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Co-composting of school food remnant: *A case study at 2 schools in Tan Binh district, Ho Chi Minh City, Vietnam*

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Abstract

Co-composting of school food remnant with dewatered septic sludge, and sawdust has been investigated in aerobic composting systems, and a case study was explored at 2 schools in Tan Binh district. In the study, two sets of experiment were fabricated in order to evaluate the capacity of reusing in-school food waste for composting and applying the finished product as a soil amendment source for the school gardens. To achieve these objectives, two different types of aerobic reactor were installed in each school, turned and forced aerated reactors. After 44 day operation, it is reported that in Au Lac School, pH of finished products measured in forced aerated reactor and turned aerated reactor were 7.77 and 7.79, and carbon content in the reactors reduced from 50% to 47% and from 51% to 46%, respectively. Similarly, in forced and turned aerated reactors at Dong Da School, pH values measured were 7.37 and 7.25. On the top of that, carbon content shows the decrease from 52% to 47% and from 53% to 51%. These above values are in the range of permission of TCVN 7185:2002. The study results also provide that aeration introduces a significant influence on organic decay efficiency, however, GI (%) (Germination Index) indicated there are no differences between compost qualities of two types of compost reactors.

Key words: *Compost, food remnant, school food waste, aerobic degradation.*

1. Introduction

Aerobic composting have been known as a biological process converting biodegradable organic fractions of solid waste into final stable products, called humus like substances, and being used as a soil amendment or organic-fertilizer (Tiquia, 2010; Coelho et al., 2011; Lashermes et al., 2012). Besides, Cekmeceliogly et al., (2005), Adhiraki et al., (2008), He et al., (2011a) pointed out that composting can provide a viable method of alternating the conventional treatment, landfilling, due to following advantages: (1) diverting waste sending to landfill; (2) minimizing groundwater contamination; (3) diminishing air pollution and greenhouse gas emission; (5) mitigating resources loss by circulating minerals and nutrients to natural environment. Apart from that, other strength of the process is time demand. A report carried out by Chittenden Solid Waste District - CSWD (2007) about establishing an effective composting program at school in Chittenden County, Vermont reveals decomposition of an organic matter under aerobic condition can be faster (in few months) than that under anaerobic condition (more than 10 years). Hence, the "NIMBY" (not in my backyard) phenomenon is not a critical issue while finding a site for constructing a new landfill.

Ho Chi Minh is a mega city, ranking second for area in Vietnam (2,095 km^2 in comparison with Hanoi – 3,325 km^2), having a population of about 10 million, and ranking the first for socioeconomic development. The total amount of waste daily generated in Ho Chi Minh varies from 10,000 to 11,000 tons (not counted for wasted sludge). At the present, lots of researches have been conducted to examine volume and composition of household municipal solid waste produced from residential areas, commercials, offices, institutes, departments, and industrial zones (cafeteria, office), non-infected medical centers (cafeterias, offices, and sickroom). The total amount of these wastes is about 9,000 tons/day, and the quantity increasing rate is about 6 – 8% per year (Nguyen Trung Viet, 2012; Tran Thi My Dieu, 2014). However, researches on measuring and identifying the composition of solid waste generated at education institutions are still limited. Chuyen and Cam, (2010) conducted a study on building a model of segregating school waste at source in Da Nang, and reported a notable variation in school waste quantity between dry and rainy season. During dry season, waste volume is about 35.0 – 42.3 kg/day, whereas during rainy season, it is 51.2 – 64.2 kg/day. The analytical result also reported that together with non-biodegradable and recyclable wastes, percentage of biodegradable waste in primary and secondary is higher (food remnant: 8.9 – 9.2%; and yard waste: 17.3 – 27.7%) when compared to that of high school (food remnant: 5.6- 13.4%; and yard waste 9.4 – 10.2%). In Guideline on waste management and resource recovery (1995), Charles R. Rhyner et al., calculated that an individual student contributes from 0.2 – 0.5 kg waste/day. As per Food waste estimation guide, school's food waste disposal from the campus of college and university varies from 0.159 kg/meal/student, accounted for 64.3 kg/student/year (residential student) and 17.8 kg/student/year (non-residential student), and in primary, secondary, and high schools, the number is 0.23 kg/student/week, accounted for 45% of waste (wet weight) (Recycling Assistance for Businesses and Institutions, 2014). A research implemented by Minnesota Pollution Control Agency (2010) also pointed out that food scraps is considered to be a significant contributor to the school waste, 26.99% for primary schools, 23.97% for secondary schools, 20.40% for high schools, and the average waste generated in all education institutions can be calculated about 23.90% (wet weight) of the total amount of waste disposal.

According to Ho Chi Minh Department of Education and Training's statistical data[1], the city has 1.657 education institutions including pre-school, primary, secondary, and high school, amounting to 979,961 students in the whole city. Among these schools, 1,376 schools have organized serving boarding, adding up to 548,144 students have served lunch and afternoon snack[2]. With the generation rate of waste at school of about 0.23 kg/student/week, the total amount of waste generated daily from education institutions in Ho Chi Minh City can be figured at about 25.2 tons/day that contains mainly biodegradable waste, accounted for 65 – 90% (Nguyen Trung Viet, 2012). On the top of that, food waste composting has showed impressive attention in the literatures Donahue et al., (1998); Nakasaki et al., (1998); Lemus and Lau (2002); Das et al., (2003); Kwon and Lee (2004); Nakasaki and Nagasaki (2004); Cekmecelioglu et al., (2005); Komilis and Han (2006); Chang et al., (2006). Various researches have been taken to assess the influence of different bulking agents, additives, and types of composting system, however, in such cities like Ho Chi Minh, study on composting of food waste at centralize sources, schools and apartment, is still limited due to lack of land use, methodology, and human power. Hence, the objective of present work is to select a simple and suitable compost design for treating school's food waste in the conditions of Vietnam, especially in Ho Chi Minh. A case study was implemented in 2 schools in Tan Binh district aiming to compare technological efficiency in term of operation time and energy consumption and quality of finished compost by applying turned and forced aerated reactors. In addition, the study results can be applied as an operational guideline for composting the school food scrap. Later that can be applied on school soil as an amendment.

To achieve the above objectives, these contents have been carried out:

- Determining composition and volume of disposed food from school's cafeteria;
- Fabricating and performing 2 reactors, turned and forced aerated composters, for treating the disposed food;
- Assessing the maturity of composts and proposing a guideline for composting unwanted school food.

2. Materials and methods

2.1 Experimental design

In the study, a total of 2 reactors, 1 turned and 1 forced aerated bin, were prepared in each school. The composters was built with a 220L PVC pipe measuring 930 mm in height and 580 mm in inside diameter. A valve of Ø 27 mm is equipped at the bottom part of the reactors to collect leachate producing during composting. A layer of 200 mm gravel was filled into the reactors prior to filling of organic waste intending to accelerate leachate collection, and the top of gravel layer was covered with a wire mesh. The composting material is filled up to the height of waste reaching the mark of 500 mm. The lower part of forced aerated composters were connected with an air blower system introducing air into the waste mix through an Ø 15 mm pipe. Air was provided into the reactors by air blower RESUN model ACO – 003. Around the turned aerated reactors was perforated with a 27 mm holes, and the total number of holes is 28 holes per reactor. The reactors were also equipped with temperature probes recording temperature data twice a day. The details of each composter are as follows (Fig. 1).

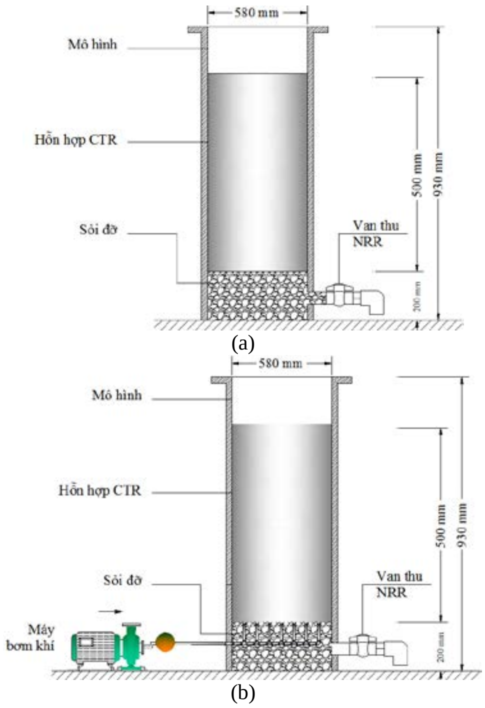
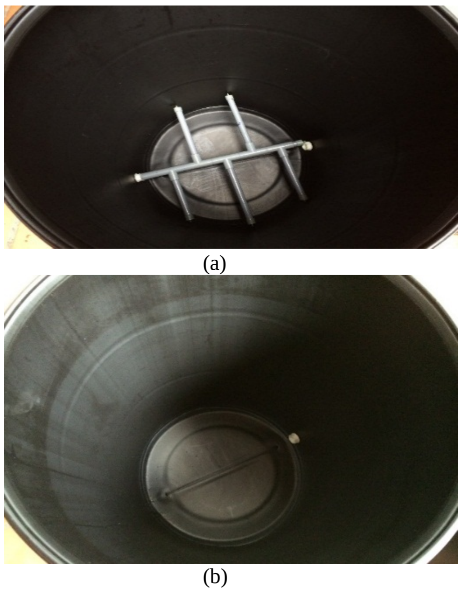


Fig. 1 Layout of composters. (a) turned aerated composter; and (b) forced aerated composter



[1] http://edu.hochiminhcity.gov.vn/
[2]http://www.baomoi.com/Nua-trieu-hoc-sinh-ban-tru-tai-TP-Ho-Chi-Minh-dang-an-uong-ra-sao/59/14993478.epi

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Fig. 2 (a) inside of forced aerated composter; and (b) inside of turned aerated composter.

(a)

(b)

Fig. 3 (a) Composters at Dong Da School; and (b) composters at Au Lac School.

2.2 Methodology

An examination in composition and quantity of school's food wastes was conducted at the kitchen of Dong Da and Au Lac School in 3 days. The volume of food waste (stored in 18 L vessel) was weighted (wet weight) by a 60 kg balance. The waste subsequently was spilled on the floor and mixed by a shovel to be sure that the mixture is turned properly. After mixing, the commingled waste was separated into 4 equal sub-portions, and a quarter of the mixture was taken. Turning and separating is carried out continuously until the quantity of residual quarter remains about 1 – 2 kg. Sample is transferred to the laboratory of Department of Environmental Technology and Management – Van Lang University for analyzing at the same day.

To analyze composition of food waste, the waste mixes (from Au Lac and Dong Da School) was weighted and transferred to a plastic vessel of 10 L. Next is adding 6 L of distilled water to the waste for diluting. Waste of different sizes is separated by a sieve of diameter of 2 mm. Ingredients segregated is starch (rice), cellulose (vegetables, bulbs, fruits), protein (meat/fish/boiled eggs), and bones (pork, beef, fish). Others waste considered as non-biodegradable such as nylon, plastic box is separated prior to weight the mixture. After sieving, the jumble is still blended with other tiny ingredients, grinded meat, chopped vegetables. It is then separated thank to the differential density. To do that, the mixture is whirled to make a vortex. The food of differential density is divided into distinct circle layers and taken out by a siphon pipe. The mixture of food waste is also used for analyzing the influent of compost material. Physiochemical characteristics of initial composting material are summarized in Table 1.

Table 1 Physiochemical characteristics of the waste materials used

No.	Parameter	Dong Da	Au Lac
1	pH	4.34	4.49
2	Density (kg/m^3)	737 – 829	796 – 860
3	Moisture (%)	77	85
4	VS (%)	82	74
5	Carbon (%)	45.5	41.1
6	TKN (%)[a]	3.0	3.0
7	Carbon to nitrogen ratio	15.1	13.6

Source: Department of Environmental Technology and Management's laboratory (2014); [a]Bijaya K. Adhikari et al., (2008)

Table 1 discloses that food scrap is an inappropriate material for making compost since its high in moisture and Carbon to Nitrogen ratio. For this reason, it is a necessity of adding sawdust and septic sludge as a bulking agent and an additive. Sawdust was collected from carpenter's shops in Tan Binh district. Septic sludge employed as an additive and an inoculum was brought from Hoa Binh Fertilizer Facility. The physiochemical characteristics of septic sludge and saw dust are illustrated in Table 2.

Table 2 Physiochemical characteristics of sawdust and septic sludge

No.	Parameters	Saw dustb	Septic sludgec
1	Moisture	7.24	44.6
2	C (%)	52.9	24.0
3	TKN (%)	0.59	3.01
4	C/N ratio	89.8	8.0

Source: Department of Environmental Technology and Management's laboratory (2014); [b]Ying Zhou et al., (2014); and [c]Le Minh Truong (2012)

In accordance with above results, raw materials were prepared in the following wet weight proportions.

Table 3 Proposed operation in 2 schools

No.	Parameters	Turned aeration	Forced aeration
1	Food remnant (kg)	1.00	1.00
2	Sawdust (kg)	0.36	0.36
3	Septic sludge (kg)	0.13	0.13
4	Aeration strategy	Turning	Blowing
5	Initial pH	6.5 – 7.5	6.5 – 7.5
6	Carbon to nitrogen ratio	25 – 35	25 – 35
7	Moisture (%)	55 – 60	55 – 60

Starting up

- Separating to remove unexpected ingredients such as nylon bag, plastic box;

- Well mixing commingled waste and dividing by 2 reactors;
- Sampling and analyzing influent parameters;
- Switching on the air blower (for the force aerated reactors).

Everyday

- Recording ambient temperature and temperature of composting masses. Temperature is monitored twice a day from 8:00 – 9:00 am and 18:00 – 20:00 at the center of the masses and 20 cm from the top;
- Turning 1 time per day to prevent too wet at the bottom (for the aerated reactor), or too dry (for the reactor without aeration);
- Checking and re-adding leachate in case of it is produced;
- Promptly and visually monitoring moisture content via temperature and fungi. Decreasing in temperature or appearing white fungi indicate that the mixture is too dry and need for re-moisture;
- Temperature's mass should be maintained at above >50^{o}C in the first 3 days to be sure that all pathogens, fungi spores, weed seeds are destructed. However, the temperature is controlled to the extent not to exceed 65^{o}C to minimize effects on microorganism activities. Aerated reactors are flowed continuously since it has started until hitting the peak (55^{o}C – 65^{o}C). When the temperature of compost mass starts to decrease and reaches the critical point of 40^{o}C, aeration is changed into intermittent mode, 15 minutes aeration and 30 minutes stop. The temperature of turned reactors is controlled through turning one a day. However, when the temperature of reactor exceeds the demand (especially during decomposition phase), turning frequency is increased until reaching the expected temperature;
- pH, carbon, and moisture are analyzed every 2 days;
- Compost is considered maturity when the temperature of the mingled waste reaches the ambient temperature and pH keeps constant for 5 days;
- Carbon and moisture analysis follows Standard Method, (2003), and determination of pH follows Test Methods for Examination of Composting and Compost, (2001);
- Maturity of composted product is assessed via Germination Index (GI %) to test for remaining phytotoxic substance in the compost, e.g Ammonia, and other forms of organic acid which occur in the immature product. Germination Index is conducted using Thai Agricultural Standard (2005), Appendix A, and the seed used is green bean.

3. Result and discussion

3.1 Food waste composition and its volume

Table 4 Composition and quantity of food waste generated at 2 study areas

Parameters	**Dong Da**			**Au Lac**		
	16/09/2014	**30/10/2014**	**31/10/2014**	**16/09/2014**	**30/10/2014**	**31/10/2014**
Weight (kg/day)	86 – 96	-	-	10 – 27	-	-
Density (kg/m3)	-	826	737	-	860	796
Moisture (%)	79	-	-	85	87	85
Rice (%)	35	18	44	63	77	26
Vegetable (%)	51	63	12	20	32	32
Meat (%)	10	11	12	11	16	2

The survey result reveals the significant difference in the composition and quantity of solid waste at 2 study areas, and the reason is due to the variation in scale and amount of student of each school. Other the explanation is difference in their grade. Au Lac is a secondary school and its student is more mature than Dong Da's student, a primary school, hence the quantity of food refuse in Au Lac is definitely less than that of Dong Da. However, result also demonstrates that moisture content and density differential between 2 schools can be negligible. The diversification in compositions of daily food waste also depends on type of food and student's taste. The result of analyzing composition of food waste at 2 schools reveals that food scrap contains mainly biodegradable organic matter, rice and cellulose. Hence, it is clearly if moisture and C/N ratio can be controlled properly food waste is an ideal material for composting. Besides, there is no evidence of fruit peels, root, and fresh bulbs in the composition of food waste since all materials for cooking is subject to preliminary treatment. From that point, it can be noted that due to the variation in food waste composition among days of a week, if considering composting food waste at school, there is a need for adjusting the ratio of food waste, a bulking agent and an additive to achieve the optimum performance.

3.2 Effects of aeration strategy on composting efficiency

During composting, temperature emerges as a most indicator indicating efficiency of the whole process. Temperature variation at the middle part of compost masses at 2 schools is presented in Fig. 4. Daily ambient temperature ranged from 28^{o}C to 33^{o}C, and during first few days, temperature of compost mass increased tremendously due to microorganism activities. In case of Au Lac, temperature of both types of reactors hit its peak at day 4th, which was 56^{o}C for forced aerated reactor and 60^{o}C for turned aerated reactor. It should be noted that in the turned aerated composter, temperature of above 50^{o}C could maintain in 3 days and longer than that of forced aerated composter, which was 1 day. Similarly, in turned aerated reactor at Dong Da School, temperature of composter reached its maximum, 50^{o}C, at day 3rd and was higher when compared to forced aerated reactor, meeting the peak of 50^{o}C at day 5th. Turned aerated reactor maintains the temperature of $\geq$ 50^{o}C at day 4th and longer than that of forced aerated composter, only in 1 day. The explanation for higher temperature of turned aerated reactors than forced aerated reactors is that ventilation have affected the amount of air passes through the material and led to the heat loss. Hence, during composting at 2 schools, turned aerated composters shows higher temperature than the others. However, operation results show that, the temperature difference in maturity phase, since day 6th in Au Lac School and day 7th in Dong Da School was inconsiderable. In this phase, aeration can cause no effect on organic decay efficiency due to the decrease in microorganism activities. In first 16 days, moisture content of turned aerated composter at Au Lac maintained in the range of 59 – 64%, and 59 – 66% in forced aerated composter. Similarly, moisture content of composter at Dong Da School was in the range of 51 – 66% in forced aerated composters, and 58 – 64% in turned aerated composter. Moisture content of compost masses at Au Lac and Dong Da after 44 day operation was 12% and 22%, and 22% and 10%, respectively. Variation in moisture content is illustrated in Fig 6.

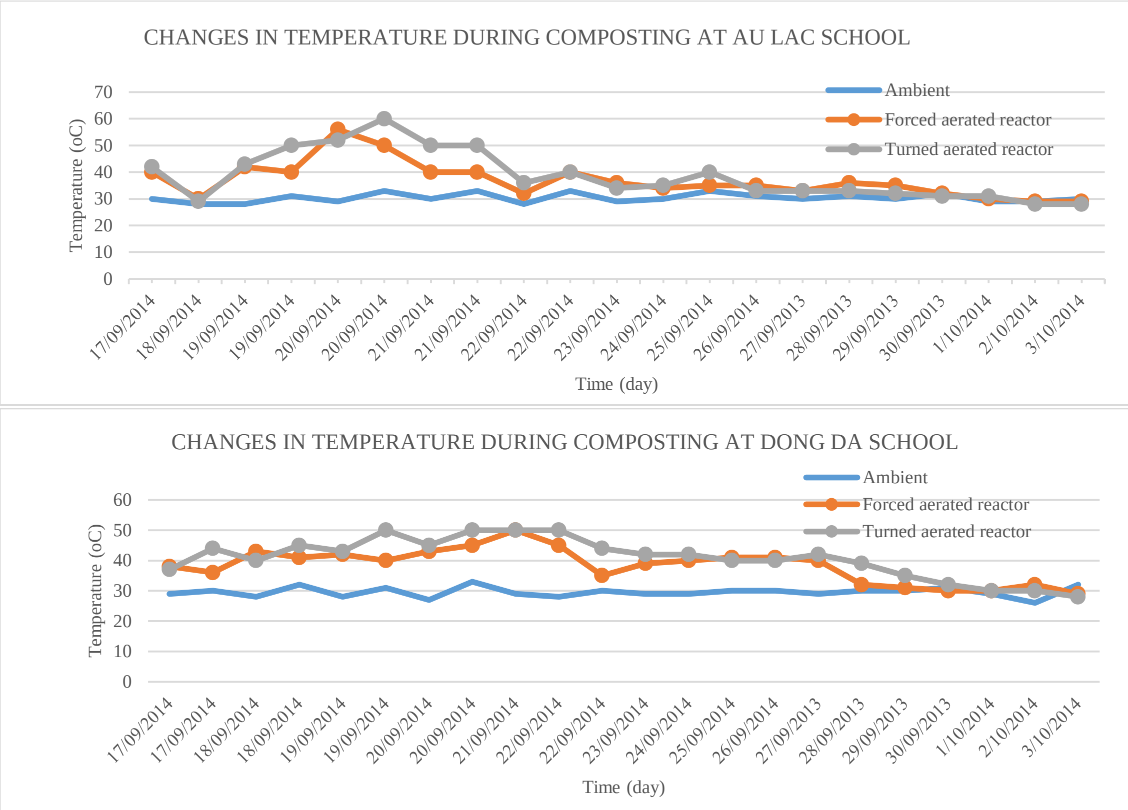

Fig. 4 Change in temperature with time.

During first 3 day period, pH of compost masses were less than the optimum required for microbial activities. Initial pH of composting material at Au Lac was 5.91 (forced aerated composter) and 5.37 (turned aerated composter). Initial pH of compost material at Dong Da was 5.01 (forced aerated composter) and 4.51 (turned aerated composter), and similar to a report of Adhikari (2008). The reliable reason is that present of organic acid in food waste. For the reactors at Au Lac, pH of composters reached the point of higher 6.50 at day 6th (6.70 at turned aerated composter and 7.20 at forced aerated composter) and faster than that measured in compost masses at Dong Da (pH higher than 6.5 at day 8th). The increase in pH value can be interpreted due to the decomposition of organic matter creates ammonium ($N\_NH_4^+$) under aerobic condition and increase in pH. pH of compost material after that started increasing slightly or reached plateau via shifting ammonium to nitrate and consuming material's alkalinity. Analytical result of reactors at 2 schools indicates that pH of forced aerated composter increased higher and faster than pH of turned aerated reactors. This means that ammonium produced in forced aerated composter is faster and higher than turned aerated composter. It is also a sign stating that the degradation of organic matter in forced aerated composter is better than turned aerated composter. However, it requires a well control of air flow whereas the compost mass is pushed to heat loss and affects the capacity of destructing pathogen as per mentioned. In matured period, pH values measured in composters at Au Lac, forced aeration and turned aeration, were 7.77 and 7.79, respectively. These values measured in Dong Da were 7.37 and 7.25, respectively. At this value, the reactors can escape from nitrogen loss due to convert of $NH_4^+\_N$ to NH_3_N at high pH.

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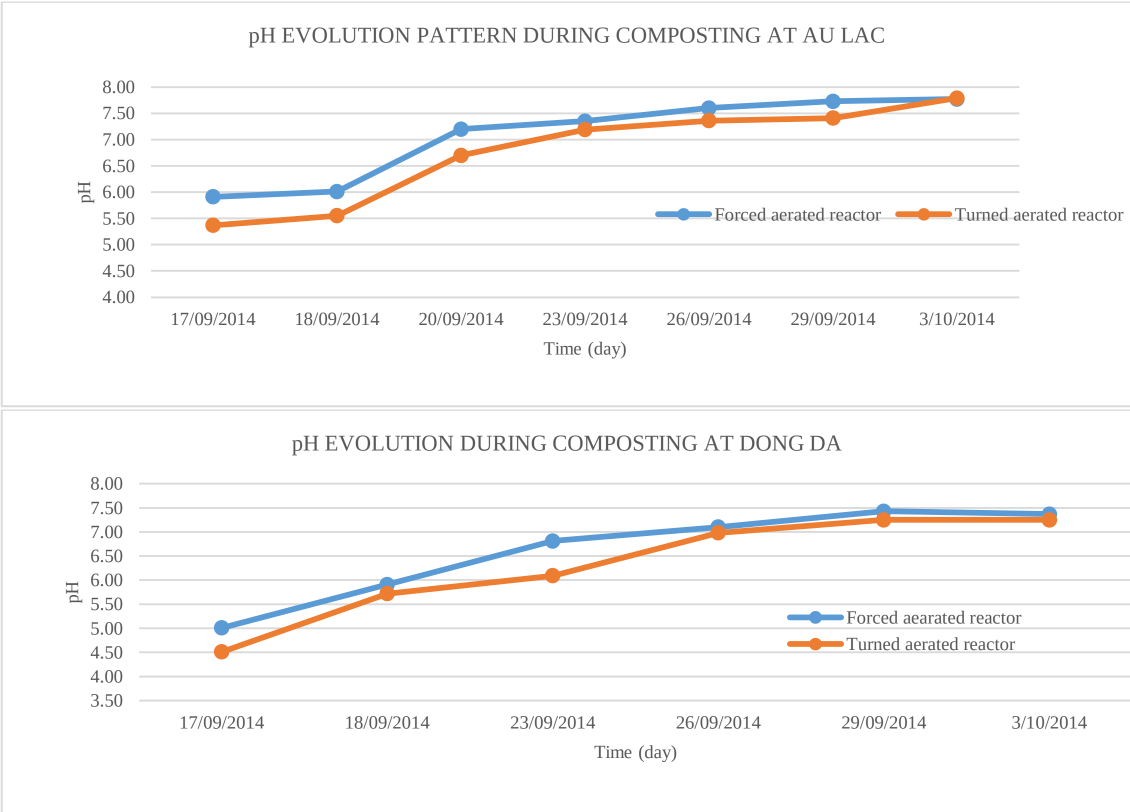

Fig 5 Change in pH in composters.

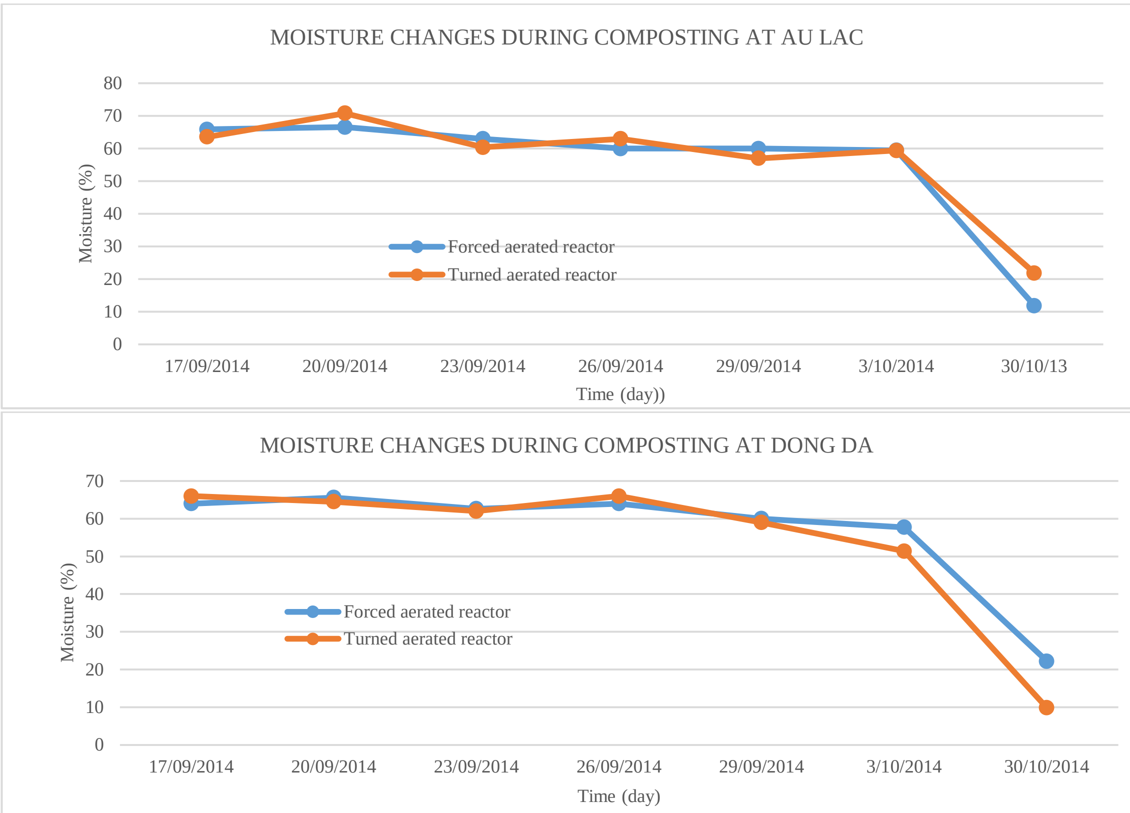

Fig 6 Changes in moisture content during composting

Carbon content decreased significantly during composting thank to microorganism activities converting organic matter into final product, CO_2, ammonia, and increasing inert content in reactors. Carbon change curves demonstrates that carbon ratio in forced aerated reactors at 2 schools tended to decrease faster in comparison with turned aerated reactors. During first 8 day, faster increase in temperature indicates that the degradation is taken place. However, when the temperature of reactors reached the ambient at day 9th, carbon content shows increase. The interpretation is due to the composition of composting material, food waste, sawdust, and additive. Beause sawdust has a hard and stable structure in compare with other, when microorganism finishes degrading organic materials to produce CO_2 and ammonium, only sawdust having a very high carbon content remains in the reactor. This is more clearly when analyzing organic content of finished compost after sieving at day 44, carbon content measured in forced aerated and turned aerated composters at Au Lac is 47% and 46% respectively, at Dong Da is 47% and 51% respectively.

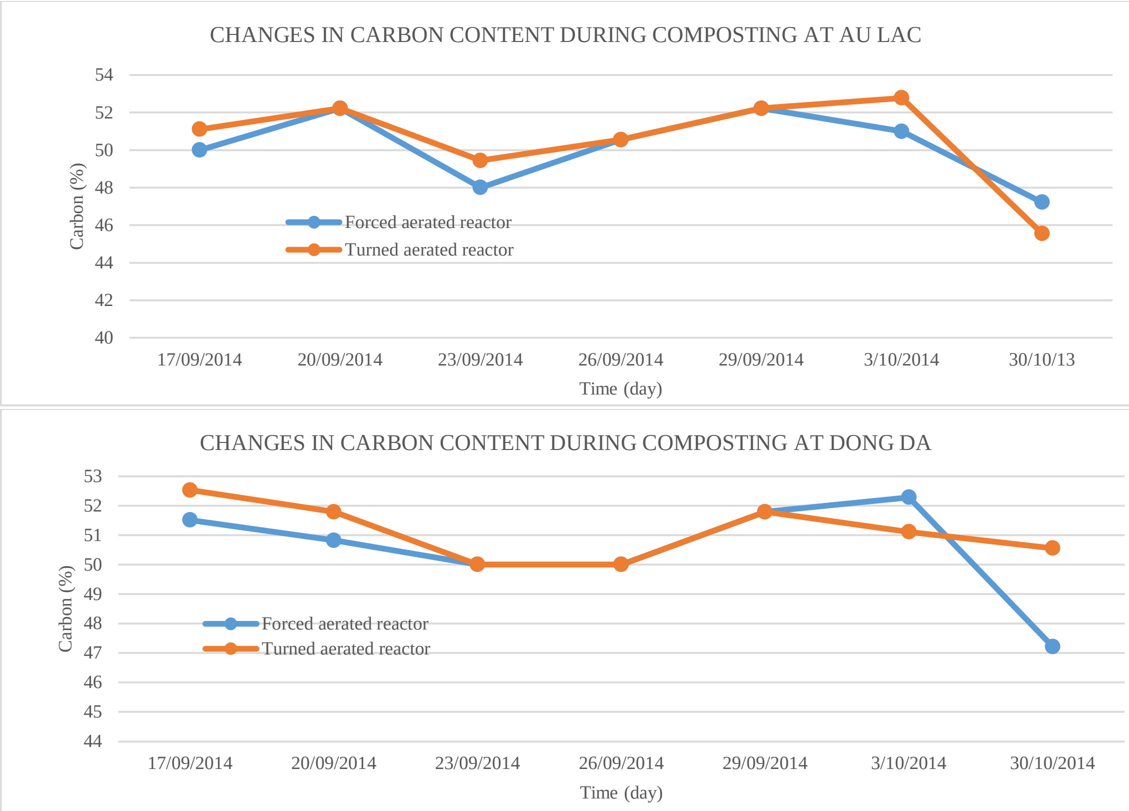

Fig 7 Carbon loss due to microorganism activities.

3.3 Assessing the maturity of composted products

Fig 8 Germination test for evaluating quality of composted products.

Germination test was conducted using green bean and the results are illustrated in table 5. Finished products from composters show a very high germination (≥ 90%), and this means that compost produced from food waste, sawdust, and septic sludge can be applied on soil in the schools as an amendment. One way ANOVA result provides that there are no significant differences in compost made by different models (Sig. > 0.05). Besides, all compost products obtains GI % of higher than 80%, and this means that composts have met the standard requirement. In addition, sample testing results give the values of GI (%) higher than 100%, and this is a proof that compost is suitable for plant growth.

Table 5 GI (%) test results

Reactors	**Germination rate**	**Root long**	**GI (%)**
Au Lac (aerated)	1.0	37.2	159
Au Lac (aerated)	1.0	26.1	84
Au Lac (aerated)	1.0	29.3	98
Au Lac (aerated)	1.0	32.3	128
Au Lac (turned)	0.9	26.1	100
Au Lac (turned)	1.0	33	106
Au Lac (turned)	1.0	26.1	88
Au Lac (turned)	0.9	23.5	84
Dong Da (aerated)	1.0	35.5	152
Dong Da (aerated)	1.0	34.7	112
Dong Da (aerated)	1.0	41.7	140
Dong Da (aerated)	1.0	34.9	138
Dong Da (turned)	1.0	41.8	179
Dong Da (turned)	1.0	31.4	101
Dong Da (turned)	1.0	31.7	106
Dong Da (turned)	1.0	38.1	151
Control	0.9	26	
Control	1.0	31.1	
Control	1.0	29.8	
Control	0.9	28.1	

4. Conclusions and recommendations

4.1 Conclusions

Base on the experiments, these following conclusions can be obtained:

- Food wastes generated from school can be an appropriate material for composting;
- Composition and quantity of daily waste varies depending on type of food served. Hence, in order to get the optimum efficiency, adding of additive and bulking agent at a suitable ratio is a requirement in order to accelerate microorganism activities, balance C/N ratio and control moisture;
- Aeration introduces an impressive influent on the overall performance efficiency. However, the result also reveals that the difference in the quality of compost produced from turned and forced aerated composter is negligible. Therefore, to save operation cost, composting of food remnant can be implemented by using turned aerated composter;
- Time required for composting food remnant is 44 days. In which, stability will take place up to day 6 – 8th, and maturity take place about 36 – 38 days;
- For the forced aerated composters, maximum temperature could be achieved at 50 – 56^{o}C. This value in turned aerated composter was 50 – 60^{o}C;
- After 44 days of operation, the pH of turned and forced aerated composter in Au Lac was 7.77 and 7.79 and carbon decreased from 50% to 47 % and 51% to 46%. Similarly, pH values of the composting masses in Dong Da were 7.37 and 7.25 Dong Da and carbon content decreased from 52% to 47% and 53% to 51%.
- Finished composts can be used as a soil amendment.

4.2 Recommendation

- Compost portions retain on the sieve can be reused as an inoculum for next batch composting;
- Composting food waste should be studied with other additives and bulking agents;
- Germination test should be carried out using other seeds;
- Due to the main composition of food waste is rice, cellulose, in the next study, compost can be done by vermicomposting.

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