THE EFFECT OF COMPOSTING FACTORS ON KLUAI NAM WA-PEEL WASTE PROPERTIES IN COMPOSTING PROCESS WITH ACTIVATOR LD-1

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THE EFFECT OF COMPOSTING FACTORS ON KLUAI NAM WA-PEEL WASTE PROPERTIES IN COMPOSTING PROCESS WITH ACTIVATOR LD-1.

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ABSTRACT

The objective of this research was to determine the effects of composting factors (size of composting material, microorganism activator LD-1 adding and composting time: within 8 weeks) on Kluai Nam Wa-peel waste's physical and chemical properties in the composting process. This research also aimed to determine the optimal composting condition that could minimize Kluai Nam Wa-peel waste and produce an end product which could be used as a soil amendment. This research was composed of six experimental treatments of Kluai Nam Wa-peel waste composting conditions. It was a 3-factor factorial design. Treatments 1 and 2 were the composting of Kluai Nam Wa-peel waste 2 inches long with non-adding and adding activator LD-1. Treatments 3 and 4 were the composting of Kluai Nam Wa-peel waste 3 inches long with non-adding and adding activator LD-1. Treatments 5 and 6 were the composting of Kluai Nam Wa-peel waste more than 3 inches long (whole fruit peel) with non-adding and adding activator LD-1.

The results showed that the size of composting material and the composting time affected both physical and chemical properties of Kluai Nam Wa-peel waste in the composting process. It also showed that the activator LD-1 adding only affected chemical properties of Kluai Nam Wa-peel waste in the composting process. Treatment 2 was the best condition that could minimize Kluai Nam Wa-peel waste by the composting process. Its decomposing efficiency was 94% and its C/N ratio was 19.64/1. It took 4 weeks to produce the end product. The end product obtained had a high percentage of organic substrate (88.47% by weight) but the pH should be adjusted before use as a soil amendment.

KEY WORDS: KLUAI NAM WA-PEEL WASTE / COMPOSTING FACTORS / COMPOSTING PROCESS / WASTE PROPERTIES / ACTIVATOR LD-1

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ผลของปัจจัยการหมักต่อลักษณะสมบัติของมูลฝอยเปลือกกล้วยน้ำว้า ในกระบวนการหมักด้วยสารเร่ง พด.1 (THE EFFECT OF COMPOSTING FACTORS ON KLUAI NAM WA-PEEL WASTE PROPERTIES IN COMPOSTING PROCESS WITH ACTIVATOR LD-1)

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บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาผลของปัจจัยที่มีผลต่อกระบวนการหมัก อันได้แก่ ขนาดของวัสดุหมัก, การเติมสารเร่งจุลินทรีย์ พ.ด.1 และ ระยะเวลาที่ใช้ในการหมัก (ภายใน 8 สัปดาห์) ต่อลักษณะสมบัติทางกายภาพและเคมีของมูลฝอยเปลือกกล้วยน้ำว้า และมีวัตถุประสงค์เพื่อหาสภาวการณ์หมักที่เหมาะสมต่อการกำจัดมูลฝอยเปลือกกล้วยน้ำว้า และสามารถผลิตผลผลิตที่ได้จากกระบวนการหมักที่มีลักษณะสมบัติเป็นสารปรับปรุงดินได้ งานวิจัยนี้ประกอบด้วย 6 สภาวะการทดลองที่มีรูปแบบการหมักมูลฝอยเปลือกกล้วยน้ำว้าแตกต่างกัน โดยเป็นการวิจัยแบบแฟคทอเรียล 3 ปัจจัย สภาวะการทดลองที่ 1 และ 2 เป็นการหมักเปลือกกล้วยน้ำว้าขนาด 2 นิ้วที่ไม่เติม และ เติมสารเร่ง พ.ด.1 สภาวะการทดลองที่ 3 และ 4 เป็นการหมักเปลือกกล้วยน้ำว้าขนาด 3 นิ้วที่ไม่เติม และ เติมสารเร่ง พ.ด.1 ส่วนสภาวะการทดลองที่ 5 และ 6 เป็นการหมักเปลือกกล้วยน้ำว้าขนาดปกติตามธรรมชาติที่ไม่เติม และเติมสารเร่ง พ.ด.1

ผลจากการวิจัยครั้งนี้แสดงให้เห็นว่าขนาดของวัสดุหมักและระยะเวลาที่ใช้ในการหมักมีผลต่อลักษณะสมบัติทางกายภาพและเคมีของมูลฝอยเปลือกกล้วยน้ำว้า ส่วนการเติมสารเร่ง พ.ด.1 มีผลต่อลักษณะสมบัติทางเคมีของมูลฝอยเปลือกกล้วยน้ำว้าเท่านั้น และสภาวะการทดลองที่ 2 ซึ่งเป็นการหมักมูลฝอยเปลือกกล้วยน้ำว้าขนาด 2 นิ้วที่มีการเติมสารเร่ง พ.ด.1 เป็นสภาวะการหมักที่มีประสิทธิภาพในการย่อยสลายมูลฝอยเปลือกกล้วยน้ำว้าสูงที่สุด โดยมีประสิทธิภาพการย่อยสลายร้อยละ 94 และมีปริมาณ C/N เท่ากับ 19.64/1 ซึ่งใช้ระยะเวลาในการหมักเพื่อย่อยสลายมูลฝอยเปลือกกล้วยน้ำว้าน้อยที่สุด คือ 4 สัปดาห์ ซึ่งผลผลิตที่ได้จากกระบวนการหมักมีปริมาณสารอินทรีย์สูง (88.47% ของน้ำหนักทั้งหมด) เหมาะแก่การนำไปใช้เป็นสารปรับปรุงดิน โดยควรมีการปรับสภาพความเป็นกรด-ด่างก่อนนำไปใช้

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CHAPTER I
INTRODUCTION

1.1 State of Problem

Agriculture is the most career of Thai people. At the present, there are many agricultural developments to support domestic consumption and to export to other countries. Banana (*Musa sapientum* "Kuai Nam Wa") is a favorite fruit of Thai and foreign consumers. In 1998 and 1999, the total products of Kluai Nam Wa were 1,229,503 tons (819,668,666.7 units) and 1,367,452 tons (911,634,666.7 units) respectively (1). The total products of Kluai Nam Wa are increasing because it can grow for every season and in all parts of Thailand. Kluai Nam Wa can be transformed to many kinds of food products that can be preserved to sale later. In agriculture, those products are banana-streamed pastry, fried banana, banana in coconut milk, sun-dried banana, banana crisp, sugar-boiled banana purce, and butter-baked banana. Furthermore, there are many kinds of Kluai Nam Wa's products which are exported from food industries such as banana puree, banana flour, banana powder, freeze dried banana slice, banana chip, banana syrup, and banana juice (2).

Accordingly, Kluai Nam Wa-peel waste is increasing in the same rate of the total products of Kluai Nam Wa. It is dumped on the ground and waiting for collecting by municipality or elimination by burning (3). These disposal methods cause many environmental impacts such as being disease carrier's breeding place and habitat, making air pollution and destroying the environmental perspective. Therefore, it needs the appropriate method to manage Kluai Nam Wa-peel waste.

At present, Thailand has more seriously soil problems. These problems were the results of more needs in land utilization for serve the basic needs of the increasing population. Especially in agriculture soils, they had not any soil conservation and improvement activity. So, it was found that there were many non-productive soil in many parts of Thailand (4). Composting is the solution option to eliminate organic waste in Thailand, because it can recover the biological waste by transforming the waste to be soil amendment or soil conditioner that used in agriculture (5, 6).

However the composting has a long composting period by natural process (7). The composting period would be decreased by adjusting some composting factors, for example: size of composting materials; using of chemical activators or microorganism activators (8). Activator LD-1 is a type of microorganism activator, which has the highest amount of cellulose – decomposting microorganisms (9). So activator LD-1 can reduce decomposting time. It is supported for free by Department of Land Development, Ministry of Agriculture and Cooperatives. Thus, activator LD-1 is better use for composting organic waste because it can reduce the cost and take a short time to compost organic waste. Thus this research is concentrated on determining the effect of composting factors such as size of Kluai Nam Wa-peel waste, activator LD-1 adding and composting time.

1.2 Objective of Study

1.2.1 General Objective

To determine the effects of composting factors on Kluai Nam Wa-peel waste's properties in composting process with activator LD-1.

1.2.2 Specific Objectives

1) To determine the effect of the size of Kluai Nam Wa-peel waste on its physical and chemical properties in composting process with activator LD-1.

2) To determine the effect of activator LD-1 adding on physical and chemical properties of Kluai Nam Wa-peel waste in composting process.

3) To determine the effect of composting time on physical and chemical properties of Kluai Nam Wa-peel waste with activator LD-1.

4) To determine the optimal composting condition that can produce the end product of Kluai Nam Wa-peel waste in composting process with activator LD-1.

1.3 Hypothesis of study

1.3.1 The size of Kluai Nam Wa-peel waste affects physical and chemical properties of Kluai Nam Wa-peel waste in composting process with activator LD-1.

1.3.2 The activator LD-1 adding affects physical and chemical properties of Kluai Nam Wa-peel waste in composting process with activator LD-1.

1.3.3 The composting time affects physical and chemical properties of Kluai Nam Wa-peel waste in composting process.

1.4 Variables of Study

1.4.1 Independent Variables

1) Size of Kluai Nam Wa-peel waste (2, 3 and the whole fruit peel)

2) 0.015% by weight Activator LD-1 adding (adding and non adding)

3) Composting time (within 8 weeks)

1.4.2 Dependent Variable

Physical and chemical properties of composting product in each composting time

1.4.3 Control Variable

1) Amount of Kluai Nam Wa-peel waste (50 kilogram / pile)

2) Aeration condition (aerate the composting pile weekly and/or aerate when the temperature of the composting pile is more than 65 ^{o}C)

1.5 Definitions of Term

1.5.1 Kluai Nam Wa-peel waste is the yellow thick skin of banana (*Musa sapientum*) without the pole part of fruit which cut into 2, 3 inches long and the whole fruit peel or not be shortened.

1.5.2 Composting factors are sizes of Kluai Nam Wa-peel waste, activator LD-1 adding, and composting time which used to compost the Kluai Nam Wa-peel waste in this research.

1.5.3 Size of Kluai Nam Wa-peel waste is the length of Kluai Nam Wa-peel waste that used in this research. This research used 3 sizes of Kluai Nam Wa-peel waste. Those are 2 inches long, 3 inches long and the whole fruit peel long (more than 3 inches long) of Kluai Nam Wa-peel waste. For the width of Kluai Nam Wa-peel waste, this research used the natural or common width of Kluai Nam Wa-peel waste.

1.5.4 Activator LD-1 is the microorganism activator produced by Department of Land Development, Ministry of Agriculture and Cooperation. It consists of high efficiency cellulose-decomposing microorganisms and used for reducing time requirement in composting process.

1.5.5 Composting time is the duration of Kluai Nam Wa-peel waste composting (within 56 days). This research classified composting time as follows:

- Daily composting time is the 24 hours of composting process. So this research had 56 days of composting process (day 1 to day 56)
- Weekly composting time is 7 days of composting process. Week 1 started form day 0 to day 7 composting process. So this research had 8 weeks of composting process (week 1 to week 8).
- The beginning day and the end day of composting process are the started day of composting process (the first minute of composting process or day 0 or the first day of week 1) and the last day of composting process (the last minute of composting process or day 56 or the end day of week 8).

1.5.6 Optimal composting condition is the condition of Kluai Nam Wa-peel waste composting that could produce the end product of Kluai Nam Wa-peel waste composting process, had highest organic decomposing efficiency and took shortest time of composting process.

1.5.7 End product is the product of Kluai Nam Wa-peel waste composting of this research, which has its properties as follow:

- Carbon to Nitrogen ratio (C/N ratio) is not more than 20:1 and/or the temperature of composted pile is constant.

1.5.8 Physical properties of Kluai Nam Wa-peel waste in composting process are the following properties: temperature, moisture content, total solids, volatile solids, density and weight. (Classify physical properties of composting material as same as physical properties of solid waste classification in referenced research number 9, 10 and 11.)

1.5.9 Chemical properties of Kluai Nam Wa-peel waste in composting process are the following properties: pH, organic carbon, total nitrogen, C/N ratio, phosphorus, and potassium.

1.5.10 Decomposing efficiency is the index that shows the efficiency of decomposing of composting process. The index consists of composting time requirement of producing the end product and the organic decomposing efficiency.

1.5.11 Organic decomposing efficiency is the comparison of the loss weight of composting material and the weight of composting product. This research used the organic decomposing efficiency to compare the efficiency of waste minimization among 6 composting conditions. It was calculated from the following formula:

Organic decomposing efficiency = loss weight x 100 / initial weight

1.6 Scope of Study

1.6.1 Kluai Nam Wa-peel waste was collected from one fried banana booth in fresh food market. It was the yellow thick peel of Kluai Nam Wa-fruit and had green pole part.

1.6.2 This research used the concrete casing to compost the Kluai Nam Wa-peel waste which had a diameter of 80 centimeters with a height of 30 centimeters and sealed the bottom.

1.6.3 The size of Kluai Nam Wa-peel waste that used in this research was 2 inches long, 3 inches long and whole fruit peel long or not be shortened (8).

1.6.4 The composting process of this research was done within 56 days - general time usage of composting process (6).

1.6.5 The physical and chemical properties analysis of composting product was done at the Department of Agriculture's laboratory, Ministry of Agriculture and Cooperatives.

1.6.6 This research was aerated into the pile of Kluai Nam Wa-peel waste by turning it every week and/or when the temperature of composting pile was more than 65^{o}C.

1.6.7 The composting process in this research was not done in laboratory-scale because the results were aimed to recommend the method of Kluai Nam Wa-peel waste minimization to agriculturists who need to improve their agriculture lands by adding the soil amendment.

1.7 Limitations of Study

1.7.1 In this research, the exact amount of cellulose-microorganism in activator LD-1's pack could not be controlled.

1.7.2 In the Klaui Nam Wa-peel waste collecting period of this research (May – June, 2003), Fried banana booths in fresh market could provide Kluai Nam Wa-peel waste only 150 kilograms per week. So researcher could not start 6 experimental treatments in the same time.

1.7.3 In the composting process period of this research (May – August, 2003), it was the rainy season. It rained frequently. So the composting products of this research might have higher amount of moisture content than the obtained composting products during the dry season period.

1.8 Expected Outcome

1.8.1 The optimal conditions of composting factors which can eliminate Kluai Nam Wa-peel waste by composting process.

1.8.2 The obtained data from this research can be applied for supporting the composting of Kluai Nam Wa-peel waste.

1.9 Conceptual Framework

Independent Variable → Dependent Variable

Composting Factors

- **Size of Kluai Nam Wa-peel**
(2, 3 inches long and the whole fruit peel long)
- **Activator LD-1 adding**
(adding and non adding)
- **Composting time**
(within 8 weeks of composting process)

Products's properties

- **Physical Properties**
(moisture content, temperature, total solids, volatile solids, density and weight)
- **Chemical Properties**
(pH, organic carbon, total nitrogen, C/N ratio, phosphorus, and potassium)

CHAPTER II
LITERATURE REVIEW

2.1 Kluai Nam Wa

2.1.1 Taxonomy

Kluai Nam Wa is a type of banana which belongs to the family Musaceae, genus *Musa*. *Musa spp*. It provides man food, clothing, tool, and shelter prior to the recorded history (12). Kluai Nam Wa-scientific name is *Musa* (ABB group) "Kluai Nam Wa" (13). Kluai Nam Wa is very important for local product manufacturing (OTOP: One Tumbon One Product), fruit production factories and banana fried booths on footpath and fresh markets.

2.1.2 Botanical description

1). Plant: Plants are large, herbaceous monocots, reaching 25 ft. in some cultivars (13). The "trunk" or pseudostem is not a true stem, but only the clustered, cylindrical aggregation of leaf stalk bases. Leaves are among the largest of all plants, becoming up to 9 ft. long and 2 ft. wide. There are 5-15 leaves on each plant. The perennial portion of the plant is the corm which may weigh several kilograms. It produces suckers, which are thinned to 2-3 per corm-one "parent" sucker for fruiting and one "follower" to take the place of the parent after it fruits and dies back. The vegetative apex spontaneously initiates a reproductive meristem after 40 leaves have been produced, usually 9 months after initiation of a sucker. A banana plant bears fruit 10-12 months after planting; plantains take longer, 14-19 months, particularly in areas with cool winters. The life of a banana plantation is 25 years or longer, but individual "stools" are removed after production declines in 4-5 years. This helps to control diseases as well. Fields are cleared, sometimes fumigated, and then replanted with "bits" of new corms.

2). Flowers: The inflorescence is a spike originating from the tip of the corm. Initially, it appears above the last leaves in an upright position, and consists only of a large, purple, tapered bud. As this bud opens, the slim, white, tubular, toothed flowers are revealed, clustered in whorled double rows along the stalk, each cluster covered by a thick, waxy, hood-like bract. The bract lifts from the first hands in 3-10 days. Female flowers, with inferior ovaries, occupy the lower 5 to 15 rows on the stalk, with neuter or hermaphrodite flowers in the center, and males at the top. Male flowers and bracts are shed one day after opening, leaving the terminal potion of the stalk naked except for the large, purple, fleshy bud at the tip containing unopened male flowers (except Dwarf Cavendish – males persistent). The flower stalk begins to droop down under its own weight shortly after opening; the flowers are negatively geotropic, and turn upright during the first 10 weeks of growth.

3) Fruits: an epigynous berry, fruits are borne in "hands" of up to 20 fruits, with 5-13 hands per spike. Fruits appear as angled, slender, green "fingers" during growth, reaching harvest maturity in 90-120 days after flower opening. The large, fleshy, terminal bud on the stalk may be removed if fruit set is high, to allow more complete filling of fruits (thinning) since this organ continues to grow throughout fruit development.

2.1.3 Harvest, Post-harvest handling

1) Maturity. Fruits can be harvested when about 75% mature, as angles are becoming less prominent and fruits on upper hands are light-green in color. At this stage, desiccated styles on tips of fruit can be easily rubbed off. This occurs at 75-80 days after opening of the first hand. Some managers manipulate the harvest date as per the direction of the buyer, and harvest may be delayed up to 100-110 days after opening of the first hand.

2) Harvest method. Entire spikes are cut from pseudostems by hand with sharp, curved knives. The cutter leaves a portion of bare stalk as a handle for transporting to the packinghouse.

3) Post-harvest handling, packing. Bananas are carried by hand to a packing shed, or in large plantations, hung on tramways and pulled out of plantings by tractors; this expedites the process and limits handling. Bananas should be kept out of light after harvest, since this hastens ripening and softening. For local consumption, hands are often left on stalks and sold to vendors who cut hands/fingers to customer's order. For export, hands are cut into units of 4-16 fingers, graded for both length and width, and carefully placed in poly-lined 40 lb boxes. Prior to packaging, fruits are sometimes floated in water or dilute sodium hypochlorite solution to remove latex which may cause black peel staining. Fruit are shipped by boat when green, and ripened by exposure to ethylene gas (1000 ppm for 24 hr) at their destination, in sealed "banana ripening rooms".

2.1.4 Kluai Nam Wa-peel waste

Kluai Nam Wa is a kind of fruits which transformed into many products. Because, there are many Kluai Nam Wa-fruits which have birth mark. So gardeners can't sell those fruits. They transform those fruits into other products that can be preserved for sale later. In agriculture, transformed products are banana streamed pasty, fried banana, banana in coconut sauce, sun-dried banana, banana crisps, sugar-boiled banana puree, and butter-baked banana.

Now, there are many food factorys which use Kluai Nam Wa as raw material. They export Kluai Nam Wa-products to many countries. Those products are banana puree, banana flour, banana powder, freeze dried banana slice, banana chip, banana syrup, and banana juice.

According to the statistic of Kluai Nam Wa plants in the year 2006 from Department of Agriculture Extension (table 2-1), it showed that in 2006, Thailand had total Kluai Nam Wa planted area about 725,728 rais and also had total Kluai Nam Wa products about 1,607,584 tons/year (14). Thailand exported Kluai Nam Wa to other countries about 131,253 tons/year (15). So Thailand had domestic Kluai Nam Wa products about 1,476,331 tons per year. Kluai Nam Wa-peel is about 1/3 of total weight of fresh Kluai Nam Wa fruit (16). This information can indicate that Thailand had Kluai Nam Wa-peel waste about 492,110 tons/year. This amount of Kluai Nam Wa-peel waste were dumped on the ground and had to wait for collecting by municipality or disposed by burning. Accordingly, many Kluai Nam Wa-peel wastes were left into the environments. These cause many environmental problems. So, it needs to use an appropriate method to dispose them.

Table 2-1: The statistic data of Kluai Nam Wa plants in year 2003.

Province	Planted Area (rai)			Average Yield (kg./rai)	Total Product (Tons)
	Bearing	Non Bearing	Total		
1. Kamphaeng Phet	4,937	360	5,297	2,608	12,877
2. Chaing Rai	10,011	682	10,693	2,266	22,682
3. Chaing Mai	13,873	345	14,218	1,483	20,571
4. Tak	15,115	727	15,842	1,250	18,893
5. Nakhon Sawan	6,066	598	6,664	2,021	12,259
6. Nan	738	203	941	1,722	1,271
7. Phichit	10,358	275	10,633	1,569	16,256
8. Phitsanulok	18,836	1,070	19,906	8,495	160,006
9. Phetchabun	9,380	405	9,785	1,594	14,955
10. Phrae	3,545	1,030	4,575	1,195	4,235
11. Phayao	7,875	535	8,410	656	5,169
12. Mae Hong on	3,410	607	4,017	3,449	11,760
13. Lampang	8,427	439	8,866	2,017	16,994
14. Lanphun	10,830	1,090	11,920	1,187	12,858
15. Sukhothai	23,918	1,753	25,671	3,560	85,155
16. Uttaradit	16,135	4,648	20,783	2,612	42,152
17. Uthai Thani	5,550	298	5,848	2,291	12,713
18. Kalasin	7,682	148	7,830	1,930	14,828
19. Khon Kean	9,726	355	10,081	1,755	17,072
20. Chaiyaphum	10,609	2,093	12,702	2,024	21,475
21. Nakhon Phanom	11,390	554	11,944	1,926	21,940
22. Nakhon Ratchasima	21,416	4,079	25,495	1,559	33,378
23. Buri Ram	6,816	588	7,404	1,909	13,009
24. Maha Sarakham	8,805	6,650	15,455	2,147	18,907
25. Yasothon	4,407	249	4,656	2,215	9,762
26. Roi Et	13,332	1,345	14,677	2,643	35,241
27. Loei	36,205	856	37,061	3,100	112,230
28. Si Sa Ket	6,886	1,527	8,413	4,644	31,976
29. Sakon Nakhon	7,537	790	8,327	1,664	12,542
30. Surin	4,916	1,495	6,411	2,163	10,635
31. Nong Khai	10,164	2,461	12,625	1,985	20,176
32. Udon Thani	24,425	18,901	43,326	2,286	55,847
33. Ubon Ratchathani	5,265	933	6,198	2,068	10,889
34. Mukdahan	8,342	2,189	10,531	2,681	22,367
35. Nong Bua Lam Phu	5,361	2,286	7,647	1,971	10,564
36. Amnat Charoen	2,665	677	3,342	2,419	6,447
37. Bangkok	1,106	849	1,955	1,716	1,898

Province	Planted Area (rai)			Average Yield (kg./rai)	Total Product (Tons)
	Bearing	Non Bearing	Total		
38. Chai Nat	7,705	235	7,940	1,783	13,740
39.Nonthaburi	4,852	1,174	6,026	2,831	13,734
40. Pathum Thani	859	812	1,671	1,743	1,497
41. Phra Nakhon Si Ayutthaya	5,922	3,399	9,321	2,191	12,978
42. Lop Buri	9,331	596	9,927	3,715	34,662
43. Sara Buri	3,327	123	3,450	1,327	4,413
44. Sing Buri	1,158	195	1,353	2,452	2,839
45. Ang Thong	14,140	792	14,932	3,387	47,889
46. Chanthaburi	28,623	665	29,288	2,929	83,823
47. Chachoengsao	1,127	55	1,182	1,359	1,532
48. Chon Buri	10,898	250	11,148	3,685	40,141
49. Trat	1,763	240	2,003	1,512	2,665
50. Nakhon Nayok	7,090	850	7,940	2,114	14,990
51. Phrachin Buri	2,701	194	2,895	1,224	3,305
52. Rayong	2,402	220	2,622	1,830	4,395
53. Samut Prakan	3,040	68	3,108	3,667	11,148
54. Sa Kaeo	4,143	730	4,873	2,408	9,978
55. Ratchaburi	4,000	393	4,393	2,704	10,818
56. Samut Songkhram	8,579	229	8,808	2,960	25,390
57. Samut Sakhon	376	76	452	1,488	559
58. Nakhon Pathom	1,252	28	1,280	3,582	4,485
59. Suphan Buri	4,420	2,715	7,135	2,451	10,832
60. Kanchanaburi	11,112	0	11,112	4,768	52,985
61. Phetchaburi	19,434	2,109	21,543	2,798	54,369
62. Prachuap Khiri Khan	6,790	2,913	9,703	2,442	16,581
63. Krabi	3,622	610	4,232	2,225	8,059
64. Chumphon	13,474	286	13,760	2,133	28,735
65. Nakhon Si Thammarat	20,639	1,844	22,483	1,669	34,444
66. Narathiwat	8,173	563	8,736	1,719	14,049
67. Pattani	4,794	841	5,635	2,108	10,104
68. Songkhla	4,607	693	5,300	2,184	10,060
69. Phuket	1,190	230	1,420	3,482	4,144
70. Ranong	9,345	1,602	10,947	1,839	17,187
71. Satun	1,444	525	1,969	2,689	3,883
72. Surat Thani	6,197	2,082	8,279	1,689	10,468
73. Phangnga	1,913	346	2,259	2,129	4,073
74. Patthalung	3,695	424	4,119	1,347	4,978
75. Yala	1,330	4,119	1,405	1,975	2,627
76. Trang	9,269	1,661	10,930	2,485	23,037
Total	**630,795**	**98,977**	**725,728**	**2,549**	**1,607,585**

Source: Department of Agriculture Extension, 2003 (14).

2.1.5 Kluai Nam Wa-peel properties.

According to the pre-test of Kluai Nam Wa-peel properties by own researcher- which was done at the laboratory of the Department of Agriculture, Ministry of

Agriculture and cooperatives- the results showed that the Kluai Nam Wa-peel had about 48% by weight of organic carbon and 56% by weight of C/N ratio, as shown in table 2-1. It was concluded that Kluai Nam Wa-peel could be composted because it had enough nutrients and organic-compound for microorganism's activities.

Table 2-2 The properties of Kluai Nam Wa-peel.

Properties	% By Weight
1. Chemical Properties	
- Organic Carbon	48.3853
- Nitrogen	0.8679
- Phosphorus	0.1364
- Potassium	2.1873
- C/N ratio	55.7499
2. Physical Properties	
- Moisture Content	35.2941
- Total Solid	64.7059
- Volatile Soil	1.5198
- Ash Content	63.1861

2.2 Soil amendment

2.2.1 Definition of Soil amendment

Soil amendment Act of the state board of Agriculture of USA defined soil amendment that is "any substance which is intended to improve the physical, chemical, or other characteristics of the soil or improve crop production, except the following: commercial fertilizer, agricultural liming materials, agricultural gypsum, un-manipulated animal manure, un-manipulated vegetable manure, and pesticide; provided that commercial fertilizer shall be included if it is represented to contain, as an active ingredient, a substance other than a recognized plant food element or if represented as promoting plant growth by other than supplying a recognized plant food element" (13,16).

Yongyut Osotsapha defined soil amendment that is “any material which added to improve the physical or chemical properties of soil such as gypsum, sawdust or synthetic substance. This material enhances plant growth but not substitute as a fertilizer, although it contains important fertilizer elements” (17).

Department of Agriculture Enhance defined soil amendment that is any substance which added to soil to improve chemical, physical and biological properties of soil for plant growth. This substance can not be used as fertilizer, although it has fertilizer elements, but it is used as soil conditioning (18).

2.2.2 Types of soil amendment

Types of soil amendment can be classified into two categories such as (19):

1) Organic amendments

Organic amendments come from something that was alive. They include sphagnum peat, wood chips, grass clippings, straw, compost, manure, biosolids, sawdust and wood ash. These are merely examples. Organic amendments increase soil organic matter content and offer many benefits. Organic matter improves soil aeration, water infiltration, and both water and nutrient holding capacity. Many organic amendments contain plant nutrients and act as organic fertilizers. Organic matter also is an important source for bacteria, fungi and earthworms that live in the soil.

2) Inorganic amendment

Inorganic amendments are either mined or man-made. They include vermiculite, perlite, tire chunks, pea gravel and sand. These are merely examples.

2.2.3 The factors to be considered when choosing an amendment

There are two factors that should be considered when choosing a soil amendment. They are longevity of the amendment and soil texture. The rapidly decomposed amendment such as using of Grass clippings and manure are used for quick improvement of the soil physical properties. Compost, which is a moderately decomposed amendment, is used for a long-lasting soil improvement (19).

When sandy soils were amended, the purpose is to increase the soil's ability to hold moisture and store nutrients. To achieve this, organic amendments that are well decomposed - like compost or aged manure - are used.

With clay soils, the purpose is to improve soil aggregation, increase porosity and permeability, as well as improve aeration and drainage. Fibrous amendments like peat, wood chips, tree bark or straw are most effective in this situation.

2.2.4 Application Rates of soil amendment

The 3 cubic yards or 2.29 cubic meters of your chosen organic amendment per 1,000 square feet or 95.88 square meters are used for soil amendment when the soil has less than three percent of organic matter (19). The soil amendment are not applied more than this in order to avoid salt buildup, and the soil should be restored before deciding whether to add more soil amendment.

2.3 Composting process

Composting process is the process of biological degradation of organic material. It can take place in two ways such as aerobic decomposition and anaerobic decomposition. Aerobic decomposition occurs in the presence of oxygen, so this called composting. But anaerobic decomposition occurs in the absence of oxygen, so this called digestion or fermentation (20).

In an aerobic condition, living organisms-which utilize oxygen-feed upon the organic matter and develop cell protoplasm from the nitrogen, phosphorus, some of the carbon, and other required nutrients. Much of the carbon serves as a source of energy for the organisms and is burned up and respired as carbon dioxide (CO_2). The amount of carbon is reduced and the limited amount of nitrogen is re-cycled. Finally, when the ratio of available carbon to available nitrogen is sufficiently low, nitrogen is released as ammonia. Under favorable conditions, some ammonia may be oxidized to nitrate. Phosphorus, Potash and various micro-nutrients are also essential for biological growth (21).

Decomposing microorganisms have the major role in a composting process. They are heterotrophic microorganisms (9).

Composting process has four phases which according to the temperature, such as (9, 22):

1) Latent phase (Ambient temperature 22 ^{o}C): decomposing microorganisms infiltrate, colonise and acclimatize to the material.

2) Growth phase (22 ^{o}C – 40 ^{o}C): growth and reproduction of Decomposing microorganisms result in a high respiration rate and consequently elevate the temperature to a mesophilic range.

3) Thermophilic phase (40 ^{o}C – 60 ^{o}C): compost pile achieves peak temperature and maximum pathogen sterilization. At the end of this phase the temperature drops to around 40^{o}C.

4) Maturation phase (40 ^{o}C – ambient): slower, secondary mesophilic phase, the temperature gradually drops to ambient temperature as the microbial activity within the material decreases. Complex organic chemicals are transformed into humic compounds and residual ammonia undergoes nitrification to nitrite and subsequent nitrate.

2.4 Major roles of microorganisms in composting process

Composting is a biological process in which organic waste is converted to substance like humus without any disturbance and danger by the activity of complex microorganisms (23, 24). There include microorganisms such as bacteria, fungi, and actinomycetes.

The organic waste is initially decomposed by bacteria, fungi and actinomycetes. Waste stabilization is accomplished mainly through the bacterial reactions. Mesophillic bacteria are the first to appear. As the temperature rises, thermophilic bacteria, which inhibit all part of the compost heap, appear. Thermophilic fungi usually grow after 5-10 days of composting. If the temperature high (i.e. grater than 65-70 ^{o}C), fungi, actinomycetes, and most bacteria become inactive. But only spore-forming bacteria can develop. In the first stage, as the temperature declines, members of actinomycetes become the dominant group which may give the heap surface a white or gray appearance (24).

Table 2-3 Microorganisms during composting process

Types of microorganisms	The duration of composting process (day)		
	0	35	79
	10^5 cells per 1 g of solid		
Aerobic bacteria	801	1,920	113
Gram-positive aerobic bacteria	552	1,300	41
Gram-negative aerobic bacteria	249	620	72
Anaerobic bacteria	136	1.8	0.97
Actinomycetes	10.2	5.5	3.7
Fungi	8.4	16.5	0.36
Ammonifer	34	240	44
Ammonia oxidizer	43	14	0.37
Nitrite oxidizer	0.08	0.003	0.003
Denitrifier	1,300	9,900	200

Source: Chino et al. (25).

Faure and Deschamps (26) stated that microorganisms play a major role in the decomposition of organic waste. These microorganisms are classified into three groups, as follows.

2.4.1 Bacteria

Bacteria are the most important microorganisms because they can rapidly breed and occur in a large quantity. They are the most about 80-90% of the quantity of microorganisms which are in the compost pile (23). Bacteria dominates in the early stages of composting about 10^8-10^9 cells per gram compost (27). Limiting factors for bacterial growth are temperature, kinds of organic matter and moisture content. High temperature and high moisture content in compost pile are appropriate conditions for growth of bacteria (23).

During decomposition process, bacteria such as *Pseudomonas sp*., *Achromobater sp*., *Flavobacterium sp*., *Micrococcus sp*. and *Bacillus sp*. are found more than others. *Bacillus subtilis* and *bacillus stearothermophilus* like high temperature and grow well at 50-55 ^{o}C or 65 ^{o}C. *Clostridium sp*. and *bacillus sp*. are important decomposing bacteria because they can release cellulose enzyme (23).

2.4.2 Fungi

Fungi have ability to degrade a wide variety of organic compounds over a broad range of environmental conditions (28). Fungi take over during the final stages of composting when the organic materials have been changed to a more digestible form (29). Most fungi have the ability to grow under low moisture conditions which is better than bacteria (23, 28). In addition, fungi can tolerate relatively low pH values. The optimum pH value for most fungal species is about 5.6, but the viable range is between 2 to 9 (28).

During composition, *Geotrichum candidum* and *Aspergillus fumigatus* are mostly found in the initial increase temperature of compost pile. *Clostidium sp*., *Aspergillus sp*. and *Mucor sp*. like high temperature and grow well at 45-55 ^{o}C. If temperature is increased more than 55^{o}C, it will found *Penicillium duponti* in compost pile (23).

2.4.3 Actinomycetes

The actinomycetes are a group of microorganisms which have intermediate properties between bacteria and fungi. They are similar forms to fungi (23, 28). They play an important role in decomposing cellulose, lignin, and other resistant materials which are attacked after the readily decomposed materials have been utilized (23, 30).

Golueke (31) indicated that actinomycetes become detectable visually in undisturbed pile near the end of the composing process. They appear as a blue-gray to light green powder of filamantous layer in the outer of 10-15 centimeter. This microorganisms have the ability to grow under high pH value but do not like to grow under high moisture conditions, for example if moisture content is between 85 and 100%, it rarely find them at these moisture content (30).

Actinomycetes can grow at 65^{o}C but stop growing at 75^{o}C. Species of them are *Micromonospora sp*., *Thermoactinomycetes spp*., *Streptomyces spp*., and *Micropolyspora sp*. (23).

2.5 Types of activators used in composting process

Activator means the necessary factor for accelerating decomposition rate in composting process. Activators are divided into 2 types as follows:

2.5.1 Chemical activators

Chemical activators mean the chemicals which accelerate or enhance the action of microorganisms in decomposing of organic matters. They are:

1) Inorganic activators such as urea, ammonium sulfate, sodium nitrate and nitrogen fertilizer.

2) Organic activators are the organic matters with high nitrogen content such as drug, rubbish from some industries, powder blood, legume residues and soil with high humus content (10).

2.5.2 Microorganism activators

Microorganisms in natural environment which have high efficiency in decomposition can be chosen and taken to culture. They are bacteria, fungi and actinomycetes.

2.6 Activator LD-1

2.6.1 General

Microorganism activator LD-1 is produced by Land Development Department (7). Microorganism activator LD-1 consists of three types of microorganisms, i.e. bacteria (2 species: *Bacillus spp.*), fungi (2 species: *Streptomyces spp.*) and actinomycetes (4 species: *Scopulariopsis sp.*, *Heliconmyces sp.*, *Chaetonium sp.* and *Trichoderma sp.*) and have microorganism cells counted by standard dilution plate count method at 30°C and 45°C as follows:

Table 2-4 The amount of microorganism cells of microorganism activator LD-1

Types of microorganisms	No. of microorganism cells (cells/g)	
	At 30°C	At 45°C
1. Fungi	$3.80 \times 10^6 - 1.80 \times 10^8$	$4.10 \times 10^6 - 5.30 \times 10^8$
2. Bacteria	$6.30 \times 10^7 - 3.98 \times 10^9$	$2.00 \times 10^6 - 1.30 \times 10^8$
3. Actinomycetes	$3.40 \times 10^7 - 2.50 \times 10^9$	$3.00 \times 10^7 - 1.39 \times 10^9$

Source: Land Development Department (32).

2.6.2 Producing of activator LD-1

The steps to produce activator LD-1 are described as follow (2).

1). Preparation of cellulose – decomposing microorganism inculum.

2). Increasing of the amount of cellulose decomposing microorganism.

3). Microorganism Mixing with compost and roughly rice bran.

4). Air-drying

6). Survival study of cellulose-decomposing microorganism in activator LD-1's pack.

2.6.3 Application of activator LD-1

There are more than 10 microorganism's cells in one pack of activator LD-1 (150 grams). The indication of activator LD-1 in organic waste composting is shown as follows (2):

1). Dissolve 1 pack of activator LD-1 with 200 liters of water. Mix the solution for 5 minutes.

2). Mix the 1 ton organic waste with 2 kilograms Urea, 200 kilograms droppings and activator LD-1.

3). Keeping the moisture content of composting pile for 50-60% (by weight) by watering.

4). Turning the composting pile every 7-10 days.

In this research, its purpose was to reclaim Kluai Nam Wa-peel waste by the low cost method and also easy to do. So, the experiment used only the activator LD-1 to compost the waste.

2.7 Factors affect the composting process

2.7.1 Composting material

The compositions of composting material govern the efficiency of composting process. Size of composting material is also important. The small individual piece and the large surface area to volume ratio make more of material available to microbial attack, thus these cause speeding up the process of decomposition (16). The suitable size - not readily compacted material such as fibrous waste, twigs, pruning, and corn stove - are from ½ inch (1.25cm) to about 2 inches (5.0cm). The particle size of the greater part of a fresh green plant mass such as vegetable waste, fruits, and lawn clippings should be not less than 2 inches (5.0cm). On the other hand, depending upon their overall decomposability, their maximum particle size can be as large as 6 inches (15.0 cm) or even larger (8). However, particles which are shredded to finely will tend to become compacted and so reduce aeration within the material. Consequently, a balance must be truck, providing the smallest possible particle size which does not interfere with air flow (22).

Normally, composting materials are dried materials because they are convenience to pile up and control environmental factors. But, be careful of moisture because using wet materials can cause too much water and poor passage of air, causing the compost pile to become anaerobic (33). So, wet composting material should be air-dried about three days or mixed with other materials (for example rice straw) to adjust the moisture content for the decomposition.

2.7.2 Temperature

Temperature is a very important factor in composting, particularly in the aerobic composting process. Temperature patterns in compost piles influence the types and species of microorganism's growth. Mesophilic temperature (24-45^{o}C) is developed first in composting followed by thermophilic temperature (50-65^{o}C). After this phase, most organic substrates will have been stabilized, resulting in a temperature decrease to mesophilic and eventually to ambient level. In many cases the thermophilic temperature can even reach to between 55 and 65^{o}C. Last for a few days, causing an effective inactivation of the pathogen (24).

High temperature is essential for the destruction of pathogenic organisms and undesirable weed seed. Decomposition also proceeds much more rapidly in the thermophilic temperature range. Furthermore, high temperature adversely affects the population of thermophilic fungi (9). Too often, high temperatures have been considered a necessary condition for good composting. Excessively, high temperature (above 65^{o}C) inhibits growth in most of microorganisms present, thus slowing down decomposition of organic matter (24). Only a few species of thermophilic sporogenous bacteria show metabolic activity above 70^{o}C. *Bacillus stearothermophilus*, *Bacillus subtilis*, *Cloatridium sp.*, and non-spore forming bacteria genus thermus (34). In addition, below their optimal temperature range microorganisms are also inactive.

Within a compost pile, there can be temperature variations. For example, a lack of oxygen can raise the temperature and high moisture content can lower it. Both of these situations should be avoided. Aeration can solve the problem of temperature control by turning the organic wastes. Cool air is introduced into the pile. Observations of temperature changes during the decomposition of organic matter can be used to indicate whether the process is functioning properly (35, 36).

2.7.3 Moisture content

Moisture is an important physical factor in composting activity. Microorganisms require water in inner cell metabolism and releasing of extracellular enzyme. In composting pile, high temperature induces volatilization. Adding water in composting process is necessary (37). The optimal moisture content in the composting process varies, depending essentially on the physical characteristics and size of the waste particles, but is usually in the range of 50-60% (38). Too little moisture means early dehydration of the pile which arrests the biological process giving physically stable but biologically unstable compost. Too much moisture will interfere with aeration by clogging the pores and anaerobic conditions are created (39).

2.7.4 Carbon to Nitrogen ratio (C/N ratio)

The ratio of carbon and nitrogen are necessary for growth and decomposition process of microorganisms. Microorganisms use carbon as a source of energy and use nitrogen as a source of nitrogen compound. So, the C/N ratio shows that most organic wastes contain the other nutrients in the required amounts and ratio for composting. The ideal ratio is about 20 to 25 part of available carbon to 1 of available nitrogen. The nitrogen content and C/N of several wastes are given in table 2-5 (8).

A C/N ratio higher than 20/1 can slow the composting process. A C/N ratio that is too low (less than 20/1) leads to loss nitrogen as ammonium nitrogen. If the initial C/N ratio of material to be composted is greater than the optimum value, the microorganisms will have growth limitations due to the lack of N. They will have to go through many life cycles, oxidizing the excessive C until a final C/N ratio of about 10 is reached in the composted products. Therefore an extra-composting time is needed, and a smaller quantity of final humus is obtained (24).

With lower than optimum initial C/N ratio, nitrogen will probably be lost as NH_3 gas, especially under conditions of high temperatures, high pH and forced aeration; hence a loss of the valuable nutrient to atmosphere (24, 34).

Table 2-5 Percent N, C/N and Moisture of Selected Materials

Material	%N (dry wt.)	C/N (weight to weight)	%moisture (wet wt.)
Corncob	0.4-0.8	56-123	9-18
Fruit wastes	0.9-2.6	20-49	62-88
Vegetable wastes	2.5-4.0	11-13	*
Garbage (food waste)	1.9-2.9	14-16	69
Grass clippings	2.0-6.0	9-25	
Leaves	0.5-1.3	40-80	

* Not reported.

Source: Modified from Kreith F. (8)

2.7.5 Aeration

The most important factor during the composting process is the availability of oxygen; without oxygen, composting is not possible (35). Oxygen is a key element in the respiratory and metabolic activities of microbes. Consequently, the oxygen content of this air must be continually replenished or the air itself must be continually replaced. The amount of oxygen required by the microbes is termed ‘oxygen demand’ (8). Oxygen demand is a direct relationship between oxygen consumption and temperature. Temperatures which enhance microbial activity are in the range of 28–55°C; with highest consumption of oxygen (40, 41). There are many factors to provide an oxygen. Those are the composition of compost, material sizes and moisture content (42).

2.7.6 pH

pH is an important factor for microorganism growth. Bacteria grow well in slightly acid, slightly base and non-acid and base conditions. Fungi and actinomycetes grow well in gravitational acid. pH also affects release of enzyme by microorganisms (43). Generally, organic matter with a wide range of pH (from 3-11) can be composted. However, optimum pH values are 5.5 to 8.0 (44).

In early stage, composting pile has an acid condition because of the activity of acid-forming bacteria. Finally, slightly acid or slightly base occurs by buffer function of humus (45). Using of organic wastes from agriculture (plant residues) has no problem about acid and base conditions. Because pH is in middle range or slightly acid and organic matter is also in good buffer.

2.8 Quality and standard of compost

Organic Matter and Waste Product Subdivision, Soil and Water Conservation, Department of Land Development recommends some criteria for the good compost (3), as follows:

1) C/N ratio equals or less than 20:1
2) Compost grades of Nitrogen - Phosphorus - Potassium (%N - %P_2O_5 - %K_2O) equal more than 0.5-0.5-1.0 respectively.
3) Compost moisture content equals or less than 35-40 % by weight
4) Organic matter is about 25-50 % by weight
5) pH is about 6.0-7.5
6) There are no toxic substances

2.9 Time Required for Composting

The period of 1 to 6 months for decomposing waste materials, which allowed by different compost operators, is usually not the minimum time required for adequate stabilization of the material. Satisfactory stabilization can be accomplished in a much shorter period. Generally, operators provide a time that fits their particular composting procedure and their schedule for utilization of the finished product.

The time required for satisfactory stabilization depends primarily upon: (a) the initial C/N ratio; (b) the particle size; (c) the maintenance of aerobic decomposition; and (d) the moisture content. Assuming that the moisture content is in the optimum range, that the compost is kept aerobic, and that the particles of the material are of such size as to be readily attacked by the organisms present, the C/N ratio determines the time required for stabilization. Low C/N ratio materials are decomposed in the shortest time, because the amount of carbon to be oxidized to reach a stabilized condition is small. Also, in low C/N ratio composts, a larger part of the carbon is usually in a more readily available form, while in higher C/N ratio materials more of the carbon is usually in the form of cellulose and lignin, which are rather resistant to attack.

The time required for active stabilization at different C/N ratio for shredded mixed municipal refuse in aerobic pile, with a moisture content below 70% is as follow: (21)

Initial C/N ratio	Approximate composting time required (days)
20	9 – 12
30-35	10 – 16
78	21

The most widely accepted criterion for the completion of composting is the reduction of C/N ratio below 20:1. The maturing time, after the active stabilization under optimum condition, has the advantage that the wastes are reduced to innocuous materials (46).

Under aerobic conditions at high temperatures and when the initial C/N ratio is in the optimum range or below, the material changes the appearance and odour of humus after 2-5 days of active decomposition. However, active decomposition is not complete at this stage, and the C/N ratio may not have been lowered to the level desired for fertilizer (21).

2.10 Relevant Research

Vittayapan (9) studied the composting of peat and water hyacinth. Composting conditions were using and non-using of activator LD-1 and control of temperature at $50^{o}C$ along the composting process. The objectives of this study were [1] to define the time requirement for peat compost and water hyacinth compost,[2] to compare the decomposition rate of peat compost and water hyacinth compost, and [3] to investigate physical, chemical and biological properties of compost. Those were moisture content, pH, organic carbon, nitrogen, phosphorus, potassium, cellulose decomposing bacteria, cellulose decomposing actinomycetes and cellulose decomposing fungi. The results showed that the time requirement for peat compost was longer than 42 days; while for water hyacinth compost was only 14 days. Decomposition rate (change of C/N ratio change) of peat was lower than the rate of water hyacinth. It was also found that peat had suitable physical and biological properties but had unsuitable chemical properties for decomposition. The physical, chemical and biological properties of water hyacinth were appropriate for making compost. The result of this research also showed that activator LD-1 could accelerate the decomposition rate of peat but could not accelerate the decomposition rate of water hyacinth.

Subjarearn (10) studied the efficiency of some microbial activators in organic composting from market waste consisted of vegetables and fruits. Three types of microorganism activators were used for this research: LD-1, F-60, and Bionic. There were 4 treatments which consisted of market waste with 3 types of microorganism activators and without microorganism activators, with 3 replications on laboratory experiment. The controlled factors were the size of market waste, moisture content, temperature, and aeration. The results indicated that the quantity of plant nutrients of all treatments was within compost standards of Land Development Department. The added market waste with activator LD-1 was highest decomposition rate (35 days).

Leemaharoungruang (11) studied the composting of municipal solid waste by forced air aeration and mixed with activator LD-1 of Land Development. In this study, 2 sets of experiments were conducted in order to speed up composting time. The first set of experiment was to determine the optimal seed ratio of activator LD-1. It was set up with 4 compost piles. The first pile, without seeding and the other 3 piles were seed with 0.015%, 0.030% and 0.045%, respectively. The second set of experiment was to determine the optimal forced aeration rate in composting pile. The results of this study showed that 0.015% seeding of activator LD-1 gave the shortest composting time. The chemical properties of finished compost from composting process are shown in table 2-6.

Table 2-6 The Composition of finished compost from both experiments (base on % dry weight)

Compositions	Set 1	Set 2
1. Carbon (%)	15 – 17	17 – 21
2. Nitrogen (%)		
Total Nitrogen	0.8 – 1.2	1.3 -1.8
Organic Nitrogen		1.2 -1.7
Nitrate Nitrogen	0.04 – 0.15	0.01 – 0.07
Ammonia Nitrogen		0.05 – 0.09
3. C/N ratio	14 - 19	11 -15
4. Total Phosphorus (%)	1.0 – 1.8	1.2 -1.6
5. Potassium (%)	0.5 – 0.9	0.6 – 0.8
6. N: P: K	1.3: 2: 1	2.25: 2: 1

Source: Modified from Leemaharoungruang S., 1988 (45).

Land Development Department (23) studied the chemical properties of pineapple-peel waste from fruit canning factory. There are 1.79% Nitrogen, 0.85 % P_2O_5, 5.46% K_2O, and 46.80% Carbon. Its C/N ratio is 26 and its pH is 7.60. Chemical properties of durian-peel waste are 0.83% N, 0.19% P_2O_5, 2.15% K_2O and 50.63% Carbon. It has 61 of C/N ratio and pH is 5.50. This study suggested that the thin peel fruit is easily composted more than thick peel fruit.

Boonsong et al. (47) studied municipal solid waste management by composting and using of activators. Their objectives were to search the appropriate activator for composting and to study the nutrients from compost with different methods of composting. They used both chemical and microorganism activators for composting to determine which to be the appropriate ones. The results showed that the best method was adding of microorganism activators in composting process because it could speed up the composting time.

Kongrod (48) studied the optimal conditions for composting process of sewage sludge and bagasse. This research purposes were to determine the optimal conditions of agriculture residues and sewage sludge composting with microorganism adding and also to analyze the physical, chemical and biological properties of composting materials in composting process. The results of this study indicated that the physical and chemical properties of sludge and bagasse were suitable properties for composting process. The pH value in composting process was acidic (pH 6.3) in the beginning and slightly increased to alkaline (pH 7.8) during the process. The C/N ratio slightly decreased the following day. At the end of composting process, C/N ratio was 20:1. The optimal condition for composting process was the condition which had the mixed ratio of sewage sludge and bagasse about 1.1: 1.5, 50% of moisture content and 50^{o}C of temperature.

Srigaze (49) studied the nutrients in high-tech compost from refuse in Phetchaburi municipality, Phetchaburi province. This research had 5 treatments of composting experiment. Those were (A) non-sorted refuse, (B) sorted refuse spread over with composting activator, (C) sorted refuse mixed with composting activator,

(D) non-sorted refuse spread over with composting activator, and (E) non-sorted refuse mixed with composting activator. The results of this research are shown in table 2-7.

Table 2-7 The main nutrients in high-tech compost from refuse in Phetchaburi municipality

Treatment	Nitrogen	Phosphorus	Potassium	C/N ratio	pH
A	1.14	1.36	1.47	8:1	7.80
B	1.01	1.19	1.48	7:1	7.86
C	1.41	1.37	1.67	6:1	7.63
D	1.37	1.35	1.27	6:1	7.80
E	1.11	1.00	1.16	7:1	7.87
LD-Standard*	1.00	1.00	0.50	20:1	6.0-7.5

Remark: * = the standard of compost recommended by Department of Land Development.

Wanyala (50) studied solid waste decomposing efficiency with aerobic process from Phetchaburi municipal solid waste, Phetchaburi province. This research aimed to investigate the efficiency of co-composting material in term of decomposition time requirement and the quality of composting products in aerobic municipal solid waste decomposing process. The research had 5 treatments of composting experiment. Those were (A) municipal solid waste, (B) municipal solid waste covered with urea fertilizer, (C) municipal solid waste covered with buffalo dung, (D) municipal solid waste covered with sewage sludge and (C) municipal solid waste covered with buffalo dung and sewage sludge. All treatments were covered with soil and aerated 8 hours per day at the rate of 0.4 m^3/kg.VS/d

The results of this study showed that treatment C was the shortest decomposing time requirement (54.67 days), whereas, treatment A was the longest composing time requirement (78 days). Treatment C had the highest efficiency of municipal solid waste decomposition. This treatment could decompose 68.03% by weight and produced the highest yield of composted product (68.80% by weight). The organic carbon and volatile solids of all treatments were decreased in the same rate (21.93-

27.52%). The content of nitrogen, phosphorus and potassium products of all treatments were 1.04 - 1.19%, 0.32 – 0.47%, and 0.52 – 0.58% respectively. The C/N ratio of all treatments was 19.44:1 – 21.76:1. The pH of all treatments was 8.20 – 8.70.

These literatures suggested that Kluai Nam Wa-peel waste, which is organic waste, can be composted to produce the soil amendment within the short period of aerobic composting process, and 0.015% activator LD-1 adding can decrease the composting time. So these studies can support this research to determine the optimal conditions of Kluai Nam Wa-peel waste composting process.

CHAPTER III
MATERIALS AND METHODS

This research aimed to determine the effects of three composting factors-[1] size of Kluai Nam Wa-peel waste, [2] activator LD-1 adding and [3] composting time- on composting product in composting process. It also aimed to determine the optimal composting factors which could produce the end product of Kluai Nam Wa-peel waste. This research was a factorial design research. It had six combinations of experimental treatments of Kluai Nam Wa-peel waste composting conditions which varied by the composting factors and it had three replications per each experimental treatment. The details of materials and methods of Kluai Nam Wa-peel waste composting and composting products analysis that used in this research were presented in this chapter.

3.1 Materials

3.1.1 Composted Materials

1) Raw material

Kluai Nam Wa-peel waste was collected from fried banana booths in fresh market.

2) Microorganism activator LD-1

Microorganism activator LD-1 (Land Development-1) was supported by Land Development Department.

3.1.2 Apparatus and Equipment

1) Concrete casing
2) Plastic bags
3) Thermometer

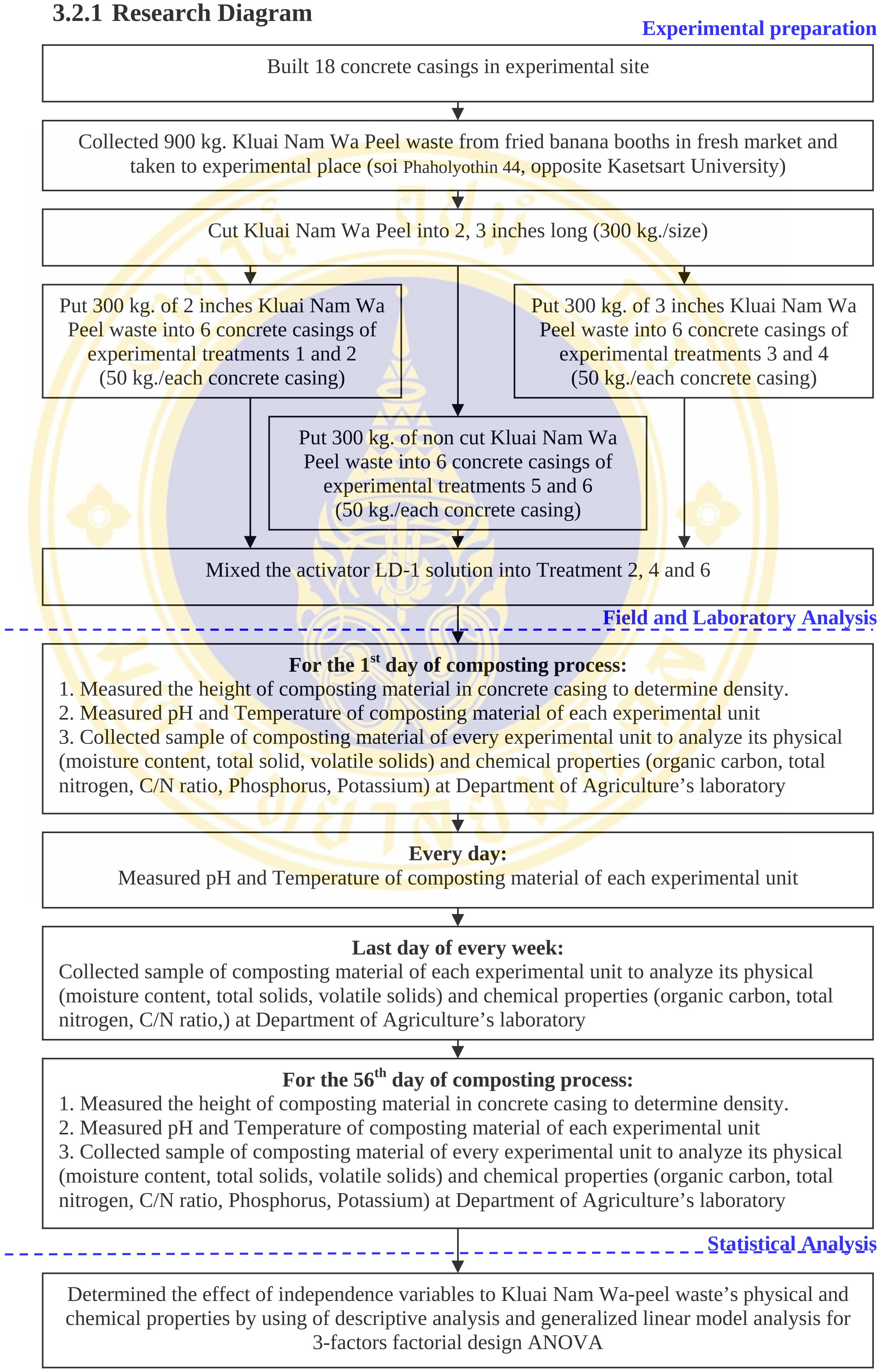
4) pH paper
5) Drying oven
6) Crucible
7) Furnace
8) Analytical balance
9) Erlenmeyer flask
10) Volumetric pipette
11) Cylinder
12) Burette
13) Volumetric flask
14) Digestion apparatus
15) Distillation apparatus
16) Kjeldahl flask
17) Block digestion
18) Spectrophotometer

3.1.3 Chemical Reagents

1) 1 N $K_2Cr_2O_7$ solution
2) Conc. H_2SO_4
3) Conc. H_3PO_4
4) Barium diphenylamine sulfonate indicator (BDS)
5) 0.5 N Ferrous ammonium sulfonate (FAS) solution
6) Mixed catalyst
7) 40% NaOH
8) 2% Boric acid indicator
9) 0.02 N H_2SO_4
10) 70-72% $HClO_4$
11) 65% HNO_3
12) Free-acid vanadomolybdate solution
13) Stock Standard solution (1000 microgram K / ml)

3.2 Methodology

3.2.1 Research Diagram



3.2.2 Kluai Nam Wa-peel waste Collecting

During May to June, 2003, Kluai Nam Wa-peel waste was collected from fried banana booths in fresh market and transferred to the experimental place near Kasetsart University. Fried banana booths in fresh market can provide Kluai Nam Wa-peel waste 150 kilograms per week. So researcher can start 1 experimental treatment per week. This research had 6 experimental treatments. So it took about 2 months to collect 900 kilograms of Kluai Nam Wa-peel waste for usage in this research.

3.2.3 Preparation of composting materials

1) Composting Material

Kluai Nam Wa-peel waste was collected from fried banana booths in fresh market. It was transferred to the experimental place. Then it was shredded in 2, 3 inches long and the whole fruit peel or not be shorten for usage in each experimental treatment. In each experimental treatment, Kluai Nam wa-peel was completely mixed before using.

2) Activator LD-1

Activator LD-1 was dissolved in 1000 ml of water and kept for 30 minutes before spreading on each composting pile.

3.2.4 Experimental Planning

Composting of Kluai Nam Wa-peel waste was performed during on May to September, 2003. The composting was done in concrete casing. Each composting pile used 50 kilograms of Kluai Nam Wa-peel waste. Treatments 2, 4 and 6 was added 0.015% adding of activator LD-1. This research was designed into 6 treatments as shown in table 3-1.

Table 3-1 Treatment combination of Kluai Nam Wa-peel waste composting.

Treatment	Size of Kluai Nam Wa-peel [1)]	Activator LD-1[2)]	Replications
1	2 inches	Non adding	3
2	2 inches	Adding	3
3	3 inches	Non adding	3
4	3 inches	Adding	3
5	The whole fruit peel	Non adding	3
6	The whole fruit peel	Adding	3

Remark: 1) Each treatment used 50 kilograms of Kluai Nam Wa-peel waste.
2) Each treatment used 7.5 grams of activator LD-1 (0.015% by weight).

3.2.5 Controlled factors for composting

1) The amount of activator LD-1

The amount of activator LD-1 that used in this research was 0.015% by weight of Kluai Nam Wa-peel waste (43).

2) The amount of Kluai Nam Wa-peel waste

In each treatment, 50 kilograms of Kluai Nam Wa-peel waste were used.

3) Aeration

Composting piles would be turned over for aeration at every 7 days (24) and/or turned over when the temperature of composting pile was more than 65^{o}C.

4) Moisture content

In composting process period, it rained frequently. So researcher controlled the moisture content of composting pile by protecting the rain drop and rain spray splashed into the composting pile. It was done by covering the top and literal side of composting area with the canvas. This research was an aerated composting process, so researcher avoided entirely covering the composting pile in concrete casing.

3.2.6 Collecting of composting material samples

This research aimed to study the change of physical and chemical properties of composting materials in composting process. As reviewed in chapter 2, each property will not be changed in the same time. So researcher divided the experimental laboratory analysis of this research into 3 studies as follows:

1) The study of composting material properties at the beginning and the changing properties at the end of composting process.
2) The study of a daily change of composting material properties.
3) The study of a weekly change of composting material properties.

So every day researcher had to collect composting material samples which were completely mixed samples to analyze their daily change properties at the field site. On the last day of every week, researcher had to collect composting material samples which were completely mixed samples to analyze their weekly change properties in the laboratory. The analysis detail of the composting material properties change was shown in 3.2.7.

3.2.7 Analysis of composted samples

There were 3 studies of laboratory analysis as mentioned in 3.2.6. From the review of the related researches and documents in chapter 2, the physical and chemical properties of composting materials did not change simultaneously: some properties could be seen on the change within 2 days such as temperature and pH; some could be seen within a week such as moisture content, total solids, volatile solids, organic carbon, total nitrogen and C/N ratio; but some could not be seen within a month such as phosphorus and potassium. So each experimental analysis was performed at different durations according to the difference of the studied properties as follows:

1) The analysis of composting material properties at the beginning and the end of composting process.

Composting material property	No.	parameters	Laboratory Analysis
Physical Properties	1	Moisture content	Oven drying method
	2	Temperature	Thermometric method
	3	Total Solids	Oven drying method
	4	Volatile Solids	Burning method
	5	Density	Calculation from Weight/Volume
	6	Weight	Weighting Method
Chemical Properties	7	Organic Carbon	Walkley-Black Method
	8	Total Nitrogen	Kjeldahl method
	9	C/N Ratio	Calculation from Organic Carbon / total Nitrogen
	10	Phosphorus(P_2O_5)	Colorimetric method
	11	Potassium (K_2O)	Spectro-emission Method
	12	pH	pH paper testing Method

2) The analysis of a daily change of composting material properties.

Composting material property	No.	parameters	Laboratory Analysis
Physical Properties	1	Temperature	Thermometric method
Chemical Properties	2	pH	pH paper testing Method

3) The analysis of a weekly change of composting material properties.

Composting material property	No.	parameters	Laboratory Analysis
Physical Properties	1	Moisture content	Oven drying method
	3	Total Solids	Oven drying method
	4	Volatile Solids	Oven drying method
Chemical Properties	7	Organic Carbon	Wet oxidation Method
	8	Total Nitrogen	Kjeldahl method
	9	C/N Ratio	Calculation from Organic Carbon / Total Nitrogen

3.2.8 Experimental error control

This research had controlled the validity of composting process study. The error controls of this research were done in the part of Kluai Nam Wa-peel waste collection, composting material preparation and composting material samples collection. The errors that controlled in this research were shown as follows:

1) Characteristic of Kluai Nam Wa-peel waste

This research controlled the properties of Kluai Nam Wa-peel waste that used in this research by collecting 900 kilograms of Kluai Nam Wa-peel waste from two fried banana booths. This booth used only the yellow thick peel of Kluai Nam Wa-fruit characteristic and disposed the peels in the black bag which only collected Kluai Nam Wa-peel waste.

2) pH of concrete casing

Before filling the composting material in concrete casing, it needed to adjust the pH of concrete casing by hold the water in the concrete casing for 1 day. Then drained the water out from the concrete casing and left the concrete casing dried for 2 days.

3) Cutting of Kluai Nam Wa-peel waste

This research had 3 sizes of Kluai Nam Wa-peel waste (without pole part of fruit) for composting. The patterns of 3 sizes Kluai Nam Wa-peel waste cutting are shown as follows:

- 2 inches long size: cut the Kluai Nam Wa-peel waste (without the pole part of fruit) into 2 pieces which had 2 inches long.
- 3 inches long size: cut the Kluai Nam Wa-peel waste (without pole part of fruit) into 3 inches long by cutting out the black pole part.
- Whole fruit long size: cutting out only the pole part of Kluai Nam Wa-peel fruit. It remained about 4 inches long of Kluai Nam Wa-peel waste with black pole part.

4) Kluai Nam Wa-peel waste sample collection

In everyday of composting process, Kluai Nam Wa-peel waste sample of all treatments were collected for analyzing the daily change properties (temperature, pH) at the composting site. On the last day of every week, Kluai Nam Wa-peel waste sample of all treatments were collected for analyzing the weekly change properties at the laboratory of Department of Agriculture, in Kasetsart University. The sample of each treatment was collected by completely mixed sampling method. It was collected from different depths (top, middle and bottom) of the composting pile and mixed in the plastic bag. All plastic bags were labelled the number of the collected treatment, date and time of collecting and the number of composting week.

3.3 Statistical Analysis

This research used [1] descriptive statistics to describe the change trend of the physical and chemical properties of Kluai Nam Wa peel-waste of each treatment in the composting process. This research also used [2] Generalized Linear Model Analysis for 3-factor factorial design ANOVA to determine the effect of independent variables (size of composting material, activator LD-1 adding and composting time) on the dependent variable (physical and chemical properties of composting materials) of this research. The significant level of this research is 0.05.

CHAPTER IV
RESULTS

The results of this research were presented in this chapter. The results concerned with the change of physical and chemical properties of Kluai Nam Wa-peel waste at the beginning and the end of composting process, the daily change and weekly change of physical and chemical properties of Kluai Nam Wa-peel waste in composting process. All results of this research were reported in this chapter as follows:

4.1 Results of Descriptive Analysis

4.1.1 The change of properties of Kluai Nam Wa-peel waste at the beginning and the end of composting process

Composting materials used in this research were Kluai Nam Wa-peel waste from fried banana booths in fresh market and microorganism activator LD-1 from Land Development Department. Physical and chemical properties of composted materials at the beginning and the end of composting process were analyzed. These properties were described as follows:

4.1.1.1 Physical properties

The physical properties of Kluai Nam Wa-peel waste which analyzed at the beginning and the end of composting process were temperature, moisture content, total solidss, volatile solid, density and weight. The change of physical properties of composting material in each treatment at the beginning and the end of composting process is shown in table 4-1.

Table 4-1 Physical properties of Kluai Nam Wa-peel waste at the beginning and the end of composting process

Tr.	Temp.* (^oC)		MC.* (%)		TS. *(%)		VS.* (%)		Dens.*(Kg/m^3)		W.*(Kg)	
*	Beg.	End	Beg.	End	Beg.	End	Beg.	End	Beg.	End	Beg.	End
T1	35.9	30.3	49.60	13.51	50.40	86.49	99.19	77.13	357.14	330.00	50.0	3.3
T2	32.4	32.0	66.37	12.39	33.63	87.61	97.64	68.74	357.14	300.00	50.0	3.0
T3	33.9	29.7	79.59	23.38	20.41	76.62	96.54	73.37	333.33	200.00	50.0	4.0
T4	32.1	27.3	87.31	40.90	12.69	59.10	97.67	83.42	333.33	150.00	50.0	4.5
T5	29.6	35.4	70.92	44.62	29.08	55.38	95.91	84.75	500.00	273.33	50.0	8.2
T6	30.0	33.0	73.46	46.22	26.54	53.78	97.45	83.42	500.00	283.33	50.0	8.5

*Remarks: Tr. = Treatment Beg. = Beginning Temp. = Temperature
MC. = Moisture Content TS. = Total Solids VS. = Volatile Solid
Dens. = Density W. = Weight T1 = 2 inches
T2 = 2 inches + LD-1 T3 = 3 inches T4 = 3 inches + LD-1
T5 = whole fruit peel T6 = whole fruit peel + LD-1

1) Temperature

The change of temperature of composting pile at the beginning and the end of composting process is shown in figure 4-1. This figure also showed the ambient air temperature at the same day of the beginning and the end of composting process. From the bar-chart in this figure, it showed that the beginning day temperature of treatments 1 – 4 were higher than the end day temperature. Treatments 5 and 6, Kluai Nam Wa-peel waste size was more than 3 inches, had lower temperature at the beginning day than the end day.

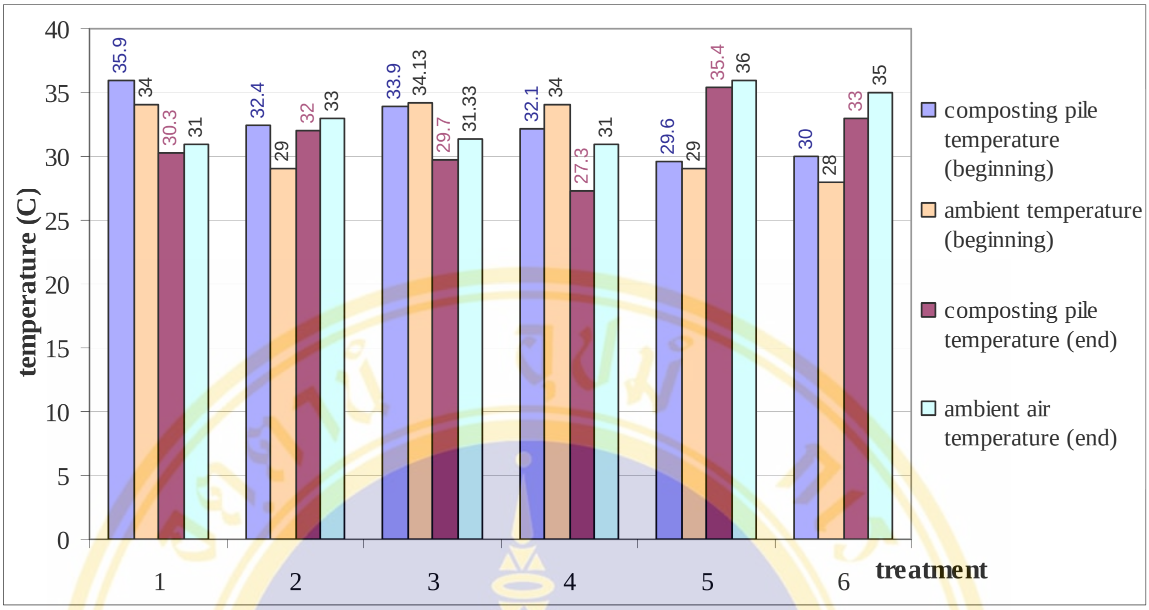


Figure 4-1: Temperature of composting pile at the beginning and the end of composting process

2) Moisture Content

The change of moisture content in composting materials at the beginning and the end of composting process is shown in figure 4-2. It showed that all treatment had declining trend of moisture content. The percentages of moisture content decreasing of treatments 1-6 were 72.76, 81.33, 70.62, 53.16, 37.08, and 37.08 respectively. The results showed that treatment 2 (composting materials were banana peel-waste 2 inches long and activator LD-1) had highest percentage of moisture content decreasing. So at the end of composting process, moisture content of treatment 2 was remained about 18.67 % by weight of total composting material at the beginning time. Treatments 5 and 6 (composting materials were banana peel-waste more than 3 inches long with and without activator LD-1) had lowest percentage of moisture content decreasing. The moisture contents of treatments 5 and 6 were remained about 62.92 % by weight of total composting material at the beginning time.

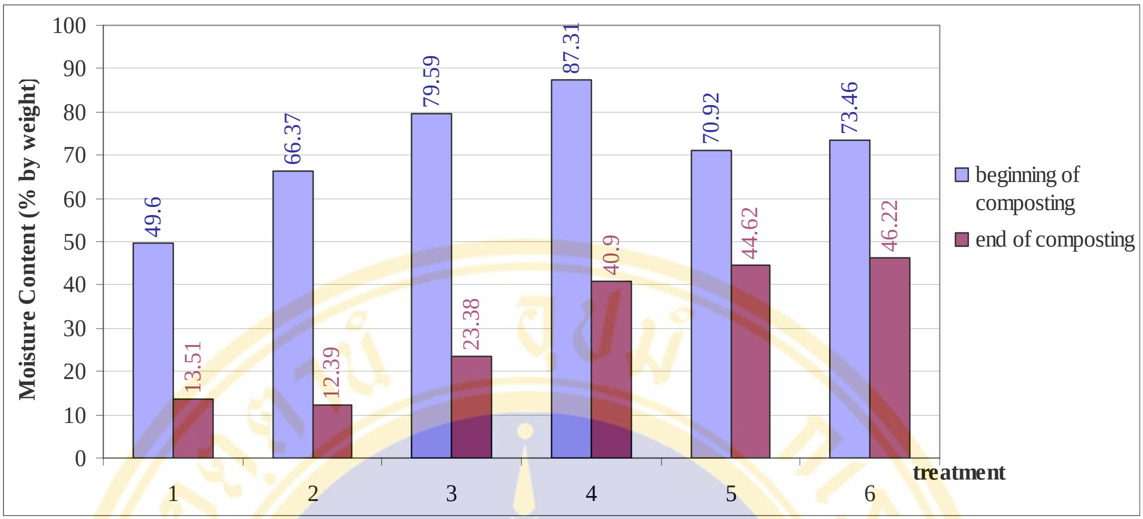


Figure 4-2: Moisture content of composting material at the beginning and the end of composting process

3) Total Solids

The change of total solids in composting materials at the beginning and the end of composting process is shown in figure 4-3. It showed that all treatments had an increasing trend of total solids. The percentages of total solids increasing of treatments 1-6 were 71.61, 160.51, 275.40, 365.72, 90.44, and 102.64 respectively. The results showed that treatment 4 (composting materials were banana peel-waste 3 inches long and activator LD-1) had highest percentage of total solids increasing. That was at the end of composting process, treatment 4 had about 3.66 times of the total solids of composting material at the beginning time. Treatment 1 (composting material was of banana peel-waste 2 inches long without activator LD-1 adding) had lowest percentage of total solids increasing. It had about 0.72 times of the beginning total solids of composting material at the beginning time.

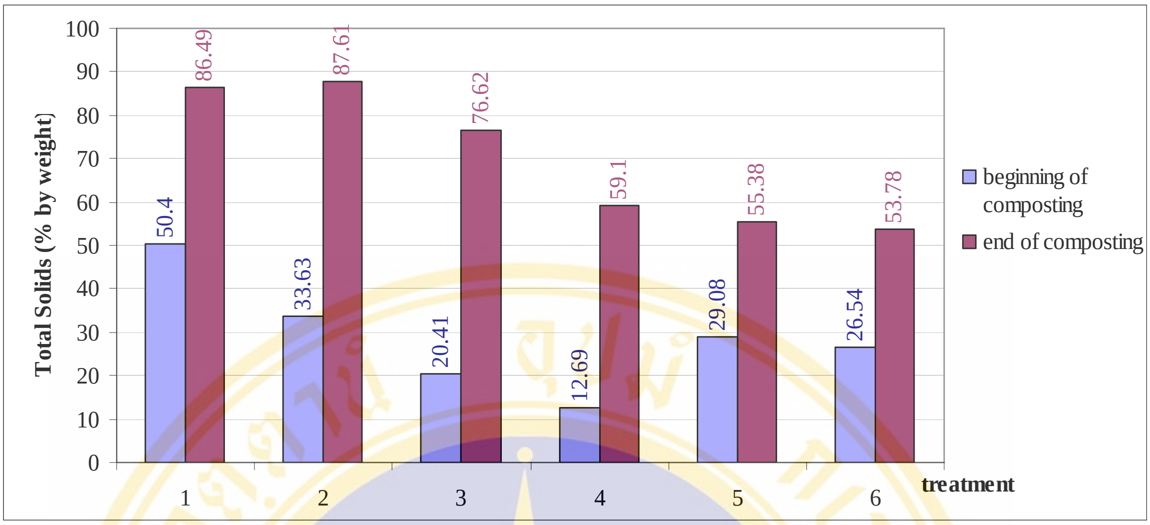


Figure 4-3: Total solids of composting material at the beginning and the end of composting process

4) Volatile Solids

The change of volatile solids in composting material at the beginning and the end of composting process is shown as figure 4-4. It showed that all treatment had decline trend of volatile solids. The percentage of volatile solids decreasing of Treatments 1-6 were 22.24, 29.60, 24.00, 14.59, 11.64, and 14.40, respectively. The results showed that treatment 2 (composting materials were banana peel-waste 2 inches long and activator LD-1) had highest percentage of volatile solids decreasing. So at the end of composting process, volatile solids of treatment 2 was remained about 70.40 % by weight of total composting material at the beginning time. Treatment 5 (composting material was banana peel-waste more than 3 inches long without activator LD-1 adding) had lowest percentage of volatile solids decreasing. It remained volatile solids about 88.36 % by weight of total composting material at the beginning time.

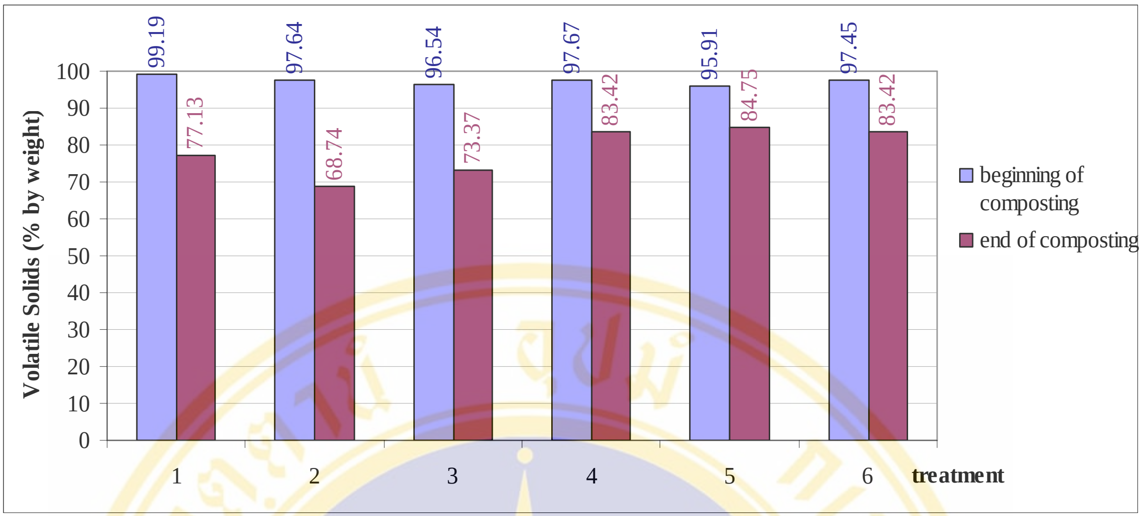


Figure 4-4: Volatile solids of composting material at the beginning and the end of composting process

5) **Density**

The change of density of composting pile at the beginning and the end of composting process is shown in figure 4-5. It showed that all treatments had a declining trend of density. The percentages of density decreasing of treatments 1-6 were 7.60, 16.00, 40.00, 55.00, 45.33, and 43.33 respectively. The results showed that treatment 4 (composting materials were banana peel-waste 3 inches long and activator LD-1) had highest percentage of density decreasing. So at the end of composting process, density of treatment 4 remained about 45.00 % by weight of total composting materials at the beginning time. Treatment 1 (composting materials was banana peel-waste 2 inches long and without activator LD-1) had lowest percentage of density decreasing. It remained density about 92.40 % by weight of total composting materials at the beginning time.

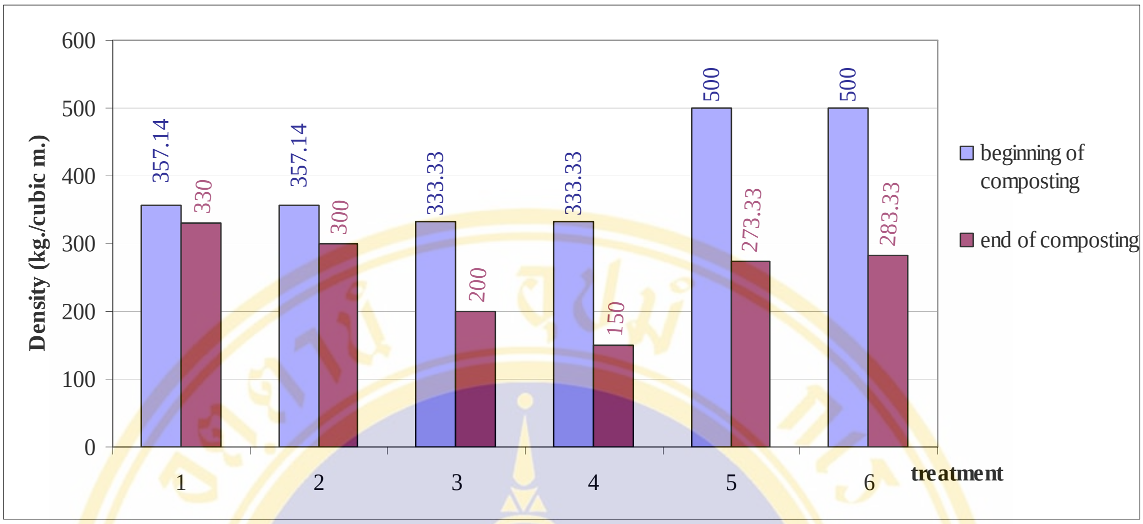


Figure 4-5: Density of composting material at the beginning and the end of composting process

6) Weight

The change of weight of composting pile at the beginning and the end of composting process showed in figure 4-6. It showed that all treatments had a declining trend of weight. The percentages of weight decreasing of treatments 1-6 were 93.40, 94.00, 92.00, 91.00, 83.60, and 83.00 respectively. The results showed that treatment 2 (composting materials were banana peel-waste 2 inches long and activator LD-1) had highest percentage of weight decreasing. So at the end of composting process, weight of treatment 2 was remained about 6.00 % by weight of total composting materials at the beginning time. Treatment 6 (composting materials were banana peel-waste more than 3 inches long and activator LD-1) had lowest percentage of weight decreasing. It remained weight about 17.00 % by weight of total composting materials at the beginning time.

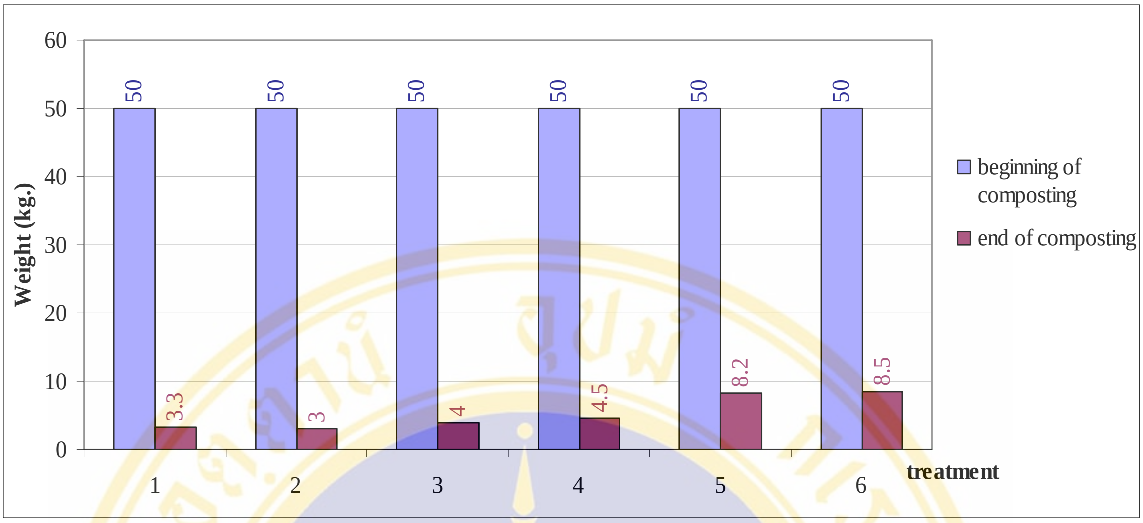


Figure 4-6: Weight of composting material at the beginning and the end of composting process

4.1.1.2 Chemical properties

The chemical properties of Kluai Nam Wa-peel waste which analyzed at the beginning and the end of composting process were pH, Organic Carbon, Total Nitrogen, Carbon/Nitrogen ratio, Phosphorus and Potassium. The change of chemical properties of each treatment at the beginning and the end of composting process is shown in table 4-2.

Table 4-2 Chemical properties of Kluai Nam Wa-peel waste at the beginning (day 1) and the end of composting process (day 56)

Tr.	pH		OC.* (%)		TN. *(%)		C/N ratio		P_2O_5 (%)		K_2O (%)	
	Beg.	End	Beg.	End	Beg.	End	Beg.	End	Beg.	End	Beg.	End
T1	7.0	8.7	48.34	40.08	0.97	2.03	49.78	19.93	0.38	0.47	8.22	10.46
T2	5.8	9.2	47.21	41.97	1.19	0.79	39.54	52.86	0.41	0.47	8.75	9.61
T3	7.7	9.0	48.16	41.46	1.19	0.80	40.44	52.14	0.32	0.53	6.36	10.27
T4	6.3	9.3	44.45	33.25	0.93	0.86	47.56	38.53	0.27	0.53	7.56	8.99
T5	7.2	8.7	45.65	40.23	0.76	2.46	60.21	16.32	0.34	0.62	6.84	13.10
T6	7.5	8.8	47.58	39.44	0.74	2.36	63.91	16.76	0.27	0.50	6.24	11.43

*Remarks: Tr. = Treatment Beg. = Beginning OC. = Organic carbon TN. = Total nitrogen
T1 = 2 inches T2 = 2 inches + LD-1 T3 = 3 inches T4 = 3 inches + LD-1
T5 = whole fruit peel T6 = whole fruit peel + LD-1

1) pH

The change of pH value of composting pile at the beginning and the end of composting process is shown in figure 4-7. From the bar-chart in this figure, it showed that all treatments had an increasing trend of pH value. The treatments started with the acid condition (pH 5.8 – 7.7) and end at the basic condition (pH 8.7-9.3). The results showed that treatment 2 (composting materials were banana peel-waste 2 inches long and activator LD-1) had more change of pH value than other treatment did. It changed from pH 5.8 to pH 9.2. Treatment 6 (composting materials were banana peel-waste more than 3 inches long and activator LD-1) had less change of pH value than other treatments. It changed from pH 7.5 to pH 8.8.

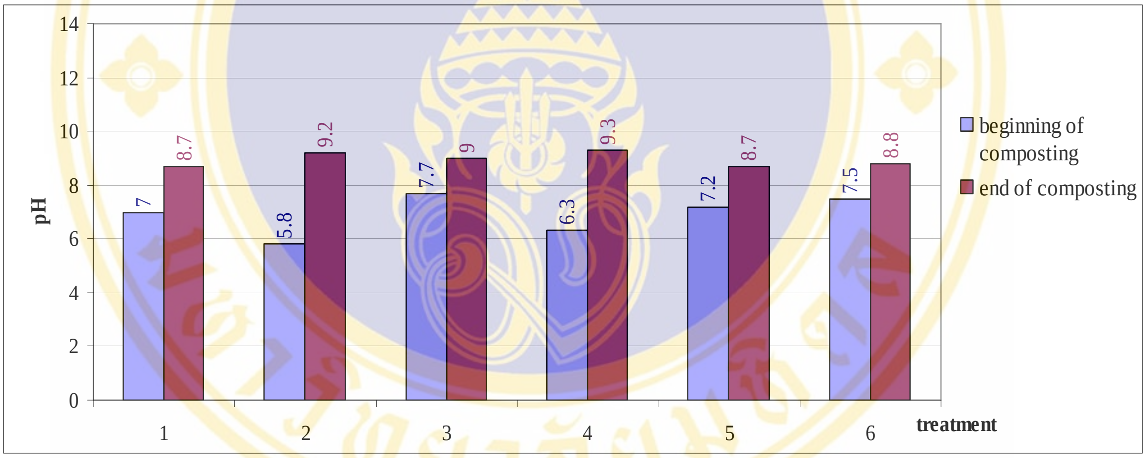


Figure 4-7: pH of composting material at the beginning and the end of composting process

2) Organic Carbon

The change of organic carbon in composting material at the beginning and the end of composting process are shown in figure 4-8. It showed that all treatments had declining trend of organic carbon. The percentages of organic carbon decreasing of treatments 1-6 were 17.09, 11.10, 13.91, 25.20, 11.87, and 17.11 respectively. The results showed that treatment 4 (composting materials were banana peel-waste 3 inches long and activator LD-1) had highest percentage of organic carbon decreasing. At the end of composting process, organic carbon of treatment 4 remained about 74.80% by weight of total composting materials at the beginning time. Treatment 2 (composting materials were banana peel-waste 2 inches long and activator LD-1) had lowest percentage of organic carbon decreasing. It had remained organic carbon about 88.90% by weight of total composting materials at the beginning time.

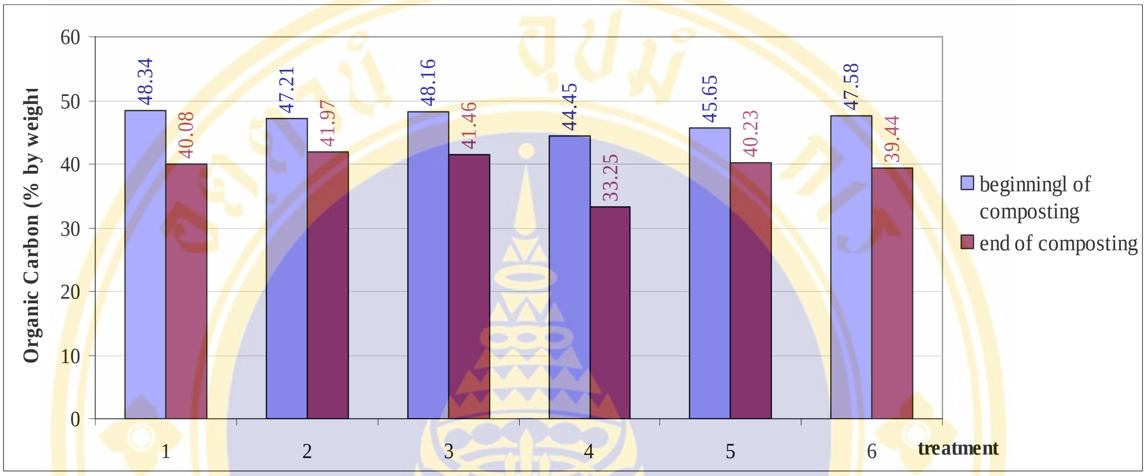


Figure 4-8: Organic Carbon of composting material at the beginning and the end of composting process

3) Total Nitrogen

The amount of total nitrogen found in composting material at the beginning time was little. It was found only 0.74 - 1.19 % by weight of total composting materials. After the composting process (56 days), It was found only 0.79 – 2.46 % by weight of total composting materials. So this result showed that it had a little change of total nitrogen. The change of total nitrogen in composting material at the beginning and the end of composting process are shown in figure 4-9. It showed that each treatment had not the same trend of total nitrogen change. Treatments 1, 5, and 6 had an increasing trend of total nitrogen change. Their percentages of total nitrogen increasing were 9.28, 23.68, and 18.92 respectively. Treatments 2, 3, and 4 had declining trend of total nitrogen. Their percentages of total nitrogen decreasing were 33.61, 32.77, and 7.53 respectively.

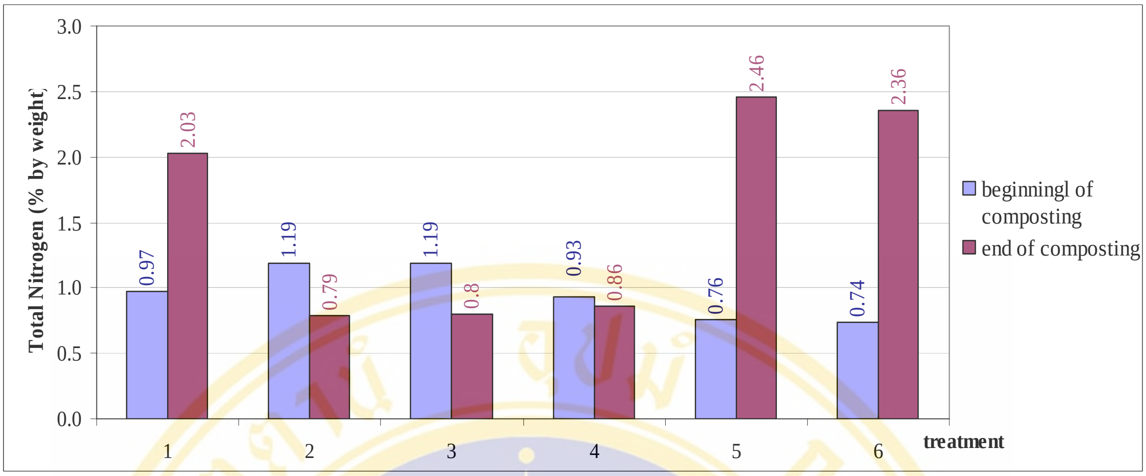


Figure 4-9: Total Nitrogen of composting material at the beginning and the end of composting process

4) C/N ratio

The change of C/N ratio in composting material at the beginning and the end of composting process are shown in figure 4-10. C/N ratio was calculated from the amount of organic carbon divided by the amount of total nitrogen of each treatment. So each treatment had not the same trend of C/N ratio change like total nitrogen change. It showed that treatments 2 and 3 had an increasing trend of C/N ratio. Their percentages of C/N ratio increasing were 33.69 and 28.93 respectively. Treatments 1, 4, 5, and 6 had a declining trend of C/N ratio. Their percentages of C/N ratio decreasing were 59.96, 18.99, 72.89, and 73.78 respectively. The results showed that treatment 6 (composting materials were banana peel-waste more than 3 inches long and activator LD-1) had highest percentage of C/N ratio change. At the end of composting process, C/N ratio of treatment 6 remained about 26.22% by weight of total composting materials at the beginning time. Treatment 4 (composting material was banana peel-waste 3 inches long without activator LD-1 adding) had lowest percentage of C/N ratio change. It remained C/N ratio remained about 81.01% by weight of total composting materials at the beginning time.

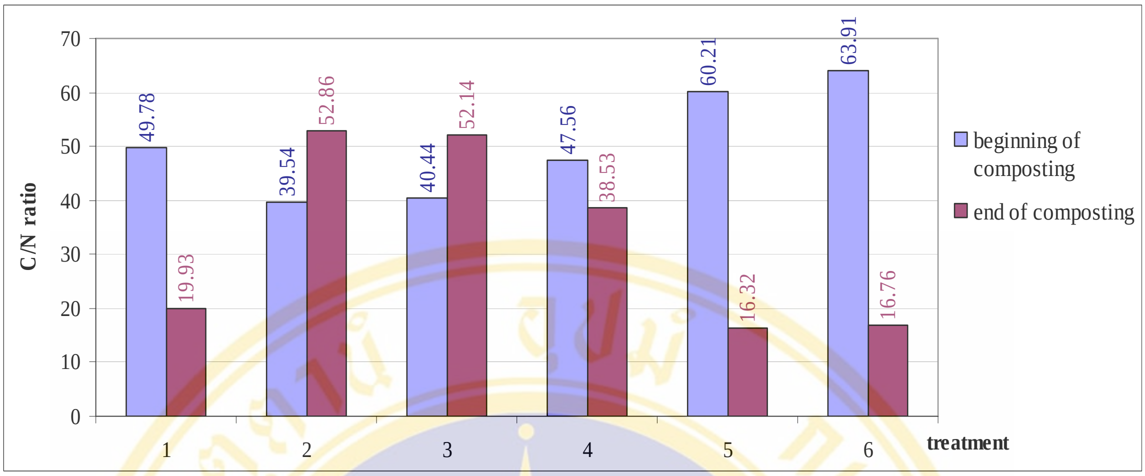


Figure 4-10: C/N ratio of composting material at the beginning and the end of composting process

5) Phosphorus (P_2O_5)

The change of phosphorus in composting material at the beginning and the end of composting process are shown in figure 4-11. It showed that all treatments had an increasing trend of phosphorus. The percentages of phosphorus increasing of treatments 1-6 were 23.68, 14.63, 65.63, 96.30, 82.35, and 85.19 respectively. The results showed that treatment 4 (composting materials were banana peel-waste 3 inches long and activator LD-1) had highest percentage of phosphorus increasing. At the end of the composting process, phosphorus of treatment 4 remained about 1.92 times of phosphorus of composting material at the beginning time. Treatment 2 (composting materials were banana peel-waste 2 inches long and activator LD-1) had lowest percentage of phosphorus increasing. It remained about 1.11 times of phosphorus of composting material at the beginning time.

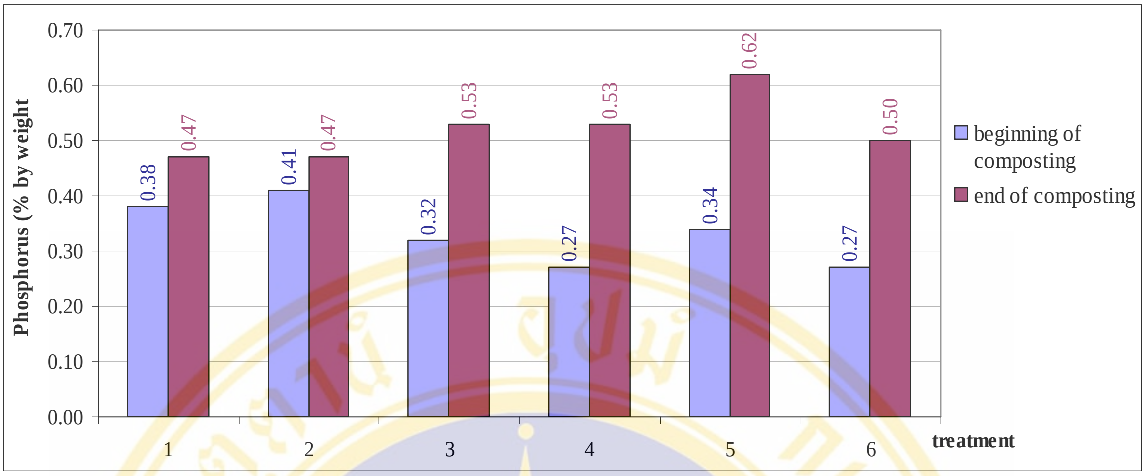


Figure 4-11: Phosphorus (P_2O_5) of composting material at the beginning and the end of composting process

6) Potassium (K_2O)

The change of potassium in composting material at the beginning and the end of composting process are shown in figure 4-12. It showed that all treatments had an increasing trend of potassium. The percentages of potassium increasing of treatments 1-6 were 27.25, 9.83, 61.48, 18.92, 91.52, and 83.17 respectively. The results showed that treatment 5 (composting materials were of banana peel-waste more than 3 inches long without activator LD-1 adding) had highest percentage of potassium increasing. At the end of composting process, potassium of treatment 5 remained about 1.91 times of potassium of composting material at the beginning time. Treatment 2 (composting materials were banana peel-waste 2 inches long and activator LD-1) had lowest percentage of potassium increasing. It remained about 1.10 times of potassium of composting material at the beginning time

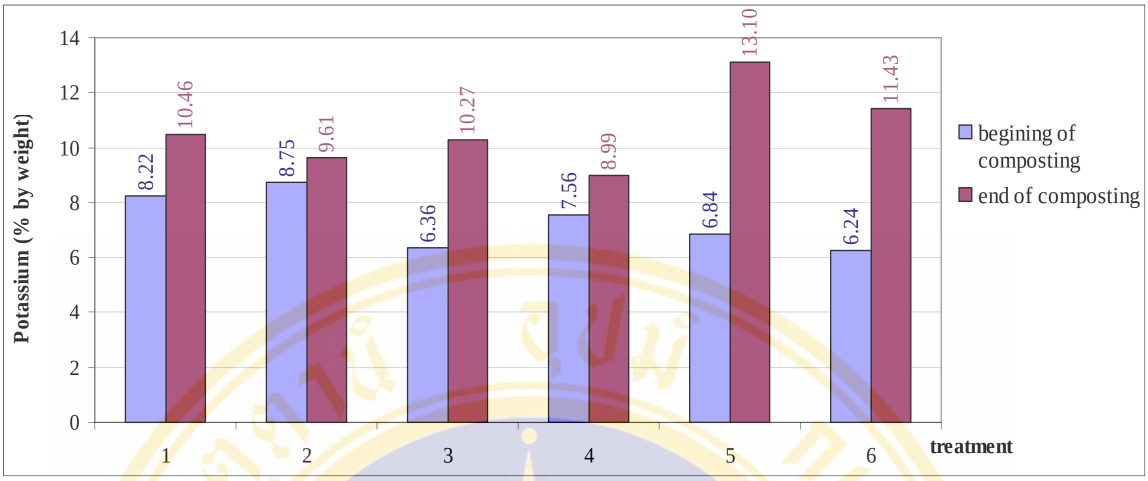


Figure 4-12: Potassium (K_2O) of composting material at the beginning and the end of composting process

4.1.2 The daily change of properties of Kluai Nam Wa-peel waste in composting process

4.1.2.1 Physical properties

1) Temperature

The trends of temperature change of each treatment in composting process are shown in table 4-3 and figure 4-13. On a few first day of composting process, the temperatures of all treatments were very high. The highest temperatures of treatments 1-6 were 39.83, 41.67, 40.00, 40.17, 45.67, and 45.33 respectively. The temperatures of treatments 5 and 6 were higher than those of the other treatments. After the 3rd day of composting process, the temperatures of all treatments went into decline. The temperatures of treatments 1-4 decreased on the 4th day to the 17th day of composting process. But the temperatures of treatments 5 and 6 decreased on the 4th day to the 28th day of composting process. After that the temperatures of all treatments were steady. That means the composting pile has the same temperature as the ambient air.

Table 4-3: The daily change of temperature in composting process (degree Celsius)

treatment	composting time (day)										
	1	**3**	**5**	**7**	**14**	**21**	**28**	**35**	**42**	**49**	**56**
1	35.94	37.50	35.33	33.61	28.22	29.67	31.61	31.22	30.67	29.67	30.33
2	32.44	37.44	35.67	32.33	31.61	30.78	29.33	30.06	32.22	30.22	32.00
3	33.94	38.89	36.33	34.83	29.78	29.39	29.28	29.94	29.61	28.83	29.67
4	32.06	38.11	34.94	32.06	29.17	28.67	29.06	29.33	30.89	29.28	27.33
5	29.56	44.67	43.44	43.22	33.56	34.67	28.67	28.39	29.83	31.33	35.44
6	30.00	39.89	41.67	37.78	36.11	30.22	29.00	29.78	32.78	34.67	33.00

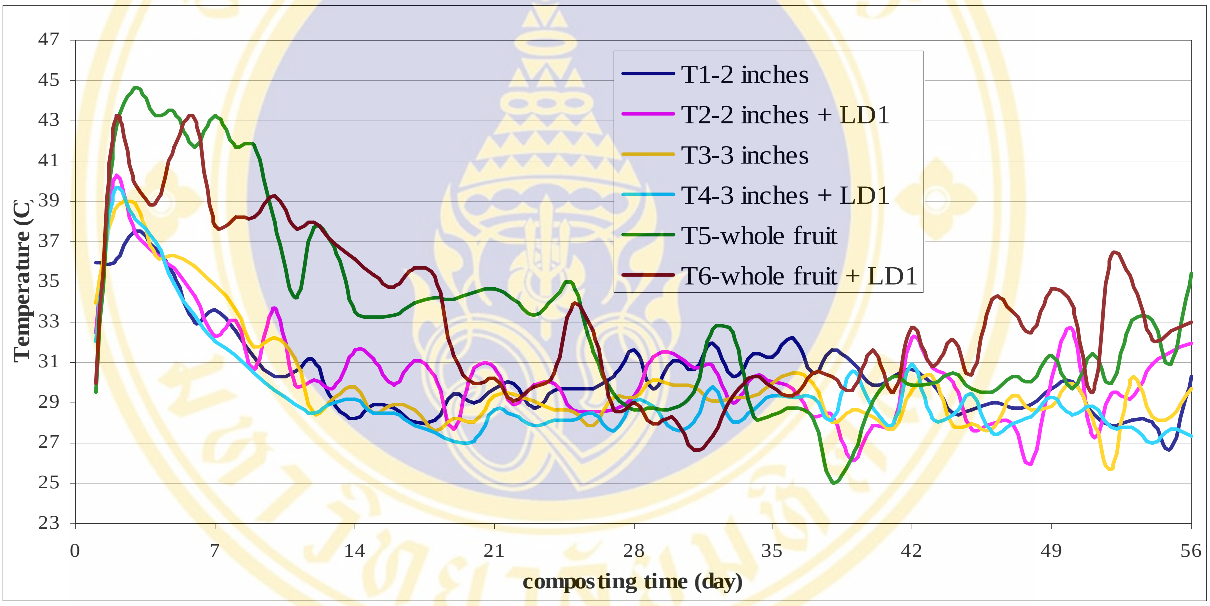


Figure 4-13: The daily temperature changing trends in composting process

4.1.2.2 Chemical properties

1) pH

The trends of pH change of each treatment in composting process are shown in table 4-4 and figure 4-14. On a few first day of composting process, the pH values of all treatments were very low (acid condition). The lowest pH values of treatments 1-6 were 5.5, 5.5, 7.5, 6.0, 4.5, and 4.5 respectively. The pH values of treatments 5 and 6 were lower than those of the other treatments. The pH values of treatments 1-4 started to increase on the 4th day of composting process. But the temperatures of treatments 5 and 6 started to increase on the 7th day of composting process. After that the pH values of all treatments were steady in the basic condition (pH value 8-9).

Table 4-4: The daily change of pH in composting process

treatment	composting time (day)										
	1	**3**	**5**	**7**	**14**	**21**	**28**	**35**	**42**	**49**	**56**
1	7.00	7.83	8.00	8.33	8.83	8.83	9.50	9.83	9.33	9.33	8.67
2	5.83	7.00	8.83	9.00	8.17	9.67	9.17	9.33	8.50	8.67	9.17
3	7.67	8.17	8.67	8.00	9.33	9.33	9.33	9.33	9.50	9.33	9.00
4	6.33	8.50	8.50	8.83	9.00	9.33	9.00	9.33	9.50	9.33	9.33
5	7.17	5.33	4.50	6.17	8.33	8.17	9.83	8.67	8.83	8.33	8.67
6	7.50	6.33	5.67	8.17	8.17	9.33	8.67	8.00	9.00	8.83	8.83

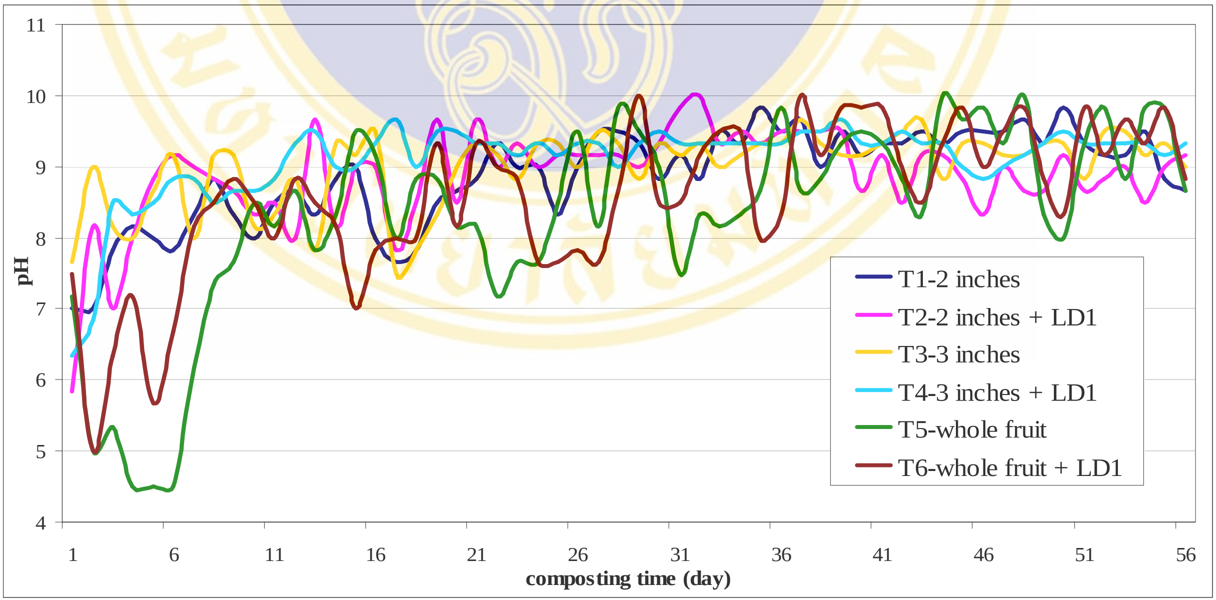


Figure 4-14: The daily pH changing trends in composting process

4.1.3 The weekly change of properties of Kluai Nam Wa-peel waste in composting process

4.1.3.1 Physical properties

1) Moisture Content

The moisture-content change of each treatment is shown in table 4-5 and figure 4-15. Moisture content change in composting process had decreased since week 1 to week 8. According to table 4-15, the highest everage of moisture content of treatment 1-6 were 72.36 (week1), 72.96 (week1), 80.69 (week2), 87.31 (week1), 76.07 (week2), and 73.89 (week3) respectively. According to figure 4-15, it showed that in week 1 to week 4, all treatments had nearly-steady amount of moisture content after week 4 their amount of moisture content started to decrease until week 8. Treatment 2 had the most moisture-content decrease. Figure 4-15 showed that treatments 1-3 had more change of moisture content than treatment 4-6. Treatments 1-3 had percentage of moisture content decrease about 70-80%. While treatments 4-6 had percentage of moisture content decrease about 35-50%.

Table 4-5: The weekly change of moisture content in composting process (% by weight)

treatment	composting time (week)								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	49.60	72.36	59.70	60.79	64.47	55.38	30.29	18.57	13.51
2	66.37	72.96	70.01	71.57	44.21	34.16	19.80	17.74	12.39
3	79.59	75.88	80.69	76.56	65.18	62.49	61.99	28.37	23.38
4	87.31	81.74	66.45	72.46	71.84	71.68	67.87	59.44	40.90
5	70.92	74.21	76.07	65.13	51.43	57.69	49.28	55.11	44.62
6	73.46	74.05	73.89	66.84	57.87	54.54	59.94	52.04	46.22

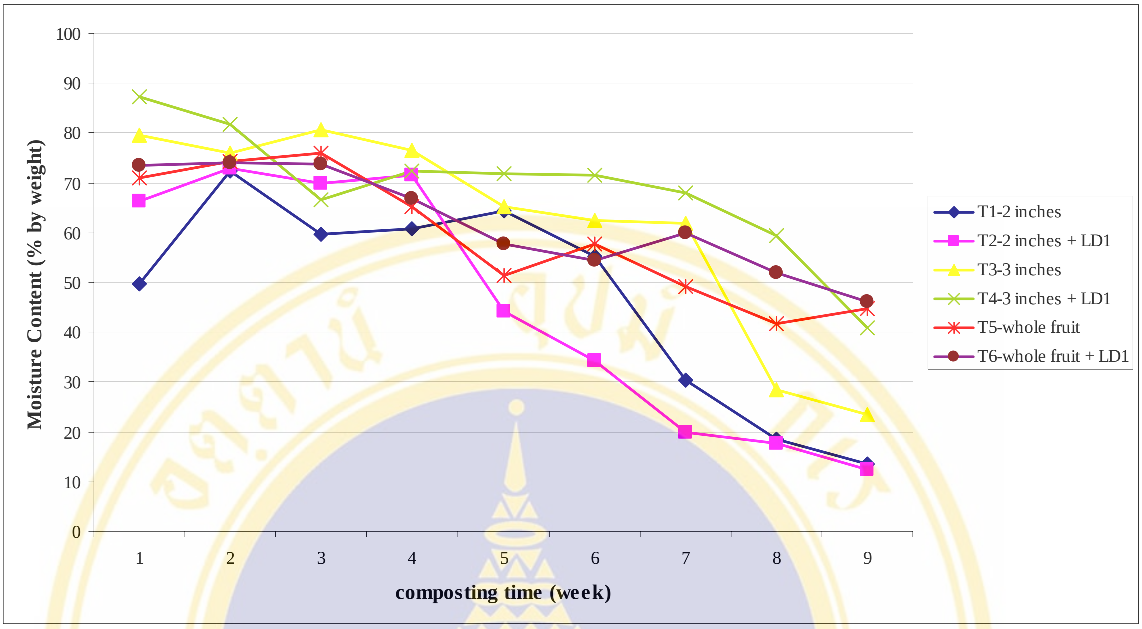


Figure 4-15: Moisture content change of each treatment in composting process

2) Total solids

The change of the amount of total solids in composting material is shown in table 4-6 and figure 4-16. Total solids change in composting process was increased since week 1 to week 8. According to figure 4-16, the lowest everage of total solids of all treatments was in week1-2 and the highest average of total solids was in week 7-8. The highest everage of total solids of treatments 1-6 were 86.94, 87.61, 76.62, 59.10, 58.22, and 53.78 respectively. Figure 4-16 also showed that in week 1 to week 4, all treatments had nearly-steady amount of total solids and after week 4 their amount of total solids started to increase until week 8. Treatment 2 had the most total solids increase. Figure 4-16 showed that treatments 1-4 had more change of total solids than treatments 5-6. Treatments 1-4 had the percentage of total solids increase about 200-300%. While treatments 5 and 6 had the percentage of total solids increase about 100%.

Table 4-6: The weekly change of total solids in composting process (% by weight)

treatment	composting time (week)								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	50.40	27.64	40.30	39.21	35.52	44.62	69.71	81.43	86.49
2	33.63	27.04	29.99	28.43	55.79	65.84	80.20	82.26	87.61
3	20.41	24.12	19.31	23.44	34.82	37.51	38.01	71.63	76.62
4	12.69	18.26	33.55	27.53	28.16	28.32	32.13	40.56	59.10
5	29.08	25.78	23.93	34.88	48.57	42.31	50.72	58.22	55.38
6	26.54	25.95	26.11	33.16	42.13	45.46	40.06	47.96	53.78

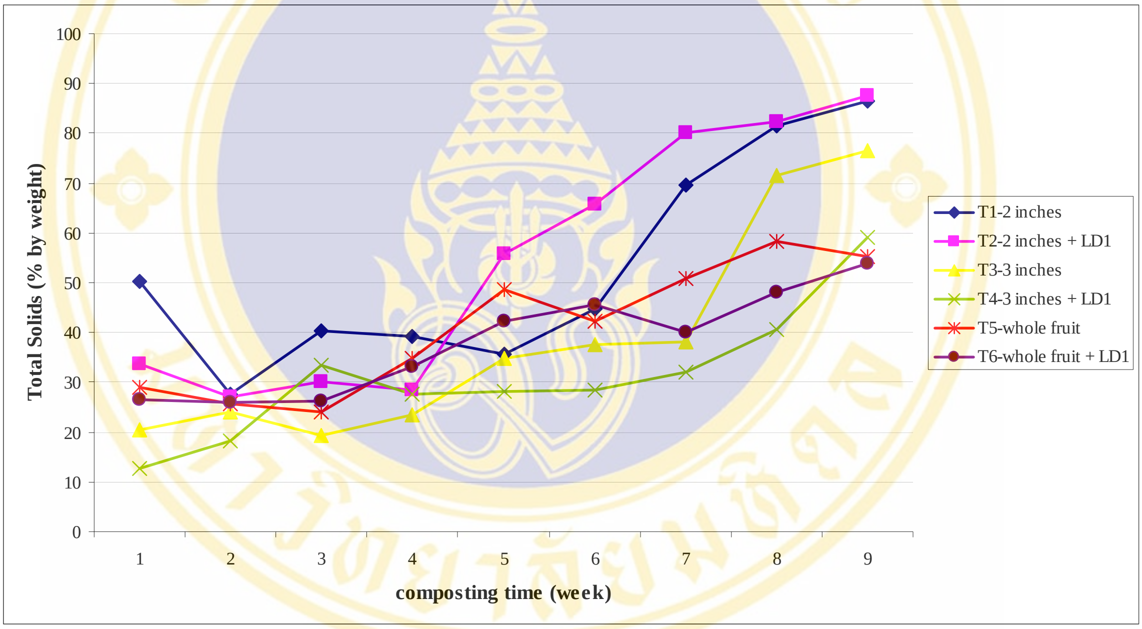


Figure 4-16: Total solids change of each treatment in composting process

3) Volatile Solids

The change of the amount of volatile solids in composting process is shown in table 4-7 and figure 4-17. Volatile solids change in composting process had decreased since week 1 to week 8. According to table 4-7, the highest average of volatile solids was in week 1-2 and the lowest everage of volatile solids of all treatment was in week 7-8. According to figure 4-17, it showed that in week 1 to week 4, all treatment had nearly-steady amount of volatile solids and after week 4 their amount of volatile solids had decreased until week 8. Treatment 2 had the most volatile solids decrease. Figure 4-17 showed that treatments 1-3 had more change of volatile solids than treatment 4-6. That was treatments 1-3 had the percentage of volatile solids decrease about 25%. While treatments 4-6 had the percentage of volatile solids decrease about 13%.

Table 4-7: The weekly change of volatile solids in composting process (% by weight)

treatment	composting time (week)								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	99.19	97.51	96.50	95.34	90.16	90.15	82.37	79.89	77.13
2	97.64	96.31	95.36	93.44	88.47	86.96	81.09	68.01	68.74
3	96.54	93.90	95.89	97.10	93.02	92.30	82.30	75.16	73.37
4	97.67	96.75	94.74	95.34	94.86	93.39	86.53	88.13	83.42
5	95.91	96.16	95.25	93.24	88.92	92.92	90.72	87.77	84.75
6	97.45	95.67	96.23	93.99	95.07	93.19	90.11	89.57	83.42

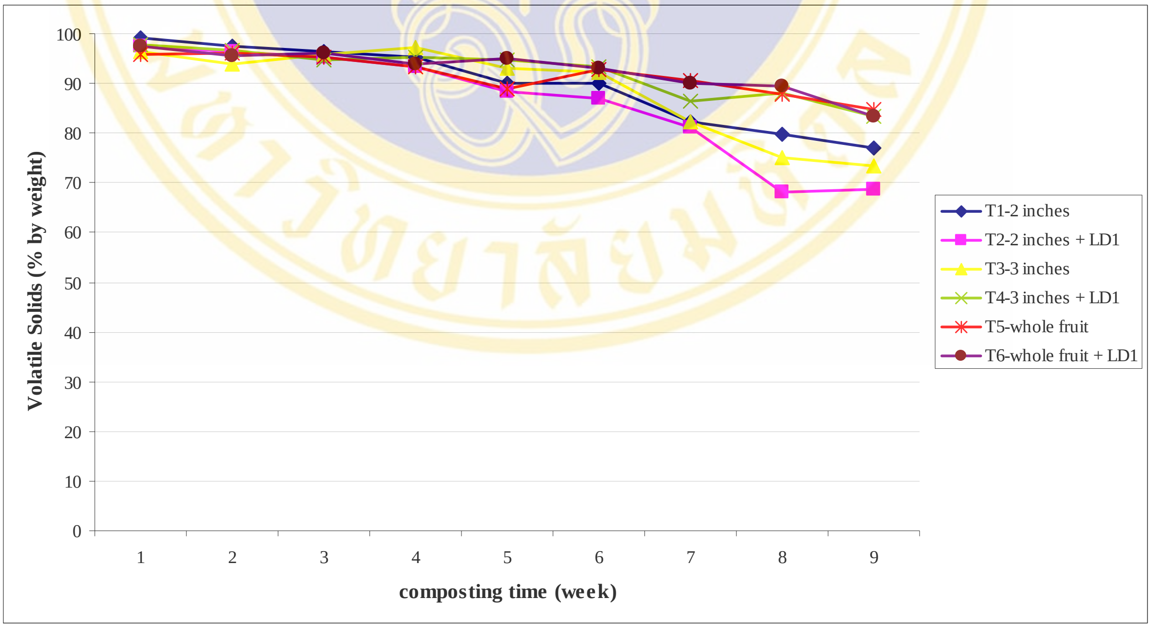


Figure 4-17: Volatile solids change of each treatment in composting process

4.1.3.2 Chemical properties

1) Organic Carbon

The change of the amount of organic carbon in composting process is shown in table 4-8 and figure 4-18. Organic carbon change in composting process had decreased little since week 1 to week 8. According to table 4-8, the highest average of organic carbon was in week 1-2 and the lowest everage of organic carbon of all treatments was in week 7-8. According to figure 4-18, it showed that in week 1 to week 5, all treatments had nearly-steady amount of organic carbon and after week 5 the amount of organic carbon had decreased until week 8. Treatment 4 had the most organic carbon decrease. It showed that treatments 1, 2, 3, 5, and 6 had the percentage of organic carbon decrease about 10-17%. While, treatment 4 had the percentage of organic carbon decrease about 25%.

Table 4-8: The weekly change of organic carbon in composting process (% by weight)

treatment	composting time (week)								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	48.33	47.37	49.16	48.03	47.77	46.78	41.04	37.93	40.08
2	47.21	48.10	48.22	47.52	39.38	37.55	34.78	38.27	41.97
3	48.16	45.99	45.91	42.09	36.26	39.97	41.67	37.51	41.46
4	44.45	42.38	43.76	41.91	42.46	43.60	39.59	38.68	33.25
5	45.65	43.09	45.24	47.95	49.68	44.06	44.35	44.08	40.23
6	47.58	44.35	45.47	46.41	46.03	45.33	47.31	42.55	39.44

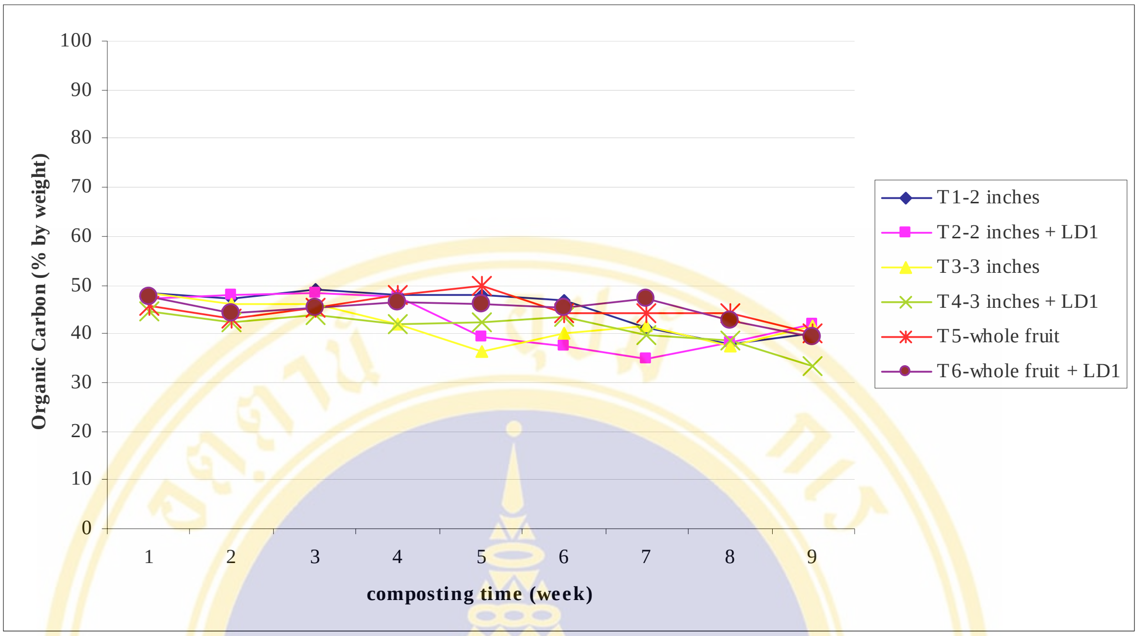


Figure 4-18: Organic carbon change of each treatment in composting process

2) Total Nitrogen

The change of the amount of total nitrogen in composting process is shown in table 4-9 and figure 4-19. In composting process total nitrogen changed not much. The percentage of change was about 1-2%. According to table 4-9, the highest average of total nitrogen of each treatment was different. The highest average of total nitrogen of treatments 1-6 were week 6, week 6, week 2, week 2, week 8, and week 7 respectively. According to figure 4-19, it showed that during week 1 to week 8 of composting process, the amount of total nitrogen did not change too much. The amounts of total nitrogen of all treatments were not much more than 3% by weight of total composting materials. It showed that treatments 1, 5 and 6 had an slightly increasing trends of total nitrogen, but treatments 2, 3, and 4 had an slightly increasing trend during week 1-6, week 1-5 and week 1-3 respectively, and after that they had an slightly decreasing trends of total nitrogen until week 8.

Table 4-9: The weekly change of total nitrogen in composting process (% by weight)

treatment	composting time (week)								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	0.97	1.58	1.58	1.94	2.02	1.96	1.97	1.95	2.03
2	1.19	1.69	1.93	1.92	2.01	1.80	2.14	0.82	0.79
3	1.19	1.62	1.70	1.55	1.65	1.90	0.77	0.85	0.80
4	0.93	1.16	1.74	1.63	1.45	0.70	0.77	0.78	0.86
5	0.76	1.08	1.31	1.53	1.54	2.09	1.95	2.35	2.46
6	0.74	1.04	1.02	1.54	1.97	2.04	2.25	2.45	2.36

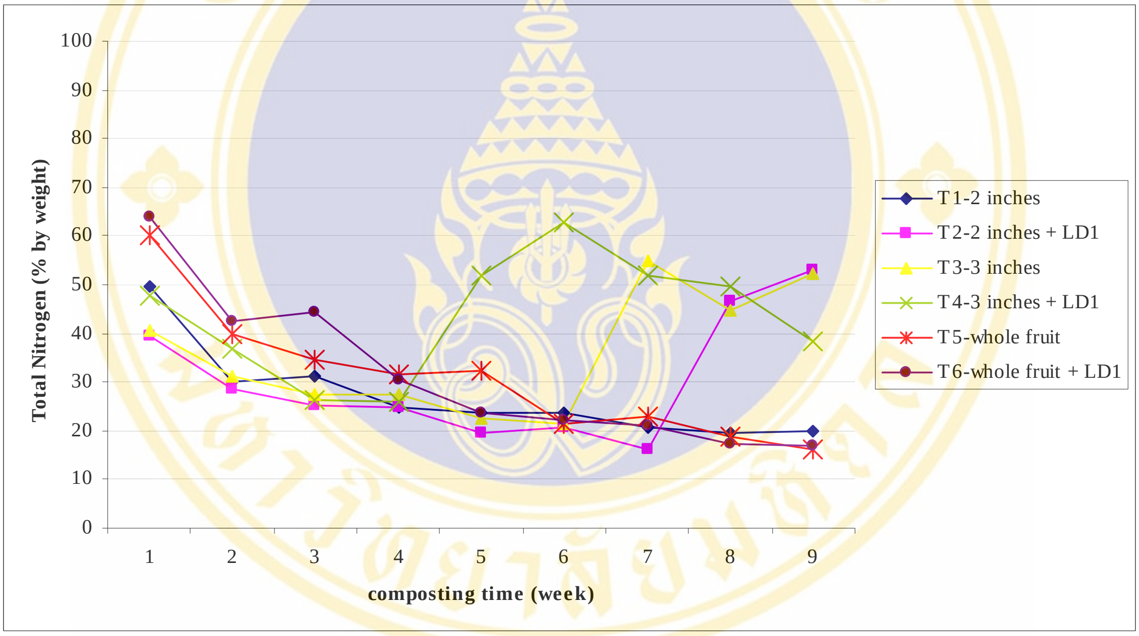


Figure 4-19: Total nitrogen change of each treatment in composting process

3) C/N ratio

The change of the amount of C/N ratio in composting process is shown in table 4-10 and figure 4-20. C/N ratio was calculated from the amount of organic carbon divided by total nitrogen in each treatment. So in composting process, C/N ratio would change inversely with total nitrogen. According to figure 4-20, treatments 1, 5, and 6 had a slightly decresing trend of C/N ratio during week 1 to week 8, but treatments 2 and 3 had an increasing trend of C/N ratio after week 7 and 6 respectively. Treatment 4 had an increasing trend of C/N ratio during week 4 to week 6 and then it turned to have a decreasing trend of C/N ratio until week 8.

According to table 4-10, the highest average of C/N ratio of each treatment was difference. The highest average of C/N ratio of treatments 1-6 were week 0, week 8, week 6, week 6, week 0, and week 0 respectively. According to figure 4-20, it showed that treatments 5 and 6 had more change of C/N ratio than the other treatments. They had the percentage of change about 70%.

Table 4-10: The weekly change of C/N ratio in composting process

treatment	Composting time (week)								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	49.78	30.20	31.09	24.74	23.70	23.87	20.85	19.62	19.93
2	39.54	28.54	25.14	24.77	19.64	20.84	16.24	46.65	52.86
3	40.44	31.26	27.63	27.46	22.67	21.55	55.01	44.71	52.14
4	47.56	36.98	26.23	25.92	52.05	62.60	51.75	49.63	38.53
5	60.21	39.97	34.61	31.44	32.22	21.27	22.86	18.76	16.32
6	63.91	42.57	44.51	30.31	23.55	22.22	21.09	17.39	16.76

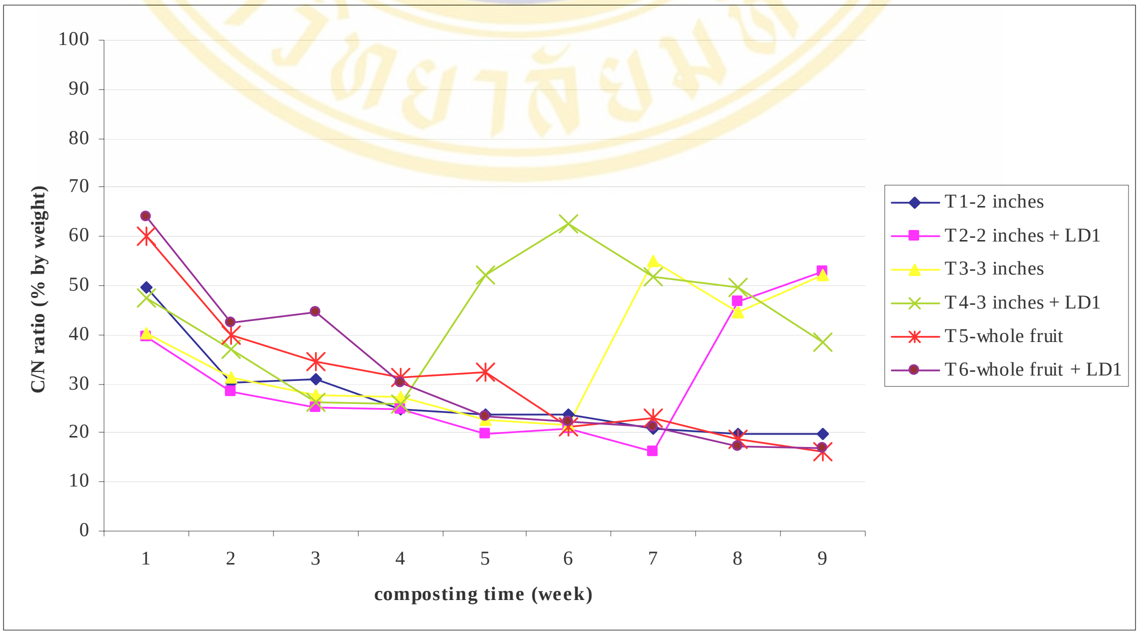


Figure 4-20: C/N ratio change of each treatment in composting process

4.2 Results of Statistical Analysis

4.3.1 The effects of composting factors on physical properties of Kluai Nam Wa-peel waste in composting process

4.2.1.1 Temperature

The 3-factor factorial design ANOVA test results between the three composting factors (size of Kluai Nam Wa-peel waste, activator LD-1 adding and composting time) and the temperature of composting piles (at significant level 0.05) are shown in table 4-11. It showed that the size of composting material and the composting time were statistically significant (p-value<0.05). The results indicated that both the size of Kluai Nam Wa-peel waste and the composting time had main effects on the temperature of composting pile in composting process, but the activator LD-1 adding had no effect on the temperature of composting pile (P-value>0.05). It also showed that there were 3 interaction effects.

Table 4-11: ANOVA table of temperature classified by sources of variation

Source	P-value	Significant
Size of composting material	<0.0001	Sig.
Activator LD-1 adding	0.0730	Non sig.
Composting time (day)	<0.0001	Sig.
Interaction between size and activator LD-1 adding	0.0010	Sig.
Interaction between size and composting time	<0.0001	Sig.
Interaction between activator LD-1 adding and composting time	<0.0001	Sig.

Remarks: Computed using alpha = .05, R Squared = .871 (Adjusted R Squared = .834)

4.2.1.2 Moisture Content

The 3-factor factorial design ANOVA test results between the three composting factors (size of Kluai Nam Wa-peel waste, activator LD-1 adding and composting time) and the amount of moisture content of composting products (at significant level 0.05) are shown in table 4-12. It showed that the size of composting material and the composting time were statistically significant (p-value<0.05). The results indicated that both the size of Kluai Nam Wa-peel waste and the composting time had main effects on the amount of moisture content of composting products, but activator LD-1 adding had no effect on the amount of moisture content in composting product (P-value>0.05). It also showed that there was only an interaction effect between the size of composting material and the composting time.

Table 4-12: ANOVA table of moisture content classified by sources of variation

Source	P-value	Significant
Size of composting material	<0.0001	Sig.
Activator LD-1 adding	0.0740	Non sig.
Composting time (Week)	<0.0001	Sig.
Interaction between size and activator LD-1 adding	0.0750	Non sig.
Interaction between size and composting time	<0.0001	Sig.
Interaction between activator LD-1 adding and composting time	0.1640	Non sig.

Remarks: Computed using alpha = .05, R Squared = .814 (Adjusted R Squared = .759)

4.2.1.3 Total solids

The 3-factor factorial design ANOVA test results between the three composting factors (size of Kluai Nam Wa-peel waste, activator LD-1 adding and composting time) and the amount of total solids of composting products (at significant level 0.05) are shown in table 4-13. It showed that the size of composting material and the composting time were statistically significant (p-value<0.05). The results indicated that both the size of Kluai Nam Wa-peel waste and the composting time had main effects on the amount of total solids in composting products, but activator LD-1 adding had no effect on the amount of total solids in composting products (P-value>0.05). It also showed that there was only an interaction effect between the size of composting material and the composting time.

Table 4-13: ANOVA table of total solids classified by sources of variation

Source	P-value	Significant
Size of composting material	<0.0001	Sig.
Activator LD-1 adding	0.0740	Non sig.
Composting time (Week)	<0.0001	Sig.
Interaction between size and activator LD-1 adding	0.0750	Non sig.
Interaction between size and composting time	<0.0001	Sig.
Interaction between activator LD-1 adding and composting time	0.1640	Non sig.

Remarks: Computed using alpha = .05, R Squared = .814 (Adjusted R Squared = .759)

4.2.1.4 Volatile Solids

The 3-factor factorial design ANOVA test results between the three composting factors (size of Kluai Nam Wa-peel waste, activator LD-1 adding and composting time) and the amount of volatile solids of composting products (at significant level 0.05) are shown in table 4-14. It showed that the size of composting material and the composting time were statistically significant (p-value<0.05). The results indicated that both the size of Kluai Nam Wa-peel waste and the composting time had main effects on the amount of volatile solids in composting products, but activator LD-1 adding had no effect on the amount of volatile solids in composting products (P-value>0.05). It also showed that there were interaction effects between the size of composting material and activator LD-1 adding as well as the size of composting material and the composting time.

Table 4-14: ANOVA table of volatile solids classified by sources of variation

Source	P-value	Significant
Size of composting material	<0.0001	Sig.
Activator LD-1 adding	0.5770	Non sig.
Composting time (Week)	<0.0001	Sig.
Interaction between size and activator LD-1 adding	<0.0001	Sig.
Interaction between size and composting time	<0.0001	Sig.
Interaction between activator LD-1 adding and composting time	0.9500	Non sig.

Remarks: Computed using alpha = .05, R Squared = .857 (Adjusted R Squared = .814)

4.3.2 The effects of composting factors on chemical properties of Kluai Nam Wa-peel waste in composting process

4.2.2.1 pH

The 3-factor factorial design ANOVA test results between the three composting factors (size of Kluai Nam Wa-peel waste, activator LD-1 adding and composting time) and pH of composting piles (at significant level 0.05) are shown in table 4-15. It showed that the size of composting material, activator LD-1 adding and the composting time were statistically significant (p-value<0.05). The results indicated that the size of Kluai Nam Wa-peel waste, activator LD-1 adding and the composting time had main effects on the pH of composting pile in the composting process. It also showed that there were 3 interaction effects.

Table 4-15: ANOVA table of pH classified by sources of variation

Source	P-value	Significant
Size of composting material	<0.0001	Sig.
Activator LD-1 adding	0.0020	Sig.
Composting time (day)	<0.0001	Sig.
Interaction between size and activator LD-1 adding	0.0380	Sig.
Interaction between size and composting time	<0.0001	Sig.
Interaction between activator LD-1 adding and composting time	<0.0001	Sig.

Remarks: Computed using alpha = .05, R Squared = .731 (Adjusted R Squared = .653)

4.2.2.2 Organic Carbon

The 3-factor factorial design ANOVA test results between the three composting factors (size of Kluai Nam Wa-peel waste, activator LD-1 adding and composting time) and the amount of organic carbon of composting products (at significant level 0.05) are shown in table 4-16. It showed that the size of composting material, activator LD-1 adding and the composting time were statistically significant (p-value<0.05). The results indicated that the size of Kluai Nam Wa-peel waste, activator LD-1 adding and the composting time had main effects on the amount of organic carbon in composting products. It also showed that there was only an interaction effect between the size of composting material and the composting time.

Table 4-16: ANOVA table of organic carbon classified by sources of variation

Source	P-value	Significant
Size of composting material	<0.0001	Sig.
Activator LD-1 adding	0.0280	Sig.
Composting time (Week)	<0.0001	Sig.
Interaction between size and activator LD-1 adding	0.1360	Non sig.
Interaction between size and composting time	0.0010	Sig.
Interaction between activator LD-1 adding and composting time	0.9870	Non sig.

Remarks: Computed using alpha = .05, R Squared = .587 (Adjusted R Squared = .464)

4.2.2.3 Total Nitrogen

The 3-factor factorial design ANOVA test results between the three composting factors (size of Kluai Nam Wa-peel waste, activator LD-1 adding and composting time) and the amount of total nitrogen in composting products (at significant level 0.05) are shown in table 4-17. It showed that the size of composting material, activator LD-1 adding and the composting time were statistically significant (p-value<0.05). The results indicated that the size of Kluai Nam Wa-peel waste, activator LD-1 adding and the composting time had main effects on the amount of total nitrogen in composting products. It also showed that there were 3 interaction effects.

Table 4-17: ANOVA table of total nitrogen classified by sources of variation

Source	P-value	Significant
Size of composting material	<0.0001	Sig.
Activator LD-1 adding	0.0030	Sig.
Composting time (day)	<0.0001	Sig.
Interaction between size and activator LD-1 adding	0.0200	Sig.
Interaction between size and composting time	<0.0001	Sig.
Interaction between activator LD-1 adding and composting time	0.0010	Sig.

Remarks: Computed using alpha = .05, R Squared = .825 (Adjusted R Squared = .773)

4.2.2.4 C/N Ratio

The 3-factor factorial design ANOVA test results between the three composting factors (size of Kluai Nam Wa-peel waste, activator LD-1 adding and composting time) and the amount of C/N ratio of composting products (at significant level 0.05) are shown in table 4-18. It showed that the size of composting material, activator LD-1 adding and the composting time were statistically significant (p-value<0.05). The results indicated that the size of Kluai Nam Wa-peel waste, activator LD-1 adding and the composting time had main effects on the amount of C/N ratio in composting products. It also showed that there was only an interaction effect between the size of composting material and the composting time.

Table 4-18: ANOVA table of C/N ratio classified by sources of variation

Source	P-value	Significant
Size of composting material	<0.0001	Sig.
Activator LD-1 adding	0.0040	Sig.
Composting time (Week)	<0.0001	Sig.
Interaction between size and activator LD-1 adding	0.0920	Non sig.
Interaction between size and composting time	<0.0001	Sig.
Interaction between activator LD-1 adding and composting time	0.0740	Non sig.

Remarks: Computed using alpha = .05, R Squared = .725 (Adjusted R Squared = .642)

4.3.3 Summary of statistical analysis results

4.2.3.1 Summary of the effects of the size of Kluai Nam Wa-peel waste on the properties of composting material

Summary of the effects of the size of Kluai Nam Wa-peel waste on the properties of composting material in composting process can be concluded in the table 4-19 as follows.

Table 4-19: Summary of the effects of the size of Kluai Nam Wa-peel waste on the properties of composting material

Properties of Kluai Nam Wa-peel waste	Significant	Non Significant
1. Physical Properties		
1.1 Temperature	✓	
1.2 Moisture content	✓	
1.3 Total solids	✓	
1.4 Volatile solid	✓	
2. Chemical Properties		
2.1 pH	✓	
2.2 Organic carbon	✓	
2.3 Total Nitrogen	✓	
2.4 C/N ratio	✓	

4.2.3.2 Summary of the effects of the activator LD-1 adding on the properties of composting material

Summary of the effects of activator LD-1 adding on the properties of composting material can be concluded in the table 4-20 as follows.

Table 4-20: Summary of the effects of activator LD-1 adding on the properties of composting material

Properties of Kluai Nam Wa-peel waste	Significant	Non Significant
1. Physical Properties		
1.1 Temperature		✓
1.2 Moisture content		✓
1.3 Total solids		✓
1.4 Volatile solid		✓
2. Chemical Properties		
2.1 pH	✓	
2.2 Organic carbon	✓	
2.3 Total Nitrogen	✓	
2.4 C/N ratio	✓	

4.2.3.3 Summary of the effects of the composting time on the properties of composting material

Summary of the effects of composting time on the properties of composting material can be concluded as the table 4-21 as follows:

Table 4-21: Summary of the effects of composting time on the properties of composting material

Properties of Kluai Nam Wa-peel waste	Significant	Non Significant
1. Physical Properties		
1.1 Temperature	✓	
1.2 Moisture content	✓	
1.3 Total solids	✓	
1.4 Volatile solid	✓	
2. Chemical Properties		
2.1 pH	✓	
2.2 Organic carbon	✓	
2.3 Total Nitrogen	✓	
2.4 C/N ratio	✓	

4.3 Decomposing Efficiency Analysis

The indexes of decomposing efficiency are composting time requirement and organic decomposing efficiency (50). So the efficiency of Kluai Nam Wa-peel waste composting of each treatment was analyzed as the following:

4.3.1 Composting time requirement

The end product of this research was the product of Kluai Nam Wa-peel waste composting which had constant temperature and/or had not more than 20:1 of C/N ratio. The composting time requirement for making the end product of each treatment is shown in table 4-22 as follows.

Table 4-22: The composting time requirement of Kluai Nam Wa-peel waste composting

Treatment	the end product producing week								
	0	1	2	3	4	5	6	7	8
1	-	-	-	-	-	-	-	✓	✓
2	-	-	-	-	✓	-	✓	-	-
3	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	✓	✓
6	-	-	-	-	-	-	-	✓	✓

Remark: ✓ = produced the end product

\- = did not produce the end product

4.3.2 Organic decomposing efficiency

The organic decomposing efficiency is the comparison of the loss weight of composting material and the weight of composting product (50). The organic decomposing efficiency in 8 weeks of each treatment is shown in table 4-23 as follows.

Table 4-23: The organic decomposing efficiency of Kluai Nam Wa-peel waste composting

Treatment	Decomposing efficiency (%)	Composting product weight (%)
1	93.33	6.67
2	94.00	6.00
3	92.00	8.00
4	91.00	9.00
5	83.67	16.33
6	83.00	17.00

CHAPTER V
DISCUSSION

The discussion of research results are presented in this chapter. The results of this study from chapter IV could be discussed and explained by the literature reviews in chapter II. According to three hypotheses of the study, this chapter showed the discussion and explanation of research results in terms of the effects of three composting factors (size of composting material, activator LD-1 adding and composting time) on physical and chemical properties of Kluai Nam Wa-peel waste. The details of discussion and explanation are shown as follows.

5.1 The effect of size of composting material on properties of Kluai Nam Wa-peel waste in composting process

5.1.1 Physical properties

5.1.1.1 Temperature

On a few day of the beginning of composting process, the temperature of composting piles was very high (about 40-45 ^{o}C). After that, the temperature of composting piles declined to ambient-air temperature till the end day of composting process. This change of temperature in composting process of this study may be explained that at the beginning of composting process, mesophilic phase (growth phase) temperature (22-40 ^{o}C) is developed and changed to thermophilic phase (40-60 ^{o}C). In these phases the microorganisms in composting pile grow up by the decomposed organic substrates (Kluai Nam Wa-peel) and the sterilization of pathogens happens. After thermophilic phase, most organic substrates will have been stabilized, resulting in a temperature decrease to mesophilic and eventually to ambient air level; this phase is called maturation phase. Complex organic chemicals are transformed into humic compound (9, 22 and 24).

According to the statistical test, the result showed that the size of Kluai Nam Wa-peel waste had effect on the temperature of composting pile. The size of composting material is an important factor to the efficiency of composting process. The small individual piece and the large ratio of surface area to volume can make more material surface which is available for microorganism attack (16). The smallest size of composting material which does not interfere with air flow can speed up the process of decomposition (22). So treatments 1 and 2, were the composting pile of 2 inches of Kluai Nam Wa-peel waste, had higher temperature than the other treatments in a first few days of composting process.

5.1.1.2 Moisture Content

The moisture content change of composting process had been a declining trend since week 1 to week 8. These change occurred because the microorganisms require water from composting material for inner cell metabolism and release their extracellular enzymes for decomposed the organic substrate (37). The result of this study also showed that treatment 2, which was the composting pile of 1 and 2 inches long of Kluai Nam Wa-peel waste, had higher percentage of moisture content decreasing (70-80%) than the others (35-50%). The optimal moisture content in composting process is in the range of 50-60% (38). So treatments 1 and 2, had the beginning moisture content about 50-60%, were more effective in organic decomposition than the other treatments. Because of too much moisture, it will interfere with the aeration by clogging the pores and anaerobic conditions are created, thus treatments 3-6 (70-80% of moisture content) had lower decomposition rate than treatment 1 and 2 (39).

Because the microorganisms need water as to be a material in decomposition activities and the size of composting material can control the amount of air and water in composting pile, so the size of composting material can also control the efficiency of decomposition rate too (38). As the same as the result of this study, it showed that the size of Kluai Nam Wa-peel waste had effect on moisture content of the composting pile.

5.1.1.3 Total solids

Total solids are total composting materials without moisture content that can be released by heat. So the change trend of total solids in composting material at the beginning and the end of composting process is an opposite trend with the moisture content change trend. It is an increasing change trend in all treatments. Treatment 4 (composting material were banana peel-waste 3 inches long and activator LD-1) had highest percentage of total solids increasing.

Because the microorganisms need moisture in composting material as to be a material in decomposition activities, so all the time of composting process the moisture content of composting material will decrease but total solids will increase. The size of composting material can control the amount of water flow and heat in the composting pile, so the size of composting material can also control the efficiency of decomposition rate too (38). Like the statistical test result, it was found that the size of Kluai Nam Wa-peel waste had effect on total solids of composting material in composting process. This statistical result can also confirm the total solids varied inversely the moisture content of composting material in composting process too.

5.1.1.4 Volatile Solids

Volatile solids are solids that volatilize at a temperature of 550^{o}C. Usually, volatile solids are considered to be organic (51). Composting process is the process of biological degradation of organic materials (20). So in the composting process, the organic matter has a decreasing trend since microorganisms started their decomposing activities till complex organic matter are transformed to humic compounds and subsequent nitrate (9, 22). As a result of this study, it showed that volatile solids changing trend in composting process had decreased since week 1 to week 8. The highest average of volatile solids was in weeks 1-2 and the lowest everage of volatile solids of all treatment was in weeks 7-8. These are because at the first period of composting process there were many organic matters for decomposing process. Then at nearly the end of composting process, the simple-structure organic substrate was decomposed and the complex-structure organic substrate started to decompose. So it took a long time for finishing the decomposition of the complex-structure organic substrate.

The result also showed that treatments 1-3 had the percentage of volatile solid decrease about 25%. Treatments 4-6 had the percentage of volatile solid decrease about 13%. This result confirmed that the lower size of composting materials can be decomposed by microorganisms easier than larger size of composting materials (16). This explanation of the relationship between the size of composting materials and the decomposition rate can be supported by the result of statistical analysis. It showed that the size of Kluai Nam Wa-peel waste had effect on volatile solids of composting materials in the composting process.

5.1.2 Chemical properties

5.1.2.1 pH

pH is an important factor related to microorganism growth. Generally, the organic matter with a wide range of pH 3-11 can be composted. However, the optimum pH values are 5.5-8.0 (44). In this study, the beginning pH values of all treatments were in the range of 4.5 – 7.5. The pH values of treatment 5 and 6 were lower than the other treatments.

In the early state of composting process, all treatments were acid condition. This is because the activity of acid-forming bacteria started to decompose the organic substrate (45). After that the pH values of all treatments were steady in the basic condition (pH value 8-9). This change is in agreement with the reviewed literature that at the end of composting process, pH of composting pile will turn to slightly acidic or slightly basic condition (45).

According to the decomposition activity of microorganism in composting process, the aeration of composting pile is the important factor that can control the decomposition rate. The aeration condition can also control the pH value of composting pile too. Oxygen is a key element in the respiratory and metabolic activities of microbes (8). The size of composting materials can control the surface area to volume ratio, make more of the materials available to microbial attack and air flow (16). If there is a lack of air (oxygen), it can cause the composting pile into anaerobic condition which had acid condition (20). As a result in the statistical analysis, it showed that the size of Kluai Nam Wa-peel waste had effect on pH values of the composting pile as the same as moisture content.

5.1.2.2 Organic Carbon

Kluai Nam Wa-peel waste is a type of organic waste. In the composting process it had only a transformation of organic waste to organic substrate. So in this study, it was found that the trend of organic carbon change was a slightly decreasing trend. All treatments had nearly steady amount of organic carbon. The size of Kluai Nam Wa-peel waste is an important factor in decomposition activities of microorganisms because it can control the surface area to volume ratio and make the material more available to microbial attack (16). So the size of composting material has more effect to the component of organic waste such as carbon and nitrogen. This reason was confirmed by the result of statistical analysis. It showed that the size of Kluai Nam Wa-peel waste had effect on organic carbon of composting materials in the composting process.

5.1.2.3 Total Nitrogen

Nitrogen is one of the most abundant elements. It is found in the cells of all living things and is a major component of proteins. Organic nitrogen is found in proteins, and is continually recycled by plants and animals (51). Kluai Nam Wa peel-waste is a product of the plant which has more organic nitrogen. In addition, the aerobic composting process was done in this study. So this composting process not more nitrogen as in anaerobic composting process which produced ammonia and nitrate (21). Thus during week 1 to week 8 of composting process, the amount of total nitrogen was not changed too much. The changing percentage is only about 1-2%.

According to table 4-9, it showed that there was nitrogen loss in treatments 2, 3 and 4. They had decreasing trends of nitrogen amount during the composting process. It can be explained by their pH values: all the time of composting process, treatments 2, 3 and 4 had higher pH value than treatments 1, 5 and 6. Most of their pH values were about 8.50 – 9.50. The results were in agreement with reviewed literatures. Under conditions of high pH (8.0-9.0), ammonium (NH_4^+) is converted to volatile ammonia (NH_3) and lost into the atmosphere (52).

The size of Kluai Nam Wa-peel waste is an important factor in decomposition activities of microorganisms because it can control the surface area to volume ratio make the material more available to microbial attack (16). So the size of composting material has more effect to the component of organic waste such as carbon and nitrogen. This reason was confirmed by the result of statistical analysis. It showed that the size of Kluai Nam Wa-peel waste had effects on total nitrogen of composting materials in the composting process.

5.1.2.4 C/N ratio

The C/N ratio was calculated from the amount of organic carbon divided by total nitrogen of each treatment. In the composting process of this study, C/N ratio changed in the form of inversion of total nitrogen. Treatments 1, 5, and 6 had a decresing trend of C/N ratio, but treatments 2, 3 and 4 had an increasing trend since the week 1 to the week 6 and turned to have a decreasing trend of C/N ratio until week 8. In the composting process, the ratio of carbon and nitrogen are necessary for the growth and decomposition process of microorganisms. Microorganisms use carbon as a source of energy and use nitrogen compound as a source of nitrogen (8). Thus all treatments had the decreasing amount of C/N ratio in the composting process.

According to the statistical test result, it showed that the size of Kluai Nam Wa-peel waste had effect on C/N ratio of composting material. The reason is that the size of Kluai Nam Wa-peel waste is an important factor that can control the surface area which makes more material surface available to microorganism decomposition activities (16)

5.1.3 Summary of the effects of composting material size on the properties of Kluai Nam Wa-peel waste in composting process

The effects of the size of Kluai Nam Wa-peel waste on the properties of composting material can be concluded in the table 5-1 as follows.

Table 5-1: The effect of the size of Kluai Nam Wa-peel waste on the properties of composting material

Properties of Kluai Nam Wa-peel waste	Effect	No Effect
1. Physical Properties		
1.1 Temperature	✓	
1.2 Moisture content	✓	
1.3 Total solids	✓	
1.4 Volatile solid	✓	
2. Chemical Properties		
2.1 pH	✓	
2.2 Organic carbon	✓	
2.3 Total Nitrogen	✓	
2.4 C/N ratio	✓	

According to table 5-1, it showed that the size of composting material factor had effect on the physical and chemical properties of Kluai Nam Wa-peel waste in the composting process. The result of this study was in agreement with all reviewed literatures about composting that the size of composting material is an important factor of composting process (8, 9, 16, 20, 22, 33,).

5.2 The effect of activator LD-1 adding on the properties of Kluai Nam Wa-peel waste in the composting process

5.2.1 Physical properties

5.2.1.1 Temperature

According to the statistical test, the result indicated that activator LD-1 adding had not a main effect on the temperature of composting material in composting process. This result can be explained that the temperature did not change too much after 2-3 days of the beginning of composting process. It seemed that microorganism had the steady rate of decomposition and Kluai Nam Wa-peel waste is not a complex substrate organic waste. So in the composting process of this study, it had no need of microorganisms to decompose the complex substrate in the last period of composting process (9, 22 and 24). So the temperatures of composting piles in all treatments, which added or non added activator LD-1, were not different.

5.2.1.2 Moisture Content

The moisture content showed a proportion of water in composting material (37). The adding of microorganism had no any effect on the amount of moisture content in composting pile. The aeration and the size of composting material can control the amount of water in the composting pile (38). So the statistical result showed that there was no any effect of activator LD-1 adding on moisture content of composting material in this composting process.

5.2.1.3 Total solids

The amount of total solids in composting material showed the amount of total composting material without moisture content that can be released by heat. The statistical result showed that there was no any effect of activator LD-1 adding on the amount of total solids of composting material in composting process. So it can be concluded that the adding of microorganism had no any effect on the amount of total solids or the amount of composting material in composting pile.

5.2.1.4 Volatile Solids

Volatile solids are considered to be an organic substrate (51). Composting process is the process of biological degradation of organic material (20). The result of this study, it also showed that activator LD-1 adding had not a main effect on the amount of volatile solids of composting material. So activator LD-1 adding had not a main effect on the amount of organic substrate in the composting pile during the composting process.

5.2.2 Chemical properties

5.2.2.1 pH

The activator LD-1 was produced by Land Development Department (7). The Benefits of this microorganism activator adding are accelerating the decomposition rate and controlling the types of microorganisms in the composting process (32). The pH is an important factor for microorganism growth. Each type of microorganisms had its optimum pH of Growth. So the result showed that activator LD-1 adding had effect on pH of composting material in the composting process.

5.2.2.2 Organic Carbon

The activator LD-1 adding is a type of microorganism activator (32). Kluai nam Wa-peel waste is a type of organic waste. So in the composting process, the microorganisms-both came from activator LD-1 adding and the natural microorganism in Kluai Nam Wa-peel waste-could transform the organic waste to organic substrate, and microorganisms used the organic carbon as an energy in decomposition activities (8). So in this study, it was found that activator LD-1 adding had effect on organic carbon of composting material in the composting process.

5.2.2.3 Total Nitrogen

Kluai Nam Wa peel-waste is a waste product of the plant which has more organic nitrogen. Microorganisms use nitrogen compound as a source of nitrogen for decomposing activities (8). The activator LD-1 is a type of microorganism activator (32). So the amount of microorganism can control the amount of nitrogen usage in the composting process. As a result of this study, it showed that activator LD-1 adding had effect on the amount of total nitrogen of composting material in the composting process.

5.2.2.4 C/N ratio

In composting process, the ratio of carbon and nitrogen is necessary for growth and decomposition process of microorganisms. Microorganisms use carbon as a source of energy and use nitrogen compound as a source of nitrogen (8). So the amount of microorganism can control the amount of carbon usage and nitrogen usage in the composting process. Thus it showed that activator LD-1 adding had effect on C/N ratio of composting material in the composting process.

5.2.3 Summary of the effect of activator LD-1 adding on properties of Kluai Nam Wa-peel waste in composting process

The effect of activator LD-1 adding on the properties of composting material can be concluded in the table 5-2 as follows.

Table 5-2: The effect of activator LD-1 adding on the properties of composting material

Properties of Kluai Nam Wa-peel waste	Effect	No Effect
1. Physical Properties		
1.1 Temperature		✓
1.2 Moisture content		✓
1.3 Total solids		✓
1.4 Volatile solid		✓
2. Chemical Properties		
2.1 pH	✓	
2.2 Organic carbon	✓	
2.3 Total Nitrogen	✓	
2.4 C/N ratio	✓	

According to table 5-2, it showed that the activator LD-1 adding factor had the main effect on the chemical properties of Kluai Nam Wa-peel waste in the composting process. But it had no effect on the physical properties of Kluai Nam Wa-peel waste in the composting process. The result of this study was in agreement with all reviewed literature about activator LD-1 that microorganism adding could enhance the organic waste decomposition (2, 10, 11, 32 and 47). The outcome of decomposition was shown in the form of necessary nutrient in the end product of Kluai Nam Wa-peel waste composting process such as carbon and nitrogen.

5.3 The effect of composting time on properties of Kluai Nam Wa-peel waste in composting process

5.3.1 Physical properties

5.3.1.1 Temperature

The change of temperature in composting process of this study can affect the activities of each type of microorganism. That was at the beginning of the composting process; mesophilic phase temperature (22-40 ^{o}C) was developed and changed to thermophilic phase (40-60 ^{o}C). In these phases the microorganism in composting pile was capable of growing by decomposed organic substrates (Kluai Nam Wa-peel) and sterilized the pathogen. After thermophilic phase, most organic substrates had been stabilized, resulting in a temperature decrease to mesophilic and eventually to the ambient air level; this phase was called maturation phase. Complex organic chemical are transformed into humic compound (9, 22 and 24). So the composting time that showed the time series of the microorganisms activities had effect on the temperature of composting material in Kluai Nam Wa-peel waste composting process.

5.3.1.2 Moisture Content

At the different time period of composting process, the moisture content of all treatments had changed as a declining trend since week 1 to week 8. The moisture content change occurred because the amount of microorganism was different in each phase of composting process. Each microorganism required the amount of water for organic substrate decomposition (37). As a result of this study it showed that the composting time had effect on the amount of moisture content of composting material in Kluai Nam Wa-peel waste composting process.

5.3.1.3 Total solids

The result showed that there was a changing trend of total solids during the composting process. The total solids change increased in all treatments. Because the composting process is a process of the organic matter decomposed to organic substrate. The total solids were the amount of the remained organic matter from Kluai Nam Wa peel-waste composting process without moisture content. So the result of statistical test showed that the composting time had effect on the amount of total solids of composting material in the composting process.

5.3.1.4 Volatile Solids

Volatile solids are considered to be organic (51). Composting process is the process of biological degradation of organic materials (20). So in the composting process, organic matter had a decreasing trend since microorganisms started their decomposing activity till complex organic matter was transformed to humic compounds and subsequent nitrate. The decomposing activities of microorganism started very quickly in the first few day of composting process. So in the first few day of composting process, it had more effective of biological degradation of organic material, and then this activities would slow down and finally it was steady (9, 22). The relationship of composting time and the amount of organic substrate remained from Kluai Nam Wa-peel waste composting process can be supported by the result of this study. It showed that the composting time had effect on the volatile solids of composting material in the composting process.

5.3.2 Chemical properties

5.3.2.1 pH

In the early state of composting process, all treatments were the acid condition. This is because the activity of acid-forming bacteria started to decompose the organic substrate (45). After that the pH values of all treatments were steady in the basic condition (pH value 8-9). This change is in agreement with the reviewed literature that at the end of composting process, pH of composting pile will turn to slightly acidic or slightly basic condition (45). So in each time of the composting process, it showed that the composting pile had the pH value change. Thus in this study, it showed that the composting time had effect on pH of composting material in the composting process.

5.3.2.2 Organic Carbon

Kluai nam Wa-peel waste is a type of organic waste. The composting process is a transformation of organic waste to organic substrate by microorganism decomposition. The decomposing activities of microorganism started very quickly in the first few day of composting process, and then this activities would slow down and finally it was steady (9, 22). The microorganism used the organic carbon as an energy in decomposition activities (8). So in the different period of composting process, it would have the different decomposition rate too. Similar to the result of this study, it was found that the trend of organic carbon changed, but it was a slightly decreasing change. The composting time had effect on the organic carbon of composting material in the composting process.

5.3.2.3 Total Nitrogen

Kluai Nam Wa peel-waste is a waste product of the plant which has more organic nitrogen. In addition, this study is an aerobic composting process. So microorganism used nitrogen from Kluai Nam Wa-peel waste as a source of nitrogen compound for decomposing the organic matter (8). In the different time of the composting process, the microorganism needed more nitrogen to decompose Kluai Nam Wa-peel waste. So it showed that the composting time had effect on the total nitrogen of composting material in the composting process.

5.3.2.4 C/N ratio

The time requirement for stabilizing the organic substrate depends on the intial C/N ratio (21). In different period of the composting process, the C/N ratio was changed by decomposing activities of microorganisms. So it showed that the composting time had effect on C/N ratio of composting material in the composting process.

5.3.3 Summary of the effect of composting time on properties of Kluai Nam Wa-peel waste in composting process

The effect of composting time on the properties of composting material can be concluded as the table 5-3 as follow:

Table 5-3: The effect of composting time on the properties of composting material

Properties of Kluai Nam Wa-peel waste	Effect	No Effect
1. Physical Properties		
1.1 Temperature	✓	
1.2 Moisture content	✓	
1.3 Total solids	✓	
1.4 Volatile solid	✓	
2. Chemical Properties		
2.1 pH	✓	
2.2 Organic carbon	✓	
2.3 Total Nitrogen	✓	
2.4 C/N ratio	✓	

According to table 5-3, it showed that the composting time factor had effect on the physical and chemical properties of Kluai Nam Wa-peel waste in the composting process. The result of this study was in agreement with all reviewed literatures about composting that the properties of composting material were changed at different composting time (9, 21, 10, 46 and 50). So the composting time is an important factor of Kluai Nam Wa-peel waste composting process.

5.4 Efficiency of Kluai Nam Wa-peel waste composting

The index of decomposing efficiency consists of the composting time requirement, the loss weight of composting material, the weight of end product, the amount of organic carbon, the amount of volatile solid (50). So the efficiency of Kluai Nam Wa-peel waste composting of each treatment was concluded by using the composting time requirement and the organic decomposing efficiency as the following:

5.4.1 Composting time Requirement

The end product of this research was the product of Kluai Nam Wa-peel waste composting which had constant temperature and/or had not more than 20:1 of C/N ratio. The composting time requirement for making the end product of each treatment is shown in table 4-22. It showed that treatment 2 had the end product faster than the other treatments. It took only 4 weeks for decomposing the Kluai Nam Wa-peel waste. So the best effectiveness condition of Kluai Nam-peel waste composting of this study was treatment 2, which was the composting of 2 inches-size of Kluai Nam Wa-peel waste and activator LD-1 adding. The 2nd effectiveness conditions of Kluai Nam-peel waste composting of this study were treatment 5 and treatment 6, which were the composting of 3 inches-size of Kluai Nam Wa-peel waste with and without activator LD-1 adding. Treatments 5 and 6 took 5 weeks for producing the end product of this research.

The results also showed that activator LD-1 adding could reduce the composting time requirement of Kluai Nam Wa-peel waste 2 inches long composting (treatment 2 and 3). Treatment 2, which was the composting of 2 inches-size of Kluai Nam Wa-peel waste and activator LD-1 adding, needed 4 weeks for produced the end product. Treatment 1, which was the composting of 2 inches-size of Kluai Nam Wa-peel waste, needed 7 weeks for produced the end product. The result of treatments 5 and 6, composting of 3 inches-size of Kluai Nam Wa-peel waste, were differenced from treatments 1 and 2. Treatments 5 and 6 needed same time requirement (7 weeks) for produced the end product.

5.4.2 Organic decomposing efficiency

The organic decomposing efficiency is the comparison of the loss weight of composting material and the weight of composting product (50). The organic decomposing efficiency in 8 weeks of each treatment is shown in table 4-23. It showed that treatment 2 had highest percentage of the decomposing efficiency (94.00 %). Treatment 2 also had the most amount of Kluai Nam Wa-peel waste reduction by the composting process too. So the 2 inches-size of Kluai Nam Wa-peel waste with activator LD-1 adding is the most suitable treatment for minimizing the Kluai Nam Wa-peel waste by the composing process in this study.

5.5 Quality of the end product of composting process

The Organic Matter and Waste Product Subdivision, Soil and Water Conservation, Department of Land Development recommended the standard for the good compost properties such as main plant nutrients (N, P2O5, K2O), C/N ratio, moisture content, pH and organic matter (3). So the qualities of the end products of composting process of each treatment are shown in table 5-4. For treatment 3 and treatment 4 of this study showed that during 8 weeks, they had not any weeks that had C/N ratio less than 20. So treatment 3 and treatment 4 did not give the end product. It can also be concluded that the conditions of treatment 3 and treatment 4 composting process were not suitable for producing the end product but it could minimize the Kluai Nam Wa-peel waste as good as the other treatments.

Table 5-4: The quality of the end product of Kluai Nam Wa-peel waste composting

Properties	T1	T2	T5	T6	Standard
The end product producing week	7	4	7	7	-
N: P_2O_5: K_2O	0.25:0.06:1	0.25:0.06:1	0.11:0.04:1	0.24:0.05:1	0.5:0.5:1
C/N ratio	19.62	19.64	18.76	17.39	≤ 20:1
%Moisture content	18.57	44.21	55.11	52.04	≤ 35
pH	9.33	9.17	8.83	9.00	6.0-7.5
%Organic matter (%Volatile Solid)	79.89	88.47	87.77	89.57	25-50

According to table 5-4, it showed that the qualities of the end product of all treatments did not meet the standard of good compost of The Organic Matter and Waste Product Subdivision, Soil and Water Conservation, Department of Land Development. Only moisture content of the end product of treatment 1 (18.57 % by weight) met the standard of good compost (≤ 35 % by weight). The moisture contents of the other treatments were higher than the amount that recommended in the standard of good compost (44.21-55.11 % by weight). The end products of all treatments were in basic condition (pH 8.83-9.33) and had high percentage of organic matter (79.89-89.57 % by weight). The amount of nutrients (N: P_2O_5: K_2O) of all treatments were lower than the amount that recommended in the standard of good compost.

CHAPTER VI
CONCLUSION AND RECOMMENDATION

This research studied the effects of three composting factors on Kluai Nam Wa peel-waste's properties in the composting process. Those factors are the size of composting material, activator LD-1 adding and the composting time. The conclusions and recommendations of this research are described as follows.

6.1 Conclusion

6.1.1 The effect of size of composting material on properties of Kluai Nam Wa-peel waste in the composting process

In this research, the size of composting material had the effects on the physical properties of Kluai Nam Wa-peel waste in composting process such as temperature, moisture content, total solids, and volatile solids. It also had the effects on the chemical properties Kluai Nam Wa-peel waste in composting process such as pH, organic carbon, total nitrogen and C/N ratio. Similar to other researches, it was found that the size of composting material factor was an important factor of the composting process (8, 9, 16, 20, 22 and 33).

6.1.2 The effect of activator LD-1 adding on properties of Kluai Nam Wa-peel waste in the composting process

In this research, the activator LD-1 adding factor had no effect on the physical properties of Kluai Nam Wa-peel waste in the composting process such as temperature, moisture content, total solids, and volatile solids. But it had the effects on the chemical properties Kluai Nam Wa-peel waste in the composting process such as pH, organic carbon, total nitrogen and C/N ratio. These are because the microorganism activator adding enhanced the amount of microorganism in the composting pile and also enhanced the decomposition activities in composting pile (2, 10, 11, 32 and 47), so the outcome of decomposition activities of microorganism was shown in the form of plant nutrients and decomposition capability in composting product such as nitrogen and C/N ratio.

6.1.3 The effect of composting time on properties of Kluai Nam Wa-peel waste in the composting process

In this research, the composting time factor had the effects on the physical properties of Kluai Nam Wa-peel waste in the composting process such as temperature, moisture content, total solids, and volatile solids. It also had the effects on the chemical properties Kluai Nam Wa-peel waste in the composting process such as pH, organic carbon, total nitrogen and C/N ratio. Similar to other researches, it was found that the properties of composting material had changed all the time of composting process (9, 21, 10, 46 and 50).

6.1.4 The efficiency of Kluai Nam Wa-peel waste composting

The efficiency of Kluai Nam Wa-peel waste composting was indicated from the composting time requirement and the organic decomposition activities. This research was found that the experimental treatment 2 - which was the composting of 2 inches-size of Kluai Nam Wa-peel waste with activator LD-1 adding - was the best condition of Kluai Nam Wa-peel waste minimization by the composting process. Its decomposing efficiency was 94.00% and took only 4 weeks to produce the end product that could be used as a soil amendment.

6.1.5 The quality of the end products of Kluai Nam Wa-peel waste composting

According to the good compost property standard which was recommended by Department of Land Development, It showed that the quality of end product of all treatments did not meet this standard. Only moisture content of the end product of treatment 1 met the standard of good compost. The others were higher than the amount of moisture that recommended in the standard of good compost. The end products of all treatments were in basic condition and had high percentage of organic matter. All end products had lower amount of nutrients (N: P_2O_5: K_2O) than the recommendation of the standard of good compost.

6.2 Recommendation

6.2.1 Recommendation of research methodology

The advantage of this research was the data recording. It had many daily and weekly data analysis of physical and chemical properties of organic-waste decomposing process. So this research will be good basic information on the change of physical and chemical properties of organic waste in the decomposing process. The advantage of this research was the validity control. The error controls of this research were done in the part of Kluai Nam Wa-peel waste collection, composting material preparation and composting product samples collection.

The disadvantage of this research was the collection of Kluai Nam Wa-peel waste for starting all treatments in the same day. It was very hard to collect 900 kilograms of the same characteristics of Kluai Nam Wa peel waste from fried-banana booth shops in one day. It needed to start each treatment in the different day. So this research could not control the same condition of climate and ambient air of all treatments.

6.2.2 Recommendation for further study

For further study about organic waste decomposing process, especially Kluai Nam Wa-peel waste. The following aspects are recommended for further investigation:

1. More controlling factors-such as the temperature and the moisture of ambient air in every day of composting process- should be studied. It can be done by setting the composting site in a closed room.

2. More studies about mixing of Kluai Nam Wa peel-waste with other organic wastes should be done for producing that the end product meets the standard of good compost - which recommended by Department of Land Development.

6.2.3 Recommendation for research application

This research aimed to study the elimination of the organic waste from agricultural part by recovering it as a soil amendment for improving the agricultural soils. So this research result is very useful for agriculturists. The composting method of this research can really be implemented corresponding with in agriculturist living because the research was done by composting the Kluai Nam Wa-peel waste in concrete casings – which were cheap, easy to access and enduring. This method also did not need much time to produce the end products.

The best condition that gave more efficiency to eliminate Kluai Nam Wa-peel by composting process was the treatment 2 (the composting of 2 inches size of Kluai Nam Wa-peel waste which added with activator LD-1). This condition needed 4 weeks for producing the end product. Its end product had high percentage of organic matter that was good for using as a soil amendment, but it needed pH adjustment before using as a soil amendment.

The condition that was easy to implement and did not take much time in the composting material preparation was the treatment 5 (the composting of the whole fruit peel size of Kluai Nam Wa-peel waste). This condition needed 7 weeks for producing the end product. Its end product had high percentage of organic matter that was good for using as a soil amendment, but it needed pH adjustment before using as a soil amendment like the treatment 2.

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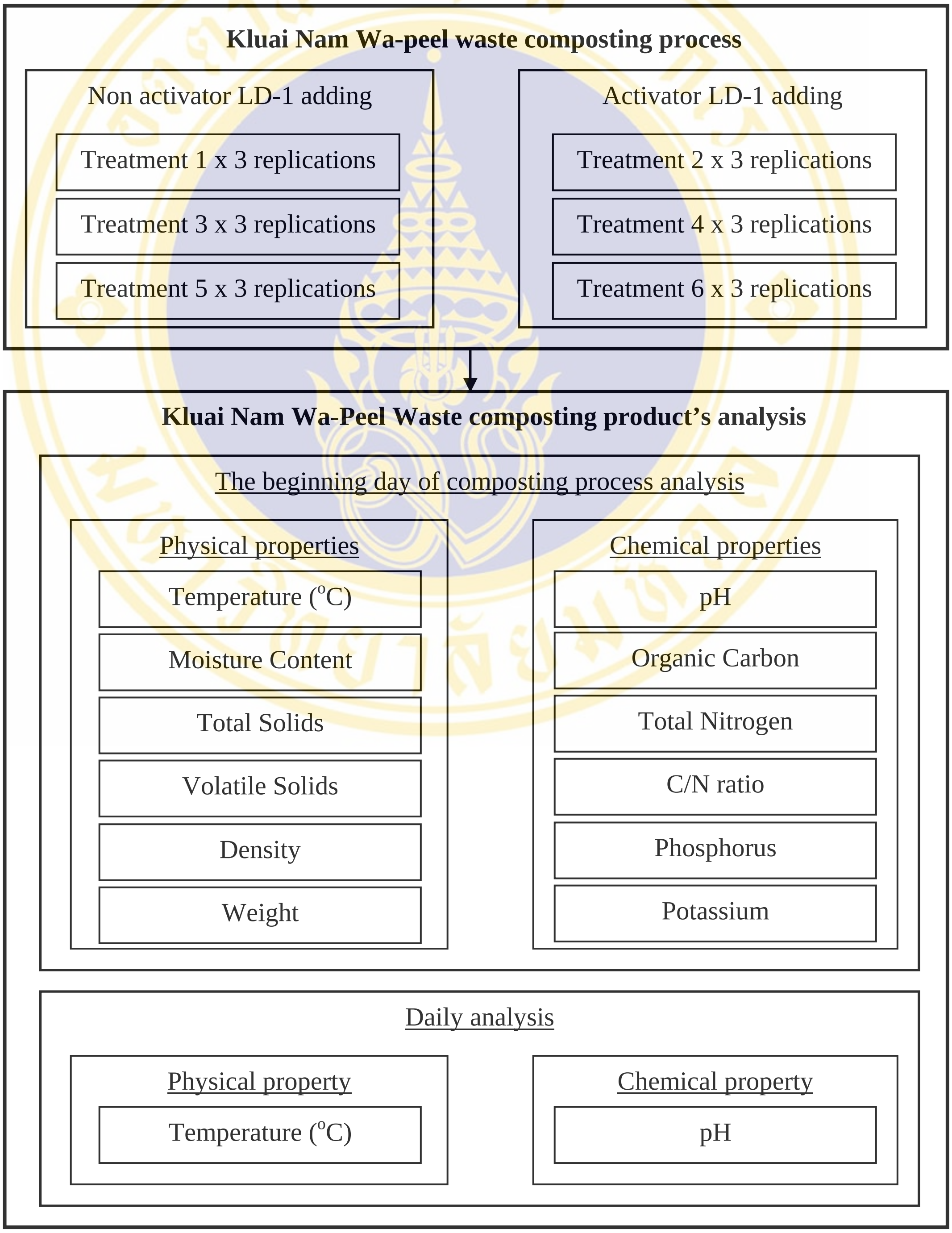
APPENDIX

APPENDIX A

Methods of composting product analysis

The procedure of composting product's physical and chemical properties analysis are shown in figure A.



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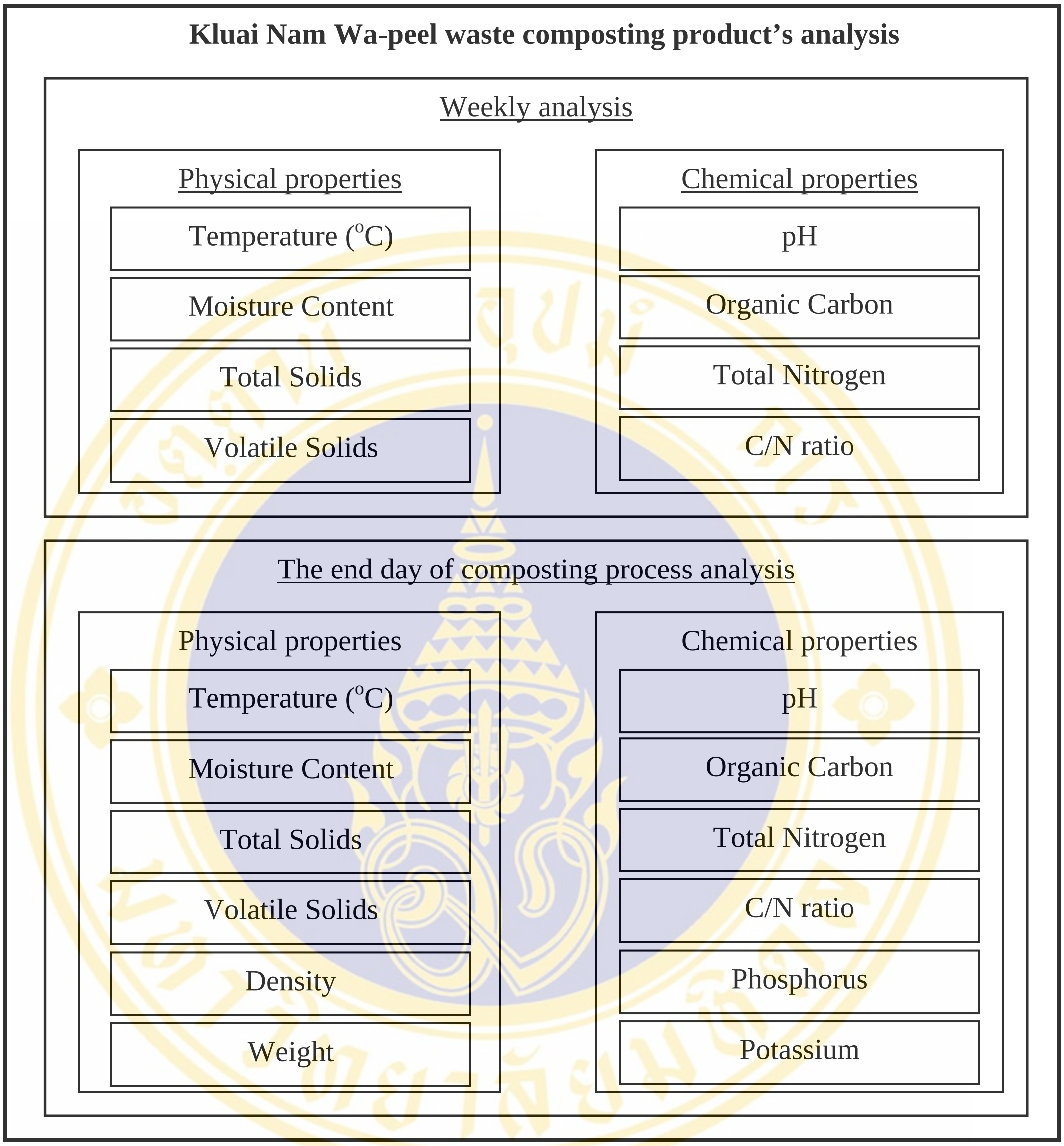


Figure A: Chart of composting products analysis of this research

The physical and chemical properties of composting product that were analyzed at the composting site were temperature, weight, density and pH. The physical properties of composting product that were analyzed at the laboratory were moisture content, total solids and volatile solids. And the chemical properties of composting product that were analyzed at the laboratory were organic carbon, total nitrogen, C/N ratio, phosphorus, and potassium.

The methods of physical and chemical properties analysis of composting products which had done at the composting site were presented as below:

1. Physical Properties

1.1 Temperature

The temperature measure method that used in this research was thermometric method. This method was done by using thermometer to measures the temperature of composting pile.

1.2 Weight

The weight measure method that used in this research was weighting method. This method was done by using scale to measures the weight of composting material which packed in a bag.

1.3 Density

The density of composting material was calculated from the weight of composting material divided by the volume of composting material. The volume of composting material was calculated by cross section area of concrete casing multiple by a height of composting material in concrete casing (H).

Calculation:

$$\text{Volume of composting material (meter}^3) = ¶ \times [0.8 \text{ (meter)}]^2 \times [\text{H (meter)}]$$

$$\text{Density (kilogram/meter}^3) = \frac{\text{Weight of composting material (kilogram)}}{\text{Volume of composting material (meter}^3)}$$

2. Chemical Properties

2.1 pH

The pH measure method that used in this research was pH paper testing. This method was done by using pH test paper to measures the pH of composting material which dissolved in distilled water for 5 minutes.

The methods of physical and chemical properties analysis of composting products which had done at the composting site and the Department of Agriculture's laboratory, Ministry of Agriculture and Cooperatives were presented as below:

1. Physical Properties

1.1 Moisture Content

The Oven drying method was used for analyze the amount of moisture content in composting product. The procedure of analysis is shown as following chart;

Weighted non moisture content porcelain cup (from desiccator) → Weight= A gram

↓

Put sample of composting product in porcelain cup

↓

Weighted porcelain cup and composting sample → Weight= B gram

↓

Dried porcelain cup and composting product sample in oven at 75^{o}C for 48 hours

↓

Cooled porcelain cup and composting sample in desiccator

↓

Weighted porcelain cup and composting product sample again → Weight= C gram

↓

Calculated moisture content by

$$\%\text{Moisture content} = \frac{(B-A) - (C-A) \times 100}{(B-A)}$$

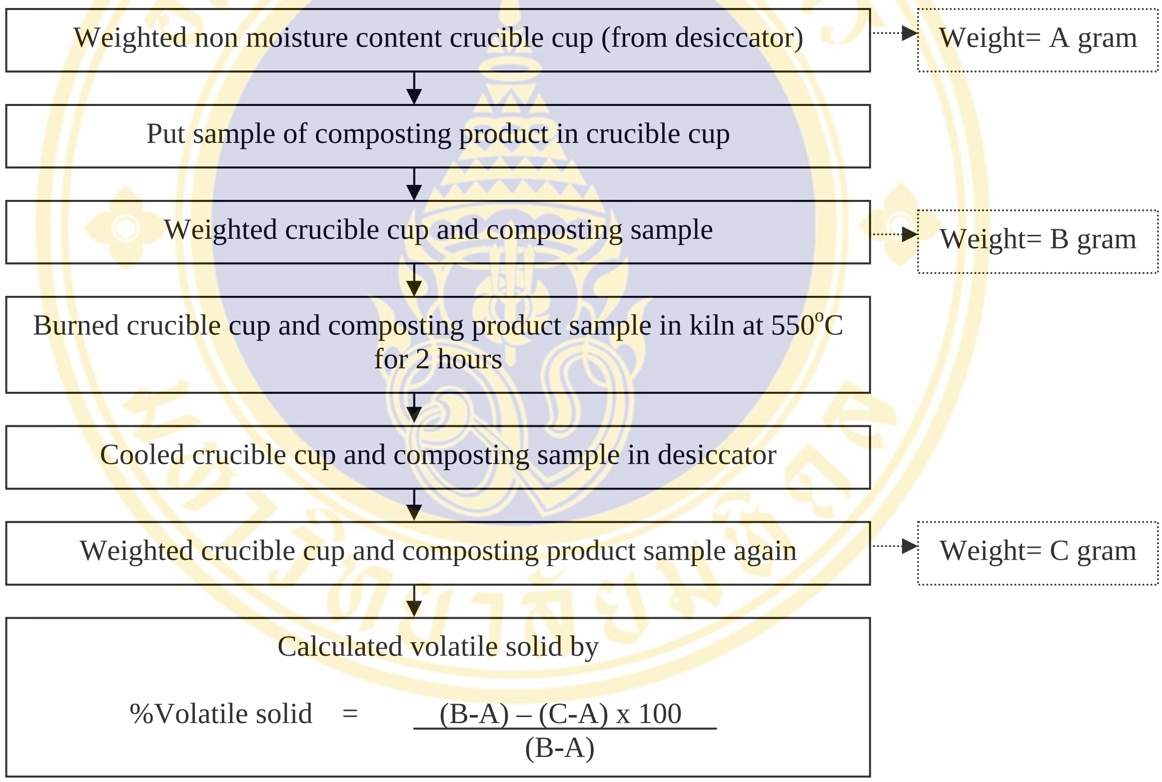
1.2 Total Solids

The total solids of composting product were calculated by the following formula.

Total Solids (% by wet weight) = 100 - % moisture content

1.3 Volatile Solids

The burning method was used for analyze the amount of volatile solids in composting product. The procedure of analysis is shown as following chart;



2. Chemical Properties

2.1 Organic Carbon

The burning method was used for analyze the amount of organic carbon in composting product. The procedure of analysis is shown as following chart;

Weighted 0.2 grams of dried composting product sample → Weight= A gram

↓

Put sample of composting product in 25ml.Erlenmeyer flask

↓

Added 10 ml. of 1N $K_2Cr_2O_7$ and shake the flask

↓

Added 20 ml. of conc.H_2SO_4 and shake the flask for 1 minute

↓

Left for 30 minutes

↓

Added 100 ml. of distilled water and 10 ml. of conc. H_3PO_4 and shake

↓

Dropped 3-4 drops of BDS indicator and shake the flask

↓

Titrated the suspension by 0.5N Ferrous ammonium sulfate (FAS) until the color change from purple to green → Blank = B ml. → Sample = S ml.

↓

Calculated Organic carbon by

$$\%\text{Organic matter} = \frac{10 \times (B-S)}{B} \times 0.6717 \times \frac{1}{A}$$

$$\%\text{Organic carbon} = \frac{\%\text{Organic matter}}{1.724}$$

2.2 Total Nitrogen

The Kjeldahl method was used for analyze the amount of total nitrogen in composting product. The procedure of analysis is shown as following chart;

Weighted 0.05 grams of dried composting product sample → Weight= A gram

↓

Put sample of composting product into Kjeldahl flask

↓

Added 1 gram of mixed catalyst and wash flask by using 1-2 ml. of distilled water

↓

Added 5 ml. of conc.H_2SO_4 and leave for 30 minutes

↓

Digested sample by heat in the hood until the color change from brown to green and leave it cool

↓

Made volume to 100 ml. by add distilled water and shake

↓

Filtered through filter paper (whatman no.1) into plastic bottle

↓

Added 5 ml. boric acid indicator into 50 ml. Erlenmeyer flask and put in to condenser of distillation apparatus

↓

Added 10 ml. blank solution in into distillation flask

↓

Added 10 ml. of 40%NaOH into distillation flask

↓

Turned on the distillation apparatus until 35 ml. of distilled solution is obtain

↓

Added 10 ml. sample solution in into distillation flask and distill it like blank

↓

Titrated the suspension by 0.05N H_2SO_4 until the color change from green to red-purple → Blank = B ml.; Sample = S ml.

↓

Calculated Organic matter by

$$\%\text{Total Nitrogen} = \frac{(S-B) \times 0.05 \times 14 \times 100 \times 100}{1000 \times 100 \times A}$$

2.3 C/N Ratio

The C/N ratio of composting product was calculated by the following formula.

$$\text{C/N ratio} = \frac{\text{\%Organic carbon}}{\text{\%Total Nitrogen}}$$

2.4 Phosphorus

The Kjeldahl method was used for analyze the amount of phosphorus in composting product. The procedure of analysis is shown as following chart;

Weighted 0.5 grams of dried composting product sample → Weight= A gram

↓

Put sample of composting product into digesting tube

↓

Added 10 ml. of conc.$HClO_4$ and leave in hood for 1 night

↓

Digested sample by 200^{o}C heat and add 5 ml. of conc.$HClO_4$ in the hood until the color change from brown to clear and leave it cool

↓

Made volume to 100 ml. by add distilled water and shake

↓

Filtered through filter paper (whatman no.5) into plastic bottle

↓

Added 5 ml. of 0, 5, 10, 15, 20, 25 and 30 µg P/ml. into 25 ml. tube

↓

Added 5 ml. of digested sample solution into 25 ml. tube

↓

Add 5 ml. of vanadomolybdate into all tubes

↓

Shook and left for 30 minutes

↓

Measured color of concentration by UV-visible spectrophotometer (at the wavelength 420 nm.) → Read = P ppm.

↓

Calculated Total phosphorus by

$$\text{\%Total Phosphorus} = \frac{\text{P x 50 x dilution factor x 100}}{\text{100000 x A}}$$

$$\% P_2O_5 = \text{\%Total P x 2.2914}$$

2.5 Potassium

The Kjeldahl method was used for analyze the amount of potassium in composting product. The procedure of analysis is shown as following chart;

Weighted 0.5 grams of dried composting product sample → Weight= A gram

↓

Put sample of composting product into digesting tube

↓

Added 10 ml. of conc.$HClO_4$ and leave in hood for 1 night

↓

Digested sample by 200°C heat and add 5 ml. of conc.$HClO_4$ in the hood until the color change from brown to clear and leave it cool

↓

Made volume to 50 ml. by add distilled water and shake

↓

Filtered through filter paper (whatman no.5) into plastic bottle

↓

Pipetted 1 ml. of 0, 2, 4, 6, 8 and 100 µg K/ml. into cubic tube

↓

Added 1 ml. of digested sample solution into 25 cubic tube

↓

Measured emission value by Atomic Emission Spectroscope and compare with K standard emission values → Read = K ppm.

↓

Calculated Total potassium by

$$\%\text{Total Potassium} = \frac{K \times 50 \times \text{dilution factor}}{10000 \times A}$$

$$\% P_2O_5 = \%\text{Total K} \times 1.2$$

APPENDIX B EXPERIMENTAL TEST RESULTS

1. The beginning and the end of composting material's properties

1.1 Temperature

Treatment	Size	Activator LD-1 adding	Beginning composting material			End composting material		
			Duplicate 1	Duplicate 2	Duplicate 3	Duplicate 1	Duplicate 2	Duplicate 3
1	2	Non added	39.83	33.00	35.00	26.50	34.33	30.17
2	2	Added	32.00	35.00	30.33	32.50	32.00	31.50
3	3	Non added	34.83	33.00	34.00	29.67	29.33	30.00
4	3	Added	31.17	32.33	32.67	25.33	28.00	28.67
5	>3	Non added	29.83	29.83	29.00	35.00	37.17	34.17
6	>3	Added	30.00	30.00	30.00	34.00	33.00	32.00

1.2 pH

Treatment	Size	Activator LD-1 adding	Beginning composting material			End composting material		
			Duplicate 1	Duplicate 2	Duplicate 3	Duplicate 1	Duplicate 2	Duplicate 3
1	2	Non added	7.0	5.5	8.5	8.5	9.0	8.5
2	2	Added	6.0	5.5	6.0	9.0	9.5	9.0
3	3	Non added	7.5	8.0	7.5	9.0	9.0	9.0
4	3	Added	6.0	6.5	6.5	9.0	9.5	9.5
5	>3	Non added	7.5	7.0	7.0	9.0	8.5	8.5
6	>3	Added	7.5	7.5	7.5	9.0	8.0	9.5

1.3 Moisture content

Treatment	Size	Activator LD-1 adding	Beginning composting material			End composting material		
			Duplicate 1	Duplicate 2	Duplicate 3	Duplicate 1	Duplicate 2	Duplicate 3
1	2	Non added	52.89	43.03	52.89	11.35	14.26	14.92
2	2	Added	66.37	66.37	66.37	12.00	12.68	12.50
3	3	Non added	79.59	79.59	79.59	22.86	22.55	24.74
4	3	Added	87.31	87.31	87.31	26.95	68.77	26.98
5	>3	Non added	70.92	70.92	70.92	57.89	52.76	23.21
6	>3	Added	73.46	73.46	73.46	56.46	50.79	31.41

1.4 Total Solid

Treatment	Size	Activator LD-1 adding	Beginning composting material			End composting material		
			Duplicate 1	Duplicate 2	Duplicate 3	Duplicate 1	Duplicate 2	Duplicate 3
1	2	Non added	47.11	56.97	47.11	88.65	85.74	85.08
2	2	Added	33.63	33.63	33.63	88.00	87.32	87.50
3	3	Non added	20.41	20.41	20.41	77.14	77.45	75.26
4	3	Added	12.69	12.69	12.69	73.05	31.23	73.02
5	>3	Non added	29.08	29.08	29.08	42.11	47.24	76.79
6	>3	Added	26.54	26.54	26.54	43.54	49.21	68.59

1.5 Volatile Solid

Treatment	Size	Activator LD-1 adding	Beginning composting material			End composting material		
			Duplicate 1	Duplicate 2	Duplicate 3	Duplicate 1	Duplicate 2	Duplicate 3
1	2	Non added	96.87	103.82	96.87	76.62	77.19	77.60
2	2	Added	97.64	97.64	97.64	70.14	68.37	67.71
3	3	Non added	96.54	96.54	96.54	72.12	76.28	71.70
4	3	Added	97.67	97.67	97.67	87.93	82.77	79.54
5	>3	Non added	95.91	95.91	95.91	86.50	89.28	78.47
6	>3	Added	97.45	97.45	97.45	84.76	88.01	77.49

1.6 Density

Treatment	Size	Activator LD-1 adding	Beginning composting material			End composting material		
			Duplicate 1	Duplicate 2	Duplicate 3	Duplicate 1	Duplicate 2	Duplicate 3
1	2	Non added	0.15	0.15	0.14	0.01	0.01	0.01
2	2	Added	0.15	0.15	0.13	0.01	0.02	0.01
3	3	Non added	0.15	0.14	0.15	0.02	0.02	0.02
4	3	Added	0.16	0.17	0.13	0.03	0.03	0.04
5	>3	Non added	0.10	0.10	0.11	0.03	0.03	0.03
6	>3	Added	0.10	0.10	0.11	0.02	0.03	0.03

1.7 Weight

Treatment	Size	Activator LD-1 adding	Beginning composting material			End composting material		
			Duplicate 1	Duplicate 2	Duplicate 3	Duplicate 1	Duplicate 2	Duplicate 3
1	2	Non added	50.0	50.0	50.0	3.5	3.6	2.9
2	2	Added	50.0	50.0	50.0	3.0	3.0	3.0
3	3	Non added	50.0	50.0	50.0	4.0	3.5	4.5
4	3	Added	50.0	50.0	50.0	4.5	4.0	5.0
5	>3	Non added	50.0	50.0	50.0	10.0	7.5	7.0
6	>3	Added	50.0	50.0	50.0	9.0	9.5	7.0

1.8 Organic Carbon

Treatment	Size	Activator LD-1 adding	Beginning composting material			End composting material		
			Duplicate 1	Duplicate 2	Duplicate 3	Duplicate 1	Duplicate 2	Duplicate 3
1	2	Non added	49.79	45.43	49.79	41.24	41.19	37.81
2	2	Added	47.21	47.21	47.21	44.23	37.67	44.00
3	3	Non added	48.16	48.16	48.16	42.25	42.92	39.20
4	3	Added	44.45	44.45	44.45	40.37	29.27	30.11
5	>3	Non added	45.65	45.65	45.65	35.00	43.14	42.54
6	>3	Added	47.58	47.58	47.58	41.97	45.00	31.36

1.9 Total Nitrogen

Treatment	Size	Activator LD-1 adding	Beginning composting material			End composting material		
			Duplicate 1	Duplicate 2	Duplicate 3	Duplicate 1	Duplicate 2	Duplicate 3
1	2	Non added	0.96	1.00	0.96	1.85	2.01	2.23
2	2	Added	1.19	1.19	1.19	0.81	0.79	0.78
3	3	Non added	1.19	1.19	1.19	0.78	0.92	0.70
4	3	Added	0.93	0.93	0.93	0.85	0.85	0.89
5	>3	Non added	0.76	0.76	0.76	2.43	2.45	2.51
6	>3	Added	0.74	0.74	0.74	2.41	2.28	2.39

1.10 C/N Ratio

Treatment	Size	Activator LD-1 adding	Beginning composting material			End composting material		
			Duplicate 1	Duplicate 2	Duplicate 3	Duplicate 1	Duplicate 2	Duplicate 3
1	2	Non added	51.86	45.62	51.86	22.34	20.46	16.98
2	2	Added	39.54	39.54	39.54	54.73	47.62	56.22
3	3	Non added	40.44	40.44	40.44	54.21	46.40	55.80
4	3	Added	47.56	47.56	47.56	47.32	34.31	33.97
5	>3	Non added	60.21	60.21	60.21	14.42	17.58	16.97
6	>3	Added	63.91	63.91	63.91	17.45	19.69	13.15

1.11 Phosphorus (P_2O_5)

Treatment	Size	Activator LD-1 adding	Beginning composting material			End composting material		
			Duplicate 1	Duplicate 2	Duplicate 3	Duplicate 1	Duplicate 2	Duplicate 3
1	2	Non added	0.39	0.37	0.39	0.55	0.46	0.41
2	2	Added	0.41	0.41	0.41	0.50	0.41	0.48
3	3	Non added	0.32	0.32	0.32	0.57	0.53	0.48
4	3	Added	0.27	0.27	0.27	0.50	0.55	0.55
5	>3	Non added	0.34	0.34	0.34	0.87	0.46	0.53
6	>3	Added	0.27	0.27	0.27	0.48	0.44	0.60

1.12 Potassium (K_2O)

Treatment	Size	Activator LD-1 adding	Beginning composting material			End composting material		
			Duplicate 1	Duplicate 2	Duplicate 3	Duplicate 1	Duplicate 2	Duplicate 3
1	2	Non added	8.38	8.05	8.22	10.67	10.66	10.07
2	2	Added	8.75	8.75	8.75	9.16	8.75	10.93
3	3	Non added	6.36	6.36	6.36	9.98	10.21	10.61
4	3	Added	7.56	7.56	7.56	9.04	8.90	9.02
5	>3	Non added	6.84	6.84	6.84	15.85	10.45	12.98
6	>3	Added	6.24	6.24	6.24	10.60	9.96	13.73

2. Daily properties

2.1 Temperature

Tr.	Day 1			Day 2			Day 3			Day 4			Day 5			Day 6			Day 7		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	39.83	33.00	35.00	37.50	35.67	34.83	38.50	38.67	35.33	37.67	36.67	35.67	33.50	35.83	36.67	30.67	34.33	34.00	32.67	35.17	33.00
2	32.00	35.00	30.33	39.33	39.33	41.67	37.67	36.67	38.00	36.33	36.67	36.17	36.33	35.00	35.67	34.00	34.33	34.67	33.33	32.00	31.67
3	34.83	33.00	34.00	37.67	38.00	40.00	38.67	39.00	39.00	35.00	34.33	39.67	35.50	35.17	38.33	35.83	35.17	36.33	35.33	35.00	34.17
4	31.17	32.33	32.67	38.00	40.33	40.17	38.67	37.33	38.33	37.33	34.33	39.33	35.50	33.67	35.67	33.83	31.00	35.17	32.67	30.67	32.83
5	29.83	29.83	29.00	42.00	41.33	43.33	45.67	44.67	43.67	42.33	43.33	44.00	42.67	43.67	44.00	41.67	41.00	42.33	43.67	42.33	43.67
6	30.00	30.00	30.00	40.33	43.00	45.33	39.33	39.33	41.00	34.33	40.33	42.17	37.33	42.50	45.17	40.83	44.00	44.50	35.67	38.00	39.67

Tr.	Day 8			Day 9			Day 10			Day 11			Day 12			Day 13			Day 14		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	31.00	35.00	31.67	30.50	30.33	32.83	29.67	30.00	31.17	32.67	29.00	30.00	32.83	29.33	31.00	28.50	28.67	29.67	28.17	28.00	28.50
2	33.83	32.67	32.67	30.50	30.67	30.67	31.33	31.00	38.67	30.00	29.67	30.00	30.33	30.00	30.00	30.00	29.67	29.67	31.33	31.67	31.83
3	33.83	33.33	33.67	32.50	32.17	30.67	34.00	32.67	30.00	32.83	31.33	29.33	29.00	28.33	28.00	29.67	30.00	28.00	31.00	30.00	28.33
4	30.67	32.33	31.00	30.33	31.50	29.67	29.33	29.83	29.67	29.00	29.83	28.00	28.00	28.67	28.67	28.33	29.67	29.00	28.67	28.83	30.00
5	41.67	42.00	41.33	43.00	41.00	41.33	38.67	37.00	38.33	34.33	34.33	34.00	36.33	37.67	39.00	36.50	36.00	37.67	33.33	32.33	35.00
6	40.83	38.50	35.33	36.00	38.33	40.33	38.33	39.17	40.33	36.67	36.83	39.50	37.00	37.00	40.00	36.00	35.83	38.83	35.33	35.50	37.50

Tr.	Day 15			Day 16			Day 17			Day 18			Day 19			Day 20			Day 21		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	27.50	28.33	30.83	28.00	30.00	28.17	25.67	29.17	29.33	26.67	29.00	28.67	28.00	30.00	30.33	29.83	29.00	28.17	29.67	28.33	31.00
2	31.33	30.67	31.50	30.00	29.83	29.83	31.33	31.00	31.00	30.00	30.67	30.33	27.67	27.67	27.67	31.00	31.00	30.33	31.00	30.67	30.67
3	28.33	27.67	29.33	29.33	28.00	29.33	29.00	28.50	28.33	28.00	27.00	27.83	28.17	27.17	29.33	28.33	27.33	28.50	29.33	29.00	29.83
4	28.00	27.83	29.67	29.00	26.67	29.67	28.50	27.00	28.00	28.00	27.17	27.33	26.33	27.50	27.33	26.67	28.33	26.33	26.67	29.83	29.50
5	32.67	33.00	34.00	33.00	31.67	35.33	33.67	33.00	35.33	33.67	33.00	36.00	33.83	33.33	35.33	33.83	33.50	36.17	35.50	33.83	34.67
6	34.33	35.33	36.33	34.00	34.17	36.00	34.83	35.17	37.17	34.33	34.67	36.67	30.67	30.00	33.33	29.50	29.50	31.00	30.00	30.00	30.67

Tr.	Day 22			Day 23			Day 24			Day 25			Day 26			Day 27			Day 28		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	29.00	30.00	31.00	28.33	28.00	30.00	28.83	30.00	30.00	28.33	28.50	32.33	30.00	30.67	28.33	29.00	29.00	33.00	30.67	31.50	32.67
2	28.67	29.00	29.00	29.83	30.17	29.67	30.00	30.00	30.00	28.67	28.33	29.00	28.33	28.00	29.33	28.67	28.33	29.00	29.33	29.33	29.33
3	30.00	29.00	29.33	29.17	29.00	29.00	29.67	28.50	27.67	28.83	28.83	28.00	28.50	28.17	27.00	30.00	29.83	28.00	30.00	29.50	28.33
4	27.00	28.17	30.00	27.33	28.17	28.00	29.00	27.00	28.50	29.00	27.33	28.00	29.00	27.33	29.00	27.67	25.50	29.67	27.83	29.33	30.00
5	33.83	34.00	34.67	33.33	32.17	34.67	34.50	33.83	34.33	35.00	34.67	35.00	33.33	30.33	31.00	28.50	28.83	31.00	29.00	28.00	29.00
6	29.33	28.00	30.00	29.33	30.00	30.00	30.33	30.17	31.00	34.50	33.50	33.67	32.33	31.83	33.50	28.00	28.33	29.67	28.33	29.00	29.67

Tr.	Day 29			Day 30			Day 31			Day 32			Day 33			Day 34			Day 35		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	28.17	31.00	30.00	31.17	30.50	31.67	29.00	30.50	32.33	32.33	33.67	26.33	31.00	30.00	30.00	30.00	34.00	30.33	30.00	32.67	33.00
2	31.00	31.33	31.33	31.67	31.67	31.00	30.67	30.67	31.00	30.67	31.17	30.67	28.67	29.33	29.00	30.00	29.83	31.00	29.67	30.00	30.50
3	29.83	29.50	31.00	29.50	30.17	30.00	29.67	30.33	29.33	29.33	30.00	28.00	29.67	29.67	28.50	30.00	30.00	28.00	31.50	31.33	27.00
4	27.17	30.00	29.33	26.00	27.83	29.33	29.17	28.00	27.00	29.67	27.67	32.00	27.00	29.50	27.67	28.00	30.00	28.00	28.00	30.50	29.50
5	28.67	27.67	30.00	28.67	28.00	29.67	29.17	29.17	30.17	32.50	32.00	33.50	31.33	32.17	34.00	28.00	28.00	29.00	28.00	28.33	28.83
6	27.33	27.67	29.00	27.83	27.67	29.17	26.00	26.33	27.67	27.00	27.00	28.00	29.00	29.00	30.00	29.67	30.00	31.17	28.67	30.17	30.50

Tr.	Day 36			Day 37			Day 38			Day 39			Day 40			Day 41			Day 42		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	33.33	32.67	30.67	29.33	32.17	29.83	33.33	32.33	29.17	32.00	27.00	30.00	29.67	31.00	28.83	30.17	30.67	30.17	32.33	34.33	29.67
2	29.67	29.83	29.50	28.67	28.17	28.17	29.00	28.17	28.00	25.83	26.00	26.67	28.17	28.00	27.50	27.67	28.00	28.00	33.00	31.83	31.83
3	31.00	30.50	29.83	30.00	30.00	30.00	27.83	28.00	28.33	28.00	28.83	29.17	28.00	28.00	29.00	26.33	26.67	30.00	29.17	30.00	29.67
4	30.00	29.67	28.00	30.00	30.00	27.67	30.00	26.00	28.33	30.00	32.00	29.67	29.00	27.00	30.33	26.00	27.17	30.67	33.00	29.33	30.33
5	27.33	27.33	31.67	28.00	28.33	28.33	24.67	25.00	25.67	26.67	26.33	26.00	29.00	29.00	29.33	30.00	30.00	30.83	29.67	29.83	30.00
6	30.00	29.17	29.00	30.00	30.00	31.33	30.00	30.00	30.83	28.83	29.67	30.33	31.00	31.17	32.67	29.67	30.67	28.17	32.33	32.67	33.33

Tr.	Day 43			Day 44			Day 45			Day 46			Day 47			Day 48			Day 49		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	27.00	31.83	29.50	28.67	29.67	27.00	29.67	29.17	27.17	30.33	30.33	26.33	30.00	28.83	27.33	28.83	29.83	28.00	27.00	29.00	33.00
2	30.33	30.83	31.00	30.00	30.00	30.17	27.33	27.67	28.00	28.00	28.00	28.00	28.00	28.00	28.00	26.17	26.00	25.83	30.67	30.00	30.00
3	31.00	30.00	30.00	27.00	27.00	29.67	28.00	28.00	28.00	28.83	27.83	26.33	28.00	29.00	31.00	29.00	29.00	28.00	29.33	29.00	28.17
4	27.17	27.00	30.50	27.67	27.17	30.33	30.33	28.00	30.00	26.83	28.67	27.00	27.83	29.67	26.33	28.33	29.50	27.00	28.67	29.17	30.00
5	30.17	30.00	29.67	30.67	30.67	30.00	30.00	29.83	29.17	30.00	29.67	29.00	30.50	30.50	30.00	29.67	30.17	30.33	31.67	31.67	30.67
6	30.33	31.00	31.17	31.33	32.50	32.67	29.00	31.33	30.83	34.00	34.67	33.67	33.00	34.50	33.00	31.67	33.67	32.00	33.67	35.33	35.00

Tr.	Day 50			Day 51			Day 52			Day 53			Day 54			Day 55			Day 56		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	30.33	29.17	30.67	28.50	26.83	30.17	29.67	27.00	27.00	29.33	27.00	28.00	29.17	27.00	28.00	26.33	28.00	26.00	26.50	34.33	30.17
2	33.33	32.67	32.00	27.83	27.17	27.17	30.33	29.17	28.83	29.67	29.17	29.00	31.00	30.83	31.00	32.00	31.00	31.67	32.50	32.00	31.50
3	31.00	30.00	29.00	29.00	27.67	28.00	25.00	26.00	26.17	31.00	30.67	29.00	28.00	28.00	29.00	28.00	28.00	29.00	29.67	29.33	30.00
4	28.67	29.00	27.50	29.00	28.33	29.17	28.67	28.00	26.67	29.00	25.67	28.67	28.00	25.33	27.67	27.17	26.67	29.33	25.33	28.00	28.67
5	29.00	29.67	30.33	31.17	31.50	31.67	29.33	30.67	30.00	33.50	34.00	31.67	32.50	33.83	33.00	31.50	32.00	29.33	35.00	37.17	34.17
6	32.00	35.67	34.00	29.67	30.00	29.00	39.33	35.33	34.33	35.67	34.67	35.00	34.00	32.67	29.67	35.33	32.33	30.00	34.00	33.00	32.00

2.2 pH

Tr.	Day 1			Day 2			Day 3			Day 4			Day 5			Day 6			Day 7		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	7.0	5.5	8.5	6.5	8.5	6.0	7.5	8.5	7.5	7.5	8.0	9.0	8.0	8.5	7.5	7.5	8.0	8.0	9.0	7.5	8.5
2	6.0	5.5	6.0	8.5	8.5	7.5	6.5	7.5	7.0	9.0	6.5	8.5	9.0	8.5	9.0	9.0	9.5	9.0	9.0	9.5	8.5
3	7.5	8.0	7.5	9.0	9.5	8.5	7.5	7.5	9.5	7.5	8.0	8.5	8.5	8.5	9.0	8.5	9.5	9.5	8.0	8.5	7.5
4	6.0	6.5	6.5	6.5	6.5	7.5	8.5	9.0	8.0	8.0	7.5	9.5	8.0	8.0	9.5	9.0	8.5	9.0	8.0	9.0	9.5
5	7.5	7.0	7.0	5.0	5.0	5.0	5.0	5.5	5.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	7.5	5.0	6.0
6	7.5	7.5	7.5	4.5	5.5	5.0	6.5	6.5	6.0	7.5	7.5	6.5	6.5	4.5	6.0	7.5	7.0	5.5	8.5	8.0	8.0

Tr.	Day 8			Day 9			Day 10			Day 11			Day 12			Day 13			Day 14		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	9.0	8.5	9.0	8.5	8.0	8.5	6.5	9.0	8.5	8.0	9.5	8.0	9.0	8.5	8.5	9.0	8.0	8.0	8.0	9.0	9.5
2	9.5	9.0	8.0	8.0	9.0	9.0	8.5	9.0	7.5	8.5	8.5	8.5	8.0	7.5	8.5	9.5	10.0	9.5	9.0	8.0	7.5
3	9.0	9.0	9.5	9.5	9.5	8.5	8.0	7.5	9.0	8.5	8.5	8.0	9.0	10.0	7.5	7.5	7.5	8.5	9.5	9.5	9.0
4	8.5	8.5	8.5	8.5	9.0	8.5	8.5	9.0	8.5	8.5	8.5	9.5	8.5	9.5	10	9.5	9.5	9.5	8.5	9.5	9.0
5	8.0	8.0	6.0	8.0	7.0	8.0	9.0	8.0	8.5	8.0	8.0	8.5	9.0	8.5	8.5	7.5	7.5	8.5	8.5	8.5	8.0
6	8.5	8.5	8.5	9.0	9.0	8.5	8.5	8.5	8.5	8.5	8.0	7.5	8.5	9.0	9.0	8.5	8.5	8.5	8.5	8.0	8.0

Tr.	Day 15			Day 16			Day 17			Day 18			Day 19			Day 20			Day 21		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	8.5	9.0	9.5	7.5	7.0	9.5	8.5	7.5	7.0	9.0	7.5	7.0	9.0	9.0	7.5	6.5	9.5	10.0	7.5	10.0	9.0
2	9.0	9.0	9.0	9.0	9.0	9.0	8.5	7.5	7.5	9.0	8.5	8.0	9.0	10.0	10.0	8.5	8.5	8.5	9.5	9.5	10.0
3	9.0	9.0	9.5	9.5	9.5	9.5	7.5	7.5	7.5	7.5	7.5	8.5	8.0	8.5	8.5	9.0	9.0	9.0	9.5	9.5	9.0
4	9.5	8.5	9.0	9.0	10.0	9.0	9.5	10.0	9.5	9.5	9.0	8.5	9.5	10.0	9.0	9.5	9.5	9.5	9.0	9.5	9.5
5	9.5	9.5	9.5	9.5	9.0	9.0	8.0	7.5	8.5	8.5	9.0	9.0	9.0	8.5	9.0	9.0	7.5	8.0	8.5	8.0	8.0
6	6.0	6.5	8.5	7.5	7.5	8.5	8.5	8.0	7.5	8.5	7.5	8.0	9.0	9.0	10.0	8.0	7.5	9.0	9.5	9.5	9.0

Tr.	Day 22			Day 23			Day 24			Day 25			Day 26			Day 27			Day 28		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	9.5	8.5	10.0	8.5	9.5	9.0	9.5	8.5	9.0	9.0	7.5	8.5	10.0	7.5	9.5	10.0	10.0	8.5	9.0	9.5	10.0
2	9.5	8.5	9.0	9.0	9.5	9.5	8.0	9.5	9.5	9.0	9.0	9.5	9.0	9.0	9.5	9.0	9.0	9.5	9.0	9.0	9.5
3	9.0	9.0	9.5	8.5	9.5	8.5	9.5	9.5	9.0	9.5	9.5	9.0	9.0	8.5	9.5	9.5	9.5	9.5	9.0	9.0	10.0
4	9.5	9.0	9.5	9.5	9.0	9.0	9.5	9.0	9.5	9.0	9.0	9.5	9.0	9.5	9.5	9.5	9.5	9.0	9.0	9.0	9.0
5	7.0	6.5	8.0	8.0	6.5	8.5	8.5	7.0	7.5	9.0	7.5	9.0	10.0	9.0	9.5	9.0	7.5	8.0	10.0	10.0	9.5
6	8.5	9.5	9.0	8.5	9.0	9.0	8.5	8.0	6.5	7.5	7.5	8.0	7.0	8.0	8.5	7.5	7.0	8.5	9.0	8.0	9.0

Tr.	Day 29			Day 30			Day 31			Day 32			Day 33			Day 34			Day 35		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	9.0	10.0	9.0	7.5	9.5	9.5	9.5	9.5	8.5	8.5	9.0	9.0	9.5	10.0	9.0	10.0	8.5	9.5	10.0	9.5	10.0
2	9.0	9.0	9.0	9.0	9.5	9.5	10.0	10.0	9.5	10.0	10.0	10.0	9.5	9.5	9.0	9.5	9.0	10.0	9.0	9.0	10.0
3	8.5	8.5	9.5	9.0	9.5	9.5	9.0	9.5	9.0	9.5	9.0	9.5	9.0	9.0	9.0	9.5	9.0	9.0	9.5	9.0	9.5
4	9.0	9.5	9.5	9.5	9.5	9.5	9.0	9.0	10.0	9.5	9.5	9.0	9.0	9.5	9.5	9.0	9.5	9.5	9.5	9.5	9.0
5	10.0	9.0	9.5	9.5	7.5	10.0	8.0	7.0	7.5	8.0	8.0	9.0	7.5	8.0	9.0	9.0	8.0	8.0	8.0	8.5	9.5
6	10.0	10.0	10.0	8.5	8.0	9.0	9.0	7.0	9.5	9.5	8.5	9.5	10.0	9.0	9.5	9.5	9.0	10.0	7.5	7.5	9.0

Tr.	Day 36			Day 37			Day 38			Day 39			Day 40			Day 41			Day 42		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	9.0	9.5	10.0	10.0	9.5	9.5	8.5	8.5	10.0	10.0	9.0	9.5	9.0	9.0	9.5	9.5	9.5	9.0	9.0	9.5	9.5
2	9.0	9.5	10.0	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	8.5	8.5	9.0	9.5	9.0	9.0	8.5	8.5	8.5
3	9.5	9.5	9.0	9.5	10.0	9.5	9.5	9.5	9.0	9.0	9.0	9.5	9.0	9.0	9.5	9.5	9.0	9.5	9.5	9.5	9.5
4	9.5	9.5	9.0	9.5	9.5	9.5	9.5	9.5	9.5	10.0	9.5	9.5	9.5	9.5	9.0	9.5	9.5	9.0	10.0	9.0	9.5
5	10.0	9.5	10.0	9.0	8.5	8.5	8.0	8.5	10.0	9.5	9.0	9.5	10.0	8.5	10.0	10.0	9.0	9.0	8.5	9.0	9.0
6	7.5	8.0	9.5	10.0	10.0	10.0	9.5	8.5	9.5	10.0	10.0	9.5	10.0	10.0	9.5	10.0	10.0	9.5	9.0	9.0	9.0

Tr.	Day 43			Day 44			Day 45			Day 46			Day 47			Day 48			Day 49		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	9.0	10.0	9.5	9.0	9.5	9.5	9.5	9.5	9.5	9.5	10.0	9.0	9.5	9.5	9.5	9.5	10.0	9.5	10.0	9.5	8.5
2	9.5	9.0	9.0	9.0	9.0	9.5	9.0	9.0	8.5	8.5	8.0	8.5	9.0	9.0	9.0	8.5	8.5	9.0	8.5	9.0	8.5
3	9.5	10.0	9.5	9.0	8.5	9.0	9.5	9.5	9.0	9.0	9.5	9.5	9.0	9.0	9.5	9.0	9.0	9.5	9.5	9.0	9.5
4	9.0	9.5	9.5	9.5	9.0	9.5	8.5	9.0	9.5	8.5	9.0	9.0	8.5	9.5	9.0	9.0	9.5	9.0	9.0	9.5	9.5
5	9.0	7.0	9.0	10.0	10.0	10.0	9.5	10.0	9.5	10.0	9.5	10.0	9.5	9.0	9.5	10.0	10.0	10.0	8.5	8.0	8.5
6	8.5	9.0	8.0	9.0	9.5	9.5	10.0	9.5	10.0	8.5	9.0	9.5	9.5	9.5	9.5	9.5	10.0	10.0	8.5	8.5	9.5

Tr.	Day 50			Day 51			Day 52			Day 53			Day 54			Day 55			Day 56		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	10.0	10.0	9.5	9.5	9.0	9.5	10.0	9.0	8.5	10.0	9.5	8.0	9.5	10.0	9.0	8.5	9.0	9.0	8.5	9.0	8.5
2	9.0	9.5	9.0	8.5	8.5	9.0	9.0	8.5	9.0	9.0	8.5	9.5	8.5	8.0	9.0	9.0	9.0	9.0	9.0	9.5	9.0
3	9.0	9.5	9.5	9.0	8.5	9.0	9.5	9.0	10.0	9.5	9.5	9.5	9.0	9.0	9.5	9.5	9.0	9.5	9.0	9.0	9.0
4	9.5	9.5	9.5	9.5	9.5	9.0	9.5	9.5	9.0	9.5	9.0	9.5	9.5	9.0	9.5	9.0	9.0	9.5	9.0	9.5	9.5
5	7.5	8.0	8.5	9.5	9.0	9.5	10.0	9.5	10.0	9.0	8.5	9.0	9.5	10.0	10.0	10.0	10.0	9.5	9.0	8.5	8.5
6	8.5	8.5	8.0	9.5	10.0	10.0	9.0	9.0	9.5	9.5	9.5	10.0	9.5	9.0	9.5	10.0	9.5	10.0	9.0	8.0	9.5

3. Weekly Properties

3.1 Moisture Content

Treatment	Week 0			Week 1			Week 2			Week 3			Week 4		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	52.89	43.03	52.89	79.83	71.85	65.40	63.34	50.97	64.78	64.02	56.77	61.57	62.93	67.36	63.13
2	66.37	66.37	66.37	79.71	69.30	69.87	72.04	72.30	65.69	72.46	70.19	72.07	33.86	63.02	35.76
3	79.59	79.59	79.59	72.03	73.54	82.06	77.15	78.91	86.02	73.41	79.62	76.65	67.55	65.65	62.34
4	87.31	87.31	87.31	87.83	84.13	73.26	68.58	65.06	65.71	67.00	77.02	73.37	70.45	72.09	72.97
5	70.92	70.92	70.92	79.45	67.47	75.72	77.30	81.09	69.82	59.11	72.83	63.44	43.39	74.25	36.64
6	73.46	73.46	73.46	71.70	84.73	65.71	80.59	80.91	60.18	66.30	70.90	63.33	57.94	57.61	58.06

Treatment	Week 5			Week 5			Week 7			Week 8		
	1	2	3	1	2	3	1	2	3	1	2	3
1	36.09	67.18	62.87	15.06	27.90	47.90	9.90	27.67	18.13	11.35	14.26	14.92
2	40.14	38.40	23.93	24.19	17.64	17.56	14.86	14.51	23.86	12.00	12.68	12.50
3	66.61	50.18	70.69	59.85	55.49	70.64	21.25	28.36	35.49	22.86	22.55	24.74
4	75.04	67.77	72.22	70.02	71.86	61.72	56.56	68.49	53.26	26.95	68.77	26.98
5	60.54	56.92	55.60	48.89	54.56	44.38	52.91	66.11	46.32	57.89	52.76	23.21
6	62.90	49.44	51.27	49.65	65.92	64.24	54.73	60.24	41.14	56.46	50.79	31.41

3.2 Total Solids

Treatment	Week 0			Week 1			Week 2			Week 3			Week 4		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	47.11	56.97	47.11	20.17	28.15	34.60	36.66	49.03	35.22	35.98	43.23	38.43	37.07	32.64	36.87
2	33.63	33.63	33.63	20.29	30.70	30.13	27.96	27.70	34.31	27.54	29.81	27.93	66.14	36.98	64.24
3	20.41	20.41	20.41	27.97	26.46	17.94	22.85	21.09	13.98	26.59	20.38	23.35	32.45	34.35	37.66
4	12.69	12.69	12.69	12.17	15.87	26.74	31.42	34.94	34.29	33.00	22.98	26.63	29.55	27.91	27.03
5	29.08	29.08	29.08	20.55	32.53	24.28	22.70	18.91	30.18	40.89	27.17	36.56	56.61	25.75	63.36
6	26.54	26.54	26.54	28.30	15.27	34.29	19.41	19.09	39.82	33.70	29.10	36.67	42.06	42.39	41.94

Treatment	Week 5			Week 5			Week 7			Week 8		
	1	2	3	1	2	3	1	2	3	1	2	3
1	63.91	32.82	37.13	84.94	72.10	52.10	90.10	72.33	81.87	88.65	85.74	85.08
2	59.86	61.60	76.07	75.81	82.36	82.44	85.14	85.49	76.14	88.00	87.32	87.50
3	33.39	49.82	29.31	40.15	44.51	29.36	78.75	71.64	64.51	77.14	77.45	75.26
4	24.96	32.23	27.78	29.98	28.14	38.28	43.44	31.51	46.74	73.05	31.23	73.02
5	39.46	43.08	44.40	51.11	45.44	55.62	47.09	33.89	93.68	42.11	47.24	76.79
6	37.10	50.56	48.73	50.35	34.08	35.76	45.27	39.76	58.86	43.54	49.21	68.59

3.3 Volatile Solids

Treatment	Week 0			Week 1			Week 2			Week 3			Week 4		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	96.87	103.82	96.87	96.94	97.48	98.12	95.58	96.73	97.21	94.93	94.76	96.34	86.38	90.87	93.23
2	97.64	97.64	97.64	96.27	97.00	95.66	94.56	96.59	94.92	92.53	92.64	95.15	85.71	86.62	93.08
3	96.54	96.54	96.54	91.16	94.14	96.40	95.13	96.07	96.46	97.11	96.80	97.39	92.20	92.40	94.46
4	97.67	97.67	97.67	97.48	97.61	95.15	94.64	93.75	95.84	96.01	95.09	94.94	95.25	94.98	94.36
5	95.91	95.91	95.91	95.57	96.31	96.61	93.13	97.07	95.56	93.28	93.96	92.48	84.09	95.98	86.68
6	97.45	97.45	97.45	96.32	94.98	95.70	97.66	97.50	93.54	97.10	94.33	90.55	95.81	93.13	96.28

Treatment	Week 5			Week 5			Week 7			Week 8		
	1	2	3	1	2	3	1	2	3	1	2	3
1	85.42	92.10	92.95	79.25	79.81	88.06	76.04	81.37	82.26	76.62	77.19	77.60
2	87.07	88.74	85.07	81.94	81.00	80.33	68.83	68.15	67.05	70.14	68.37	67.71
3	92.58	90.37	93.95	76.33	79.22	91.34	70.96	72.01	82.51	72.12	76.28	71.70
4	94.58	93.97	91.61	86.02	85.37	88.20	88.01	91.52	84.85	87.93	82.77	79.54
5	93.50	95.42	89.85	89.71	95.19	87.25	83.46	93.53	86.30	86.50	89.28	78.47
6	95.69	93.75	90.13	88.85	90.36	91.12	93.54	85.49	89.69	84.76	88.01	77.49

3.4 Organic Carbon

Treatment	Week 0			Week 1			Week 2			Week 3			Week 4		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	49.79	45.43	49.79	47.20	47.86	47.07	50.57	50.49	46.42	47.72	47.94	48.44	47.11	48.90	47.29
2	47.21	47.21	47.21	47.50	48.12	48.69	46.59	51.03	47.04	46.92	46.93	48.70	34.87	41.53	41.73
3	48.16	48.16	48.16	46.37	45.26	46.33	49.43	45.84	42.45	43.47	45.95	36.85	32.74	34.24	41.80
4	44.45	44.45	44.45	45.07	45.65	36.43	48.06	42.08	41.15	40.64	43.40	41.68	43.54	38.41	45.44
5	45.65	45.65	45.65	44.14	44.44	40.68	45.93	45.94	43.84	47.61	48.62	47.63	47.69	50.46	50.88
6	47.58	47.58	47.58	42.72	45.01	45.66	42.02	47.22	47.16	44.19	46.84	48.20	44.30	51.15	42.65

Treatment	Week 5			Week 5			Week 7			Week 8		
	1	2	3	1	2	3	1	2	3	1	2	3
1	47.25	48.43	44.67	40.31	41.09	41.72	40.49	37.14	36.16	41.24	41.19	37.81
2	36.84	36.23	39.59	36.95	33.67	33.71	35.77	35.97	43.07	44.23	37.67	44.00
3	39.15	37.32	43.44	37.40	42.31	45.28	36.93	36.13	39.47	42.25	42.92	39.20
4	44.71	43.11	42.97	41.50	37.83	39.43	46.43	31.31	38.30	40.37	29.27	30.11
5	43.13	48.23	40.81	43.75	45.88	43.42	42.40	47.16	42.68	35.00	43.14	42.54
6	45.48	45.76	44.75	49.64	49.31	42.99	44.63	43.63	39.39	41.97	45.00	31.36

3.5 Nitrogen

Treatment	Week 0			Week 1			Week 2			Week 3			Week 4		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	0.96	1.00	0.96	1.80	1.45	1.50	1.71	1.51	1.54	1.92	1.91	1.99	2.04	1.93	2.09
2	1.19	1.19	1.19	1.69	1.68	1.69	2.06	1.84	1.88	1.87	1.89	1.99	2.05	1.98	2.00
3	1.19	1.19	1.19	1.67	2.17	1.03	1.89	1.90	1.30	1.67	1.77	1.21	1.72	1.88	1.36
4	0.93	0.93	0.93	1.16	1.04	1.28	1.80	2.14	1.27	1.45	1.85	1.59	1.68	2.10	0.57
5	0.76	0.76	0.76	1.12	1.09	1.02	1.39	1.33	1.21	1.53	1.49	1.56	1.53	1.49	1.61
6	0.74	0.74	0.74	1.05	1.07	1.01	1.02	1.01	1.03	1.41	1.52	1.67	1.88	1.90	2.12

Treatment	Week 5			Week 5			Week 7			Week 8		
	1	2	3	1	2	3	1	2	3	1	2	3
1	1.91	1.97	2.00	1.83	1.99	2.10	1.88	1.80	2.17	1.85	2.01	2.23
2	1.76	1.85	1.81	2.10	2.20	2.13	0.78	0.83	0.85	0.81	0.79	0.78
3	1.94	2.14	1.61	0.78	0.87	0.66	0.89	0.93	0.73	0.78	0.92	0.70
4	0.73	0.69	0.67	0.80	0.77	0.72	0.80	0.80	0.74	0.85	0.85	0.89
5	1.89	2.06	2.32	1.88	1.83	2.14	2.40	2.40	2.25	2.43	2.45	2.51
6	2.00	1.99	2.15	2.33	2.09	2.34	2.42	2.54	2.38	2.41	2.28	2.39

3.6 C/N ratio

Treatment	Week 0			Week 1			Week 2			Week 3			Week 4		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	51.86	45.62	51.86	26.26	33.00	31.33	29.52	33.53	30.22	24.79	25.12	24.31	23.10	25.40	22.60
2	39.54	39.54	39.54	28.19	28.64	28.79	22.60	27.77	25.06	25.06	24.76	24.50	17.01	21.01	20.91
3	40.44	40.44	40.44	27.84	20.85	45.10	26.19	24.09	32.60	26.09	25.90	30.39	19.05	18.22	30.75
4	47.56	47.56	47.56	38.73	43.85	28.35	26.64	19.65	32.41	28.09	23.44	26.21	44.56	31.51	80.07
5	60.21	60.21	60.21	39.25	40.83	39.83	33.07	34.61	36.15	31.06	32.67	30.59	31.18	33.93	31.56
6	63.91	63.91	63.91	40.80	42.18	44.74	41.29	46.57	45.65	31.38	30.77	28.78	23.52	26.97	20.16

Treatment	Week 5			Week 5			Week 7			Week 8		
	1	2	3	1	2	3	1	2	3	1	2	3
1	24.70	24.56	22.34	22.02	20.66	19.87	21.53	20.62	16.70	22.34	20.46	16.98
2	20.98	19.61	21.93	17.63	15.29	15.81	45.76	43.48	50.71	54.73	47.62	56.22
3	20.17	17.46	27.00	47.81	48.36	68.85	41.55	38.83	53.77	54.21	46.40	55.80
4	61.24	62.14	64.41	51.97	48.88	54.41	57.93	39.04	51.91	47.32	34.31	33.97
5	22.76	23.43	17.63	23.28	25.01	20.28	17.65	19.66	18.96	14.42	17.58	16.97
6	22.77	23.04	20.86	21.31	23.56	18.39	18.43	17.17	16.56	17.45	19.69	13.15

APPENDIX C
STATISTICAL ANALYSIS RESULTS

1. Three factors factorial design of ANOVA analysis hypothesis

H_0: No effect of size on physical/chemical property of Kluai Nam Wa peel-waste.

H_0: No effect of activator LD.1 adding on physical/chemical property of Kluai Nam Wa peel-waste.

H_0: No effect of composting time on physical/chemical property of Kluai Nam Wa peel-waste.

H_0: No effect of interaction between size and activator LD.1 adding on physical/chemical property of Kluai Nam Wa peel-waste.

H_0: No effect of interaction between size and composting time on physical/chemical property of Kluai Nam Wa peel-waste.

H_0: No effect of interaction between activator LD.1 adding and composting time on physical/chemical property of Kluai Nam Wa peel-waste.

H_1: There is effect of size on physical/chemical property of Kluai Nam Wa peel-waste.

H_1: There is effect of activator LD.1 adding on physical/chemical property of Kluai Nam Wa peel-waste.

H_1: There is effect of composting time on physical/chemical property of Kluai Nam Wa peel-waste.

H_1: There is effect of interaction between size and activator LD.1 adding on physical/chemical property of Kluai Nam Wa peel-waste.

H_1: There is effect of interaction between size and composting time on physical/chemical property of Kluai Nam Wa peel-waste.

H_1: There is effect of interaction between activator LD.1 adding and composting time on physical/chemical property of Kluai Nam Wa peel-waste.

2. Results of 3 factors factorial design of ANOVA analysis

2.1 Temperature

Tests of Between-Subjects Effects

Dependent Variable: Temperature

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power
Corrected Model	12445.675	225	55.314	23.490	<0.0001	5285.262	1.000
Intercept	976987.039	1	976987.039	414893.744	<0.0001	414893.744	1.000
Size	2138.478	2	1069.239	454.070	<0.0001	908.140	1.000
LD-1 adding	7.587	1	7.587	3.222	0.0730	3.222	0.434
Composting day	7465.897	55	135.744	57.646	<0.0001	3170.517	1.000
Size * Adding	31.921	2	15.960	6.778	0.0010	13.556	0.919
Size * Day	2377.371	110	21.612	9.178	<0.0001	1009.590	1.000
Adding* Day	424.420	55	7.717	3.277	<0.0001	180.237	1.000
Error	1841.445	782	2.355				
Total	991274.158	1008					
Corrected Total	14287.119	1007					

a. Computed using alpha = .05

b. R Squared = .871 (Adjusted R Squared = .834)

2.2 pH

Tests of Between-Subjects Effects

Dependent Variable: pH

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power
Corrected Model	756.642	225	3.363	9.439	<0.0001	2123.755	1.000
Intercept	77911.750	1	77911.750	218683.841	<0.0001	218683.841	1.000
Size	64.046	2	32.023	89.883	<0.0001	179.766	1.000
LD-1 adding	3.337	1	3.337	9.367	0.0020	9.367	0.864
Composting day	416.444	55	7.572	21.252	<0.0001	1168.882	1.000
Size * Adding	2.337	2	1.168	3.279	0.0380	6.559	0.623
Size * Day	210.176	110	1.911	5.363	<0.0001	589.925	1.000
Adding* Day	60.302	55	1.096	3.077	<0.0001	169.255	1.000
Error	278.608	782	.356				
Total	78947.000	1008					
Corrected Total	1035.250	1007					

a. Computed using alpha = .05

b. R Squared = .731 (Adjusted R Squared = .653)

2.3 Moisture Content

Tests of Between-Subjects Effects

Dependent Variable: Moisture content

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power
Corrected Model	56338.105	37	1522.651	14.679	<0.0001	543.112	1.000
Intercept	533083.193	1	533083.193	5139.043	<0.0001	5139.043	1.000
Size	10453.722	2	5226.861	50.388	<0.0001	100.776	1.000
LD-1 adding	336.442	1	336.442	3.243	0.0740	3.243	0.431
Composting week	37868.869	8	4733.609	45.633	<0.0001	365.065	1.000
Size * Adding	547.410	2	273.705	2.639	0.0750	5.277	0.516
Size * Week	5887.556	16	367.972	3.547	<0.0001	56.757	0.999
Adding* Week	1244.106	8	155.513	1.499	0.1640	11.993	0.652
Error	12862.767	124	103.732				
Total	602284.064	162					
Corrected Total	69200.871	161					

a. Computed using alpha = .05

b. R Squared = .814 (Adjusted R Squared = .759)

2.4 Total Solids

Tests of Between-Subjects Effects

Dependent Variable: Total Solids

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power
Corrected Model	56338.105	37	1522.651	14.679	<0.0001	543.112	1.000
Intercept	294487.193	1	294487.193	2838.924	<0.0001	2838.924	1.000
Size	10453.722	2	5226.861	50.388	<0.0001	100.776	1.000
LD-1 adding	336.442	1	336.442	3.243	0.0740	3.243	0.431
Composting week	37868.869	8	4733.609	45.633	<0.0001	365.065	1.000
Size * Adding	547.410	2	273.705	2.639	0.0750	5.277	0.516
Size * Week	5887.556	16	367.972	3.547	<0.0001	56.757	0.999
Adding* Week	1244.106	8	155.513	1.499	0.1640	11.993	0.652
Error	12862.767	124	103.732				
Total	363688.064	162					
Corrected Total	69200.871	161					

a. Computed using alpha = .05

b. R Squared = .814 (Adjusted R Squared = .759)

2.5 Volatile Solids

Tests of Between-Subjects Effects

Dependent Variable: Volatile Solids

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power
Corrected Model	8611.663	37	232.748	20.018	<0.0001	740.681	1.000
Intercept	1320326.944	1	1320326.944	113560.029	<0.0001	113560.029	1.000
Size	489.393	2	244.696	21.046	<0.0001	42.092	1.000
LD-1 adding	3.627	1	3.627	.312	0.5770	.312	0.086
Composting week	6787.902	8	848.488	72.978	<0.0001	583.821	1.000
Size * Adding	346.267	2	173.134	14.891	<0.0001	29.782	0.999
Size * Week	953.135	16	59.571	5.124	<0.0001	81.978	1.000
Adding* Week	31.338	8	3.917	.337	0.9500	2.695	0.158
Error	1441.709	124	11.627				
Total	1330380.316	162					
Corrected Total	10053.372	161					

a. Computed using alpha = .05

b. R Squared = .857 (Adjusted R Squared = .814)

2.6 Organic Carbon

Tests of Between-Subjects Effects

Dependent Variable: Organic Carbon

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power
Corrected Model	2066.728	37	55.858	4.767	<0.0001	176.371	1.000
Intercept	306121.826	1	306121.826	26123.915	<0.0001	26123.915	1.000
Size	309.531	2	154.765	13.207	<0.0001	26.415	0.997
LD-1 adding	57.865	1	57.865	4.938	0.0280	4.938	0.597
Composting week	1110.167	8	138.771	11.842	<0.0001	94.740	1.000
Size * Adding	47.557	2	23.778	2.029	0.1360	4.058	0.412
Size * Week	521.315	16	32.582	2.781	0.0010	44.488	0.994
Adding* Week	20.295	8	2.537	.216	0.9870	1.732	0.114
Error	1453.040	124	11.718				
Total	309641.595	162					
Corrected Total	3519.769	161					

a. Computed using alpha = .05

b. R Squared = .587 (Adjusted R Squared = .464)

2.7 Total Nitrogen

Tests of Between-Subjects Effects

Dependent Variable: Total Nitrogen

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power
Corrected Model	40.198	37	1.086	15.844	<0.0001	586.241	1.000
Intercept	381.156	1	381.156	5558.729	<0.0001	5558.729	1.000
Size	7.759	2	3.879	56.575	<0.0001	113.151	1.000
LD-1 adding	.643	1	.643	9.384	0.0030	9.384	0.860
Composting week	8.870	8	1.109	16.171	<0.0001	129.366	1.000
Size * Adding	.551	2	.275	4.017	0.0200	8.033	0.708
Size * Week	20.403	16	1.275	18.597	<0.0001	297.550	1.000
Adding* Week	1.972	8	.246	3.595	0.0010	28.757	0.979
Error	8.503	124	6.857E-02				
Total	429.857	162					
Corrected Total	48.700	161					

a. Computed using alpha = .05

b. R Squared = .825 (Adjusted R Squared = .773)

2.8 C/N Ratio

Tests of Between-Subjects Effects

Dependent Variable: C/N ratio

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power
Corrected Model	22973.576	37	620.907	8.816	<0.0001	326.206	1.000
Intercept	178418.157	1	178418.157	2533.390	<0.0001	2533.390	1.000
Size	3554.389	2	1777.195	25.235	<0.0001	50.469	1.000
LD-1 adding	594.895	1	594.895	8.447	0.0040	8.447	0.822
Composting week	6680.815	8	835.102	11.858	<0.0001	94.862	1.000
Size * Adding	342.520	2	171.260	2.432	0.0920	4.863	0.482
Size * Week	10759.569	16	672.473	9.549	<0.0001	152.777	1.000
Adding* Week	1041.388	8	130.174	1.848	0.0740	14.787	0.762
Error	8732.905	124	70.427				
Total	210124.638	162					
Corrected Total	31706.481	161					

a. Computed using alpha = .05

b. R Squared = .725 (Adjusted R Squared = .642)

APPENDIX D
RESEARCH EXPERIMENT

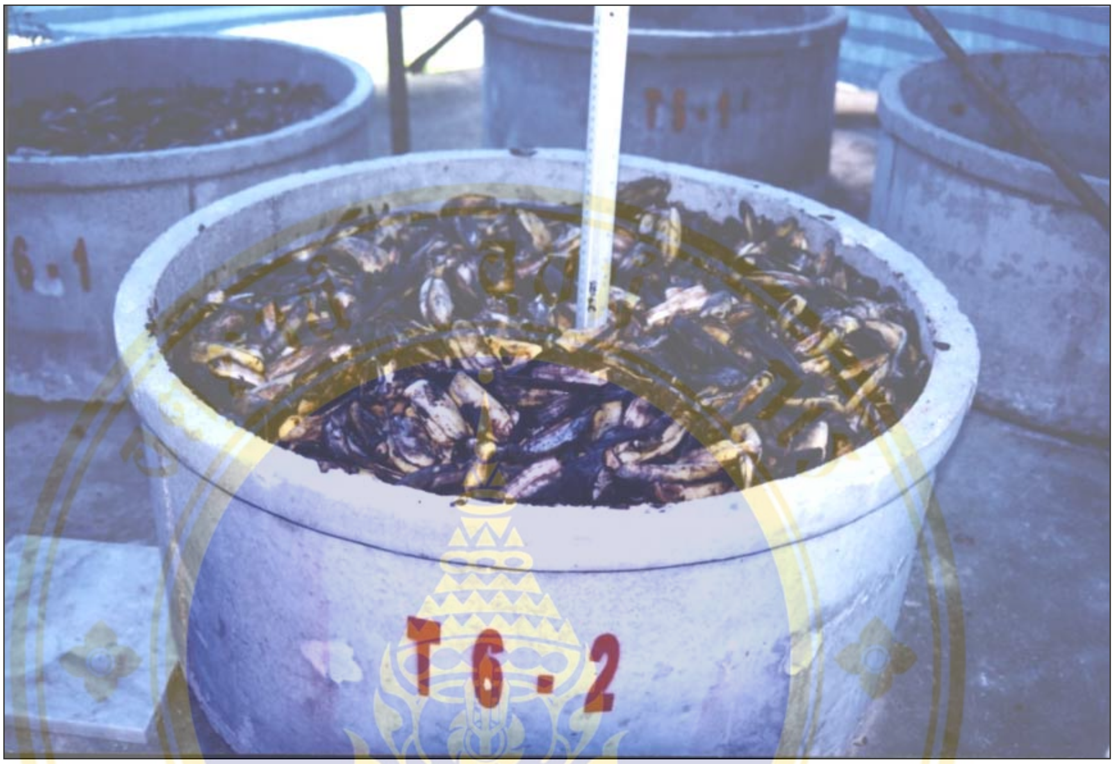
1. Experimental Site

2. Experimental Preparation

Concrete Casing - pH Adjusting

Activator LD-1 Solution and Experimental Tools

3. Composting Material



The Initial Day of Composting Process

The Last Day of Composting Process

BIOGRAPHY

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