APPLICATION OF SERIAL SELF-TURNING REACTOR COMPOSTING SYSTEM TO TREATMENT OF CHICKEN MANURE

BY

LINH HOANG TRAN

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE (ENGINEERING AND TECHNOLOGY)
SIRINDHORN INTERNATIONAL INSTITUTE OF TECHNOLOGY
THAMMASAT UNIVERSITY
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A Thesis Presented

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LINH HOANG TRAN

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Abstract

APPLICATION OF SERIAL SELF-TURNING REACTOR COMPOSTING SYSTEM TO TREATMENT OF CHICKEN MANURE

By

LINH HOANG TRAN

Engineer of Hydro-technical Construction (Civil Engineering), Moscow State University of Civil Engineering

The research work was to study the effects of mixing proportion and aeration on co-composting of chicken manure, vegetable waste, rice husk, and recycled compost by using 'Serial Self-Turning Reactor (STR)' composting system. At first, fourteen lab-scale composting trials of chicken manure (CM), vegetable scraps (VS), rice husk (RH), and recycled compost (RC), divided into five experiments, were conducted to evaluate the performance of different mixing proportions, and aeration rate. From the results of the small-scale experiments, two mixing proportions of 1:0.5:0.5:0.25 and 1:0.5:0.5:0.5 CM: VS: RH: RC were chosen to apply STR composting technology in large scale during twenty eight days. The final results revealed that the mixing ratio of 1:0.5:0.5:0.5 CM: VS: RH: RC at aeration rate of 0.5 l/min/kg dry organic matter was appropriate in terms of pathogen destruction and the quality of final products.

Keywords: STR system, chicken manure, vegetable waste, rice husk, and recycled compost

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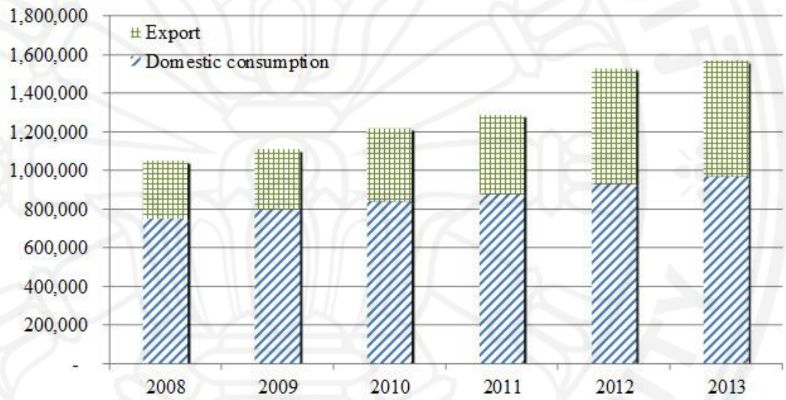
Chapter 1

Introduction

1.1 Statement of problem

1.1.1 Chicken manure

The consumption of chicken meat in Thailand is increasing by the time. Up to the data of office of agriculture department (Figure 1 - 1) in 2013, domestic consumption has increased nearly 1 million ton. In the same way, 60 Thais consume 1 ton of chicken meat in 2013. This is really a warning number for the increase of chicken industry in Thailand.



Source: Office of agriculture department, Thailand, 2013

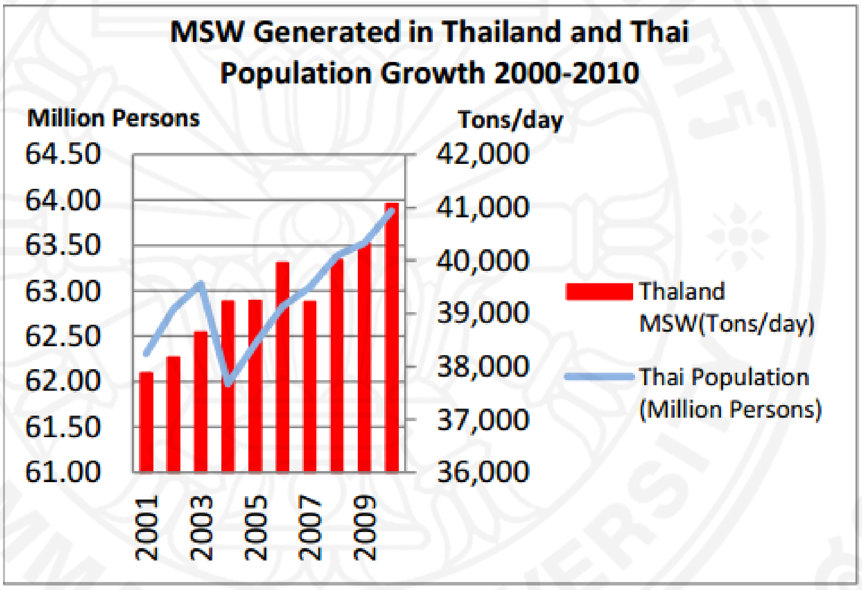
Figure 1 - 1. The consumption of chicken meat (in tons)

Due to high nutrient content, chicken manure has been used as an organic fertilizer for crop growth or soil amendment by adding organic matter to improve the soil structure (moisture content and nutrient retention). However, using fresh chicken manure for agricultural activity can cause serious environmental problems such as pathogen, weed seeds, odour pollution, and pollutants of surface and ground water.

Increasingly, composting is chosen as a treatment method for municipal solid waste because it is the best solution to transform organic matter into safer and more stable substance by biodegradable process.

1.1.2 Current municipal solid waste (MSW) management in Thailand

Due to growth in economic development and population, the volume of Thailand's MSW increases day by day. Figure 1-2 shows the comparison between MSW generation and population growth in Thailand. As Figure 1-2 shown, it is clear to say that the MSW generated increased with population growth in the same period from 2001 to 2010 based on data from Thai Pollution Control Department (PCD)'s website, National Statistical office (NSO) of Thailand. Those MSW mentioned above cause many environmental impact on animal and human activity nearby if they are not treated properly.



Source: Thai Pollution Control Department (PCD)'s website, 2010

Figure 1 - 2. Comparison of MSW generation with population growth in Thailand

However, according to records from Thailand's PCD, approximately 78.2% MSW in Thailand was disposed in unregulated open dumps (Table 1-1) while in sanitary landfills and other proper MSW management facilities about 10% of MSW were conducted. For recycling, merely 11% of waste in Thailand was carried out.

Table 1 - 1. Thailand MSW breakdown by means of disposal

	Annual Country Waste(tons)	**% of total**
Recycling	1,650,000	11.0%
Anaerobic digestion	29,200	0.2%
Windrow composting	36,500	0.2%
Incineration	142,350	0.9%
Sanitary landfilling	1,420,000	9.4%
Open dumps	11,751,950	78.2%
Total	**15,030,000**	**100%**

Due to mechanical problems, some of MSW management facilities have been stopped in incineration facilities such as an incineration plant in Phuket (250 tons/day) and a plant on Samui Island (150 tons/day).

Furthermore, those MSW management projects above usually cost a lot and cannot bring benefits to investors. Therefore, it is necessary to find a new appropriate technology for adopting Thailand's MSW management.

1.2 STR technology

The STR technology was developed based on the concrete mixing unit 'MY-BOX'. This advanced technology was designed for small communities which generated approximate 50 tons municipal solid waste (MSW) per day. Due to the using of gravity, STR technology requires low fixed cost and low operating cost. Most interestingly, only two unskilled workers can control the whole system. The major components of STR system are: 1) Reactors, 2) STR tower, 3) Bio-mybox and 4) Air system. The STR operation processes, which is demonstrated in Figure 1 - 3 had some potential changes to be the simple method to handle. For example, the ability of reactors' mobility makes the control and observation of parameters simply, and the uses of many reactors at the same time with only one STR tower optimums the area.

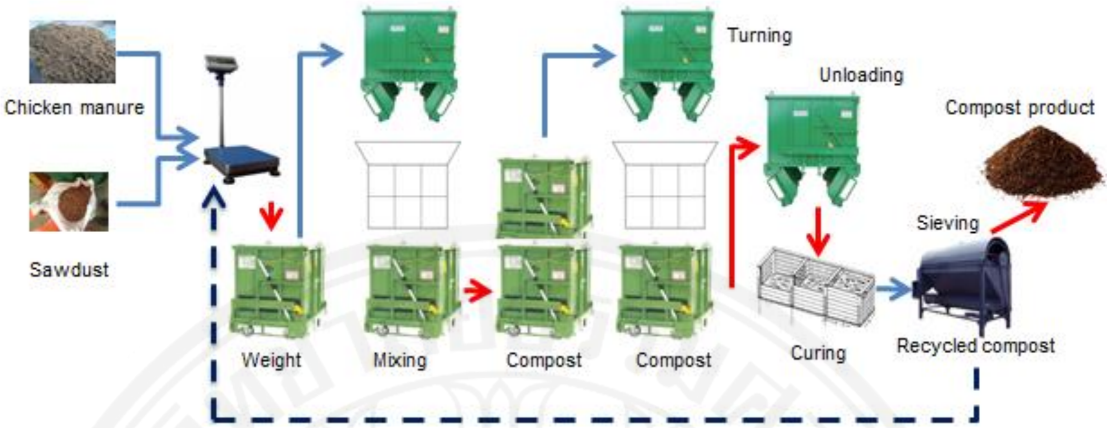


Figure 1 - 3. STR process for chicken manure

Reactors: Figure 1 - 4 shows the structure of the composting reactor. Reactors are made of stainless steel with dimensions of 1.25 m wide, 1.51 m long and 1.10 m high. With the volume of about 1.7 cubic meters, reactors are filled with composting mixtures. The opening mechanism is located at the bottom of each reactor and installed for controlling the composted mass flowing through the self-turning units below. The doors are able to be opened by pulling the line connected to the reactor and closed automatically when lifting down.

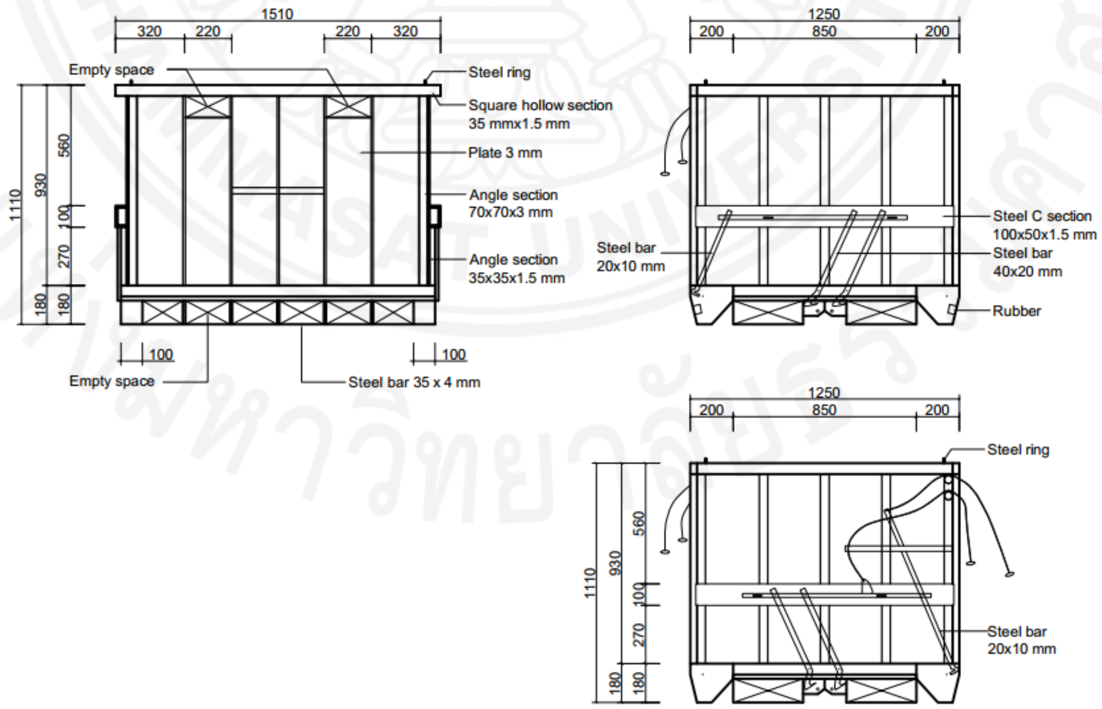


Figure 1 - 4. Structure of the stainless reactor

Bio-mybox: is used for mixing material and is assembled from the 2×3 layers of mixing boxes. There are two main types of mixing boxes: Clockwise types (CW) and counter-clockwise (CCW), which is named according to the direction of the passage. Each type is put side by side in the STR tower (Figure 1 - 4). The combination of two types separates materials into parts and mixes them together while they are falling through the tower. Compared to previous researches, this Bio-mybox has changed from 4×1 layers into 2×3 layers. There are two purposes of this change: 1) To reduce the height of the tower while still produce well-mixing material outputs, and 2) to increase more area to receive more materials at the same time so that the process could speed up.

1.3 Objectives of study

According to data from figure 1-1, it is easy to observe that the amount of chicken meat consumption has been increasing yearly. Consequently, the bulk quantity of chicken manure generated has also rise linearly and has increasingly caused potential risk for human and animals. Currently, composting is considered the best solution to handle chicken waste and transfer it into a valuable substance for land application. Moreover, as the results of MSW management in Thailand, STR is becoming the best choice to treatment MSW as well as chicken manure because of low operational cost, low labor cost, low maintenance cost, low energy consumption, and environment friendly. Therefore, there is a strong support for exploring the application of composting in dealing with chicken manure. As a result, the purpose of this research is to study of application of co-composting process in treating chicken's waste. In particular, this research aims at examining the effects of mixing proportion, and aeration rate on the co-composting process for:

- Chicken manure
- Vegetable waste
- Amendments (rice husk, and recycled compost).

Chicken was taken from one of the largest food production company in Thailand while vegetable waste was collected from Talad Thai-the biggest wholesale market in Thailand. Rice husk and recycled were used as amendments for enhance the composting process.

Chapter 2
Literature Review

2.1. Review on composting of poultry manure

In general, there are two main methods to treat poultry manure, including bio-digestion and composting. Each method has their own advantages. Bio-digestion is able to generate the electricity but require huge facilities. On the other hand, composting produces fertilizers or soil amendment and the facilities also simple.

In term of bio-digestion, chicken manure often combines with other materials to be co-digestion, for example: MSW (Borowski and Weatherley 2013), whey (Gelegenis, Georgakakis et al. 2007). In this method, the results have shown that the product was rich in phosphate, ammonium nitrogen and organic carbon. However, pathogen requirement has failed due to the low temperature during the treatment period.

As regards to composting technology, chicken manure was also treated with other amendment. China, one of the biggest chicken meat consumption, has applied composting technology between chicken manure and sawdust in aeration condition (Gao, Li et al. 2010)

Furthermore, there were a few researches to figure out which reasonable level of each parameter in composting technology.

Guo, Li et al. (2012)researched about the order of important factor such as the aeration rate, moisture content, C/N ratio. Aeration rate was the main factor influencing compost stability, while the C/N ratio mainly contributed to compost maturity, and the moisture content had an insignificant effect on the compost quality.

- Why aeration rate at 5-l/min/kg organic matter?

  Mengchun Gao suggested that the suitable aeration rate should be 0.5 l/min/kg organic matter with chicken manure and saw dust (Gao, Li et al. 2010). In that test, evaluation of the stability and maturity of the final products between chicken manure and sawdust have been conducted at aeration rates of 0.3, 0.5, and 0.7-l/min/kg organic matter, respectively. It is clear to say that the final compost at aeration rate 0.5-l/min/kg organic matters revealed the better results of the quality of composting products than those at 0.3 and 0.7 l/min/kg organic matter.
- Why is C/N ratio 28?

G.F Huang (Huang, Wong et al. 2004) evaluated the effect of C/N on the composting process of pig manure with the purpose of reducing the amount of sawdust normally used as co-composting materials. Two aerobic static piles were prepared consisting of pig manure mixed with sawdust at an initial C/N of 30 (pile A) and 15 (pile B), respectively. Pile B containing larger amount of pig manure showed a slower rise in temperature, lower maximum temperature, and shorter thermophilic phase than pile A. It also resulted in higher pH and electrical conductivity (EC) values, and even higher contents of soluble NH4-N and volatile solids throughout the composting period.

Moreover, Guo experienced on three cases of different value of C/N ratio as 15, 18 and 21. The results showed that The compost with the lowest initial C/N ratio was significantly different from the other treatments and had the lowest germination index (53–66%) (Guo, Li et al. 2012). Also, C/N ratio could affect the NH3 and CH4 emissions significantly, but not the N2O. Lower C/N ratio caused higher NH3 and CH4 emissions. The initial moisture content cannot influence the gaseous emission significantly. Most treatments were matured after 37 days with pig feces, except a trial with high moisture content and a low C/N ratio(Jiang, Schuchardt et al. 2011).

Gao, Liang et al. (2010) examined physicochemical and biological parameters in order to assess their effectiveness as stability and maturity indicators during the forced-aeration composting process of chicken manure mixed with different amounts of pig feces the temperature exceeding 55 °C for more than 3 days, but the period with temperature above 55 °C in the bottom layer of the composting mixtures with initial C/N ratios of 12 and 18 did not meet the requirement of pathogen destruction.

However, in the test in China (Zhu 2007) , economical analysis showed a lower initial C/N ratio (20) could reduce 172 kg rice straw per ton fresh swine manure than a higher C/N ratio (25), and more swine manure could also be treated. Therefore, a low initial C/N ratio (20) could be suggested in the composting of swine manure with rice straw.

- Why is moisture content as 55-65%?

RuiGuo suggested that moisture content in composting of pig feces and corn stalks should be 65-75% (Jiang, Schuchardt et al. 2011, Guo, Li et al. 2012)

However, Ivan Petric(Petric, Šestan et al. 2009) suggested in his research study concerning the effect of initial moisture content (MC) on composting between poultry manure and wheat straw that the appropriate initial MC was around 69% for the composting efficiency of poultry manure and wheat straw.

2.2 Standard organic fertilizer

According to Land Development department in Thailand.

Compost (grade 1) is a non-liquid organic fertilizer, organic matter content of no less than 30 percent by weight, get or made from organic materials. And through the decomposition is complete until converted from the original. When fed to the plants will provide the necessary nutrients to the plants. The standard configuration are

1) The amount of organic matter (Organic Matter) no less than 30 percent by weight.

2) The ratio of carbon to nitrogen (C / N Ratio) up to 20:1

3) The conductance (Electrical Conductivity) does not exceed 10 dS per meter.

4) The pH and alkalinity (pH) is between 5.5-8.5.

5) Sodium (Na), no more than 1 percent by weight.

6) Main nutrient

- Total nitrogen (Total N) no less than 1.00 percent by weight
- Total Phosphate (Total P_2O_5) no less than 0.50 percent by weight
- Total Potash (Total K_2O) no less than 0.50 percent by weight.

7) No more than 30 percent moisture by weight.

8) The size of fertilizer does not exceed 12.5x12.5 mm.

9) The amount of stones and gravel up to 5 mm in size from less than 2 percent by weight

10) Have no sharp shards of glass, plastic or metal

11) The amount of heavy metals

- Arsenic (As)	No more than 50 milligrams per kilogram.
- Cadmium (Cd)	No more than 5 milligrams per kilogram.
- Chromium (Cr)	No more than 300 milligrams per kilogram

- Copper (Cu) No more than 500 milligrams per kilogram.
- Lead (Pb) No more than 500 milligrams per kilogram.
- Mercury (Hg) No more than 2 milligrams per kilogram.

Note: These are minimum standard follow the Fertilizers Act, No. 2 (2550).

12) The complete composting not less than 80 percent

Compost (grade 2) the non-liquid organic fertilizer which has organic matter content of not less than 20 percent by weight, get or made from organic materials. Which is produced by fermenting, crushed chopped, damp, heat, extraction or by other means. The organic material is decomposed by microorganisms, but no chemical fertilizers or fertilizer. The standard configuration are

1) The amount of organic matter (Organic Matter) no less than 20 percent by weight.

2) The ratio of carbon to nitrogen (C / N Ratio) up to 20:1

3) The conductance (Electrical Conductivity) does not exceed 10 dS per meter.

4) Sodium (Na), no more than 1 percent by weight.

5) Main nutrient

- Total nitrogen (Total N) no less than 1.00 percent by weight
- Total Phosphate (Total P_2O_5) no less than 0.50 percent by weight
- Total Potash (Total K_2O) no less than 0.50 percent by weight.

The total amount of main nutrient no more than 2 percent by weight

6) No more than 30 percent moisture by weight.

7) The size of fertilizer does not exceed 12.5x12.5 mm.

8) The amount of stones and gravel up to 5 mm in size from less than 2 percent by weight

9) Have no sharp shards of glass, plastic or metal.

10) The amount of heavy metals

- Arsenic (As) No more than 50 milligrams per kilogram.
- Cadmium (Cd) No more than 5 milligrams per kilogram.
- Chromium (Cr) No more than 300 milligrams per kilogram.
- Copper (Cu) No more than 500 milligrams per kilogram.
- Lead (Pb) No more than 500 milligrams per kilogram.
- Mercury (Hg) No more than 2 milligrams per kilogram.

11) The complete decomposition no less than 80 percent.

Note: These are minimum standard follow the Fertilizers Act, No. 2 (2550).

12) The complete composting no less than 80 percent.

High quality of organic fertilizer the non-liquid organic fertilizer which has macro-nutrient not less than 9 percent and not more than 20 percent by weight, obtained from organic materials or inorganic nature of agricultural nutrients through a fermentation process until complete dissolution. Or applying fertilizer through the complete dissolution and then mixed with organic or inorganic nature and agriculture with high nutrients. The standard configuration are

1) The amount of organic matter (Organic Matter) no less than 20 percent by weight.

2) The ratio of carbon to nitrogen (C / N Ratio) up to 20:1

3) The conductance (Electrical Conductivity) does not exceed 15 dS per meter.

4) The pH and alkalinity (pH) is between 5.5-10

5) Sodium (Na), no more than 1 percent by weight.

6) Main nutrient

- Total nitrogen (Total N) no less than 1.00 percent by weight
- Total Phosphate (Total P_2O_5) no less than 2.50 percent by weight
- Total Potash (Total K_2O) no less than 1.00 percent by weight.

The total amount of main nutrient no less than 9 percent and no more than 20 percent by weight

7) No more than 30 percent moisture by weight.

8) The size of fertilizer does not exceed 12.5x12.5 mm.

9) The amount of stones and gravel up to 5 mm in size from less than 2 percent by weight

10) Have no sharp shards of glass, plastic or metal.

11) The amount of heavy metals

- Arsenic (As)	No more than 50 milligrams per kilogram.
- Cadmium (Cd)	No more than 5 milligrams per kilogram.
- Chromium (Cr)	No more than 300 milligrams per kilogram.
- Copper (Cu)	No more than 500 milligrams per kilogram.
- Lead (Pb)	No more than 500 milligrams per kilogram.

- Mercury (Hg)　　　No more than 2 milligrams per kilogram.

Chapter 3
Methodology

3.1 Research framework

The following figure shows the tentative research framework. There are two main stages in this study framework. The first stage is to review literature to find gaps of the previous studies. This is followed by addressing problem and then making data collection. After that, there two detailed steps namely planning experimental tests and checking state of equipment which are conducted in parallel process. In the second stage, making a trial test (with small scale) to evaluate mixing proportions and aeration rates. After that, the large scale is conducted according to mixing proportion and aeration rates of small scale test. Finally, using experimental results to rise for practical use.

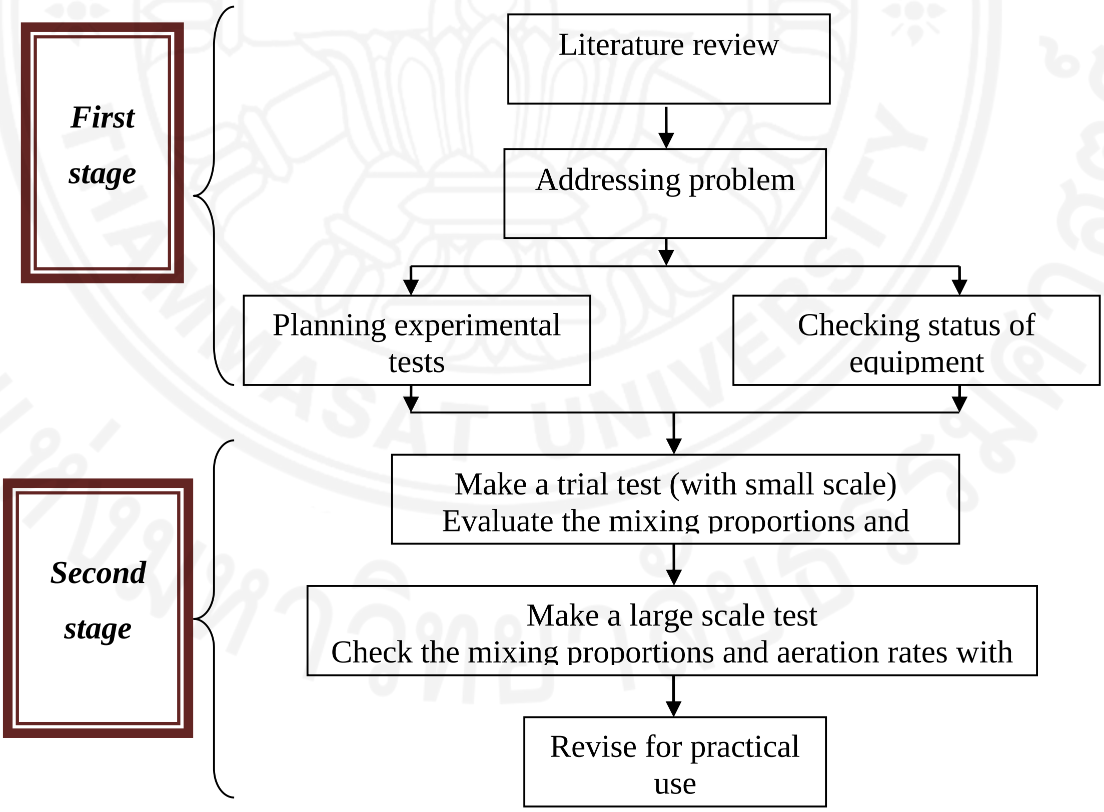


Figure 3 - 1. Framework of study

3.2 Test methods for evaluation of composting and compost

Follow one of the joint project of the United states of agriculture and the United States composting council named Test methods for the examination of composting and compost (council, 2001), those factors are tested during the decomposition of composting:

Physical examination: Air capacity, ash, bulk density, wet ability, film plastics, glass, metal fragments and hard plastic, process to reduce sharps, man-made inert, total solids and moisture, water holding capacity.

Chemical properties: organic carbon, nitrogen, phosphorus, potassium, secondary and micro-nutrient, heavy metals and hazardous elements, inorganic carbon, electrical conductivity for compost, electrometric pH determinations for compost, soluble salts.

Organic and biological properties: Biodegradable volatile solids, indicator ratios, color, enzyme activity and analysis, biological assays, odor, organic matter, viable weed seed in compost, volatile fatty acids.

Synthetic organic compounds: Chlorinated herbicides, dioxin/furans, organophosphorus pesticides, organochlorine pesticides, polychlorinated biphenyls, semi-volatile organic compounds, volatile organic compounds.

In initial process, the composting factors that current machines and methods control are:

- Density (Measure at Lab by simple methods)
- pH
- Moisture content (Moisture analyzer)
- C/N ratio (Chemical Laboratory)
- Particle size (shredder machine)

During the composting decomposition, there are some observed factors

- Temperature (Data logger and thermal copper)
- Moisture content (Moisture analyzer)
- Density
- Odors

Chapter 4
Experiments on Co-composting between Chicken Manure and Vegetable Waste

4.1 Small-scale experimental study

In this study, five lab-scale experiments were carried out which is shown in Table 4 - 1 to identify the degradation of composting of each ratio. Then, the STR composting will be performed after analysis of the lab-scale degradation by using the same conditions as lab-scale composting.

Table 4 - 1. Design of experiment

	Mixing proportion CM:VS:RH:RC	Aeration rate (l/min/kg OM)
Experiment 1	1:0.25:0.5:0.5	0.5
	1:0.5:0.5:0.5	0.5
	1:0.75:0.5:0.5	0.5
Experiment 2	1:0.25:0.25:0.5	0.5
	1:0.5:0.25:0.5	0.5
	1:0.75:0.25:0.5	0.5
Experiment 3	1:0.25:0.5:0.25	0.5
	1:0.5:0.5:0.25	0.5
	1:0.75:0.5:0.25	0.5
Experiment 4	1:0.25:0.5:0.25	0.75
	1:0.25:0.25:0.5	0.75
	1:0.25:0.5:0.5	0.75
Experiment 5	0.5:1:0.5:0.5	0.5
	1:1:0.5:0.5	0.5

4.1.1 Materials and methods

Composting materials

Figure 4 - 1. Chicken manure and Chinese cabbage

Figure 4 - 2. Rice husk and recycled compost

The raw materials were chicken manure, vegetable waste, rice husk, and recycled compost. Chicken manure was collected from chicken egg farms of Laemthong Corporation Group. Vegetable waste was taken from Talad Thai located in Pathum Thani province, Thailand.

Before mixing, vegetable waste was cut into small pieces (vegetable scraps) by shredding machine. Rice husk was used as a carbon source to adjust the C/N ratio and moisture content of composting mixtures while recycled compost was used as a bulking agent to increase the porosity of mixtures.

Fourteen composting trials of chicken manure (CM), vegetable scraps (VS), rice husk (RH), and recycled compost (RC) were carried out in this study. The initial properties of raw material was shown in Table 4 - 2.

Table 4 - 2. Initial properties of raw materials

Parameter	CM	VS	RH	RC
MC (%)[a]	52.76	85.03	11.80	33.68
TOC (%)[b]	30.43	3.00	42.18	9.92
C/N ratio	9.22	10.00	136.06	12.05

MC = moisture content
TOC = total organic carbon
[a] = wet weight basis
[b] = dry weight basis

Composting set-up

Figure 4 - 3. Small-scale experimental set-up

Composting mixtures were performed in insulated boxes with dimension of 0.45 m × 0.45 m ×0. 45 m in a composting plant at Thammasat University, Rangsit Campus, Pathum Thani province. This box comprises of two components: a steel box (a galvanized sheet box) with insulation panels (foam).

Air was forced by air compressor through perforated polyvinyl chloride (PVC) tube positioned in the center of each box. The air flow rate meter was used to control oxygen supply for the composting mixture.

Figure 4 - 4. Equipment set-up of a small scale

Thermocouples were placed in the center of each reactor to measure the temperature during the composting process. The temperature readings were recorded every 5 minutes by the data logger.

Figure 4 - 5. Data logger

Five lab-scale experiments were conducted during 28 days, including two phases: 14 days for composting and 14 days for curing. During the composting process, composting mixtures were turned once on day 7 to provide oxygen to the microbial activity.

Experiments of 1, 2 and 3 were performed to study the effects of rice husk and recycled compost on co-composting efficiency of CM, VS, RH, and RC at the same aeration rate of 0.5 l/min/kg dry organic matter, while experiment 4 was conducted to examine the effect of different proportions of CM, VS, RH and RC (1:0.25:0.5:0.25, 1:0.25:0.25:0.5, and

1:0.25:0.5:0.5) at the same aeration rate of 0.75 l/min/kg dry organic matter.

Experiment 5 was implemented to study the effect of mixing proportion of CM, VS, RH, and RC at an aeration rate of 0.5 l/min/kg dry organic matter. The mixing of the proportions of 5 experiments were shown in Table 4 – 3, Table 4 – 4, Table 4 – 5, Table 4 – 6, Table 4 – 7, respectively.

Table 4 - 3. Mixing proportions of experiment 1

Description	**C1**	**C2**	**C3**
Initial MC (%)[a]	51.09	56.86	60.66
OM (%)[b]	43.75	39.89	36.73
Initial C/N ratio	14.63	14.55	14.46
CM (kg)[a]	13.80	10.96	9.08
VS (kg)[a]	7.79	12.37	15.39
RH (kg)[a]	3.73	2.96	2.46
RC (kg)[a]	4.67	3.71	3.07

MC = moisture content
OM = organic matter
[a] = wet weight basis
[b] = dry weight basis

Table 4 - 4. Mixing proportions of experiment 2

Description	**C4**	**C5**	**C6**
Initial MC (%)[a]	53.64	59.16	62.71
OM (%)[b]	40.15	36.26	33.15
Initial C/N ratio	12.18	12.14	12.10
CM (kg)[a]	14.72	11.53	9.47
VS (kg)[a]	8.31	13.01	16.04
RH (kg)[a]	1.99	1.56	1.28
RC (kg)[a]	4.98	3.90	3.20

Table 4 - 5. Mixing proportion of experiment 3

Description	C7	C8	C9
Initial MC (%)[a]	57.68	64.82	69.00
OM (%)[b]	47.09	42.43	38.70
Initial C/N ratio	14.72	14.62	14.53
CM (kg)[a]	13.44	9.93	7.87
VS (kg)[a]	10.60	15.67	18.63
RH (kg)[a]	3.57	2.64	2.09
RC (kg)[a]	2.39	1.77	1.40

Table 4 - 6. Mixing proportions of experiment 4

Description	C10	C11	C12
Initial MC (%)[a]	57.58	58.52	55.91
OM (%)[b]	47.09	40.15	43.75
Initial C/N ratio	14.72	12.18	14.63
CM (kg)[a]	13.44	13.17	12.45
VS (kg)[a]	10.60	10.39	9.82
RH (kg)[a]	3.57	1.75	3.30
RC (kg)[a]	2.39	4.69	4.43

Table 4 - 7. Mixing proportions of experiment 5

Description	C13	C14
Initial MC (%)[a]	72.38	70.32
OM (%)[b]	30.45	34.10
Initial C/N ratio	17.81	14.38
CM (kg)[a]	3.50	6.27
VS (kg)[a]	22.14	19.82
RH (kg)[a]	1.86	1.67
RC (kg)[a]	2.50	2.24

Sampling and analysis

The samples of the final products were collected and sent to the lab for analyzing their characteristics. The lab results were compared to Thai fertilizer criteria to evaluate the compost quality.

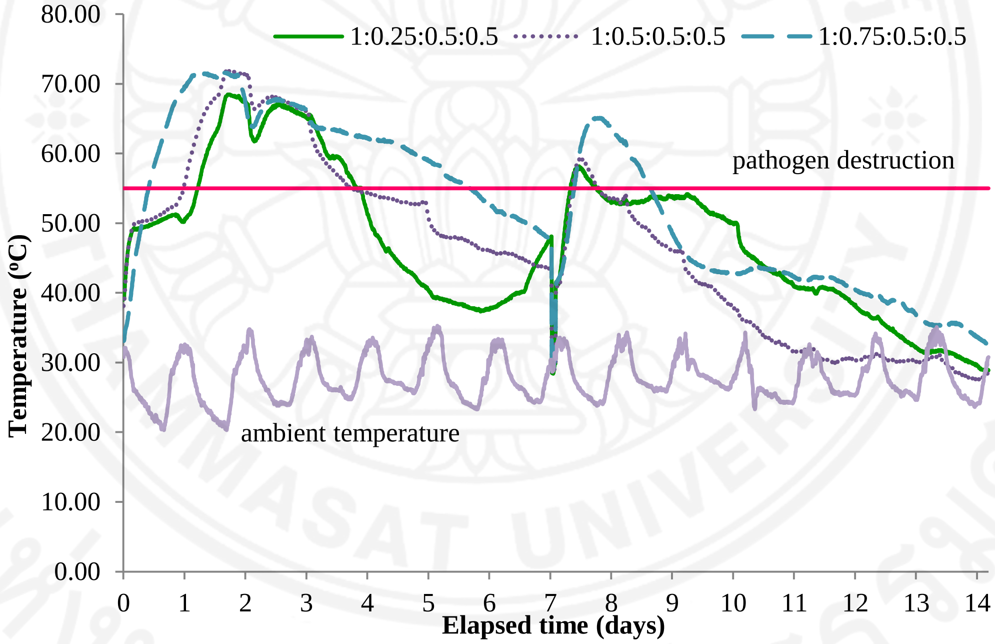
Time-temperature control during the composting process is important to produce hygienic product. The requirement of pathogen destruction is that temperatures be maintained above 55ºC for 3 continuous days.

4.1.2 Results and discussion

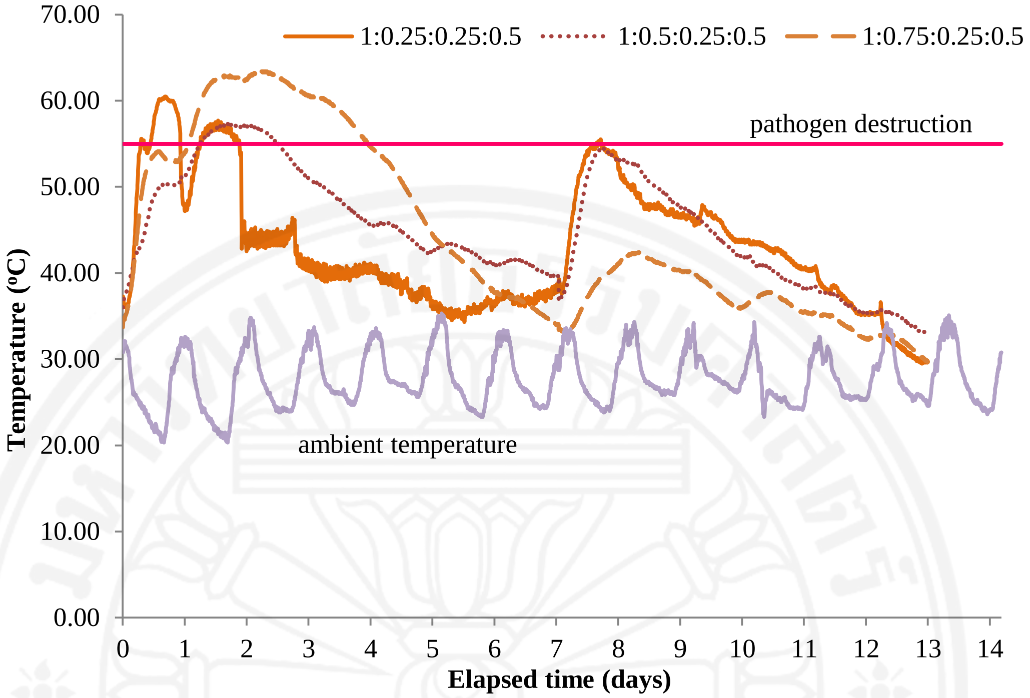
Temperature profiles

The temperature variation throughout the composting process has been reported to correlate with microbial activity. The temperature profiles obtained with mean values during the composting process were shown in Figure 4 - 6.

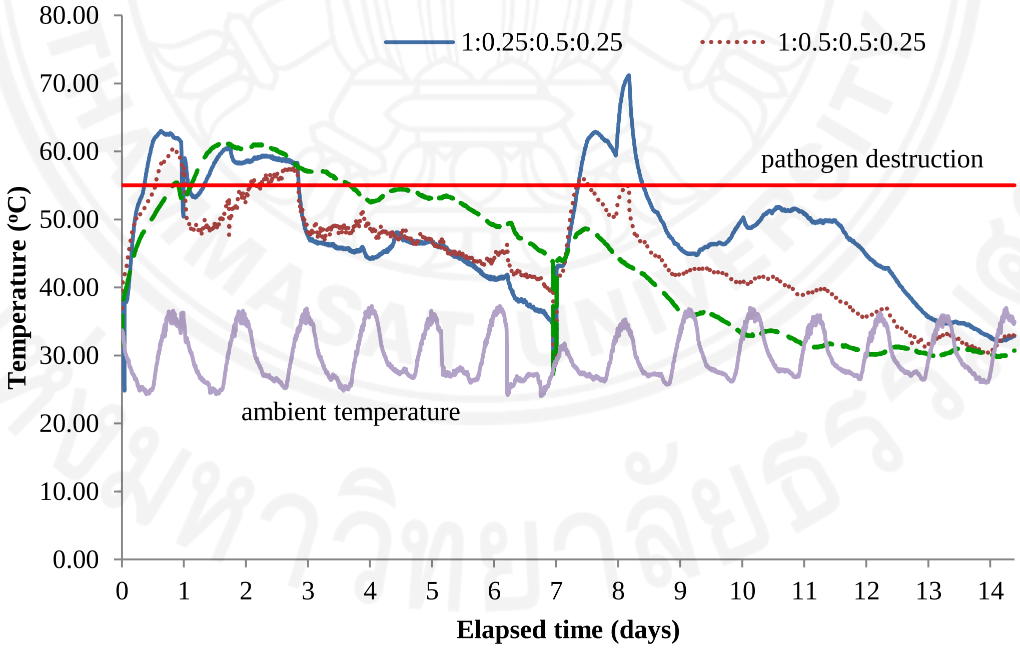
a)



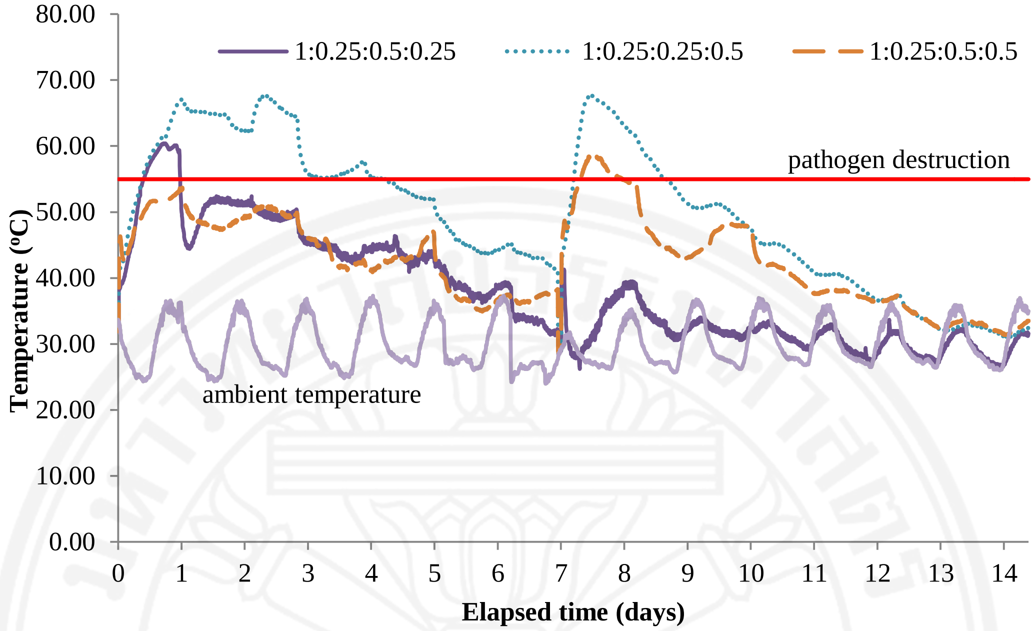
b)


70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Temperature (ºC)
1:0.25:0.25:0.5
1:0.5:0.25:0.5
1:0.75:0.25:0.5
pathogen destruction
ambient temperature
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Elapsed time (days)

c)


80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Temperature (ºC)
1:0.25:0.5:0.25
1:0.5:0.5:0.25
pathogen destruction
ambient temperature
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Elapsed time (days)

d)



e)

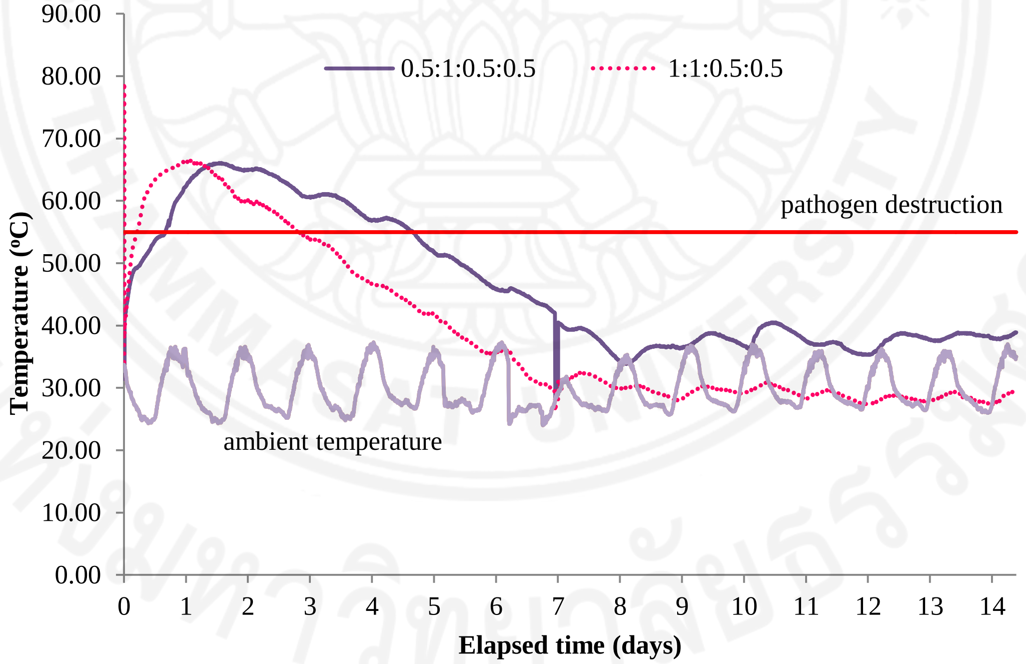


Figure 4 - 6. Temperature profile during composting process

a) Experiment 1, b) Experiment 2, c) Experiment 3 d) Experiment 4, and e) Experiment 5

The temperatures of experiments 1, 2, and 3 presented in the thermophilic phase within 5 days of composting, showed rapid initiation of the composting process. However, the differences were found in the 3 experiments. Before turning, for experiment 1, the temperatures reached the maximum of 71.2ºC, 71.1ºC, and 68.5ºC for the 1:0.5:0.5:0.5, 1:0.75:0.5:0.5, and 1:0.25:0.5:0.5 mixtures on day 1.8, day 1, and day 1.8, respectively. The temperature then decreased gradually after reaching the peak. The temperatures above 55ºC were sustained for 5.5 days in the case of 1:0.75:0.5:0.5 and 3 days in the case of 1:0.5:0.5:0.5 while the rest case did not satisfy the requirement of pathogen destruction. After turning, the temperatures of 3 mixtures rose rapidly and reached the peak of 65ºC, 59.1ºC, and 57.6ºC for the 1:0.75:0.5:0.5, 1:0.5:0.5:0.5, and 1:0.25:0.5:0.5 mixtures on day 7.8, day 7.5, and day 7.3, respectively. The decline of the temperatures occurred faster after peak. In contrast, for the second experiment, the only one case of 1:0.75:0.25:0.5 met the requirement of pathogen destruction, reaching the maximum of 63.1ºC on day 2.6 and remained above 55ºC within 3.2 days before turning. Meanwhile, the temperatures reached peak of 60.3ºC and 57.1ºC in the cases of 1:0.25:0.25:0.5 and 1:0.5:0.25:0.5 ratios on day 0.5 and day 1.8, respectively. After turning, the temperatures of 3 mixtures dramatically increased to the peak of 55.3ºC, 54.8ºC, and 42ºC for the 1:0.25:0.25:0.5, 1:0.5:0.25:0.5, and 1:0.75:0.25:0.5 mixtures on day 7.6, day 7.6, and day 8.2, respectively. However, the trend of increase occurred in the short term after reaching the peak. For the third experiment, the trend of temperature changes was not much different from the experiment 1. After turning, the temperature profiles of 3 mixtures rose rapidly and reached the peak of 70ºC, 56ºC, and 48.6ºC in the case of 1:0.25:0.5:0.25, 1:0.5:0.5:0.25, and 1:0.75:0.5:0.5, respectively. The differences found between the experiment 1 and experiment 2 were due to the fact that the reduction in rice husk (RH) ration in experiment 2 compared to the experiment 1 has caused the lack of carbon resource which is essential for the composting process. The utilization of rice husk was to provide necessary carbon resource to microbial activity. In case of experiment 3, the decrease of temperature profile was faster than experiment 1 because the more ratios of added recycled compost (RC) gave the better result in the reheating potential of composting mixtures after turning.

For experiment 4, the best result found in the case of 1:0.25:0.25:0.5 mixture when the 3 composting mixtures were conducted at the same aeration rate of 0.75 l/min/kg dry matter. Before turning, the temperatures reached the peak of 67.2ºC, 59.9ºC, and 52.7ºC in the cases of 1:0.25:0.25:0.5, 1:0.25:0.5:0.25, and 1:0.25:0.5:0.5 mixtures, respectively. After turning, the temperatures in the case of 1:0.25:0.25:0.5 increased dramatically to the peak of 67.2ºC and then decreased rapidly. The thermophilic phase of this case occurred between day 7.5 and 9. This case satisfied the requirement of pathogen destruction.

Experiment 5 failed because the mixing ratios of composting mixtures were not reasonable in practice. The initial moisture content of those mixtures exceeded 65% that may cause the limitation of oxygen to provide microbial activity.

Properties for final products

The results of the final composts satisfied the Thai fertilizer criteria as well as the requirement of pathogen destruction were shown in Table 4 - 8.

Table 4 - 8. Properties of the final products

Test items	**Thai criteria**	**C2 (1:0.5:0.5:0.5)**	**C7 (1:0.25:0.5:0.25)**
C/N ratio	< 20	7.43	13.56
MC (%)	< 35	22.14	22.97
OM (%)	> 30	33.08	33.09
TN (%)	> 1	2.58	1.41
TOC (%)		19.19	19.19
P (%)	> 0.5	1.34	1.60
K (%)	> 0.5	1.46	1.95
pH	5.5-8.5	8.15	8.35
EC (dS/m)	< 3.5	1.27	2.62

MC = moisture content
OM = organic matter

TN = total Nitrogen
TOC = total organic carbon

From the lab results, it is obviously seen that the 1:0.5:0.5:0.5 and 1:0.25:0.5:0.25 mixing proportions at the aeration rate of 0.5 l/min/kg dry organic matter passed all of Thai fertilizer criteria, so the composts can be considered as fertilizers.

4.2 Large-scale experimental study

From the results from pilot scale, the mixings of CM, MSW, RH and RC as 1:0.5:0.5:0.25 and 1:0.5:0.5 has shown the suitable results. Two of these experiment were set up into large scale to test the efficiency of the STR technology on chicken manure and consider the application of the final product.

4.2.1 Materials and methods

Composting materials

Chicken manure was taken from the same chicken egg farm of Laemthong Corporation Group. Cabbage waste, used as municipal solid waste (MSW), was obtained from Talad Thai located in Pathumthani province, Thailand.

Before mixing, cabbage waste was cut into small pieces (vegetable scraps) by shredding. Rice husk was used as a carbon source to adjust the C/N ratio and the moisture content of composting mixtures while recycled compost was used as a bulking agent to increase the porosity of mixtures. Chicken manure, cabbage waste, rice husk and recycled compost were mixed in different proportions of 1:0.5:0.5:0.25 (C-1) and 1:0.5:0.5:0.5 (C-2) on dry weight basis, respectively. The initial properties of mixing materials and mixing proportion were shown in Table 4 – 9 and Table 4 – 10, respectively.

Table 4 - 9. Initial properties of raw materials

Parameter	CM	VS	RH	RC
Moisture content (%)[aa]	64.48	82.05	11.80	33.68
Total organic carbon (%)[b]	30.43	3.00	42.18	9.92
C/N ratio	9.22	10	136.06	13.05

[a] = Wet weight basis
[b] = Dry weight basis

Table 4 - 10. Mixing proportion

Description	C-1	C-2
CM: VS: RH: RC	1:0.5:0.5:0.25	1:0.5:0.5:0.5
Initial moisture content (%)[a]	65.62	63.88
Aeration rate (l/min/kg dry OM)	0.5	0.5
Organic matter (%)[b]	42.43	39.89
C/N ratio	14.62	14.55
Chicken manure (kg)[a]	193.58	183.03
Vegetable scraps (kg)[a]	191.53	181.10
Rice husk (kg)[a]	38.98	36.86
Recycled compost (kg)[a]	25.92	49.01

Checking STR mechanism

Due to safety and effectiveness during mixing day, the work of checking STR system was done.

- Checking a crane
- Mechanism of bottom door of reactor
- Bio-mybox with fine materials and solid material

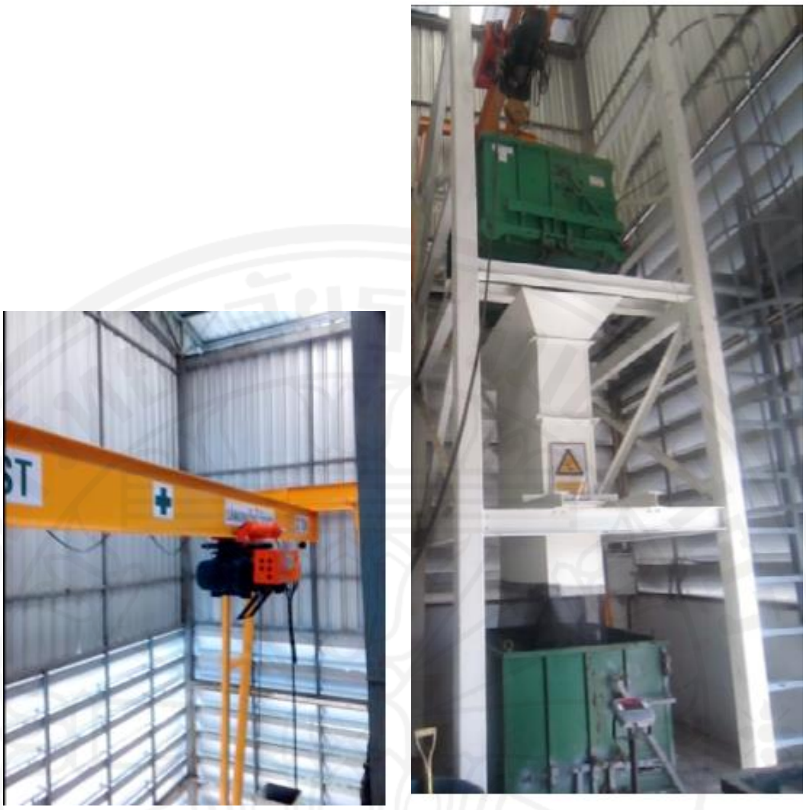


Figure 4 - 7. Checking STR tower and crane mechanism

Figure 4 - 8. Checking mechanism of bottom door in reactor

Process

Step 1: Input chicken manure: put into small bucket (20 litters), weigh for the total weight and deduct the self-weigh bucket.

Step 2: Input vegetables: put into the same bucket and then weigh them before put into the reactor

Step 3: Input the sawdust: weigh the sawdust bag and put into the reactor, on the surface of chicken manure and vegetables input before.

Step 4: Input the recycled compost.

Step 5: When the weight reached 1/3 of expected weigh, lift up to the tower and mixing through bio-mybox.

Repeat from the step 1 to 4 until the last of material is inputted

Step 6: Move reactor out and ready for next case.

Step 7: Install the thermocouple to measure the temperature at 4 positions in case 1 and case 2 (Figure 4 - 10)

Composting set-up

Two same forced-aeration composting systems were set up following the STR composting process in this study. The composting process of each mixture was carried out in each reactor with dimensions of 1.51 m long, 1.25 m wide and 1.11 m high, and the volume of 1.7 cubic meters was filled with composting mixtures. The research was carried out during 28 days, including two phases: composting process (14 days) and curing (14 days) were turned once on day 7.

Perforated polyvinyl chloride (PVC) system connecting an air compressor was installed in each reactor to provide the oxygen for the compost microbes to work efficiently. From the study of composting of chicken manure with sawdust [10], pointed that an aeration rate of 0.5 l/min/kg dry OM was optimal. Therefore, 0.5 l/min/kg dry OM was chosen to apply in this study.

Figure 4 - 9. Setting-up large-scale trials

Sampling and analysis

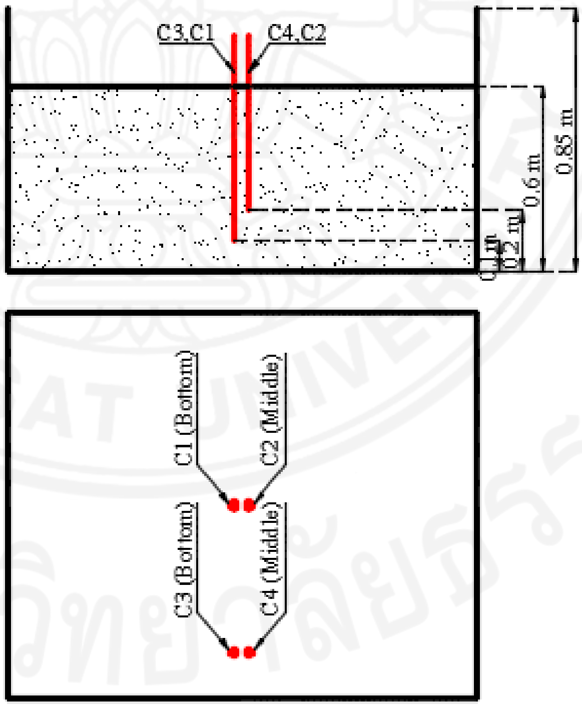


Figure 4 - 10. Thermocouple positions in each reactor

Samples were taken from mature compost after curing phase and sent to Central Lab (Thailand) for the analysis of organic matter (OM), C/N ratio, total organic carbon and total nitrogen.

Temperature is the most important and practical parameter to control pathogens as well as to destroy weed seeds. Furthermore, temperature indicates that the material is stable and mature when it declines to near ambient temperature. The composting temperature and ambient were recorded every 5 minutes by thermo-copper and data logger with a resolution of 0.1^{0}C in each reactor. Four thermo-coppers were set up at 0.1 am (bottom layer), 0.2 m (middle layer) in the center and the area near the wall of each reactor. Figure 3 shows the positions of thermo-copper located in each reactor.

4.2.2 Results and discussion

Temperature profile

Changes in temperature are result of microbial activity. The composting mixtures underwent three typical phases: mesophilic, thermophilic and curing. The microbial population changes during composting time. The temperature is a key role to kill the pathogens. Figure 4 shows the changes in composting temperature and the ambient temperature in C1 and C2, respectively. The ambient temperature ranged between 26.9^{o}C and 38.1^{o}C during composting days. In order to destroy pathogens, the temperature of the composting mixture needs to maintain at 55^{o}C and higher for at least 3 days.

For C-1, before turning, the temperature shows the significant rise in the center of the reactor (CH1-bottom and CH2-middle) with values between 69.8^{o}C and 72^{o}C on the first day due to the rapid breakdown of the available organic matter by microbial activities. Thereafter, the decline of temperature was slowly and remained higher 55^{o}C during 7 days. However, the temperature of near the wall (CH3-bottom and CH4 middle) in composting reactor did not meet the requirement of pathogen destruction. After turning, the temperature near the wall of reactor increased dramatically to 58.6-63.5^{o}C on day 7.5. After reaching peaks, it rose erratically and maintained higher 55^{o}C during 3 days, peaked at 66.5^{o}C on day 10.5.

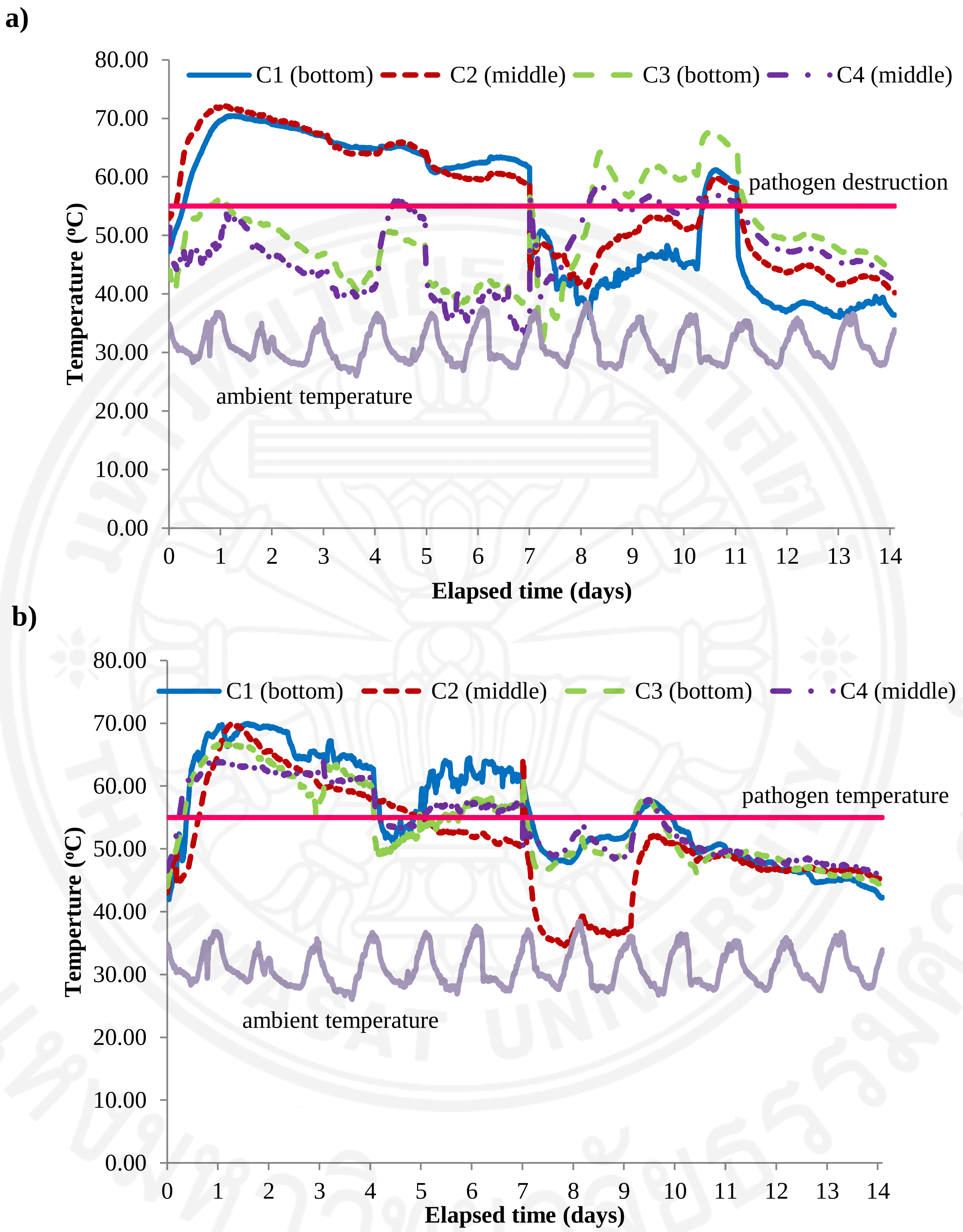


Figure 4 - 11. Temperature profiles during the composting process

a) case 1 (1:0.5:0.5:0.25); b) case 2 (1:0.5:0.5:0.5)

For C-2, before turning, the temperature trend of all positions was quite similar each other. Similar to C-1, the temperature of C-2 went up rapidly to 63.6-69.9ºC on the first day and then decreased after reaching peaks. The temperature exceeding 55ºC maintained more than 3 days, which satisfied the requirement of pathogen destruction. However, after turning, the temperature of C-2 rose slowly and lower than the first 7 days due to exhaustion of substrate.

The temperature in the center areas of each reactor was the hottest zone and well supplied oxygen. It is important that through turning, every part of composting mixture is moved to the central. The more recycled compost added to composting mixture the better temperature result got.

Properties of final products

The final products were sent to Central lab to analyze the quality of compost. Table 4 - 11 shows the comparison of STR products with Thai fertilizer criteria.

Table 4 - 11. The comparison of STR products with Thai fertilizer criteria

Properties	**Thai criteria**	**C-1 (1:0.5:0.5:0.25)**	**C-2 (1:0.5:0.5:0.5)**
C/N ratio	< 20	19.03	15.70
Moisture content	< 35%	19.88	27.17
Organic matter	> 30%	45.94	33.10
Total Nitrogen	> 1%	1.40	1.22
Total organic carbon (%)		26.64	19.20
Total Phosphate	> 0.5%	2.05	2.28
Potassium	> 0.5%	2.03	1.97
pH	5.5-8.5	8.44	8.25
Electrical conductivity	< 6dS/m	1.16	1.11

From the results of lab test, it is clear to recognize that the final products of two cases satisfied Thai fertilizer criteria so the compost can be considered as a fertilizer.

Chapter 5
Conclusions and Recommendations

5.1 Conclusions

STR technology has shown the effective system that can be applied to MSW, chicken manure in specific. STR has proved the advantages itself when creating the well-mixing mixtures and proceeding long time enough for the final composting product. Moreover, 2 weeks were considered as long time enough to control the pathogen and shortest time among current composting technologies. Besides, turning will be proceeded after 1 week, which is suitable period because the temperature has no sign to increase more from that point of time. More importantly, the population of microorganisms increases again after turning. This situation leads to put the composting mixture in thermophilic phase again.

Lab-scale have indicated that the mixing proportion of 1:0.5:0.5:0.5 CM: VS: RH: RC at the aeration rate of 0.5 l/min/kg dry organic matter was the appropriate mixing ratio in terms of the quality of the final product as well as the requirement of pathogen destruction.

Large-scale have revealed that before turning the mixing proportion of 1:0.5:0.5:0.5 CM: VS: RH: RC at the aeration of 0.5 l/min/kg dry organic matter showed the better result in terms of thermal conditions and satisfied the requirement of pathogen destruction compared with the mixing proportion of 1:0.5:0.5:0.25 CM: VS: RH: RC at the same aeration rate. After turning, however, the result indicated that the mixing proportion of 1:0.5:0.5:0.25 CM: VS: RH: RC was better than the proportion of 1:0.5:0.5:0.5 CM: VS: RH: RC in terms of thermal consideration.

Rice husk plays an important role to microbial activity as a carbon-rich material, while recycled compost provides air movement through composting mass. Furthermore, recycled compost contains activated bacteria supporting composting process.

Moreover, it is found that the moisture content affects the microbial activity during the composting process. Therefore, when co-composting chicken manure, vegetable waste, rice husk, and recycled compost, the moisture content is recommended 50% to 65%.

5.2 Recommendations

The present study has achieved the targets on operating the STR system and applying successfully this technology on chicken manure. The results have shown the possibility to apply in the chicken farm. The air pollution at the chicken farm land is solved. Another benefit we can get from this solution is to produce the fertilizer or soil amendment. However, the economic aspects should be put more consideration to make this application become true.

In term of the operation, bio-mybox is suggested to have some modification to avoid the stuck of materials during the mixing process. Reactors often work with the toxic material as chicken manure so that the damages from corrosion happen at the mechanism bottom doors.

To achieve more targets in chicken manure composting, the co-composting should be concerned. Chicken manure would be composted by an amendment which is also an organic waste. If this goal is accomplished, that would be the amazing step in the composting technology and contribute a crucially important step to solve the issue of climate change in the world.

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