COMPOSTING EMPTY FRUIT BUNCHES OF OIL PALM

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ABSTRACT

Two methods (open and closed) of composting the empty fruit bunches (EFB) of oil palm were studied. Mixtures of EFB, fermentation liquid waste and chicken manure (open) and EFB, palm oil mill effluent and chicken manure (closed) were the ingredients for composting. Natural aeration was carried out in the open system and controlled aeration in the closed system. Windrow piles of 80 mt were used for the closed system, and smaller piles of 1mt for the open system.

EFB were used differently in the open and closed systems. For the closed system, the EFB were reduced in size by a hammer mill. For the open system, they were cut into pieces. The conventional and readily available mixing technique was found to be inefficient. The distribution of the other inputs was uneven resulting in a high initial C/N ratio (41, open; 56, closed). The distribution of moisture during composting was uneven in the closed system. This resulted in uneven biological activity. The composting process progressed at a reasonable rate, being faster for the open than the closed system. A C/N ratio of about 16 was achieved in about 50 days (open) and 85 days (closed).

INTRODUCTION

Oil palm production is a major agricultural industry in Malaysia. It contributes about US$ 7.3 billion in export earnings each year, mostly from the export of palm oil.

Currently, there are more than three million hectares of oil palm plantations (Lim 2000). In total, about 90 million mt of renewable biomass (trunks, fronds, shells, palm press fiber and the empty fruit bunches) are produced each year. The empty fruit bunches (EFB) represent about 9% (Lim 2000) of this total. They are the residue left after the fruit bunches are pressed at oil mills, and the oil extracted. The oil mills are located near or in the plantation itself (Ma *et al.* 1993; Kamarudin *et al.* 1997).

EFB is a suitable raw material for recycling because it is produced in large quantities in localized areas. In the past, it was often used as fuel to generate steam at the mills (Ma *et al.* 1993). The ash, with a potassium content of about 30%, (Lim 2000) was used as fertilizer. Burning is now prohibited by regulations to prevent air pollution. The EFB is now used mainly as a mulch (Hamdan *et al.* 1998). Placed around young palms, EFB helps to control weeds, prevent erosion and maintain soil moisture. However, due to the current labor shortage, the transportation and distribution of EFB in the field is getting more expensive. There is a growing interest in composting EFB, in order to add value, and also to reduce the volume to make application easier (Yusri *et al.* 1995, Thambirajah *et al.* 1995; Damanhuri 1998). This paper discusses quality issues of EFB compost. These are related to the physical characteristics of the raw material.

COMPOSTING OF EFB

An average oil palm mill can handle about 100 mt of fresh fruit bunches daily. At the mills where oil extraction takes place, solid residues and

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liquid wastes are generated. The solid residues, mainly EFB, are more than 20% of the fresh fruit weight (Ma *et al.* 1993, Kamarudin *et al.* 1997). More than 500 kg (around 0.5 m^3) of liquid wastes, mainly in the form of palm oil mill effluent (POME), are discharged during the processing of 1.0 mt of fresh fruit bunches (Ma *et al.* 1996). Thus, we would expect to get more than 20 mt of EFB and more than 50 m^3 of POME from a mill after processing 100 mt of fresh fruit bunches.

EFB is a common raw material used in composting. Other materials are often added, particularly chicken manure and POME. However, POME has a high nutrient content (Zakaria *et al.* 1994), and large oil palm plantations prefer to use it directly as fertilizer. The POME is first treated to reduce the organic load (Ma *et al.* 1993). The sediments left after treatment, which have a higher nutrient value than the slurry (Zakaria *et al.* 1994), are either recycled to the field or sold to the public.

Composting of EFB is being extended to farmers by the Department of Agriculture of Malaysia (Damanhuri 1998). The initial method the Department adopted was to mix the EFB with 20% chicken manure, heap it in 3 x 3 x 0.7 m boxes, and cover it with plastic. It took 11 to 12 months to mature. In 1995, the method was modified by first exposing big piles of EFB in the open for two months. The EFB was then mixed with 20% chicken manure and heaped in sheds measuring 12 x 36 x 3 m. The heap was mixed at regular monthly intervals. The time taken to reach maturity was about four months. Maturity was determined when the temperature of the heap stabilized at 30°C, and the pH reading was 4.5 - 6.0.

Mixing was carried out with a tractor equipped with a backhoe. It was reported (Damanhuri 1998) that about 15 m^3 of compost could be turned in one hour. Shredding of the compost was carried out at the end of the composting period. The shredded material was left for one to two weeks prior to packing. The final product contained a reasonable amount of nitrogen (3.3%), phosphate (0.05%), potassium (0.2%), calcium (1.0%) and magnesium (0.2%).

A large EFB composting installation is currently being operated by a commercial company. The daily throughput is about 10 mt. Operations are semi-mechanized. The EFB is passed through a hammer mill, collected by tractors and piled in windrows. Chicken manure (around 15-20%) is added, and mixed in by a mechanical implement which straddles and moves along the windrow. The whole process is carried out in the open. Leachates or run-off after rain are collected in specially constructed drains to prevent the loss of added nutrients. The water from these drains is used to moisten the compost. Mixing is carried out regularly, to maintain an even distribution of moisture and to prevent the build-up of heat. The process takes a total of 45 to 60 days. The sieved compost is dark brown, and has an earthy smell.

The decomposition of EFB in oil palm plantations was studied by Hamdan *et al.* 1998. The EFB was spread in the field as a mulch on top of a nylon net, at a rate of 30, 60 and 90 mt/ha/year. At each EFB application rate, spots were selected for nitrogen supplementation to meet a C/N ratio of 15, 30 and 60 (control).

Decomposition was estimated by the weight of EFB remaining in the nylon net. The EFB was found to be completely decomposed after 10 months of application. It appeared that the more detailed studies of decomposition of EFB in the field was independent of N supplementation (Table 1). More detailed studies of EFB decomposition have also been carried out, using microorganisms.

Different organic nitrogen sources, such as the manure of goats, cattle and chickens, have also been evaluated as nitrogen additives for the composting of EFB (Thambirajah *et al.* 1995). Adding 25 kg of manure per 90 kg shredded EFB reduced the CN ratio. EFB compost with goat manure, cattle manure and chicken manure had a C/N ratio of 14:1, 18:1 and 12:1, respectively, after 60 days of composting, while the control without manure had a C/N ratio of 1:24.

Our research into the composting of EFB is intended to develop a commercially viable compost production system. Of utmost importance is the production of high-quality compost in a short period of time. Chicken manure, POME and liquid fermentation wastes from the food processing industry, have all been investigated as additives. Both POME and liquid fermentation wastes are generated in large quantities, and there is considerable interest in recycling them. They were the main additives used in this study. The chemical characteristics of these materials and EFB are shown in Table 2.

Two types of composting methods, open and closed, were tested. In the closed system, a semi-permeable membrane was used to cover the windrow pile. The height of the pile was 1.5 m. The closed composting process was carried out with aeration at a rate of about 250 mt/day/m^3. The air was supplied by a electric pump through perforated tubes laid at the bottom of the pile. Eighty mt of EFB were mixed

Table 1. Decomposition of EFB in the field

Treatment		Decomposition rate (%) Months after application				
EFB application rate mt/ha/year	C/N ratio	2	4	6	8	10
30	60	42.84	64.40	82.14	98.17	100
30	30	17.82	53.40	71.16	96.93	100
30	15	32.71	36.85	68.17	98.90	100
60	60	36.19	68.14	85.81	98.34	100
60	30	28.16	49.54	89.87	99.59	100
60	15	26.30	52.54	78.90	99.15	100
90	60	26.47	56.61	85.00	96.27	100
90	30	38.26	63.02	87.36	97.96	100
90	15	25.27	66.94	83.88	97.97	100

Adapted from Hamdan *et al.* 1998

with POME and chicken manure.

In the open system, the pile was not covered. One mt of EFB was used, to which was added liquid fermentation wastes and chicken manure. Regular turning was carried out manually with the aid of a tractor equipped with a front loader. Both lots of composting material had an initial C/N ratio of about 30, and a moisture content of about 65%. Water was added to maintain the required moisture level. Temperatures were monitored at 10 and 100 cm from the surface of the compost heaps.

Changes in C/N ratio and chemical composition were monitored by sampling as composting progressed.

RESULTS

EFB is composed of 45-50% cellulose and about equal amounts (25-35%) of hemicellulose and lignin (Deraman 1993). It is fibrous, and the fibers stick together to form vascular bundles. A common method used to reduce the size of EFB before composting is hammer milling. This results in the production of stringy strands of different lengths and sizes. Short, uniform, fibers can be obtained by mechanical cutting of the EFB. The cutting process subjects the EFB to a great deal of pressure, so that a substantial amount of moisture is lost. The strands dehydrate quite fast, and when this happens they appear crystalline.

Disintegrated EFB tend to form porous clumps. Mechanical mixing of this material using a tractor and front loader did not break up the lumps of material. Indeed, mixing was found to make the problem worse. Pushing part of the heap before lifting it during mixing tended to push the whole pile together into clumps. Chicken manure added during mixing was deposited only on the surface of the clumps, and did not reach inside them. The liquid wastes (POME and fermentation wastes) and water added drained off quite freely. They were not absorbed by the EFB. The resulting compost mixture was not homogeneous, and as a result the C/N ratio value was higher than expected (Table 3 and Table 4). It was as high as 52 in a large compost heap using 80 mt of EFB. When a smaller amount (1 mt) of EFB was used, mixing was found to be more effective and the C/N ratio was lower, at 41. The C/N ratio of fresh EFB is about 60 (Hamdan *et al.* 1998).

Despite these problems, the composting process was able to proceed favorably. A high initial C/N ratio, particularly for the closed composting process (Table 3), which had more mixing problems associated with it, did not affect the fermentation process significantly. A reasonable C/N ratio level was achieved after composting for more than 80 days. The smaller open compost heap was more efficient, giving a stable compost after only 52 days. The C/N ratio had fallen to about 16 by this time.

The two processes differ in their constituents, in that POME was used only in the closed system. Fermentation wastes contain more sulfur (Table 2), and were used in the open system. Other differences are the organic load and the nitrogen concentration. Overall, the amount of nitrogen supplemented through the addition of POME and chicken manure would have met the target ratio, but due to the inefficient mixing of the closed system, might not have been evenly distributed. The appropriate level of nitrogen is undoubtedly very important, especially during the latter stage of the composting process when most of the easily metabolisable carbon constituents have already been exhausted. The water content of the large closed compost leap was also uneven, and moisture content is critical.

The reason why we tested the closed composting system was to evaluate the effect of reduced mixing. The temperature profile (Fig. 1) reflects the importance of mixing. The initial temperature was quite high. The lag phase was brief, indicating composting started early on. This early high temperature was the same at 10 and 100 cm. Marked differences appeared as composting progressed. In the closed system, the temperature deep in the pile was higher than near the surface, except after turning. In the open system, where regular mixing was carried out, the temperature (Fig. 2) was evenly distributed during the course of the composting period. The decline in temperature occurred in pace with decomposition. The gradual decline in temperature corresponded with the decline in the C/N ratio. However, composting was not completed, as the final temperature was more than 35°C.

The EFB was very fibrous. Even when it was piled up to more than 1.5 m in height, the bottom mass was still loose and porous, allowing air to pass freely through the pile. It was therefore considered suitable for the production of good quality compost. It was also expected that added nitrogen could be retained as aerobic conditions could easily be maintained. Liquid fermentation waste, one of the raw material inputs used, contained a high amount of ammonia-N. An estimate based on the initial carbon content of the total compost mass showed that most of the nitrogen was immobilized during composting (Fig. 3). It seems that in general, the nitrogen added before composting was retained.

It was observed that the most important precautionary measures to be taken is to ensure that the EFB does not dry out. Loss of too much moisture may make the material crystalline. Cutting the EFB under slight pressure resulted in uniform fiber length. However, moisture was lost during the process, and this extra water had to be added. Pressed and cut fiber has a very low waterholding capacity. Most of the liquid applied to the EFB percolated down to the floor. Hammer-milled EFB produced fibers that were not uniform in length. However, they retained moisture better. In both cases, the fibers remained lumpy. The availability of moisture was the critical factor which determined the decomposition rate.

The C:N ratio, the moisture content and aeration are all important factors in composting. However, in large-scale composting of EFB, preparation of the raw EFB for composting is vital. Reducing the size of the EFB to increase the surface area should not reduce the moisture content by too much. The available moisture within the EFB provides a favorable environment for microbiological activity. Dehydrated bundles take time to absorb moisture, and this complicates the mixing process. Our experience indicated that dehydration of the cut EFB was difficult and time-consuming to reverse. Aeration was found to be unnecessary, as this accelerates dehydration at the bottom of the pile. Mechanical mixing that breaks up the clumps is preferable to aeration. Mixing facilitates the transfer of oxygen, and the even distribution of moisture and heat and helps break down the fibers.

CONCLUSION

From our observation and experience, the successful composting of EFB on a large scale will need:

- The use of methods to cut up the EFB that limits the loss of its moisture content;
- A mechanical device which can break down the lumpy fibers, and mix them evenly; *and*
- An open composting system, provided that it is not exposed to rain;
- Forced aeration will not be needed, as the material is very porous and air can pass through freely

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Table 2. Chemical characteristics of materials for compost

Material	pH	Oil and fat	BOD	COD	Total carbon	TS	SS	TVS	Nitrate	Total nitrogen	Phosphorus	Potassium	Manganese	Sulfur	Calcium	Boron	Iron	Magnesium	Copper	Zinc	Reference
Empty fruit bunches	ND	ND	ND	ND	43.7%	ND	ND	ND	ND	0.52%	0.05%	1.34%	0.07%	0.07	0.19%	4	649	20	13	21	This study
Fermen-tation wastes	3.54	ND	86,100	154,046	ND	ND	ND	ND	3.33%	4.75%	0.64%	0.37%	0.p3%	4.2%	0.08%	ND	ND	0.0002%	ND	ND	This study
POME	4.7	4,000	25,000	50,000	NA	40,000	18,000	34,000	35	750	180	2,270	615	NA	439	7.6	46.5	2	0.89	2.3	Ngan,M. A. *et al.* 1996

Except pH, unless indicated the figures are in ppm
ND = Not determined; NA = Not available

Time	Nutrient content (%)							Nutrient content (ppm)					C/N
	C	N	P	K	Ca	Mg	S	Mn	Fe	Cu	Zn	B	
0	43.11	0.76	0.21	2.60	0.58	0.20		97.0	7,256	30.0	68.0	21.0	56.7
3	45.67	1.05	0.34	2.71	1.10	0.27	0.17	131.0	8,136	38.0	105.0	13.0	43.5
17	44.21	0.98	0.32	2.95	0.98	0.26	0.18	102.0	4,618	30.0	94.0	13.0	45.1
42	39.00	1.92	0.55	2.97	1.80	0.45	0.22	168.0	5,694	36.0	149.0	17.5	27.5
58	38.90	1.46	0.34	2.14	1.19	0.34		117.0	3,244	26.0	105.0	11.0	26.6
85	39.70	2.43	0.65	2.56	2.21	0.57	0.25	214.0	6,414	37.0	177.0	17.0	16.3

Time (days)	Nutrient content (% DM)								Nutrient content					C/N
	C	N	NH4+-N	P	K	Ca	Mg	S	Mn	Fe	Cu	Zn	B	
0	44.86	1.09	0.23	0.10	0.69	0.33	0.07	0.66	31.3	1673	20.9	135.4	5.9	41.2
8	42.18	0.98	0.02	0.25	0.84	0.61	0.10	0.45	44.8	2525	23.9	57.1	2.8	43.9
19	42.43	1.80	0.02	0.22	1.51	0.72	0.16	0.79	55.1	1699	19.6	187.0	10.6	23.6
26	39.12	1.87	0.02	0.25	0.98	1.01	0.15	0.55	67.7	2455	21.8	78.8	11.5	20.9
33	37.09	1.96	0.02	0.30	1.03		0.18	0.63	77.5	2644	26.5	87.9	12.1	18.9
52	37.08	2.34		0.30	0.96	1.15	0.17	0.54	76.3	2691	28.3	93.0	13.7	15.9

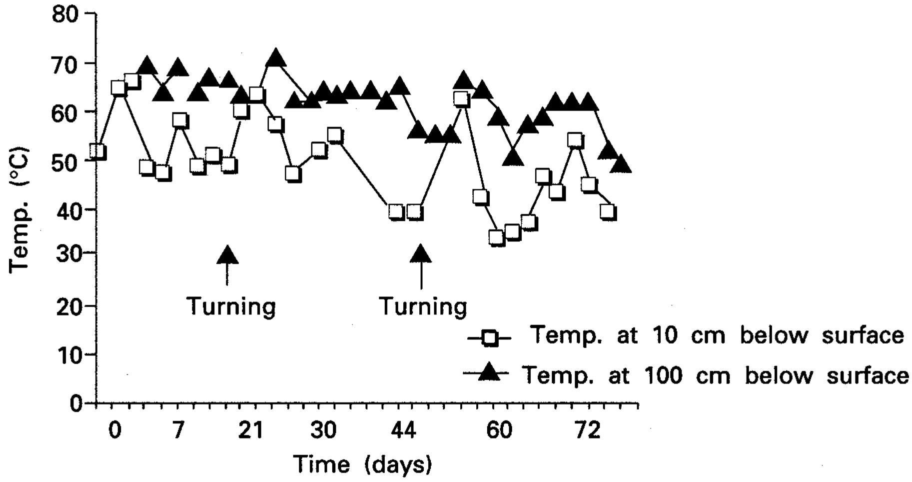

Fig. 1. Temperature variations in the closed composting system

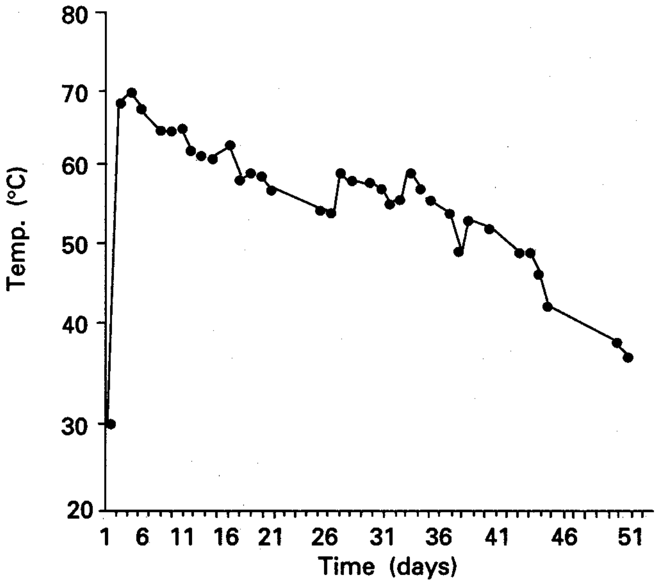

Fig. 2. Temperature profile of the open composting system

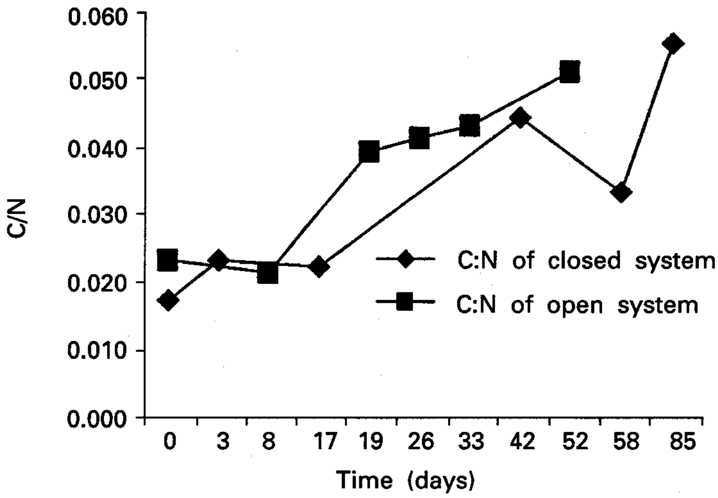

Fig. 3. Nitrogen stability attributes

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