CHINESE-AMERICAN

JOINT COMMISSION ON RURAL RECONSTRUCTION

Plant Industry Series No. 16

REPORT ON COMPOST STUDIES AT THE PINGTUNG EXPERIMENTAL PLANT

By
Organic Wastes Section
Taiwan Institute of Environmental Sanitation
Provincial Health Administration

TAIPEI, TAIWAN, CHINA

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Contents

Foreword

In view of the limited arable land and an over-crowded and rapidly growing population, one of the basic agricultural policies of Taiwan is to raise the unit crop yield as much as possible. Technical improvements of various nature are being made to raise the individual crop yield, and special crop rotation systems have also been adopted for growing three or four crops a year on the same tract of land. The planting of winter crops, following the second rice crop, has been widely practised in central and southern Taiwan, and is now rapidly spreading to all parts of the Island.

Undoubtedly, the expansion of winter crops, i.e., wheat, sweet potato, soybean, corn, tobacco, vegetables, etc., increases agricultural production; nevertheless at the same time, it reduces also the acreage originally intended for green manure crops. This may be borne out by the fact that the total green manure acreage of Taiwan has steadily decreased from around 200,000 hectares during the period 1948-1953 to around 160,000 hectares in 1955 and 1956, and to around 140,000 hectares in 1957. Such reduction in the production of green manure crops will in the long run impoverish the soil fertility. It is necessary that some remedy be made to this effect.

Farmers in Taiwan are already using as much compost manure as they can produce on the farms. The amount they use is likely to be increased, but will be limited by the raw materials available on the average farms, e.g. rice straw, other crop residue and farm livestock manure. One of the main sources of organic material, so far being utilized to only a small extent, is the city refuse. The city garbage, while creating increasingly a disposal problem to all municipal and township governments, is virtually untouched for agricultural use. Night soil is being used by farmers to a considerable extent, but is not treated to insure sanitary safety.

To solve this rather serious problem, JCRR was glad to help promote the necessary studies and to finance a part of the expenditures required for the construction of a pilot compost plant, procurement of additional garbage and night soil trucks and some laboratory equipment. The Pingtung Composting Experimental Plant was established jointly by the Pingtung City Office and the Taiwan Institute of Environmental Sanitation of the Provincial Health Administration. Utilizing the garbage and night soil of Pingtung City, the plant is to produce, aside from good compost for the farmers' use, experimental data as reference for other cities and towns for economic and sanitary disposal and utilization of city refuse.

JCRR is most gratified to find in this project the most enthusiastic support of the Pingtung City Office and the high technical competence of the Taiwan Institute of Environmental Sanitation.

At a time when many municipal governments, including those of Taipei, Kaohsiung, Ilan and Taitung, are earnestly drawing up plans for building city refuse disposal plants, the publication of the present report is indeed timely and valuable. Agricultural improvement programs based on careful studies have so far been successful on this Island. We are looking forward to the solid contribution of this program to the economic and social development of Taiwan

H.T. Chang
Chief
Plant Industry Division, JCRR

April 1959

Compost Studies at the Pingtung Experimental Plant

I. Introduction

Composting is an age old process, long practised by the Chinese farmers in the rural areas for returning valuable organic material to the soil. Composting on a municipal scale, although practised to a certain extent in China, has never been carried out under properly controlled conditions.

To improve environmental sanitation and increase agricultural productivity through utilization of organic refuse, composting studies were undertaken by Organic Wastes Section of the Taiwan Institute of Environmental Sanitation (IES) at Pingtung City. A pilot compost plant was established in July 1956, with various facilities installed as described in the 1956 Annual Report of IES. Experimental studies were conducted on the composting process, particularly on the bin-type batch system with forced air and also with turning of the piles.

Following these experimental studies, a full scale forced air bin compost plant of 25 tons capacity per day was constructed with the financial support of the Chinese-American Joint Commission on Rural Reconstruction (JCRR) in 1957. This project represented an important stage in the field of composting in China. Great impetus was given this project following the timely WHO Zone I Environmental Sanitation Seminar held in Taipei during October and November 1956, which covered the subject of composting in details. The 1 1/2 year of studies involved the full time efforts of the following staff members of the Organic Wastes Section, IES.

Mr. T. C. Sun, Chief of the Organic Wastes Section

Mr. C. Y. Chuang, Chemical Engineer

Mr. C. Y. Shen, Agricultural Technician

Mr. H. S. Chung, Chemist

This study was directed by Mr. D. F. Yung, Director of IES. Valuable technical assistance was also rendered by Mr. S. W. Kao, Deputy Director of IES, and Dr. A. Q. Y. Tom, WHO Sanitary Engineer. This report is prepared by Mr. T. C. Sun with the assistance of Dr. Tom. It is hoped that the studies and results as presented in this report can serve as guideposts for the development of better compost practices here in China as well as in other countries.

II. Experimental Studies

A. Objectives

1. To obtain reliable data on the refuse collected from the Pingtung City and its finished compost.
2. To compare the operational problems and suitability of the method of bin composting with forced air against the method of hand turning.
3. To study the various operational controlling practices such as:
   a. Length of aeration period and rate of air feed for the forced air bin method.
   b. Frequency of turning the bin piles.
4. To compare these two alternate processes in terms of sanitation and operating costs.
5. To assess the acceptance and marketability of the compost in the Pingtung area.

B. Equipment and Facilities

The experimental plant, located on the west outskirts of Pingtung City, is on a 2-hectare lot of land furnished by the Pingtung City Office. Equipment and facilities initially provided for these studies, with funds from IES, WHO and JCRR, include a laboratory, refuse unloading platform, mechanical screening unit, sorting conveyor belt, grinder and shredder. These units are of sufficient capacity to allow full scale plant operation of 25 tons per day.

For the experimental studies, ten open brick bins were constructed, each being 1.44M square and 0.7M high. Each bin drains into a small pit to permit collection and recycling of any drainage liquid.

For the forced air method studies, four of the above ten bins were provided with bamboo pipe system for supplying air. This system consists of a 3" dia. main line and six 2" dia. branch pipes on which 0.75 cm holes are drilled. A bamboo platform is laid 15 cm above the floor and over the air grid piping to support the mass of refuse. Three small locally manufactured air blowers ($0.5 m^3/min$ capacity) were provided to be interchangeably connected to each inlet of the piping system.

Six bins without aeration systems were used for composting with turning of the refuse. The materials were turned periodically with hand shovels and pitchforks, being transferred to the adjacent empty bins at each turning.

C. Operation and Control

1. Raw refuse is trucked to the plant from Pingtung City, screened through a mechanically vibrated $^1/_2$ inch mesh screen, removed of its paper, rag, bricks, metals and non-compostable materials, passed through a hammer mill grinder and then through a shredder which renders further grinding and flinging of the larger stone particles.
2. The prepared refuse is carted to the compost bins, stacked in each bin to a meter in height (total volume 2.07 cu. meter).
3. Optimum moisture content between 55% and 65% is maintained constantly. Samples for moisture determination are taken everyday at 5 p.m. and the moisture adjusted at 9 a.m. the following morning.
4. Temperatures of the compost pile are recorded daily at 9 a.m. with the measurements taken at points 2", 4", 8", and 12" from the surface. Temperature measurements are made with two indicating mercury dial thermometers.
5. The pH of the materials is determined daily by finely grinding a representative sample, mixing 1/10 of which with distilled water, filtering the suspension and determining the pH of the filtrate with a colorimetric kit. Due to the yellow coloration caused by the organic materials, this method is far from being satisfactory but still is the only available measurement in the absence of a pH meter. The pH values recorded may therefore be on the low side

6 Samples from three different points are taken every five days, then combined and finely pulverized for analyses on organic matter, carbon, ash, nitrogen, P_2O_5, K_2O and C/N ratio.

7. The depth of each pile is measured every five days to determine on the volume reduction.

8. The forced air, after passing through the compost pile and exiting through the horizontal bamboo vents, is collected and analyzed to determine on the extent of oxygen utilization in some of the runs. Determination on the percentage of CO_2 and oxygen in the expended air is made by means of absorption of CO_2 in KOH and absorption of oxygen in alkaline pyrogallate.

9. Forced air is blown through the compost on schedules and intervals, which vary from time to time in accordance with the conditions prescribed for each run.

10. Hand turning of the materials in the bins is also scheduled at varying intervals to determine optimum turning periods.

11. Excess refuse materials, after screening, sorting and grinding, are piled in windrows and turned twice after the 5th and 15th days.

D. Experimental Runs

Seven experimental runs were completed, each run with seven bins operated under varying conditions. For each run one control was set up, this being without any aeration or turning. Appendix 1 summarizes these different runs.

III. Presentation of Analytical Data

The summary results of all the experimental runs are presented in Appendices 2, 3 and 4. Values included therein are the temperature variations during the 20-day compost period, decomposition of organic matter, initial and final values of C/N ratio, total nitrogen, P_2O_5 and K_2O. Appendix 2 shows the results of the control batches, Appendix 3 the batches without aeration and different frequencies of turning and Appendix 4 the batches with various durations of aeration.

The experimental data will be discussed in each of the following categories of measurements or observations.

A. pH Value

Regardless of the different processes used in composting, all pH values are kept within a narrow range, 6.5 to 7.4 throughout the 20-day period. The initial pH is generally around 7.4 and decreases gradually to a figure of 6.5 due to acid formation. In all cases, no rise in pH was observed after this downward trend. Since optimum pH for most organisms is around 6.5 to 7.5, it is felt that pH control is not necessary.

Table 1 shows the pH changes during the 20-day compost period of Experimental Run A.

Table 1

pH Changes in Experimental Compost Piles

Expt. run / Day of composting	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
1	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
2	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
3	7.2	7.2	7.3	7.3	7.4	7.4	7.4	7.4
4	7.2	7.2	7.3	7.3	7.2	7.2	7.2	7.2
5	7.1	7.0	7.2	7.2	7.1	7.1	7.1	7.1
6	7.2	7.0	7.0	7.2	7.2	7.1	7.1	7.1
7	7.0	7.1	7.0	7.0	7.0	7.0	7.0	7.0
8	7.0	7.0	7.2	7.0	7.0	7.0	7.0	7.0
9	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
10	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
11	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.0
12	7.2	7.2	7.2	7.2	7.2	7.0	7.0	7.1
13	7.2	7.2	7.2	7.2	7.2	7.0	7.0	7.2
14	7.0	7.2	7.0	7.2	7.2	7.0	7.0	7.0
15	7.0	7.0	6.7	7.0	7.0	7.0	7.0	7.0
16	6.7	6.7	6.7	6.7	7.0	6.7	6.7	6.7
17	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7
18	6.7	6.5	6.5	6.5	6.7	6.7	6.7	6.7
19	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
20	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5

B. Moisture

The moisture content of the refuse, after screening, sorting and grinding, varies from 30% to 65%, with an average of 45%. Addition of water or nightsoil is therefore necessary to adjust the moisture content to a desired level of 60%. Daily addition during the compost period is also necessary for our open bins due to rapid evaporation. Final moisture content of the compost at the 20th day should be between 45% to 50%.

C. Temperature

1. General observations

The temperature within each pile increases from the surface to the 12" depth, is fairly constant at the 12" to 30" layer and decreases at the 30" to 40" depths. The average temperature of the pile was taken as the average of the measurements at the 2", 4", 8" and 12" depth, this average being almost the same as the measurement at the 8" depth. Ambient air temperature seems to affect the temperature of the pile only down to a depth of 2" from the surface.

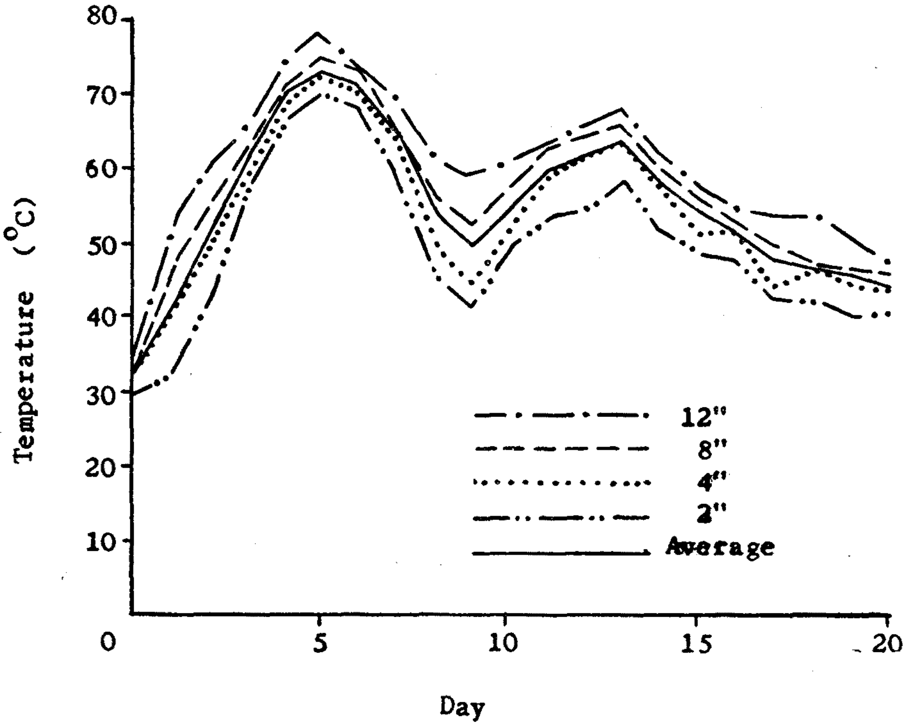
The range in temperature at various depths during a 20-day period of composting is as follows:

Depth	Range of temperature
2"	30°—60°C
4"	40°—70°C
8"	45°—75°C
12"	50°—78°C

Figure 1 shows the temperature changes at various depths of the pile in our C_2 Experimental Run.

Figure 1.

The Temperature Curve of C_2 Experimental Run



In general, temperature of the pile is about 30°C initially, 40°C on the first day, 50°C on the second day and may rise as high as 70°C from the third to the fifth day.

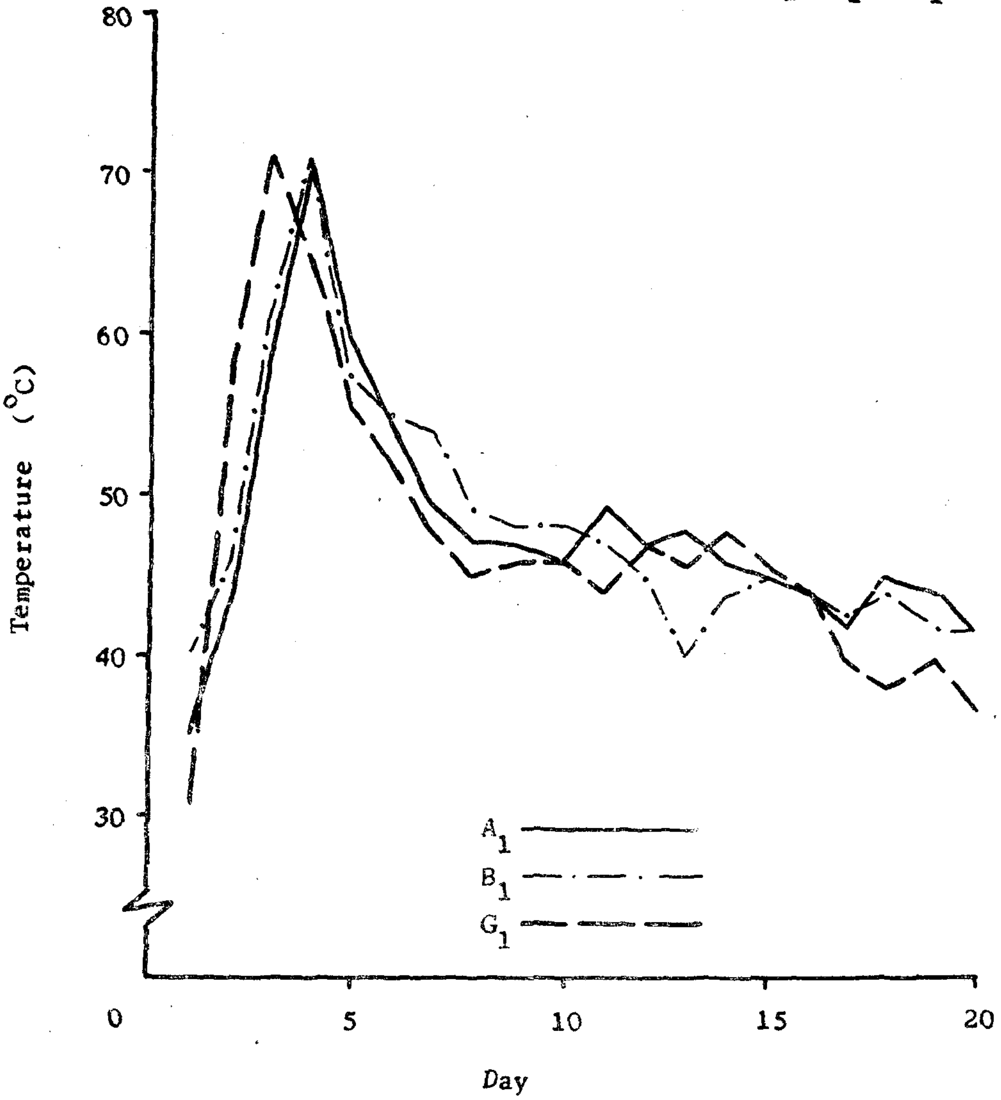
2. Control piles

The seven control piles A_1, B_1, D_1, D_2, F_1, F_2 and G_1 show very little variation in their average pile temperatures during their initial 20-day period. Out of these seven piles, only two, B_1 and G_1, had temperatures exceeding 60°C during more than 1 day. The pile temperature remained below 50°C during 15 days or more of the twenty days.

Maximum temperature was reached within the first five days, after which the temperature dereased progressively to below 40°C. Figure 2 shows the average temperatures of the A_1, B_1, and G_1 experimental runs, and illustrates

Figure 2.

Temperature Curve of Control Piles (A_1, B_1 & G_1)



the typical trend found among the control piles, which were not given any form of aeration.

3. Piles aerated by turning

As may be expected, the temperature in the piles turned periodically is higher than that without any turning. With one turning at the 4th, 5th or 6th day, we can expect temperatures over 60°C for 2 to 4 days and temperatures over 50°C for 6 to 12 days. With two turnings at the 5th and 10th days or 7th and 14th days, we can expect temperatures over 60°C for 3 to 6 days and temperatures over 50°C for 8 to 13 days. With three or more turnings, we can expect temperatures over 60°C for 6 to 11 days and temperatures over 50°C for 10 to 19 days.

Figure 3.

Temperature Curve of Piles Aerated by Turning

(A_8, B_6 & G_6)

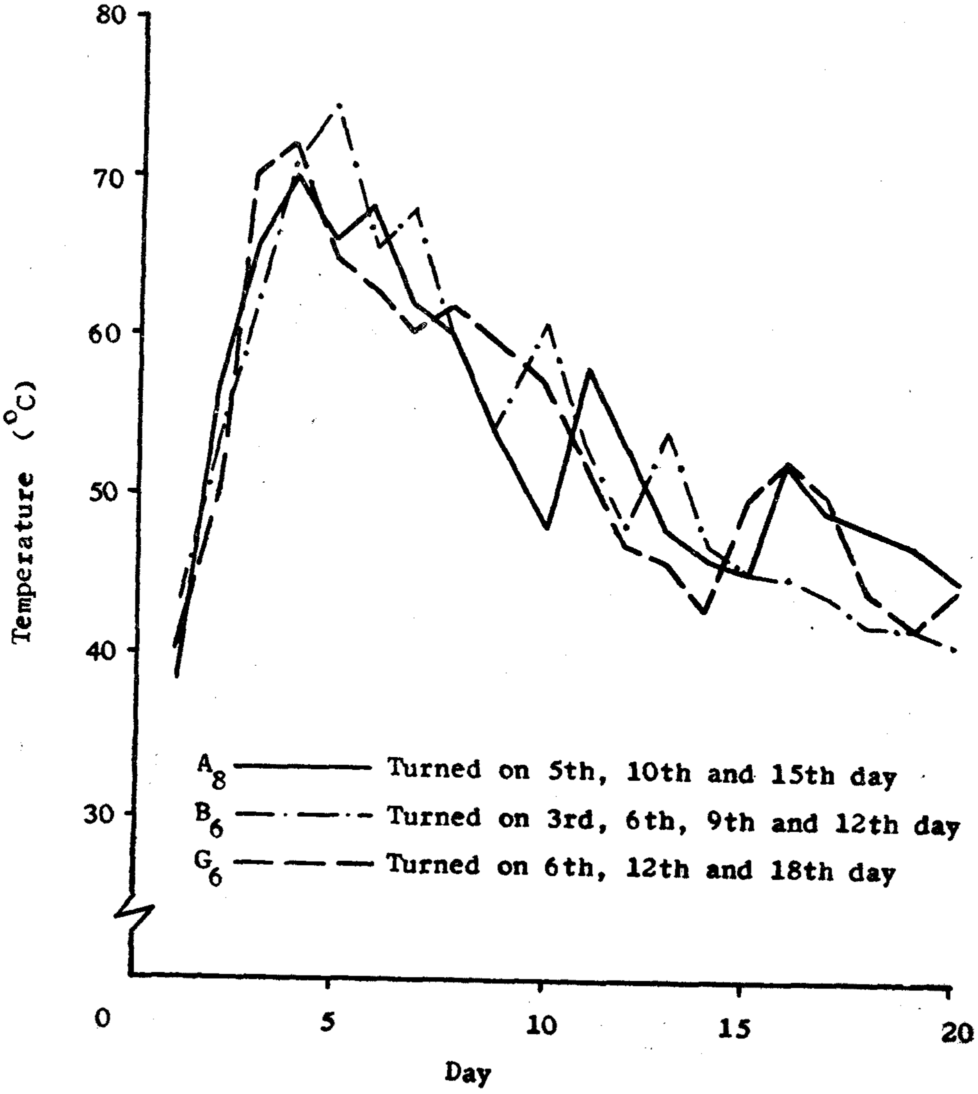


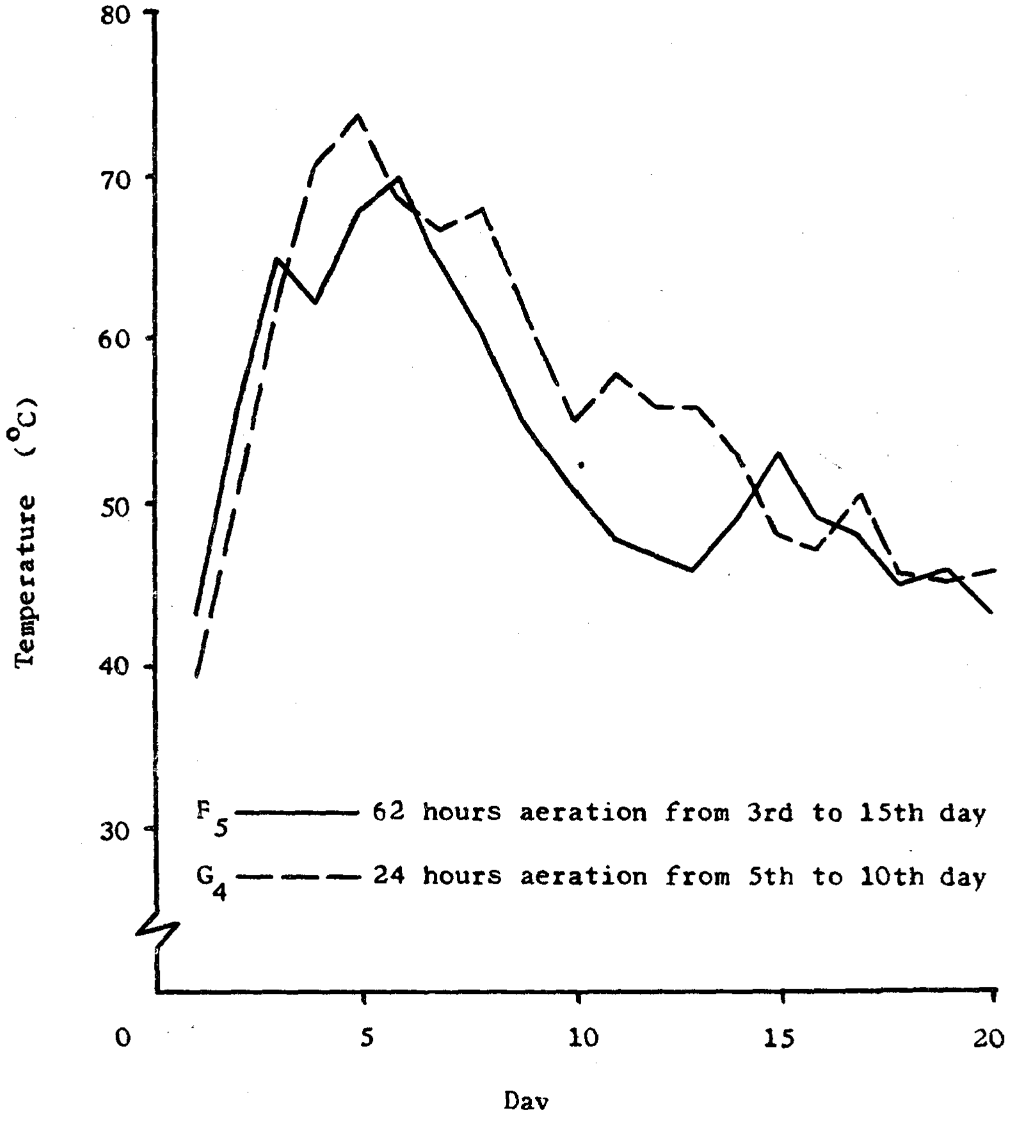
Figure 3 shows the trend of temperature in piles A_8, B_6 and G_6. One important rule to be observed is that the piles should be turned just prior to the time the temperature of the pile decreases. The first turning should be scheduled before the 5th day.

4. Piles aerated by forced air

The temperature of the piles fed with forced air displays very curious tendencies. When air is continuously fed from the lst to the 5th or 15th day, a rise in temperature occurs, but reaches a maximum only on about the 5th day. Contrary to our expectations, Expt. Runs B_2 to B_5 show very low temperatures, with just one pile showing temperature above 60°C for one day and with temperatures above 50°C occuring for less than 8 days. Intermittent feeding of air proved to be even more effective in maintaining higher temperatures in the piles.

Figure 4.

Temperature Curve of Forced Air Piles (F_5 & G_4)



Experimental runs on the other hand show higher temperatures, though the aeration is delayed until after the fifth day. Expt. Runs C_2, C_3, F_5, $G_{[illegible]}$, G_3 and G_4 with total aeration hours ranging from 72 hours to as low as 24 hours show the most days with temperatures exceeding 60°C and 50°C. Figure 4 shows the trend of temperature in the F_5 and G_4 piles.

Considerably more studies are necessary to indicate what the optimum aeration period should be. Our experimental studies were handicapped by the use of fixed capacity blowers, which made it impossible to vary the rate of air feed to each fixed volume of compost pile. Excessive air was largely responsible for the cooling of the piles. The introduction of composted material to seed the raw refuse might be necessary to eliminate any possible lag phase and to bring about maximum utilization of the early air feed. Tapered aeration may also prove to be worth investigating. These variables will be investigated in the operation of the full scale compost plant.

5. For a better comparison of the temperatures developed by the three methods of composting, the temperature curves of three different piles in the Experimental Run B are shown in Figure 5 and those of the Experimental Run G in Figure 6. In Pile B_2, which is fed with forced air continuously from the 1st to the 10th day, the temperatures are lower than those of the control pile, B_1. Excessive aeration prevented any temperature from developing beyond 58°C. The B_8 pile, turned three times on the 5th, 8th and 11th day, show very high temperature values.

Figure 5.

Temperature Curve of B_1, B_8 and B_2 Piles

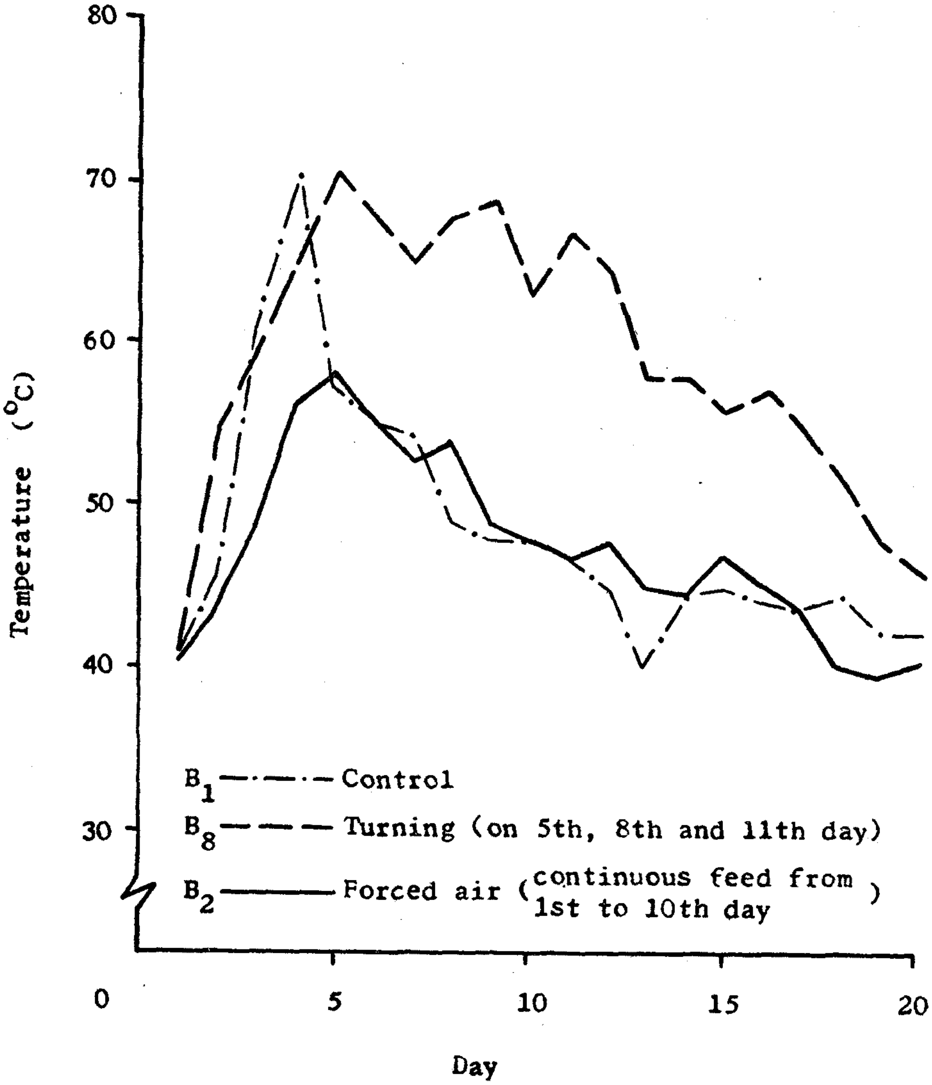
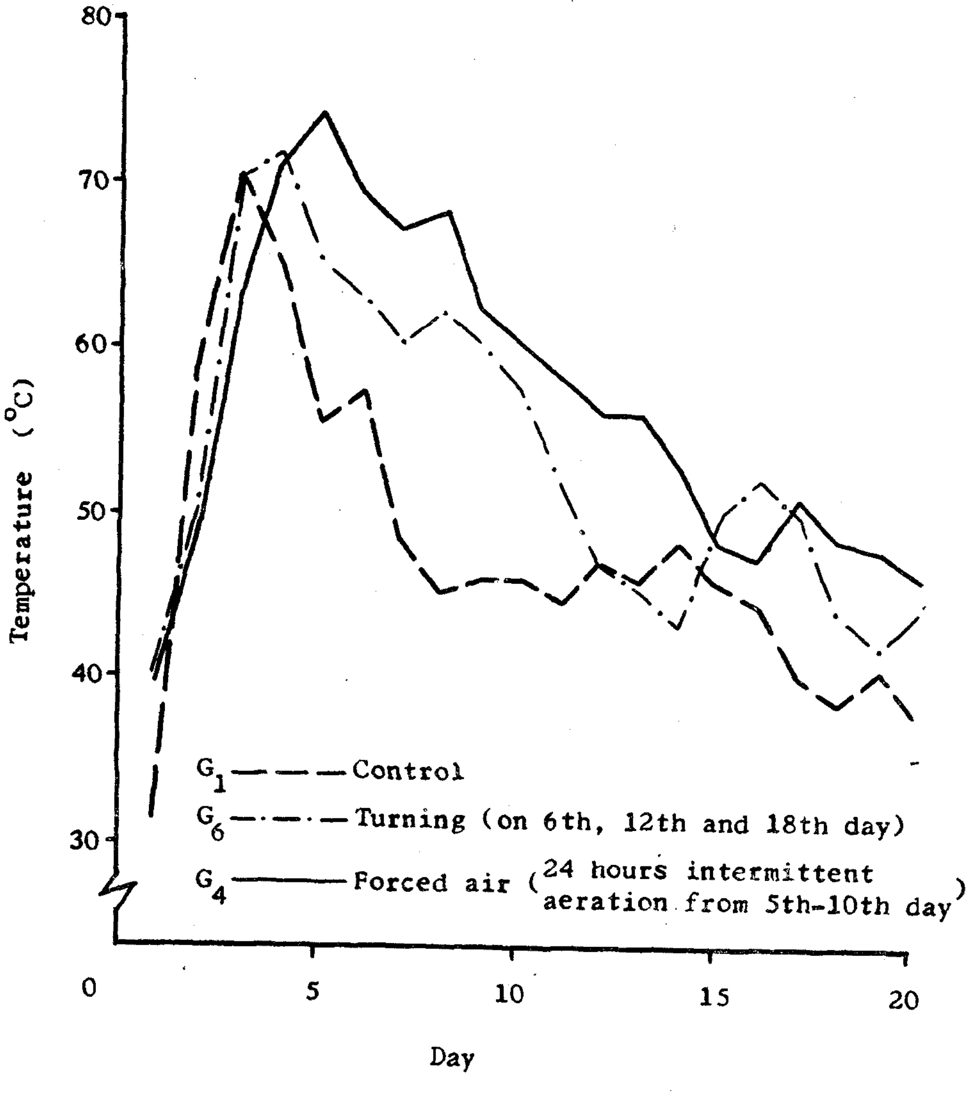


Figure 6 shows that higher temperatures can be developed in the forced air piles, if aeration is held up to the 5th day and fed intermittently. The temperatures of the G_4 pile (24 hours of intermittent air feeding) are considerably higher than those of the G_6 pile (turned on the 6th, 12th and 18th day).

Figure 6.

Temperature Curve of G_1, G_6 and G_4 Piles



D. Organic Matter

In the Experimental Runs A_1 to A_8, the initial refuse contained only 29% of organic matter, due to the large amount of sand and ashes in the raw refuse. Screening of the raw refuse was carried out for the other runs, which resulted in a higher organic content of 36% to 54% in the compost material.

After screening, our average compost material therefore should contain at least 40% of organic matter.

In the control piles, without forced air or turning, the decomposition of organic matter ranges from 20% to 34%, most of them being below 30%.

In the piles aerated by turnings, the decomposition of organic matter is generally as follows:

Frequency of turnings	Organic decomposition (%)
1	27—36
2	30—37
3 or more	33—44

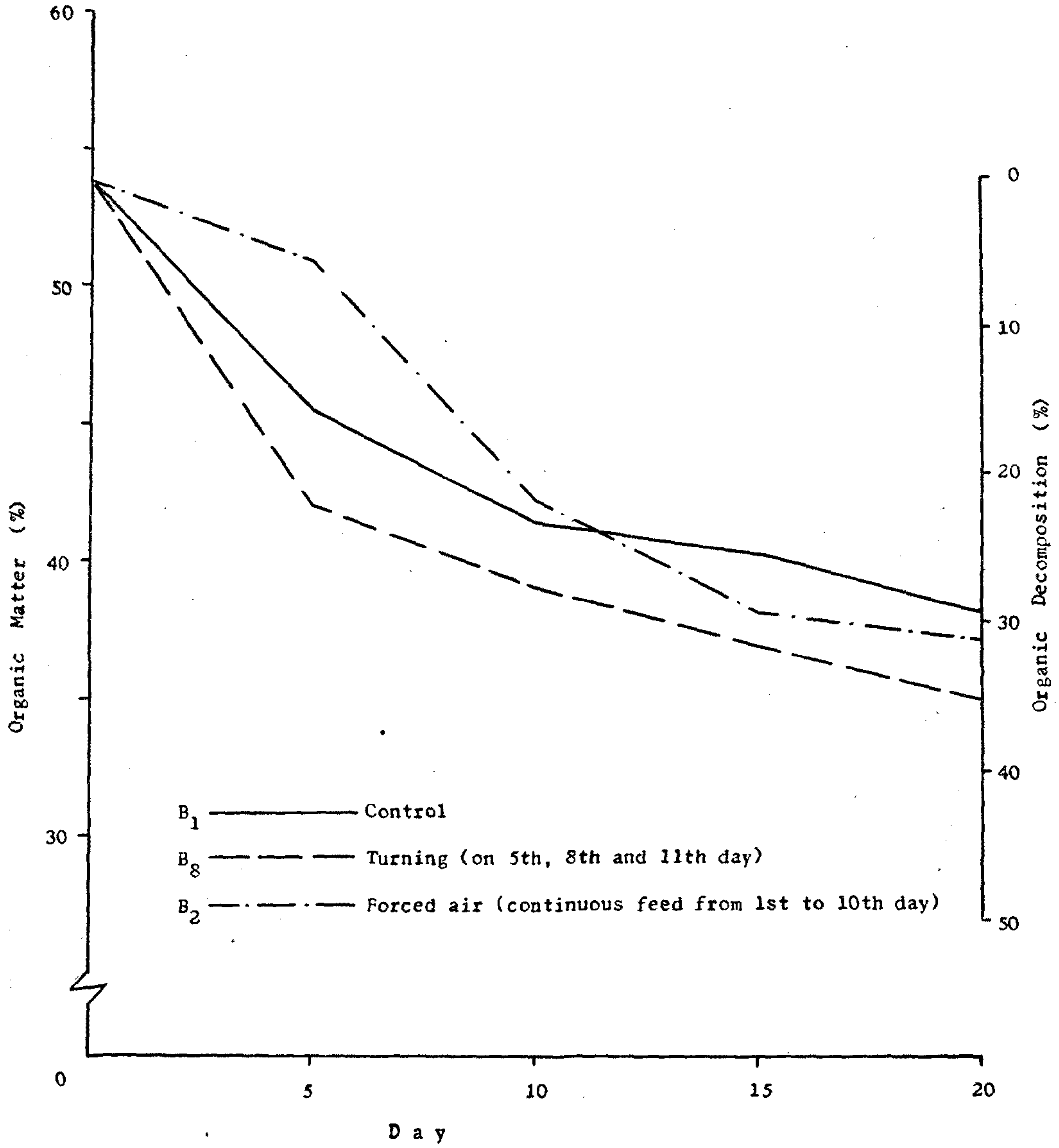
In the piles aerated by forced air, the range of organic matter decomposition is between 25% to 45%. Greater breakdown of the organic matter occurred with the aeration period commencing on the 5th day and with intermittent air feeding, C and G experimental runs. Figures 7 and 8 show the trend of organic matter decomposition of B_1, B_2, B_8 and the G_1, G_4 and G_6 series, respectively.

Figure 7 shows that excessive aeration from the 1st day to the 10th day in the B_2 pile resulted in a slower rate of organic decomposition, the final organic matter in this pile being only slightly less than that of the control pile. The turning process produced the best organic breakdown.

Pigure 7.

Decomposition Curve of Organic Matter in Experimental Compost Piles

(B_1, B_8 & B_2)

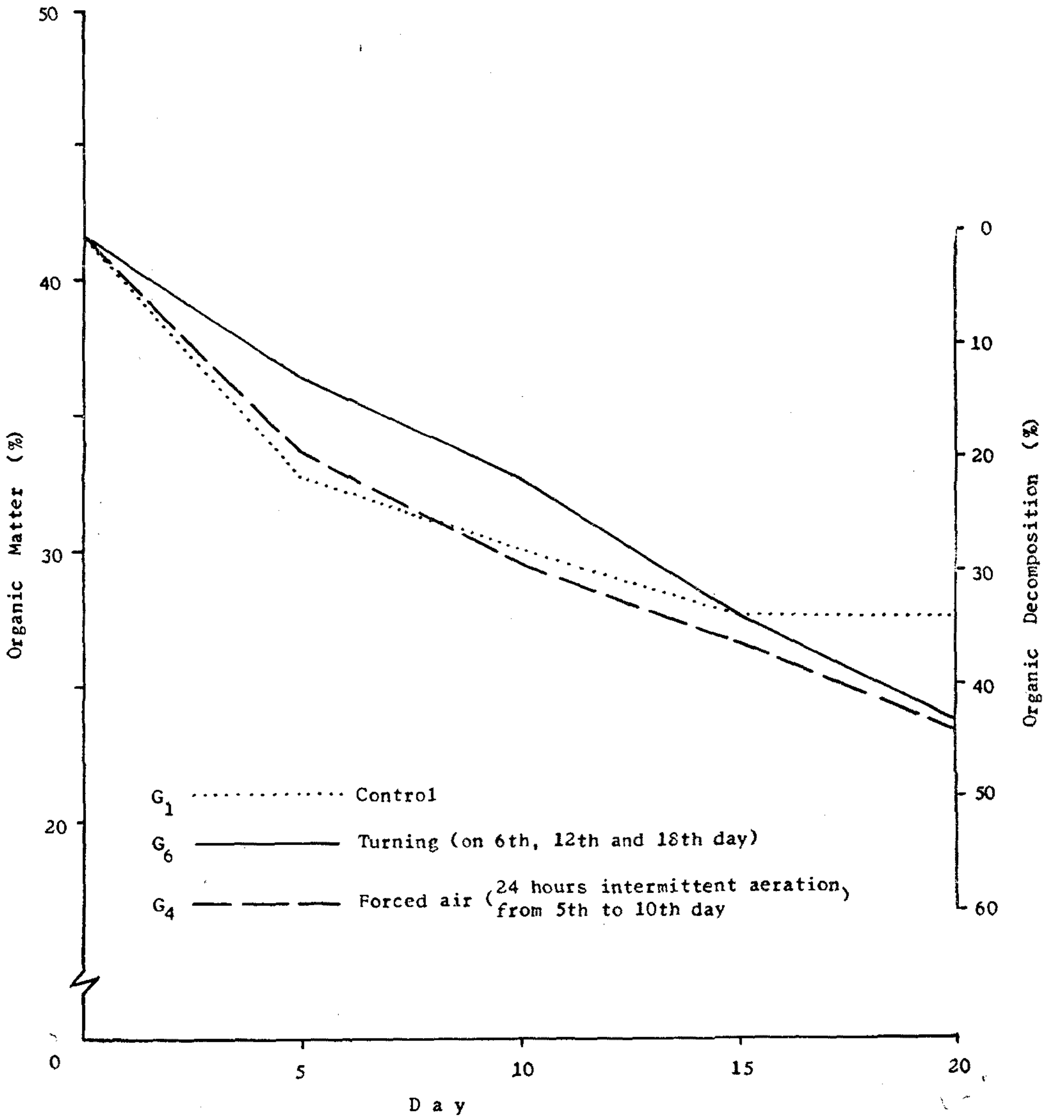


B_1	53.8	45.4	41.3	40.2	38.0
B_8	53.8	42.0	39.0	36.8	34.8
B_2	53.8	50.9	42.2	38.0	37.0

Figure 8 shows nearly identical levels of organic matter content in the 20-day compost processed by the turning and forced air methods. What is curious and probably questionable is the fact that the rate of decomposition during the first five days in the G_6 pile (turning) is less than that of the other two piles.

Figure 8.

Decomposition Curve of Organic Matter in Experimental Compost Piles (G_1, G_6 and G_4)



G_1	41.6	32.7	30.0	27.5	27.5
G_6	41.6	36.4	32.6	27.5	23.6
G_4	41.6	33.6	29.5	26.5	23.2

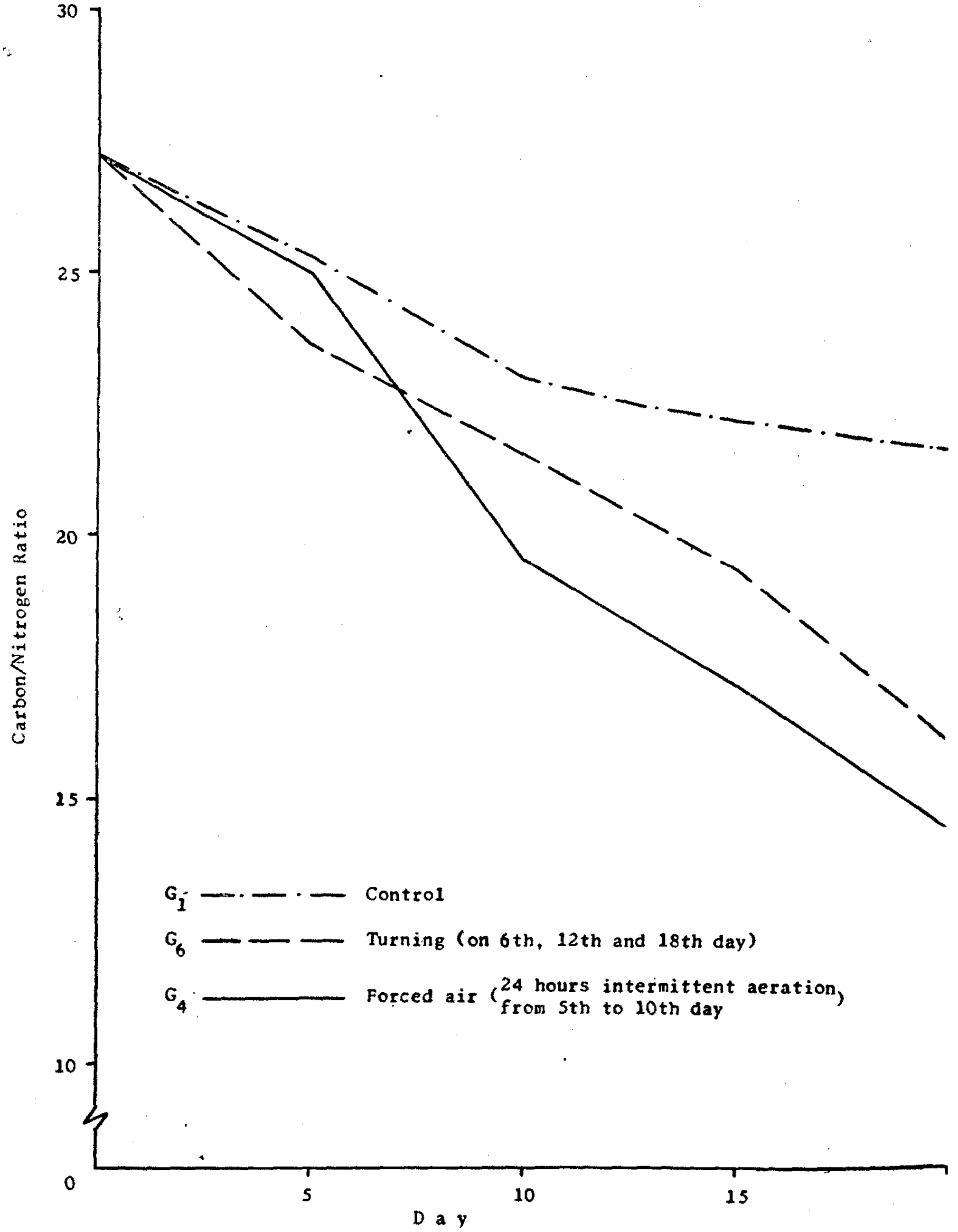
E. Carbon/Nitrogen Ratio

The C/N ratio of the refuse collected in Pingtung after screening and sorting falls between 26 to 34, with 28 being a typical value. This is very suitable for composting and requires no addition of nightsoil for adjusting the optimum value. We did, however, make some experimental runs with addition of about 20% (by weight) of nightsoil, the amount being limited by moisture consideration. This decreased the C/N ratio by a maximum value of 2.

At the end of the 20-day period, the C/N ratio of the control piles remains slightly above 20. In the piles aerated by turnings or forced air, the C/N ratio decreases to values 23 on the 5th day, 20 on the 10th day, 18 on the 15th day and 16 on the 20th day. Figure 9 shows a typical trend in the G_1, G_4 and G_6 runs.

Figure 9.

Carbon/Nitrogen Variation Curve of Piles G_1, G_6 and G_4



G_1	27.2	25.3	23.0	22.0	21.6
G_6	27.2	23.6	21.5	19.3	16.1
G_4	27.2	25.0	19.5	17.1	14.4

F. NPK Content

Appendices 2, 3 and 4 show the NPK content of the initial refuse and the compost product.

The initial values in Experimental Run A_1 to A_8 showed low total nitrogen (0.59%) and K_2O (0.69%) and very high P_2O_5 (1.72%). The other runs were made with screened refuse, resulting in higher N and K_2O but greatly reduced P_2O_5 values. The range of NPK values in the screened refuse at the start and at the end of the compost period is shown below.

Constituent	At start (%)	At end (%)
Total N	0.69—0.87	0.68—1.23
P_2O_5	0.49—0.88	0.59—0.99
K_2O	0.84—0.98	0.89—1.14

While the NPK values in the final compost may show an increase when expressed on a percentage basis, substantial loss in NPK actually occurs. This loss may be greatly due to the affect of the rain, leaching off these valuable constituents. Up to 31% loss in nitrogen, 25% loss in P_2O_5 and 28% loss in K_2O resulted as shown in Table 2.

Table 2.

NPK Losses Occuring in Piles B_1, G_6 and C_2

Expt. Run No.	N			P_2O_5			K_2O		
	Initial (kg)	Final (kg)	Loss (%)	Initial (kg)	Final (kg)	Loss (%)	Initial (kg)	Final (kg)	Loss (%)
B_1	3.66	2.54	31	2.06	1.93	6	4.13	2.97	28
G_6	3.68	2.66	28	3.37	2.54	25	4.11	3.00	27
C_2	3.42	2.48	28	2.60	2.19	16	4.15	3.06	26

Note: Values of NPK (kilograms) in the above table are computed on the following basis:

kg = (volume of pile from Table 3) × (unit weight from Table 3) × (1—moisture content) × (% of NPK from Appendices 2, 3 and 4).

Moisture content of initial pile (before moisture adjustment) is 45% and of final is 50%.

G. Changes in Volume and Unit Weight of Compost Piles

The volume of the compost pile decreases progressively during the compost period. The volume of the compost pile may be reduced to 77% of the original volume on the 5th day, 65% on the 10th day, 56% on the 15th day and 53% on the 20th day.

As the volume of the heap decreases, the unit weight of the material increases. This may be 0.37 to 0.38 ton/m³ at the start, 0.39 to 0.41 ton/m³ on the 5th day, 0.43 to 0.45 ton/m³ on the 10th day, 0.47 to 0.48 ton/m³ on the 15th day and finally 0.49 to 0.53 ton/m³ on the 20th day.

Comparing the compaction resulted from the three different methods of composting, it appears that aeration by forced air produces the greatest reduction in volume and the greatest unit weight in the final product. The changes observed in these respects are shown in Table 3, indicating that the final compost may amount to about 75% to 80% by weight of the initial material.

Table 3.

Changes in Volume and Unit Weight of Compost Piles

Date	Pile B_1				Pile G_6				Pile C_2			
	Volume		Unit weight		Volume		Unit weight		Volume		Unit weight	
	m³	%	ton/m³	%	m³	%	ton/m³	%	m³	%	ton/m³	%
1st day	2.07	100	0.37	100	2.07	100	0.38	100	2.07	100	0.38	100
5th Day	1.60	77	0.39	106	1.73	84	0.40	105	1.72	83	0.41	108
10th day	1.34	65	0.45	122	1.44	70	0.43	113	1.35	65	0.45	118
15th day	1.24	60	0.47	127	1.30	63	0.47	123	1.15	56	0.48	126
20th day	1.12	55	0.51	138	1.25	60	0.49	129	1.10	53	0.53	140

H. Oxygen Consumption during Composting

According to the studies made at the Michigan University (as shown in Dr. J. R. Snell's report), oxygen fed at the rate of 0.0244 gm./min./100 gm.

of refuse (dry weight) resulted in 50% oxygen utilization. On the basis of 65% of organic matter, assumed to be present in the refuse, this is equivalent to 1.3 liter of air/min./kg. of organic matter (dry weight). During an aeration period of 4 days, the amount of air provided would equal to 7.5 cubic meters per kg. of dry organic matter.

Each of our experimental piles contains 173 kg. of organic matter, based on a total wet weight of 787 kg., 45% moisture and 40% organic matter content (before addition of nightsoil or water for moisture adjustment). With our blowers operating at 0.5 cubic meter per minute, our air feed rate is $500 \div 173 = 2.9$ liter/min./kg. of organic matter. On the basis of 7.5 cubic meter of air/kg. of organic matter, our required aeration period should be $7{,}500/(2.9 \times 60) = 43$ hours. Total aeration time needed in our various experimental runs varied from 12 hours to 360 hours.

At this rate of air feed (2.9 liter/min./kg. of organic matter), which is twice more than that of the Michigan University studies, our oxygen utilization falls behind the expectations. Table 4 shows some of the observed oxygen utilization in our earlier runs. Oxygen utilization on the first day is below 1.6%, increases to a maximum of 23% on the fourth day and decreases to below 10% after the fifth day.

Further studies on the extent of oxygen utilization are very necessary for determining on the optimum rate of air feed and on how this may be varied during each day of the aeration period.

Table 4

Precentage of O_2 in Forced Air Utilized by Compost Pile

Day	A_2 (120 hrs. Air)		A_3 (64 hrs. Air)		A_4 (130 hrs. Air)		A_5 (194 hrs. Air)	
	X	Y	X	Y	X	Y	X	Y
1	0.10	0.5	1.10	0.5	0.10	0.5	0.34	1.6
2	2.43	11.7	2.15	10.4	2.40	11.7	3.30	16.0
3	2.53	12.3	4.01	19.5	3.50	17.0	2.99	14.6
4	3.85	18.7	4.25	20.6	3.20	15.7	4.72	22.8
5	1.95	9.7	2.21	10.8	4.05	19.7	3.20	15.5
6	1.43	7.0	2.06	10.0	2.54	12.4	2.02	9.9
7					1.90	9.3	2.01	9.8
8					1.41	6.9	1.78	8.6
9					0.52	2.5	0.85	4.1
10					2.40	11.6	1.97	9.5
11					1.92	9.3	1.91	9.3
12							1.72	8.3
13							1.78	8.6
14							1.71	8.3
15							1.69	8.3

X = Decrease in O_2 content (%) of air after passing through compost (initial O_2 content in air between 20.46% to 20.75%)

Y = % of available O_2 in air utilized by compost

I. Other Data

1. Screenings: Screening of the raw refuse was considered desirable to decrease the high content of inert material and increase the organic content of the refuse used in composting. The screenings ($^1/_2$" screen) however, have considerable value and can be used as top-soil. Table 5 shows the composition of the screenings when composted for 20 days with three turnings.

Table 5

Composition of Screenings from Raw Refuse

(Average of 5 Samples Composted with 3 Turnings)

Days of Composting	Organic Matter (%)	Ash (%)	Carbon (%)	Total N (%)	C/N ratio	P_2O_5 (%)	K_2O (%)
1	10.4	89.6	5.78	0.35	16.7	0.96	0.22
5	9.6	90.4	5.33	0.32	16.6	—	—
10	8.0	92.0	4.44	0.27	16.3	—	—
15	8.0	92.0	4.44	0.28	15.8	—	—
20	7.8	92.2	4.33	0.27	15.9	0.98	0.26

2. Physical analyses of the raw refuse from Pingtung: Analyses of the raw refuse during a year show the following composition.

Item	%
Garbage	15.2
Paper	4.9
Straw	35.8
Rag	2.0
Wood	1.0
Metal	0.8
Brick, porcelain & pottery	6.6
Leather & rubber	0.3
Sand, ashes and others	33.4

3. Unit weight of refuse from Pingtung

Refuse	Unit weight
Raw	0.33 ton/m^3
After being processed for composting	0.38 ton/m^3
20-day compost	0.52 ton/m^3

4. Chemical analyses of the refuse and compost in Pingtung

Item	Ground refuse	20-day compost
pH value	7.0-7.8	6.2-7.2
Moisture	35 -45%	50%
Organic matter	41%	26%
Ash	59%	74%
Total N	0.75%	0.80%
P_2O_5	0.65%	0.80%
K_2O	0.80%	0.95%
Carbon*	22.7%	14.4%
CO_2	4.5%	5.0%
C/N	28	14-19

$$\text{*Carbon}\% = \frac{100 - \text{Ash}\%}{18}$$

5. Comparison of refuse compost with compost produced by farmers

Type of compost	Organic matter (%)	Total N (%)	P_2O_5 (%)	K_2O (%)	C/N ratio	Compost period
Hog waste & sugarcane leaves	31.1	1.2	1.1	0.65	14.4	5 months
Cow waste & straw	27.4	1.2	1.2	0.76	15.4	6 months
Refuse compost	26.0	0.8	0.8	0.95	14-19	20 days

IV. Economic Considerations

A. Production of Compost

During the past year, the experimental plant processed an average quantity of 10 tons of refuse per day. After screening, sorting and grinding, the final product amounted to about 60% of the original weight. The total production for the 234 working days of a year therefore amounted to $234 \times 10 \times .6 = 1400$ tons of compost.

B. Sale of Compost

Of the above production, 400 tons were ordered by the Land Reclamation Office of the Provincial Department of Agriculture and Forestry; the balance was sold to the farmers in Pingtung who came for the compost in oxcarts.

There is a definite demand by the farmers for compost, because of the local recognition of its value for the sandy type of farm land in Pingtung The compost is used mainly for sugarcane, sweet potato, tobacco and fruit cultivation. A little is also utilized for vegetables and rice crops. Sale price for the product has been at NT$40 (US$1.10) per ton, self-transported by the purchasers.

With the completion of the full scale plant operated at 20 tons of raw refuse per day, the City of Pingtung has entered into a contract with two Retired Servicemen's Cooperative Farms located in Pingtung Hsien to supply them with a total of 2,500 tons of compost over a period of one year. These two farms, Ailian Farm with 617 hectares of land and Chutien Farm with 189 hectares of land, are essentially waste lands with sandy soil and gravel. Application of compost on these reclaimed farm land (10 to 30 tons per hectare) is considered necessary for enriching the soil and increasing its moisture holding capacity. The compost is sold at a contract price of NT$40 per ton.

C. Operational Cost of the Full Scale Plant

1. *Description of the full scale plant*

The refuse is unloaded by 4 unskilled laborers from flat bed refuse trucks on two steel platforms which can be tilted, so that the material can be readily pushed into a central conveyor belt feeding into a mechanically vibrating screen. The screenings are removed by hand rail cars and spread over low land area that is filled with larger inert materials sorted from the refuse. The screened refuse is conveyed to the grinder by a 1M wide belt, running at a speed of 8M per minute. Four laborers hand pick the large noncompostable materials, salvable paper and metals off this conveyor belt. The materials, after passing under a magnetic separator, go to the first coarse grinder, which is followed by a shredder which flings off the heavier stones, shells, glass and porcelain particles. The second grinder and the magnetic separator have not been installed yet. The grinders are locally made with a rated capacity of 3 tons per hour, hammer mill-type, rotating at 1,800 rpm with a 15HP motor.

The ground material is then transported to the covered compost bins by push carts (made of aluminum) running on rails. There are 20 bins, each being 6M × 5M in size and 1.5M in depth with air fed through 4 lines of 3" perforated asbestos cement pipes. Air feed to each of these bins can be controlled by individual valves. The air is supplied by two blowers, which operate alternately and feed into a 12" diameter main. The blowers are locally made, 5HP motors, capacity $40m^3/min$, 2600 rpm and 150 mm (water) pressure. Three air meters (ring balanced type 6", $16m^3/min$ capacity) have been installed at individual bins to permit air flow measurements.

The materials placed into the bins are sprayed with nightsoil, which is pumped from a storage tank. Moisture adjustments during the 20-day period of composting is done with well water supplied by the same pump. Necessary laboratory tests are conducted to obtain analytical data and to guide the operation of the plants. The compost, after 20 days of aerobic decompostion, is unloaded from the bins manually.

A schematic diagram of the full scale composting plant is appended.

2. *Capital cost of plant*

The construction cost of the full scale plant of 25 tons per day utilizing forced air aeration is as follows:

Structures:	
Office building	NT$ 60,000
Unloading & feeding platform	174,000
Compost bin	252,000
Nightsoil tank	48,000
Pumping & blower room	16,000
Rail system	67,000
Air and nightsoil piping system	75,000
Power installation	43,000
Roadway & drainage system	120,000
Gate and fence	18,000
Sub-total	NT$873,000
Equipment:	
Vibrating screen	NT$ 12,000
Sorting conveyor	64,000
Grinders (two)	109,000
Shredder	83,000

Belt conveyor to shredder	8,000
Blowers & air meters	60,000
Magnetic separator	12,000
Sub-total	NT$348,000
Total capital cost	NT$1,221,000

3. *Amortization of plant*

Item	Capital cost (NT$)	Period (year)	Factor (6% interest)	Annual amortization (NT$)
Land*	250,000			
Structures	873,000	40	0.0664	57,100
Equipment	348,000	10	0.136	47,500
Total				104,600

*** Land belonging to the city with amortization not provided.**

4. *Operational cost*

2 supervisors	2 × NT$500/mon. × 13mon.	=	NT$13,000
16 unskilled workers	16 × NT$400/mon. × 13mon.	=	83,200
Electrical power	NT$2,100/mon. × 12mon.	=	25,200
Maintenance			
Building	1% of NT$873,000	=	8,700
Equipment	3.5% of NT$348,000	=	12,200
Administrative expenses	NT$500/mon. × 12mon.	=	6,000
			NT$148,300

5. *Annual cost*

Plant amortization	=	NT$104,600
Operational cost		148,300
Total annual cost	=	NT$252,900

6 *Revenue*

From sale of compost (25 tons/day × 322 days × 0.6 = 4830 tons/year)

4830 tons × NT$40/ton = NT$193,000

From sale of salvaged paper (100 kg./day × 322 days = 32,200 kg./year)

32,200 kg. × NT$0.40/kg. = NT$12,900

Total revenue = NT$205,900

Net loss NT$252,900—NT$205,900 = NT$47,000

To break even, price of compost must be raised to NT$50 per ton.

$$\frac{\text{NT\$47,000}}{4830} + \text{NT\$40} \doteqdot \text{NT\$50}$$

D. Comparison of Cost of Turning vs. Aeration by Forced Air

1. *Turning method*

From experimental studies, a minimum of three turnings of the piles during the 20-day period is necessary to compare with the forced air aeration method. It has been found that one laborer can turn 5 tons of the material (based on finished compost weight) per day.

Total weight of compost turned per year = 3 × 4830 = 14,490 tons

Work output of 1 laborer = 5 × 322 = 1610 tons/year

$$\text{No. of laborers required} = \frac{14,490}{1610} = 9$$

Wage for 9 laborers = 9 × NT$5,200 = NT$46,800/year

$$\text{Unit cost of turning} = \frac{46,800}{4830} = \text{NT\$9.70/tons}$$

2. *Forced air aeration*

Capital Expenditure:

Item	Capital Cost	Amortization
Blower building and piping	= NT$75,000	NT$5,000
Blowers and air meters	= 60,000	8,200
Total	= NT$135,000	T$13,200

Annual operational cost:

Power for 5 HP blower = 5 × 0.746 × 24 × 365 = 32,500 kwh/year		
Cost = 32,500 kwh@NT$0.25/kwh =		NT$8,130
Laborer (one required) @ NT$5,200/year =		5,200
Maintenance = 1% of NT$75,000	=	750
3.5% of NT$60,000	=	2,100
		NT$ 16,180

Annual cost of aeration NT$ 13,200 + NT$16,180 = NT$29,380

Unit cost of aeration $= \frac{\text{NT\$29,380}}{4830} \doteqdot$ NT$6.10/ton

Based on the above estimate the forced air aeration method is more economical than the manual turning, being about 60% of the cost by turning.

E. NPK Value of Compost

The following approximate content of NPK can normally be expected in our compost product.

Item	Dry basis (%)	Finished compost (kg./ton)	Market price (NT$/kg.)	Est. value (NT$)
Nitrogen	0.8	4.0	10	40
P_2O_5	0.8	4.0	5	20
K_2O	0.95	4.8	5	24
Total				84

Based on the above estimated NT$84 as the value of the NPK present in a ton of compost, it can be seen that there is a very favorable balance in the production cost and the minimum worth of the product. Moreover, the value of the organic matter has not been included.

While field tests yielding data on the efficacy of the compost on various crops would be valuable, systematic studies have not been attempted. Arrangements have been made with the Provincial Pingtung Junior College of Agriculture to undertake this phase of study. Some fragmentary reports from the farmers, who have applied this compost to their fields, do indicate a definite increase in crop yield. One farmer, who has grown soybean on one plot with compost applied and one plot without, reported a 30% increase in yield.

V. Public Health Considerations

During the period of experimental study and the early months of the operation of the full scale plant, no studies on the hygienic quality of the finished product were carried out. The presence of pathogens and indicators such as E. coli, particularly where nightsoil was added, would be of research value; nevertheless studies on them were omitted due to the unavailability of qualified personnel and equipment. This phase of studies is now in the process of being initiated. Efforts will be made to correlate pathogen destruction with the temperature-time factors. Inasmuch as the temperature varies at different depths of the piles, data on the effectiveness of pasteurization at different depths would also be necessary.

Flies were not present at the compost bins, indicating that the fly breeding is unlikely to develop with the temperatures. Some flies were present at the unloading platform, being introduced to the plant with the incoming refuse.

Rodent breeding about the plant is not a problem. There is, however, a need for dust control at the vibrating screen and the grinder

VI. Summary

A. The raw refuse of Pingtung City has an excessive amount of noncompostable materials. Screening, sorting and grinding are essential preliminary processes before composting.

B. In the control piles (without turning or aeration), the temperatures developed are inadequate as sanitary safeguards, breakdown of organic matter averages less than 26%, C/N ratio remains above 20 after 20 days, and greater loss in nitrogen occurs.

C. With proper turning of the compost piles or forced air aeration, satisfactory composting can be achieved which will produce a valuable organic product without any nuisance condition.

D. Turning of the compost pile every 4 to 5 days for at least three times can yield similar results as forced air composting during a 20-day period.

E. A comparison of the cost of turning against aeration by forced air shows that the latter method as being more economical.

F. Our experimental studies with forced air aeration show that:

(1) Continuous air feed at the rate of 2.9 liter/min./kg. of organic matter is excessive, resulting in ineffecient utilization of available oxygen. The cooling and drying effect of the air fed at this rate was highly evident.

(2) At the above rate of air feed, (2.9 liter/min./kg. of organic matter) best results were obtained with 20 to 60 hours (average 40 hours) of intermittent aeration, beginning from as late as the fifth day and ending at the 10th day. The total amount of air thus required is $1.53m^3$ for one kg. of ground refuse or $6.9m^3$ for one kg. of dry organic matter. ($60 \times 40 \times 0.5/787 = 1.53m_3$/kg. ground refuse, $60 \times 40 \times 0.5/(787 \times 0.55 \times 0.40) = 6.9m^3$/kg. organic matter)

(3) Oxygen requirements vary with each different day of composting. Further studies to establish the optimum rate of air feed during each day and length of aeration period are needed. The value of such studies is obvious.

G. Losses in NPK from the refuse during composting in our open experimental bins were caused to a considerable extent by rain and its leaching action. A cover over the compost bin is highly desirable not only to conserve NPK but to reduce moisture losses through evaporation.

H. The hygienic quality of the compost has not been studied and should be pursued in the future to determine the effectiveness of pasteurization by the high temperatures developed in the piles. Flies and rodent problems were not evident at this plant.

I. Total production at the Pingtung plant during the first year of operation amounted to 1400 tons of compost. These were sold very readily at NT$40 per ton. Computed worth of the NPK present in each ton of compost was around NT$84.

J. Estimated production cost of compost with the full scale forced air bin plant is about NT$50 (US$1.40) per ton. It is anticipated that marketing will not be a problem if the sale price of compost is adjusted to NT$50 per ton.

Appendix 1

Summary Description of Experimental Runs

Group	Run No.	Air Feed			Turnings		Remarks
		Feed Days	Intervals Between Feeds**	Total hours	Fre-quency	Date for Turnings	
1	A_1	—	—	—	—	—	Control
	A_2	1—5	0/24	120			Air Feed
	A_3	1—5	8/8	64			〃 〃
	A_4	1—10	8/8	120			〃 〃
	A_5	1—15	8/8	184			〃 〃
	A_6				1	5	Turning
	A_7				2	5,10	〃
	A_8				3	5,10,15	〃
2	B_1	—	—	—	—	—	Control
	B_2	1—10	0/24	240			Air Feed
	B_3	1—15	0/24	360			〃 〃
	B_4	1—10	3/3	120			〃 〃
	B_5	1—15	3/3	180			〃 〃
	B_6				4	3,6,9,12	Turning
	B_7				3	4,7,10	〃
	B_8				3	5,8,11	〃
3	C_1	5—14	3/1	60			Air Feed
	C_2	5—14	6/2	60			〃 〃
	C_3	5—14	2/0.5	48			〃 〃
4	D_1	—	—	—	—	—	Control
	D_2*	—	—	—	—	—	〃
	D_3*	1—10	3/1	60			Air Feed
	D_4*	5—14	2/0.5	48			〃 〃
	D_5*	5—9	3/0.5	17			〃 〃
	D_6*	5—9	4/0.5	13.3			〃 〃
	D_7*				1	5	Turning
	D_8*				2	5,10	〃

Appendix 1 (Cont'd)

Group	Run No.	Air Feed			Turnings		Remarks
		Feed Days	Interval Between Feeds**	Total hours	Fre-quency	Date for Turnings	
5	E_1*	5—9	12/12	60			Air Feed
	E_2	5—9	12/12	60			〃 〃
	E_3*				1	4	Turning
	E_4				1	4	〃
	E_5*				2	7,14	〃
	E_6				2	7,14	〃
6	F_1	—	—	—	—	—	Control
	F_2*	—	—	—	—	—	〃
	F_3*	3—15	12/12	156			Air Feed
	F_4	3—15	12/12	156			〃 〃
	F_5*	3—15	4/1	62.4			〃 〃
	F_6	3—15	4/1	62.4			〃 〃
	F_7*				5	3,6,9,12,15	Turning
	F_8				5	3,6,9,12,15	〃
7	G_1	—	—	—	—	—	Control
	G_2	5—10	2/2	72			Air Feed
	G_3	5—10	4/2	48			〃 〃
	G_4	5—10	10/2	24			〃 〃
	G_5	5—10	22/2	12			〃 〃
	G_6				3	6,12,18	Turning
	G_7				2	6,12	〃
	G_8				1	6	〃

* 150 kg. night soil added.

**8/8 means 8 hours of non-aeration followed by 8 hours of air feeding

Appendix 2 Chemical Analysis of Experimental Composting **Check pile**

Experiment No.	No. of days which compost exceeds			Organic Matter (%)			C/N Ratio		Total N (%)		P_2O_5 (%)		K_2O (%)	
	70°C	60°C	50°C	Ground refuse	Finished compost	Decomposition	Ground refuse	Finished compost	Ground refuse	Finished compost	Ground refuse	Finished compost	Ground refuse	Finished compost
A_1	1	1	4	29.0	19.6	32	27.2	19.6	0.59	0.55	1.72	1.88	0.69	0.74
B_1	1	2	5	53.8	38.0	29	34.3	24.0	0.87	0.88	0.49	0.67	0.98	1.03
D_1	-	1	3	35.7	28.5	20	27.2	20.5	0.72	0.77	0.50	0.60	0.92	1.04
D_2*	-	1	3	35.7	27.8	22	26.0	20.8	0.76	0.72	0.84	0.85	0.86	1.08
F_1	-	1	3	35.8	27.2	24	28.7	21.8	0.69	0.69	0.87	0.93	0.84	0.95
F_2*	-	1	3	35.8	27.2	24	26.7	20.1	0.74	0.71	0.88	0.96	0.86	0.98
G_1	1	2	5	41.6	27.5	34	27.2	21.6	0.85	0.70	0.78	0.78	0.95	0.99

* Night soil added.

Appendix 3 — Chemical Analysis of Experimental Composting — Turning pile

Expt. No.	Frequency of turnings	Date for turnings	No. of days which compost exceeds			Organic Matter (%)			C/N Ratio		Total N (%)		P_2O_5 (%)		K_2O (%)	
			70°C	60°C	50°C	Ground refuse	Finished compost	Decomposition	Ground refuse	Finished compost	Ground refuse	Finished compost	Ground refuse	Finished compost	Ground refuse	Finished compost
A_6	1	5	1	3	12	29.0	18.6	36	27.2	19.6	0.59	0.53	1.72	1.92	0.69	0.74
A_7	2	5-10	-	2	13	29.0	19.2	34	27.2	19.5	0.59	0.54	1.72	1.95	0.69	0.75
A_8	3	5-10-15	1	6	11	29.0	19.2	34	27.2	19.1	0.59	0.56	1.72	1.91	0.69	0.73
B_6	4	3-6-9-12	2	8	11	53.8	36.0	33	34.3	17.3	0.87	1.15	0.49	0.67	0.98	1.07
B_7	3	4-7-10	1	11	19	53.8	36.0	33	34.3	17.5	0.87	1.14	0.49	0.64	0.98	1.05
B_8	3	5-8-11	1	10	17	53.8	34.8	35	34.3	16.7	0.87	1.15	0.49	0.67	0.98	1.05
D_7*	1	5	-	2	11	35.7	23.8	33	26.0	18.7	0.76	0.83	0.84	0.94	0.86	0.90
D_8*	2	5-10	1	6	11	35.7	23.6	34	26.0	15.5	0.76	0.83	0.84	0.90	0.86	0.90
E_3*	1	4	-	3	6	40.1	29.1	27	25.6	17.5	0.87	0.92	0.79	0.92	0.94	0.96
E_4	1	4	-	2	9	40.1	28.8	28	27.2	18.5	0.81	0.85	0.78	0.89	0.89	0.94
E_5*	2	7-14	-	5	12	40.1	27.0	33	25.6	16.0	0.87	0.93	0.79	0.92	0.94	0.96
E_6	2	7-14	1	6	11	40.1	28.1	30	27.2	18.0	0.81	0.86	0.78	0.91	0.89	0.90
F_7*	5	3-6-9-12-15	3	8	11	35.8	20.0	44	26.7	16.3	0.74	0.68	0.88	0.94	0.86	0.89
F_8	5	3-6-9-12-15	3	7	10	35.8	21.4	40	28.7	17.0	0.69	0.70	0.87	0.90	0.84	0.90
G_6	3	6-12-18	2	7	13	41.6	23.6	43	27.2	16.1	0.85	0.87	0.78	0.83	0.95	0.98
G_7	2	6-12	-	4	8	41.6	26.1	37	27.2	18.1	0.85	0.79	0.78	0.83	0.95	0.95
G_8	1	6	1	4	6	41.6	27.8	33	27.2	20.8	0.85	0.74	0.78	0.83	0.95	1.00

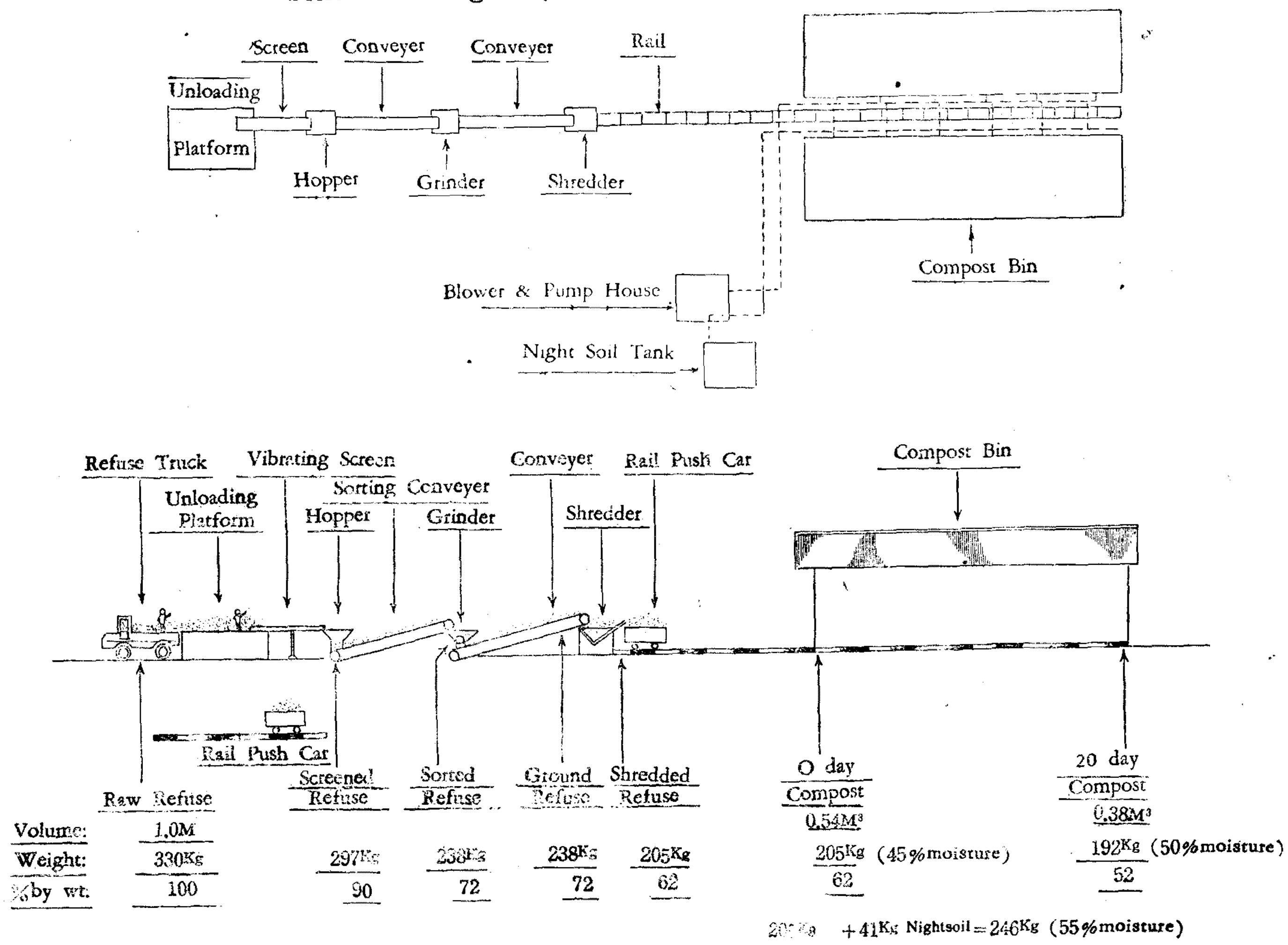
* Night soil added.

Appendix 4 | Chemical Analysis of Experimental Composting | **Blowing pile**

Expt. No.	Air feed (hr/day)	Days of air feed	Intervals between feeds #	Total air feed hours	No. of days which compost exceeds 70°C	60°C	50°C	Organic Matter (%) Ground refuse	Organic Matter (%) Finished compost	Organic Matter (%) Decomposition	C/N Ratio Ground refuse	C/N Ratio Finished compost	Total N (%) Ground refuse	Total N (%) Finished compost	P_2O_5 (%) Ground refuse	P_2O_5 (%) Finished compost	K_2O (%) Ground refuse	K_2O (%) Finished compost
A_2	24	1-5	---	120	1	4	11	29.0	18.5	36	27.2	18.2	0.59	0.56	1.72	1.86	0.69	0.83
A_3	12	1-5	8-8	64	-	3	13	29.0	20.0	31	27.2	19.8	0.59	0.56	1.72	2.07	0.69	0.93
A_4	12	1-10	8-8	120	-	5	9	29.0	19.2	34	27.2	18.8	0.59	0.56	1.72	1.88	0.69	0.91
A_5	12	1-15	8-8	184	-	4	10	29.0	18.4	37	27.2	18.4	0.59	0.54	1.72	1.92	0.69	0.89
B_2	24	1-10	---	240	-	-	6	53.8	37.0	31	34.3	17.6	0.87	1.17	0.49	0.68	0.98	1.06
B_3	24	1-15	---	360	-	-	6	53.8	38.0	29	34.3	19.5	0.87	1.08	0.49	0.73	0.98	1.10
B_4	12	1-10	3-3	120	-	-	7	53.8	40.0	26	34.3	18.0	0.87	1.23	0.49	0.59	0.98	1.12
B_5	12	1-15	3-3	180	-	1	8	53.8	37.2	31	34.3	17.7	0.87	1.17	0.49	0.65	0.98	1.14
C_1	6	5-14	3-1	60	1	5	10	42.2	25.2	40	29.4	15.1	0.79	0.92	0.60	0.75	0.96	1.06
C_2	6	5-14	6-2	60	3	8	15	42.2	23.2	45	29.4	14.2	0.79	0.85	0.60	0.75	0.96	1.05
C_3	4.8	5-14	2-½	48	2	6	16	42.2	26.6	37	29.4	16.5	0.79	0.89	0.60	0.75	0.96	1.05
D_3*	6	1-10	3-1	60	-	4	10	35.7	26.7	25	26.0	17.8	0.76	0.83	0.84	0.90	0.86	0.96
D_4*	4.8	5-14	2-½	48	1	6	10	35.7	23.9	33	26.0	16.2	0.76	0.82	0.84	0.94	0.86	0.95
D_5*	3.4	5-9	3-¾	17	2	8	11	35.7	24.5	31	26.0	16.7	0.76	0.81	0.84	0.99	0.86	0.91
D_6*	2.7	5-9	4-½	13.3	1	2	13	35.7	25.5	29	26.0	17.0	0.76	0.82	0.84	0.94	0.86	0.96
E_1*	12	5-9	12-12	60	-	4	7	40.1	28.1	30	25.6	16.8	0.87	0.92	0.79	0.80	0.94	1.02
E_2	12	5-9	12-12	60	-	4	7	40.1	28.8	28	27.2	18.5	0.81	0.86	0.78	0.76	0.89	1.01
F_3*	12	3-15	12-12	156	-	3	10	35.8	25.0	30	26.7	17.0	0.74	0.84	0.88	0.96	0.86	0.98
F_4	12	3-15	12-12	156	-	4	10	35.8	27.0	25	28.7	18.9	0.69	0.79	0.87	0.94	0.84	0.96
F_5*	4.8	3-15	4-1	62.4	1	6	10	35.8	24.2	32	26.7	15.1	0.74	0.89	0.88	0.96	0.86	0.99
F_6	4.8	3-15	4-1	62.4	1	5	10	35.8	24.4	32	28.7	18.3	0.69	0.74	0.87	0.93	0.84	0.94
G_2	12	5-10	2-2	72	1	6	13	41.6	25.1	40	27.2	10.0	0.85	0.87	0.78	0.93	0.95	1.04
G_3	8	5-10	4-2	48	1	7	12	41.6	25.0	40	27.2	16.4	0.85	0.86	0.78	0.89	0.95	1.03
G_4	4	5-10	10-2	24	2	7	14	41.6	23.2	44	27.2	14.4	0.85	0.89	0.78	0.98	0.95	1.07
G_5	2	5-10	22-2	12	-	4	8	41.6	24.4	41	27.2	15.8	0.85	0.79	0.78	0.93	0.95	1.05

\# Air feed interval= 8-8: 8 hours of non-air followed by 8 hours of air feed. 3-1: 3 hours of non-air followed by 1 hour of air feed.
* Night soil added.

Schematic Diagram of Pingtung Compost Plant



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