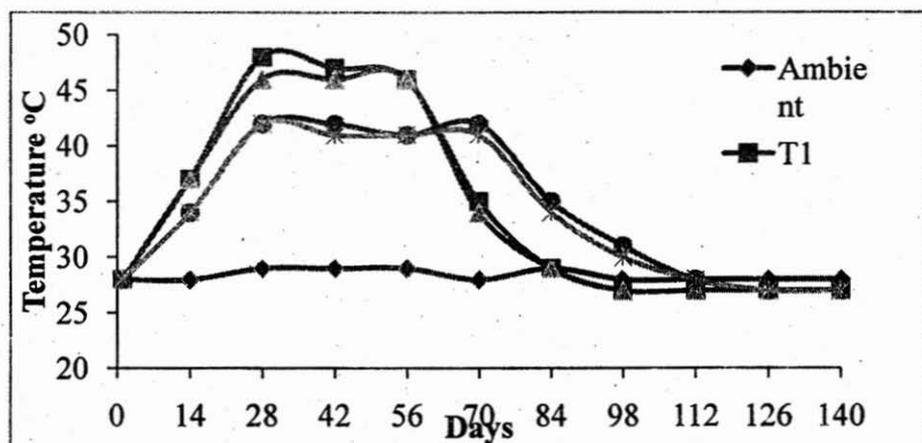


Figure (3) Temperature Changes during Composting Process

Physicochemical Characteristics of Compost Piles

Characteristics of compost piles at the beginning of composting and those of matured compost samples are shown in Tables (3) and (4).

One of the often used parameters to assess the rate of decomposition in the composting process is the C/N ratio, since it can reflect the maturity of the compost. Tables (3) and (4) show the decrease in C/N ratio in all treatments due to the mineralization of organic matter. The initial C/N ratio for T₁ and C₁ were 26.0, while for T₂ and C₂, they were 34.0. The final values of C/N ratio were 11.9 for T₁, 12.4 for T₂, 16.1 for C₁ and 17.3 for C₂. These results are in agreement with those of other researchers, such as Makan *et al.* (2012), Roca-Peréz *et al.* (2009) and Tumuhairwe *et al.* (2009). A C/N ratio of less than 20 is considered as mature and can be used without any restriction.

The Total Organic Carbon (TOC) concentration declined for all treatments. The initial values of TOC were 41.7% for T₁ and C₁, and 42.4% for T₂ and C₂. The final values of TOC were 15.0% for T₁, 17.2% for T₂, 22.3% for C₁ and 23.1% for C₂. It was found that the results fall within the range of literature value.

Excessive moisture may damage the granular structure of fertilizers, affect their quality and influence their nutrient content by increasing the weight of fertilizers. Therefore, moisture content is critical to determine the quality of a fertilizer. According to ICRISAT (2006), the moisture content of compost ranges between 32 and 66%. The results showed that the moisture content of all compost were 35-36%.

The initial values of pH were 6.8 for T₁ and C₁, and 6.7 for T₂ and C₂. The final values increased to 7.6 for T₁ and C₂, and 7.5 for T₂ and C₁. These values indicated that the compost products had good quality since the values were within the suggested range of 6-8.5 which was reported by Fogarty, A. *et al.* (1991).

Table (3) Physicochemical Characteristics of Compost Piles at the Beginning of Composting

Parameters	Compost Pile (T ₁)	Compost Pile (T ₂)	Compost Pile (C ₁)	Compost Pile (C ₂)	Literature Value***
C/N Ratio*	26	34	26	34	25-35
Total Organic Carbon * (%w/w)	41.7	42.4	41.7	42.4	25-80
Moisture Content** (%w/w)	39.2	30.5	39.8	30.9	32-66
pH**	6.8	6.7	6.8	6.7	6.0-7.5

* The data were determined at the Laboratory of Department of Land Use Division, Myanmar Agriculture Service (MAS), Ministry of Agriculture and Irrigation.

** The data were measured at the Laboratory of Department of Industrial Chemistry, West Yangon University.

*** Dalzell, H.W. *et al.* (1987), ICRISAT (2006), Makan, A. *et al.* (2012), Fogarty, A. *et al.* (1991)

Table (4) Physicochemical Characteristics of Matured Compost Samples

Parameters	Compost (T ₁)	Compost (T ₂) [#]	Compost (C ₁)	Compost (C ₂)	Literature Value***
C/N Ratio*	11.9	12.4	16.1	17.3	10-20
Total Organic Carbon * (%w/w)	15.0	17.2	22.3	23.1	15-50
Moisture Content** (%w/w)	35.3	35.8	35.0	35.7	32-66
pH**	7.6	7.5	7.5	7.6	6.0-8.5

- # The most suitable condition
- * The data were determined at the Laboratory of Department of Land Use Division, Myanmar Agriculture Service (MAS), Ministry of Agriculture and Irrigation.
- ** The data were measured at the Laboratory of Department of Industrial Chemistry, West Yangon University.
- *** Dalzell, H.W. *et al.* (1987), ICRISAT (2006), Mekan, A. *et al.* (2012), Fogarty, A. *et al.* (1991)

Macronutrients of Matured Compost Samples

The macronutrients of compost samples are indicated in Table (5). It was found that the nutrient contents of samples in T₁ and T₂ were significantly higher than those of C₁ and C₂. Specifically, the primary macronutrients (N, P, K contents) of all samples fall within the range of literature value. For secondary macronutrient Ca content only T₂ fall within the literature range whereas T₁, C₁ and C₂ were found to be below the range. For Mg and S content, there was no significant difference between treatments.

Table (5) Macronutrients of Compost Samples

Macronutrients	Compost (T ₁)	Compost (T ₂) [#]	Compost (C ₁)	Compost (C ₂)	Literature Value ^{**}
Primary Macronutrients*					
N (%)	1.26	1.52	0.76	0.92	0.40-1.61
P (%)	0.21	0.34	0.17	0.18	0.10-1.02
K (%)	1.19	1.36	0.83	0.91	0.15-1.73
Secondary Macronutrients*					
Ca (%)	0.98	1.22	0.92	0.93	1.00-7.61
Mg (%)	0.59	0.60	0.58	0.59	0.09-0.60
S (%)	0.02	0.02	0.01	0.01	-

[#] The most suitable condition

* The data were determined at the Laboratory of Department of Land Use Division, Myanmar Agriculture Service (MAS), Ministry of Agriculture and Irrigation.

** ICRISAT (2006)

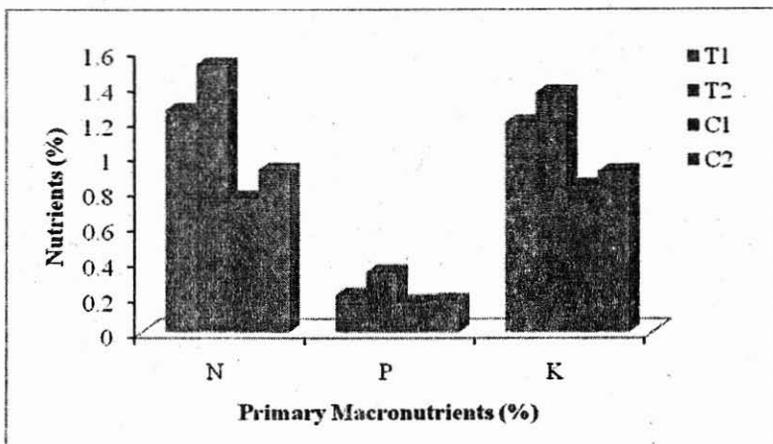


Figure (4) Primary Macronutrients of Compost

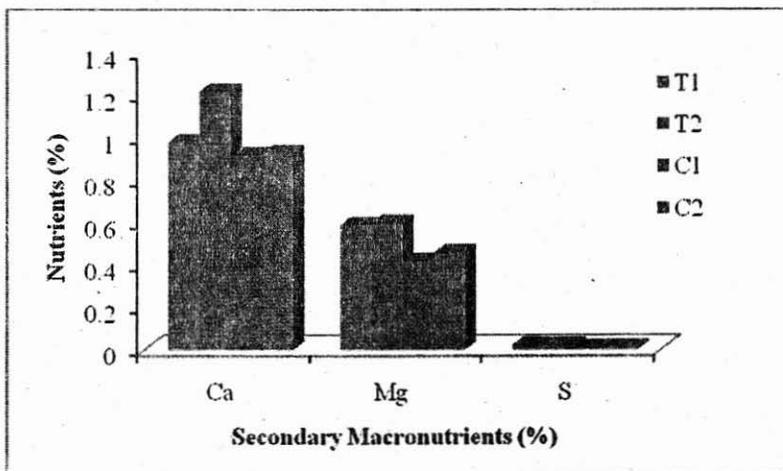


Figure (5) Secondary Macronutrients of Compost

Conclusion

All the parameters measured indicated that the decomposition processes took place in all different treatment methods. Changes in temperature and pH showed that the decomposition of organic matter occurred during the 90 days of period for the treatments with EM and 120 days of period for the treatments without EM. These results proved that the application of EM speeded up the composting process. The decrease in C/N

ratio also showed that an organic compound was being consumed by microorganisms. It was also found that the composts produced from rice straw and cow dung ratio of 2:1 possessed better characteristics and higher nutrient values than those produced from raw materials ratio of 1:1. The application of EM in compost increased the macro and micronutrient contents. The following parameters support this conclusion: compost applied with EM had more N, P and K content (1.52%, 0.34%, and 1.36%) compared to compost without EM (0.92%, 0.18%, and 0.91%). The final resultant composts indicated that they were in the range of the matured level and can be used without any restriction.

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<http://en.wikipedia.org/wiki/EM>