CTE-15

COMPOSTING OF EMPTY OIL PALM FRUIT BUNCH (EFB) WITH SIMULTANEOUS EVAPOARATION OF OIL MILL WASTE WATER (POME)

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ABSTRACT

Trials had been carried out about the composting of empty fruit bunch (EFB) from oil palms with addition of waste water (effluent) from palm oil mills (POME) under wet tropical climate in Medan, Indonesia. In the rotting process first the empty fruit bunch were chopped with a cutting mill. After that the fibrous material was set up to longitudinal heaps (width 2.7 m, height 1.1 m, length 15 to 20 m) and turned with a self-driving windrow turning machine. During the composting process the fresh POME was added to balance the high water evaporation. Although the EFB fibres have a high resistance against microbial degradation it was possible to produce mature compost (C/N <20) within 3 weeks. The optimum amount of POME addition is 3.2 m³/t EFB, the maximum is up to 5.3 m³/t EFB within 9 weeks, even at rainfall of >2000 mm/a without roof. At an average amount of 0.8 m³ POME/t EFB total POME can be evaporated (3.5 m³/t). During rotting process of 12 weeks the mass of the dry matter and the carbon is decreased >60 %, the volume and the mass at about 50 %, and the C/N ratio from 50 at the beginning is reduced to 15. In the process all the nutrients from POME and EFB were concentrated in the product compost, which has a monetary nutrient value of about 25 EUR/t dry matter. The investment cost for a composting plant for an oil mill with a capacity of 30 t/h (120,000 t fresh fruit bunch per year) is about 430,500 EUR, the specific production cost 0.969 EUR/t crude palm oil or 14.994 EUR/t compost dry matter.

Key words: oil palm, EFB, POME, compost, C/N ratio

Abbreviations:

EFB	empty fruit bunch from oil palm
FFB	fresh fruit bunch from oil palm
POME	palm oil mill effluent (waste water)
dm	dry matter

INTRODUCTION

In a palm oil mill 0.6 to 1.2 m³ of wastewater is produced from every ton of fresh fruit bunch (FFB). In mills with new technology the production of this palm oil mill effluent (POME) still at least 0.2 m³. Along with the wastewater, 0.23 t of empty fruit bunch (EFB), 0,13 t of mesocarp fibre and 0,55 t of kernel shells are also produced. 96,000 m³ of POME and 27,600 t of EFB are produced annually by a 30 t/h capacity mill with an input of 120,000 t FFB. Whereas the fibre and the kernel are used as boiler fuel for energy production, for most mills POME and EFB are still considered as unwanted waste mainly because of their storage, transport, distribution and treatment costs. Since the prohibition of EFB incineration in Malaysia and Indonesia due to its high air pollution, oil mills have started to bring EFB back to the plantation or just dump them. The treatment of POME in anaerobic and facultative ponds is the most conventional and commonly adopted systems for most mills. Only few started to reuse POME in plantation (land irrigation).

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The utilization of EFB for mulching (30 to 80 t/ha), unfortunately, also has some disadvantages. High transportation and distribution costs, long degradation time (up to one year), water pollution by the rest oil (about 1.25 %) and its attractiveness for beetles and snakes have been a number of downsides that hardly are solved. A number of disadvantages of POME treatment in ponds still can not be avoided as well: (a) high air pollution by the green house gas methane; (b) water pollution by the effluent to the river; (c) nutrient loss; (d) high cost for maintenance of the ponds; and sludge transportation and distribution to name of some. Pond treatment of POME also results in the loss of the potential energy source methane.

On the bright side, nevertheless, POME and EFB are residues with high monetary value of about 383,000 € per year in a 30t oil mill (nutrients and methane from POME that might be produced; Schuchardt et al. 2002). They also stated that the utilization of POME and EFB is a necessity for an integrated bio-system.

Composting EFB is a possible way to transform the bulky bunches into a valuable, manageable product for use in the plantation or as market product. The investigation of the rotting characteristic of empty fruit bunch (EFB) during composting has been conducted in the last 10 years (Lim 1989, Darnoko 1993, Theo 1993, Theo and Chia 1993, Thambirajah et al. 1995, Goenadi et al. 1998, Franke 1998, Schuchardt et al. 1998, Schuchardt et al. 1999, Schuchardt et al. 2000 a, Schuchardt et al. 2000 b). It has been found out that it would be possible to produce compost from EFB within 2 to 12 weeks. An addition of a nitrogen source, e.g. manure, urea or POME can speed up the process by reducing the wide C/N ratio of the EFB from 50 to 70. However, the addition of inoculum has been found to be inconsistent. Schuchardt et al. (1998) found no effect, whereas Goenadi et al. (1998) found a positive influence on the degradation speed.

As it has been reported so far, in practice there was only one technical scale of composting plant for EFB running at that time in Malaysia by Asia Green Environmental Sdn Bhd, Kuala Lumpur.

Trials on EFB composting had been carried out in the frame of German-Indonesian cooperation project between the Indonesian Oil Palm Research Institute (IOPRI), Medan and the Federal Agricultural Research Centre (FAL), Braunschweig. The project was coordinated by the TUEV Rheinland, Cologne and financed by the German Federal Ministry of Education and Research, IOPRI and FAL, The trials were conducted in rotting boxes (V=1.5 m^3) and in windrows (V>20 m^3) with a turning machine. The task of the trials in windrows was to develop a rotting process and to demonstrate the process in practical scale.

From the results obtained from trials in rotting boxes (Schuchardt et al., 1998 and Schuchardt et al., 1999), it was concluded that the addition of inoculum is not necessary and that the water evaporation rate of the porous and chopped EFB is very high. However, some reinvestigation in practical scale is still necessary to find out the consistency of the results. The results presented in this paper are the summary of 11 trials in windrows and 22 trials in rotting boxes.

Rotting Process

The rotting process in practical scale is presented diagrammatically on Figure 1. The process includes several activities such as: (a) the chopping of the EFB using a cutting mill; (b) the forming of longitudinal heaps; (c) the turning of the heaps using a self driving windrow turning machine; (d) the watering of the heaps using waste water (POME) in order to balance the high water evaporation and (e) the screening of the finished compost. The screened and finished compost is then ready to be used for land application, while the oversized compost is usually used as mulching material. The illustration of the process is presented step-wisely through Figure 1 to Figure 6.

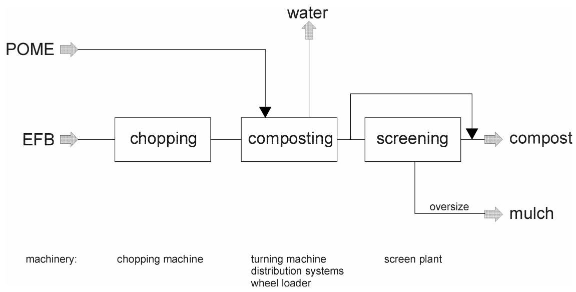

Figure 1. Flow sheet of EFB composting

Figure 4. Chopped EFB

Figure 2. Empty fruit bunch (EFB)

Figure 5. Windrow turning machine (Backhus Kompomat 1.27, year of construction 1989)

Figure 3. Cutting mill

Figure 6. Screened compost from EFB

MATERIAL AND METHODS

Composting trials in heaps were conducted in the palm oil mill of IOPRI in Aek Pancur, a small town near Medan, North Sumatra. The figures of some atmospheric parameters for the year of 1999 and 2000 during which the trials were conducted are: (a) minimum air temperature ranging from 23 to 25 °C; (b) maximum air temperature 30 to 34 °C and (c) rain fall 2,000 mm/a. The POME used in the trials was taken from the palm oil mill in Pagar Merbau, North Sumatra. The Tables 1 and 2 below show the composition of the EFB and POME used in the trials.

Table 1. Composition of empty fruit bunch (EFB) and compost after 10 weeks of rotting time (with addition of 4 m³ POME/t EFB)

		EFB	Compost
Dry matter DM	[kg/t]	300 - 320	836
org. DM	[kg/t]	240	562
org. DM	[kg/t DM]	880	673
C	[kg/t DM]	480 – 490	351
C/N	[-]	50 – 65	15
$N_{Kj.}$	[kg/t DM]	7.4 – 9.8	23.4
P	[kg/t DM]	0.6 – 0.7	3.1
K	[kg/t DM]	20.1 – 21.8	55.3
Ca	[kg/t DM]	1.6 – 4	14.6
Mg	[kg/t DM]	1.3 – 1.5	9.6
B	[kg/t DM]	0.01	0.10
Cr	[g/t DM]	49.9	29.7
Ni	[g/t DM]	30.5	10.1
Cu	[g/t DM]	14.0	38.0
Zn	[g/t DM]	37.9	154.0
As	[g/t DM]	<1	2.5
Cd	[g/t DM]	<0.3	<0.3
Hg	[g/t DM]	<0.5	<0.5
Pb	[g/t DM]	1.8	69.9
pH	[-]	5.5 – 7.7	7.5
bulk density	[t/m³]	0.340	0.45

DM dry matter

Table 2. Composition of fresh palm oil mill waste water (POME)

		POME
Dry matter DM	[kg/t]	40.5
$N_{Kj.}$	[kg/t DM]	0.750
P	[kg/t DM]	0.180
K	[kg/t DM]	2.270
Ca	[kg/t DM]	0.439
Mg	[kg/t DM]	0.615
B	[kg/t DM]	0.008
pH	[-]	4.7

DM dry matter

RESULTS

Rotting characteristic and POME evaporation

The self-heating of EFB started immediately when it was stored in a heap, both chopped and not chopped. Within 1 to 3 days, the temperature grew up from 70 to 75 °C, and felt down again to the ambient temperature, which was around 30 °C after ten weeks. The heap temperature of during composting period is shown graphically through Figure 7.

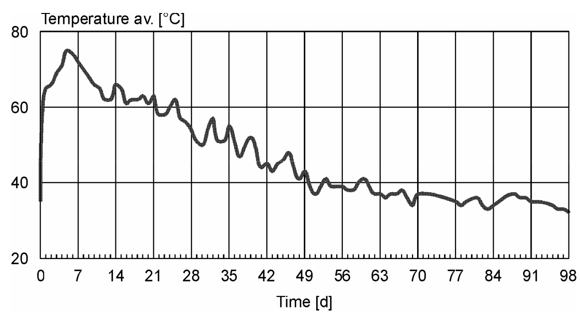

Figure 7. Temperature during composting of EFB

Commencing from the second week of composting, white mycelium of fungi started to be visible. When the heaps were not turned, after 4 to 5 weeks some fruits of fungi grew. During the first 3 to 4 weeks of composting time, the rotting material was from the interest for flies, which lay their eggs on the surface of the warm substrate. The temperature in the center of the heap was >60°C. By turning the heaps during that time most of the larvae would be killed. After 4 to 5 weeks of rotting time the EFB could be attractive for rhinoceros beetle. After 6 to 7 weeks of composting, at the time the temperature was reduced, some earthworms were found. At no time of the composting of EFB, there was a disagreeable smell. With the addition of some fresh wastewater or urea, some ammonia could evaporate. After 3 to 5 weeks when the rotting EFB was wet enough for the microbial process, the color of the compost became dark brown.

The EFB fibre had high resistance against microbial degradation. Although it became softer from time to time, its structure was visible for more than 8 weeks. After a rotting time of about 10 to 12 weeks, the structure of the compost gets finer and the dry matter content grew up to >45 % so that the compost can be screened to meet the market requirement.

The water evaporation rate of EFB in open heaps or boxes was detected to be very high. Without any addition of water or strict reduction of evaporation, for example by protecting it with plastic foil, the rotting process comes to an end in short period of time due to water shortage. It was found possible to add more than 5.3 m^3 of waste water per ton of EFB (maximum water addition) during composting in windrows under roof and 4.5 m^3 per t EFB without roof (during rainy season with about 700 mm rainfall) within 9 weeks (evaporation rate only for POME: 84 l/[t EFB*d] in average). To reach this evaporation rate of 84 l/(t*d), the POME had to be added and the windrows had to be turned 5 to 6 times a week. The optimum water addition was identified of about 3.2 m^3/t EFB within 9 weeks (roofed windrow, POME addition and turning 3 times a week, evaporation rate: 51 l/[t EFB*d]). It was also found possible to produce compost out of chopped EFB without roof, even when the rainfall was about 2000 mm/year.

Calculated from 0.8 m^3 POME/t FFB and 0.23 t EFB/t FFB, the amount of POME was 3.48 m^3/t EFB. From there it should be possible to evaporate the total wastewater from a palm oil mill via composting ("biological drying"). The POME could be used freshly or after anaerobic fermentation. In both cases the nutrients from EFB and from POME were concentrated in one product compost. If water leakage occurs during heavy rainfall, the liquid could be collected in a pond and later added to composting process.

During the first 9 weeks, the dry matter content at the composting of chopped EFB was 30 to 40 %. It was during the period when (waste) water was added to an optimum rate of 3.2 m^3/t and 18 to 30 %. For screening and packaging, the dry matter content of the compost should be >45 %. The reduction of dry matter (the degradation of organic matter) was more than 60 % within 12 weeks (Figure 9). The volume reduction during the composting of EFB was about 50 % within 10 to 12 weeks (Figure 10).

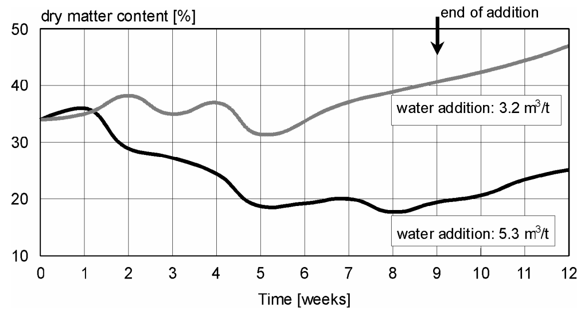

Figure 8. Dry matter content during composting of EFB with addition of 3.2 and 5.3 m^3 POME/t EFB

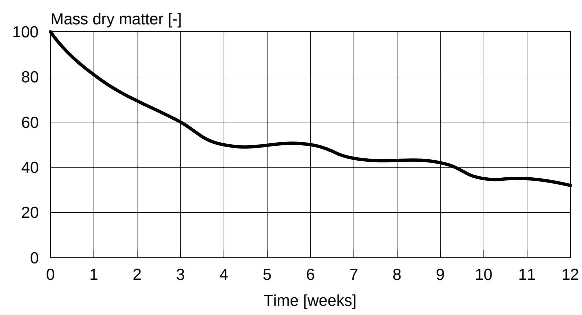

Figure 9. Mass of dry matter during composting of EFB

Figure 10. Volume during composting of EFB

The bulk density during the composting of EFB depended on the addition of water (Figure 11). When the water addition was at an optimum range (3.2 m^3/t EFB), it was between 0.2 and 0.3 t/m^3. When the water addition was in the maximum range (5.3 m^3/t EFB) it could be up to 0.7 t/m^3.

After the addition of 1 to 2 kg N/t EFB (= 3 to 6 kg N/t EFB dm), compost with a C/N ratio <20 could be produced within 2 to 3 weeks. Without the addition of the nitrogen, the same C/N ratio would only be reached after

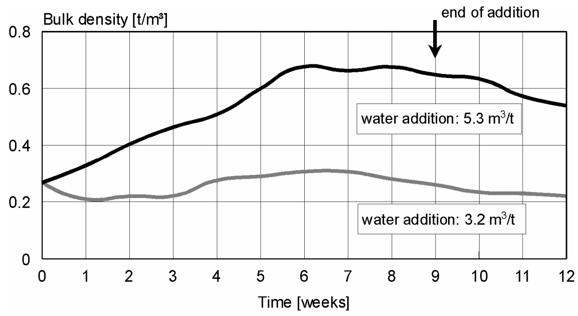

Figure 11. Bulk density during composting of EFB with addition of 3.2 and 5.3 m³ POME/t EFB

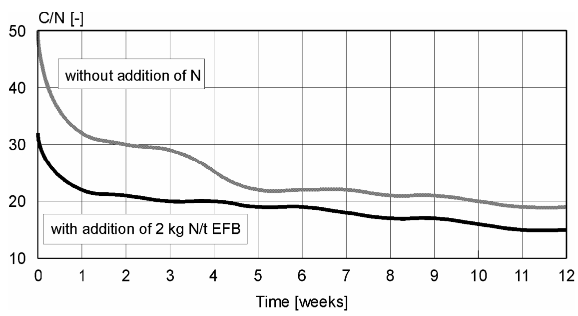

Figure 12. C/N ratio during composting of EFB with addition of 2kg N/t EFB and without addition of N

more than 10 weeks (Figure 12). The source of Nitrogen could be urea, any other source like chicken manure or POME. If 4 m³ of POME was added for each ton of EFB as N source, the amount of N was about 2 to 3.2 kg N/t EFB (500 to 800 g N/m³ POME). An addition of inoculum to the rotting of EFB was not necessary to produce mature compost.

The carbon content was reduced during the composting process from about 42 % in dry matter at the beginning to about 35 % after 10 weeks (Figure 13). The degradation of carbon (mass) was about 50 % within the first 4 weeks and only 10 % more during the next 8 weeks (Figure 14).

The content of Nitrogen increased during the rotting process because of the degradation of organic matter from about 1.6 % of dm at the start (after the addition of 2 kg N/t EFB) to about 2.3 % of dm after 12 weeks (Figure 15).

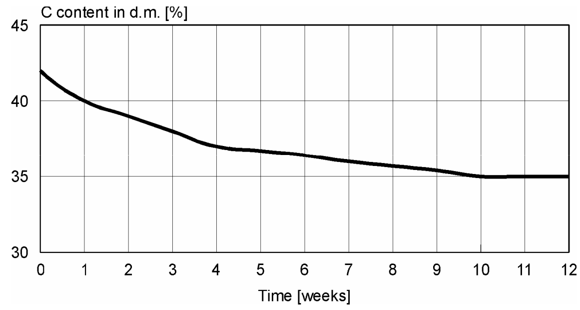

Figure 13. Carbon content during composting of EFB

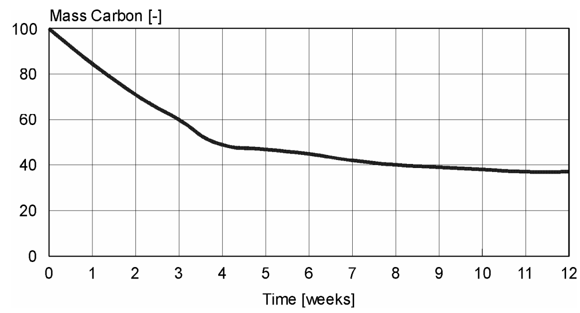

Figure 14. Mass of carbon during composting of EFB

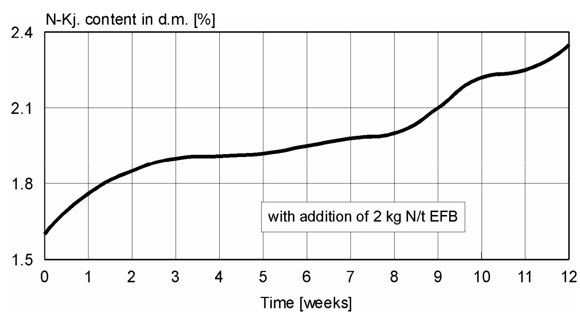

Figure 15. Nitrogen content during composting of EFB with addition of 2 kg N/t EFB

After the rotting time of about 10 weeks, the compost was characterized by high content of organic matter, nitrogen, potassium and calcium and low content of phosphorus (Table 1). The content of the relevant heavy metals was under the limit regulated for compost in European community.

Capacity of turning machine

The speed of the turning machine (Backhus Kompomat 1.27) grew up from about 0.08 m/s (height of the heap was 1.1 m) at the start to about 0.24 m/s after 12 weeks (height of the heap was 0.6 m) as presented through Figure 16 below. The trial was performed with maximum water addition during the first 9 weeks. The turning capacity of the machine was about 890 m³/h. It was calculated based on average speed of 0.11 m/sec and heap volume over windrow length ratio of 2.25 m³/m. The machine used in the trials was considered relatively small. With bigger machines a turning capacity of >3,000 m/h would be possible.

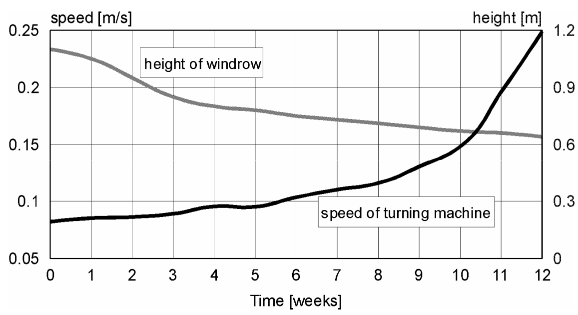

Figure 16. Speed of turning machine (Backhus Kompomat 1.27) during composting of EFB

Trials on the composting of mesocarp fibre showed similar rotting characteristics as chopped EFB, with the advantage that the structure of the compost was fine enough for selling without screening.

Cost calculation

It should be noted that all cost calculation was based on the prices and the cost on Indonesian market in the year of 2001. For a composting plant with a capacity of 27,600 t EFB/a (30 t oil mill), an investment of about 430,500 € would be necessary for chopping, composting and screening equipment (Table 3). Costs for the area and buildings (if necessary for office, social rooms, store for compost) had not been included. The specific production cost (without packing) was about 7.5 €/t compost (dry matter content 50 %) as shown in Table 4. The value of the nutrients in the EFB/POME compost was 12,57 €/t compost or 25,14 €/t compost dry matter (Table 5). The market price for compost in Indonesia was in the range of 10 to 20 €/t. From there it was not overwhelming to state that it could be possible to make a profit from compost production and selling or use on plantation area.

Table 3. Investment cost for EFB composting plant with a capacity of 27,600 t EFB/a (oil mill with a capacity of 30 t/h)

Process step	Equipment	€
chopping	cutting mill	30,000
	belt conveyor	4,000
	installation	2,000
	sum	*36,000*
composting	storage basin for POME (320 m³)	600
	pump	2,000
	distribution system for POME	14,600
	wheel loader	60,000
	composting area	
	(24,000 m² concrete)	241,500
	turning machine	63,000
	sum	*381,700*
screening	screen plant	11,800
	installation	1,000
	sum	*12,800*
	Sum total	**430,500**

Calculated on market prices and cost in Indonesia in 2001 (1 € =8,500 IDR)

Table 4. Specific production cost for EFB compost in a composting plant with a capacity of 27.600 t EFB/a (oil mill with a capacity of 30 t/h)

	€/t CPO[1)]	€/t FFB[2)]	€/t EFB[3)]	€/t compost[4)]
chopping	0.028	0.142	0.619	0.310
composting[5)]	0.130	0.671	2.919	5.830
screening	0.031	0.156	0.031	1.357
sum	0.189	0.969	2.217	7.497

1) crude palm oil 2) fresh fruit bunch 3) empty fruit bunch 4) dry matter 50 %
calculated on market prices and cost in Indonesia in 2001 (1 € =8,500 IDR) including cost for labor, fuel, current, interest of bank (10 %), insurance (3 %) and maintenance (1 % for concrete floor, 3 % for screen plant and distribution system, 4 % for wheel loader and turning machine, 10 % for pump);
depreciation charge: pumps and machines 10 years, concrete floor 15 years;
compost yield 50 % of EFB input

Table 5. Monetary value of the nutrients in EFB compost on the basis of 1 t EFB + 4 m³ POME

Nutrient	Content	Price[1)]	Value of compost	
	[kg/t DM]	[€/kg]	[€/t DM]	[€/t compost][2)]
$N_{Kj.}$	23,4	0,27	2,52[3)]	1,26
P	3,1	0,24	0,73	0,36
K	55,3	0,32	17,92	8,96
Ca	14,6	0,11	1,55	0,77
Mg	9,6	0,24	2,26	1,13
B	0,1	1,72	0,17	0,09
			25,14	12,57

1) market price in Indonesia in 2001
2) DM=50 %
3) availability of N is calculated with 40 % (30 % of EFB, 50 % of POME), all other nutrients are calculated with 100 %

DISCUSSION AND CONCLUSIONS

The unification of the residues in POME and EFB from palm oil production as one product offers the possibility for the realization a profitable integrated palm oil production system. In order to utilize its potential value as energy source via methane production, POME should be applied for composting after anaerobic fermentation in a reactor. The compost produced is a source of nutrients and humus not only in oil palm plantation but also in other crop production (vegetable, fruits, nursery, and horticulture e.g.). Its final use depends on the local situation and market price for the compost. The high mass and volume losses during composting sharply reduce the costs for transportation and distribution. The fine structure of the product makes the distribution easier as well. From the interest of plantation production, it could also be checked if adding some mineral components to the compost can produce compound fertilizer.

More trials about the fertilizing effect of the new compost would be necessary to find the optimum rotting time and compost preparation.

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