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Development of a Turning Machine for a Windrow Composting Process of Oil Palm Empty Fruit Bunch

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Abstract: A turning machine prototype has been designed to mix and to aerate oil palm empty fruit bunch (EFB) cuts composted in windrows. The machine was equipped with four wheels and a rotating drum with tines which enables it to move through a free – standing windrow of approximately 120 cm high by 220 cm across. The rear wheels and the rotating drum were hydraulically driven by a 54 hp engine.
The turning machine was tested with EFB cuts and compost piled separately on a concrete floor. The average turning capacities for the EFB cuts and the compost were 22,020 kg/hr and 25,040 kg/hr respectively. At this setting, the average actual forward speeds of the machine were 104.4 m/hr for the EFB cuts and 75.0 m/hr for the compost. The wheel slips for these turning operations were almost constant at about 23%.
Key words: oil palm, empty fruit bunch, compost, turning machine

INTRODUCTION

Palm oil is one of the most important sources of ediblie oil. As the main producers of the palm oil in the world, Malaysia and Indonesia have a total oil palm plantaiton area of about 8 million ha yeilding fresh fruit bunch (FFB) of 25 ton/ha annually. The approximate percentage of empty fruit bunches (EFB) weight in FFB is 25%. However, there is about 50 million ton EFB dumped, burned or transported to the field as mulch or compost (Adlin, 1992; Abdullah et al., 1990). These EFB are rich of nutrients and possible to be applied back to the crops. Bachy and Regaud (1968) reported that the application of EFB as mulch increased production of FFB from 25 ton/ha to 32 ton/ha. Chan et al., (1981) reported that the response of mulching to FFB yield was about 7% annually. Similar response was also reported by Thye and Soon (1978) where the greatest response to fertilizer application within the non-mulched plots was 15%, while that in the mulched plots was 30% in the cumulative FFB yield. Having been composted in 60 days, the mixture of EFB and different manures produced a stable humus that is suitable for crop production (Thambirajah et al., 1995). An application of the EFB compost in oil palm plantation has often been recommended as a complement to fertilizers.

Natural composting of EFB occurs at very slow rate. It is hindered by high percentage of lignin and relatively small bunch surface area which can be penetrated by microorganisms. The EFB need to be chopped into small pieces and composted in windrows. This composting process is more efficient when the compost windrow is exposed to sufficient oxygen in order to increase the microbial activities. It is important that the windrow is turned frequently and efficiently. The more the windrow is turned the sooner the cut EFB matures (Haug, 1993). A machinery for turning the windrows is a key component in the production of quality compost. The use of these machines has been the source of high fixed and operating costs to farmers (Das et al, 2002; Nelson, 2007, Chiumenti et al., 2007).

Imported turning machines are basically designed for agricultural and animal's waste having different properties from the EFB cuts. The machine is usually equipped with a track, which is considered as a costly gearing system. Besides having high first cost, the machine is also known for its high repair and maintenance cost due to the imported spare parts.

An attempt will be made in this study to develop a new compost turning technology by designing a self propelled turning machine prototype suitable for the EFB.

The specific objectives of this study are as follows:

1. To design and to evaluate performances of a self propelled compost turning machine.
2. To study characteristcs of EFB composting process.

METHODOLOGY

A self propelled turning machine was developed through the following steps:

1. Designing components and mechanism of the machine that can turn EFB compost on a large open area. A turning capacity of more than the average EFB production of oil palm mills (10 ton/hour) is considered.
2. Fabricating the proposed machine by using materials which were locally availabe.

The performances of the machine were evaluated by using EFB cuts and compost heaps laid on a concrete floor. The heap was 200 cm wide and 90 cm high. Empty fruit bunch (EFB) and compost are represented in Figure 1.

The windrows were turned by the machine in a single pass. Observations were carried out for several parameters such as rotational speed of the tire and rotor (with and without load), forward speed of the machine, and turning capacity. Initially, The speed of rotor was set at about 300 rpm.

Figure 1. Empty fruit bunch and compost

A composting process was studied by using two different heaps of small and big cut materials. These materials were dominated by spikelets and stalk. Temperatures of materials were measured daily at the top and bottom layers until the composting process was completed (Figure 2). At the end of composting process, samples of 250 g were taken randomly from the center of the heap for the analyses of nutrient contents.

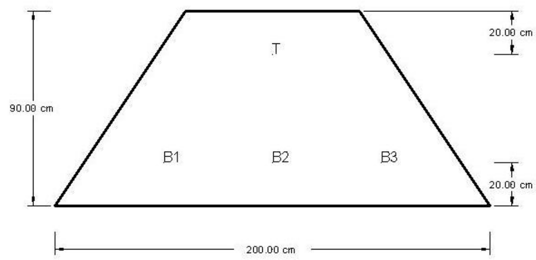

Figure 2. Locations of temperature measurements inside the heap (T, B1, B2, and B3)

RESULTS AND DICUSSION

Development of the Turning Machine

The turning machine was developed with the following components: (a) wheels which can provide an optimum tractive efficiency, (b) hydraulic system to drive wheels and rotor (c) rotating drum or rotor, (d) steering system, (e) diesel engine, and (f) frame. The engineering drawing of the machine is shown in Figure 3.

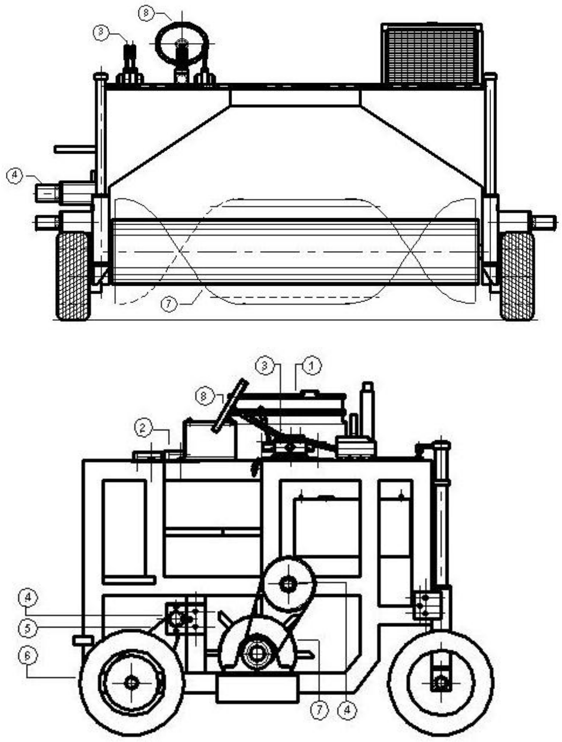

Figure 3. Front view (top) and side view (bottom) showing (1) engine, (2) hydraulic pump, (3) directional control valve, (4) motor, (5) chain, (6) driven wheel, (7) rotor, (8) steer

A diesel engine of 54 hp was selected as a source of mechanical power to drive hidydraulic pumps. The flow is directed by the pumps to motors and back to the tank though chech valve, relieve valve, directional valve, and flow control valve. Two motors of the same characteristics are chosen to drive the rear wheels up to 2.5 km/hr. Another motor was installed to drive the rotor with the maximum speed of 500 rpm (no-load).

This machine was able to go over the top of the EFB pile and turns the entire windrow. The rotor consisted of a horizontal cylinder and paddles mounted at the cylinder periphery. This rotor can be used to shred compost materials and to develop a new windrow.

To reduce tire sliding and scrubbing, a steering mechanism was developed for the front wheels. For steering, the inner wheel was disconnected from the hydraulic system and the outer wheel was driven by the hydraulic motor.

The steering wheels were turned manually through a handle.

This machine can be used for the windrow composting process with a pile of less than 220 cm wide and 120 cm high. Its overall width and length are 320 cm and 180 cm respectively. Figure 4 shows the prototype machine turning EFB compost windrow.

Figure 4. The turning machine and the EFB compost windrow

Evaluation of the Turning Machine and the Composting Process

The average forward speed of the machine was influenced by the materials of windrow i.e. 104.4 m/hr for empty fruit bunch cuts and 75 m/hr for mature compost. The turning capacity for the EFB cuts and compost were 22,020 and 25,040 t/hr respectively (Table 1).

Table 1. Performance of the turning machine

	Material	
	EFB cuts	Compost
Speed of turning machine, m/hr	104.4	75
Wheel slip, %	23.60	22.8
Turning capacity, kg/hr	22,020	25,040
Bulk density, kg/m^3	257	379

It was found that the rotational speed of the rotor for turning the compost materials was between 200-300 rpm. For the mature compost, it was almost constant at about 275 rpm due to the homogeneous size and bulk density of this material (Figure 5).

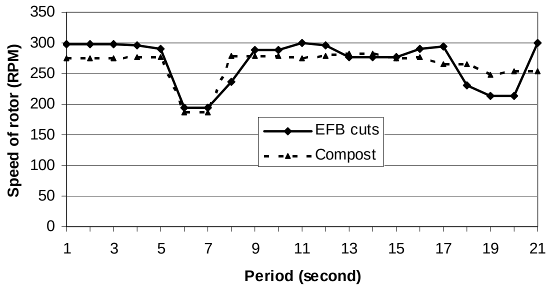

Figure 5. Rotational speed of rotor during the turning period

The temperature of the compost material increased rapidly to about 77 ^oC in two days and dropped gradually to 48 ^oC in eight days. In order to improve the composting condition, the heap was turned and sprayed with water to maintain the moisture content at about 60%, after which the activities of the micro organisms and compost temperature increased rapidly. The materials were turned every 10 days until the end of the composting process.

From the Figures 6 and 7, it was observed that the composting temperature of the small cuts was higher than that of the big cuts. It was as a result of the larger surface area of the small cut materials that can be penetrated by the micro organisms.

The lowest temperatures recorded in the compost were due to the low availability of oxygen at the bottom-centre of the material (B2) which reduces the microorganisms' activities.

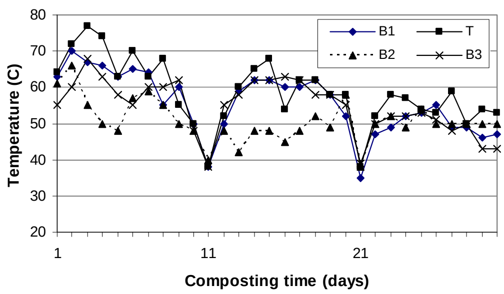

Figure 6. Temperature – composting time plot of the small cut EFB pile

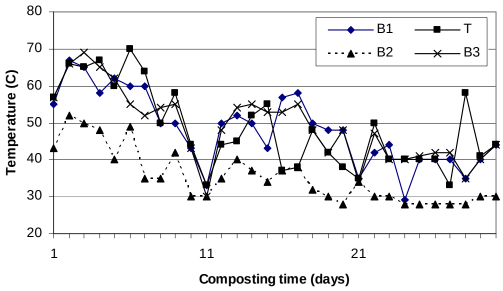

Figure 7. Temperature – composting time plot of the big cut EFB pile

From Figure 8, it was apparent that the temperature of the windrow decreased slowly reaching about 35 ^{o}C after 55 days. After this, turning operations did not strongly affect the temperature of the composting process. It is likely to happen due to the limited organic matter available for the microorganims.

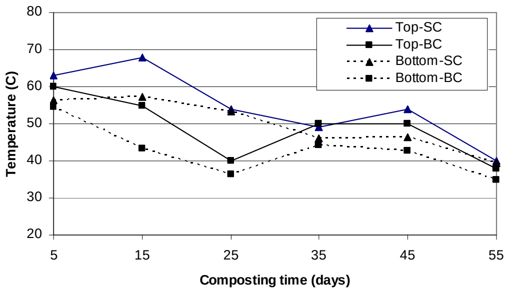

Figure 8. Average temperature trend during the composting process of small (SC) and big cut (BC) materials

The study also showed that pH of the compost material increased from 8.8 to 9.9 due to K, Ca, Mg, and Na released during the decomposition process. Percentage of C losses was 42.89-47.51%. The percentages of K and Na in both composts were relatively high (Table 2).

Table 2. Nutrients composition of the compost

Nutrient content (%)	Compost from	
	Small cut EFB	Big cut EFB
N	0.42	0.52
P	0.55	0.54
K	2.72	2.92
Ca	0.30	0.41
Mg	0.94	1.02
Na	1.87	2.07

CONCLUSIONS

The self propelled machine of 22,020 kg/hr and 25,040 kg/hr capacities has been developed for turning EFB and compost respectively.

The turning operation increased compost temperature and microorganisms activity. However, the temperature of the small cuts was higher than that of the big cuts. The composting process was completed in two months.

The nutrient contents of the composts were determined. It contained high percentage of K and Na.

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