Bokashi Composting Study at Project Farm of the Management Agreement Scheme at Lai Chi Wo Enclave

Introduction and Background

Lai Chi Wo Village is located in a remote protected area without any direct driveway for vehicles. The community relies on boats or a certain amount of human power to transport necessities and other materials for daily lives. Since the community revitalization projects started a decade ago, eco-friendly agriculture practices have been adopted for the conservation of habitats and biodiversity at Lai Chi Wo.

The farming community adopts the organic farming principles of HKORC and genetically modified (GM) crops, chemical fertilizers and pesticides are prohibited.

Recycling and reusing the materials within the community are encouraged, which can reduce the dependence on importing materials for agricultural activities. Therefore, applying composting of the organic materials of farm residues, animal dung and food waste would be one of the potential nature-based solutions on resource management.

According to the United Nations Environment Assembly in March 2022 Nature-based solutions are actions to protect, conserve, restore, sustainably use, and manage resources and varied circumstances in order to addressing social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits.

Composting methods have been operated currently on a domestic scale or relatively small scale by some community farm groups. It has been observed that some semi-products of traditional open-air composting may produce some unpleasant smells, due to several factors, such as types of materials and insufficient air supply for aerobic bacteria. Wild animals such as wild boars, voles, rats, etc. were drawn by the strong odour of compost to enter the farmland. Since frequent public activities take place in the project farmland, aforementioned issues would be considered when operating the compost study in the area.

The effective microorganisms (EM) have the ability to inhibit bad microorganisms. It can be beneficial to both the microorganism community in soil and the plant growth.

This study targeted to figure out the feasibility of Bokashi Composting in Lai Chi Wo to recycle the organic resources to soil conditioner and fertilizer to enhance the productivity of the farmland more sustainably, efficiently and cost-effectively.

“Bokashi” is a Japanese word which means “fermentation”. Similar to other composting methods, EM is involved. EM present in the Bokashi mixture or bran ferments these materials into organic soil conditioner, solid and liquid fertilizer.

Bokashi composting involves anaerobic fermentation. Therefore, buckets with lids were essential to the experiment in this study. The product of the anaerobic fermentation was the semi-product and it was mixed with the soil afterwards. Since the semi-product was acidic and it possibly hurt the plant if it was directly used in the soil. An extra aerobic curing process was necessary to turn the anaerobic compost semi-product to mature compost product.

In this study, a great amount of effective microorganisms were involved in the experiment. The Bokashi bran utilized for the experiment was from Kadoorie Farm and Botanic Garden, a reliable supplier of agricultural materials in Hong Kong. EM materials or EM liquid can be found in different sources and the Bokashi bran can be even made in the village, but the process takes time. To consider the cost, time, materials in the area and the facilities, only this source of EM material was chosen for conducting the experiment in this study.

Varied amounts of Bokashi bran were implemented in different buckets of compost. It targeted to find out if the quantity of the substance containing EM used in Bokashi composting would bring proportional enhancement of the soil productivity. During the fermentation process, temperature and pH value were monitored. After the curing process of the compost, the mixture of compost materials and the soil was tested in the content of nutrients. The mixture was applied on turnip planting later. The germination rate, growth of plants, and the length, weight and taste of the turnip were recorded and compared.

Objectives
This study aimed to figure out the methods which can recycle and reuse the organic materials in Lai Chi Wo community for farm use more sustainably, efficiently and cost-effectively. Using different amount of EM materials, it targeted to figure out the optimal amount of EM for composting which could suit the rural community. Local nutrient transformation would be promoted in Lai Chi Wo community.

Assumptions
- The quantity of EM is equal in each gram of the Bokashi bran.
- The nutrient content of the soil is equal in each setting.
- The nutrient content of the compost materials is equal in each setting.

Experiment Setup
There are 3 phases of the experiment.
Phase 1: Bokashi anaerobic compost and compost curing
- Location: Sheltered farm shed
- Duration: 5 weeks
- Items to be monitored: Temperature and pH value of the compost materials after 4 weeks, before mixing with soil

Phase 2: Mixing the semi-product of compost materials with soil from the farm
- Location: sheltered farm shed
- Duration: 4 weeks
- Items to be monitored:
    i. Temperature and pH value of the mixture of the compost materials and soil
    ii. Content of nutrients and minerals: total Nitrogen (N) content, contents of Phosphorus(P), Potassium (K), Calcium (Ca), Magnesium (Mg), Boron (B), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo), Zinc (Zn), Cadmium (Cd), Arsenic (As)

Phase 3: Turnip planting
- Location: open area next to the sheltered farm shed (The bags were moved into the sheltered farm shed when there were poor weather conditions)
- Duration: 7 weeks
- Items to be monitored:
    i. Germination days of seeds
    ii. Quality of the harvested turnip : appearance, length and taste of turnips

Materials
Phase 1:
- 4 sets of 100L compost bucket with filter, lid and tap
- Bokashi bran (Total 6kg)
- Soil in the farm

- Bricks for supporting
- Thermo-pH metre
- Bottles for receiving the compost fluid
- Cups for filling compost buckets
- Shovels
- Large buckets for containing raw materials and simple mixing before filling the compost buckets

- Compost raw materials (farm residues, raw food waste from community, animal dung; the materials will be mixed and filled the buckets)
- Weeds
- Leaves and stems
- Paddy residues
- Lotus residues
- Fruit peels
- Rotten fruits
- Banana tree residues
- Cow dung
- Other farm residues and raw food waste from community

Phase 2:

- 200L buckets
- Semi-product of compost materials from the compost buckets
- Water

Phase 3:

- Turnip seeds
- 5 Round-shape planting bags (60cm diameter)
- 5 Insect protection nets
- Mature compost materials
- Thermo-pH metre

Methodology, Results and Findings

In phase 1, it took 5 weeks from 15/8/2023 to 19/9/2023 to conduct the anaerobic composting process. The compost materials were collected in Lai Chi Wo village and the farmland 1-2 days before putting into the compost buckets. 4 buckets were marked as "Bucket A", "Bucket B", "Bucket C" and "Bucket D".

The materials were separated into different layers. Each layer of raw compost materials (e.g. food waste, rice bran, plant residues, etc.) was covered with a thin layer of soil. After putting the raw compost materials and soil layers, a thin layer of Bokashi bran was spread on top.

The above process repeated around 10 times until the buckets were full. Around 80L of raw compost materials were placed in each bucket.

The amount of Bokashi bran put into the buckets varied. For Buckets A, B and C, different portions of Bokashi bran in 3 kg, 2kg and 1kg were added respectively. For Bucket D as control, had no Bokashi bran added.

Photo 1. Raw composting materials: lotus and fruit residues

Photo 2. Raw composting materials: cow dung and weeds


Photo 3. Raw composting materials: banana leaves


Photo 4. Raw composting materials: weeds

Photo 5. Raw composting materials: paddy stems

Photo 6. Raw composting materials: paddy residues

Photo 7. Putting the raw composting materials into the buckets

Photo 8. Putting Bokashi bran on top of the raw materials and soil layers

Photo 9. Filling the bucket around 90% volume

Photo 10. Putting all the raw materials in the buckets and ready to close the lids

Photo 11. Closing the buckets with lids

Temperature and pH value of the compost materials of each bucket was recorded as below.

	Bucket A		Bucket B		Bucket C		Bucket D	
	pH	°C	pH	°C	pH	°C	pH	°C
Week 0 (15/8)	4.6	33	4.8	33	5.3	31	5.5	31
Week 1 (22/8)	4.8	34	5.4	34	5.4	37	5.2	36
Week 2 (29/8)	3.6	30	4.5	30	3.6	30	4.6	30
Week 3 (5/9)	4.1	30	4.0	30	3.8	30	4.3	30
Week 4 (12/9)	4.6	30	4.1	30	4.0	30	4.4	30
Week 5 (19/9)	4.3	32	4.4	31	4.1	31	5.2	31

Table 1. Temperature and pH value of Bucket A to D in phase 1 composting

Photo 12. Measuring the pH value and temperature of the compost

The temperature of each bucket was close to the ambient temperature. There was no significant change during this phase. The pH values showed that the compost materials were acidic. The pH value slightly fluctuated but remained around pH 4-5. After setting up for a week, the pH values of all buckets slightly increased, it was suspected that the high temperature would influence the process. The temperature in the shred shelter was around 36°C in the daytime. Although there was no Bokashi bran in Bucket D, the pH value also slightly fluctuated which would possibly result from other soil organisms' aerobic activities in the bucket.

In Phase 2, from 19/9/2023 to 17/10/2023, it took 4 weeks to cure the compost materials. The semi-product was mixed with the soil in a 1:1 ratio. The mixture was put into four big grey buckets marked as "A", "B", "C" and "D" respectively. These four big grey buckets were placed in the sheltered farm shed for 4 weeks. There was water loss from the mixture due to evaporation. 2L of water was added to each bucket every week. Mixture of each bucket was stirred.

Temperature and pH value of the mixture of the compost materials and soil was recorded as below.

	Bucket A		Bucket B		Bucket C		Bucket D	
	pH	°C	pH	°C	pH	°C	pH	°C
Week 5 (19/9)	4.3	32	4.4	31	4.1	31	5.2	31
Week 6 (26/9)	4.5	31	4.4	31	4.3	31	5	31
Week 7 (3/10)	5.4	33	5.3	33	4.4	33	4.8	33
Week 8 (10/10)	5.3	31	5.3	31	5.2	31	5.4	31
Week 9 (17/10)	5.3	29	5.2	29	5.2	29	5.2	29

Table 2. Temperature and pH value of Bucket A to D in curing process

The temperature of each bucket was similar to the circumstance temperature. There was a trend of slight increase of the pH value of Buckets A, B and C from week 5 to week 9. The change of pH value of Bucket D was the smallest and it remained at around pH 5.

After 4 weeks of curing process, some of the plant residues such as banana leaves, paddy residues and stems remained in their original shape. Other compost materials such as fruit, fruit peels and cow dung were decomposed and they were not recognised from the mixture.


Photo 13. Curing the semi-product after anaerobic composting

After the curing process of the compost, the products were tested in the content of nutrients and minerals, included total content of Nitrogen (N), and the content of Phosphorus(P), Potassium (K), Calcium (Ca), Magnesium (Mg), Boron (B), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo), Zinc (Zn), Cadmium (Cd), Arsenic (As).

Most of the tested items were the essential nutrients for plant growth except Cd and As in turnip planting. Cd and As were heavy metal easily found in the soil in Lai Chi Wo. There were no industrial activities in the upper streams of Lai Chi Wo. However, the heavy metal naturally existed in the soil and rocks.

Paddy residues were included in the raw materials of the compost, therefore the content of Cd and As were included in the test.

The test report tables were issued in November 2023 by Castco Testing Centre Limited.

	A	B	C	D

Total nitrogen content	mg/g	%	mg/g	%	mg/g	%	mg/g	%
	4.22	0.422%	4.98	0.498%	5.20	0.520%	4.13	0.413%

Table 3. Total nitrogen content of compost samples of A to D

	A	B	C	D
	mg/kg	mg/kg	mg/kg	mg/kg
Phosphorus(P)	2100	2700	2200	1700
Potassium (K)	11000	14000	13000	11000
Calcium (Ca)	3800	4300	3200	2800
Magnesium (Mg)	1300	1500	1300	1100
Boron (B)	<1.0	<1.0	<1.0	<1.0
Copper (Cu)	12	12	12	11
Iron (Fe)	18000	15000	14000	14000
Manganese (Mn)	210	240	210	190
Molybdenum (Mo)	2.0	2.4	1.5	1.6
Zinc (Zn)	150	150	110	120
Cadmium (Cd)	<1.0	1.1	<1.0	<1.0
Arsenic (As)	94	79	71	120

Table 4. Chemical content of compost samples A to D

The high Arsenic (As) level and marginally high content of Cadmium (Cd) exceeded the HKORC Soil and Compost Quality Standards (2011) . The content of As and Cd in the cured compost samples were expected (As and Cd have been estimated to come naturally from the composition of volcanic rocks of this region instead of anthropogenic source).

Different types of raw materials for composting in the previous phase were distributed to each bucket evenly. Although the contents of P, K, Ca, Mg, Mn, Mo and Zn of bucket B compost sample were slightly higher than the other samples, the sample size from each bucket was small and it could hardly conclude whether there would be a significant difference. There would be potential to figure out if the amount of EM and the nutrient content of the compost in future study are correlated in future study.

In phase 3, from 17/10 to 6/12, it took around 50 days to plant turnips with the mature compost in the planting bags. The germination time, growth of plants, and the length, weight and taste of the turnip were recorded and compared.

There were 5 planting bags marked as “A”, “B”, “C”, “D” and “E”. The growing media of Bags A to D are derived from the materials from Bucket A to D respectively. In Bag E, soil from the farm was utilised to plant turnips directly.

Photo 14. Planting the turnips in planting bags

In each planting bag, there were 10 holes marked 1 to 10 for putting the turnip seeds. Two consecutive holes are around 15 cm apart. There were 2 seeds in each hole.

The turnip seed type chosen was “Chinese Radish SL 13”, which was from Hong Kong Clover Seed and it was suitable for South China autumn weather conditions. The suggested sowing time in Hong Kong would be September to October. It would be a very fast-growing turnip variety with 45 to 50 days maturity and with high heat and rain tolerance, suitable for early autumn sowing. The suggested germination day would be around 4 days.

Watering daily or once every two days once the turnip seeds were planted except on rainy days. During the turnip planting process, no other fertilizers or soil conditioners were added to the planting bags.

Photo 15. Marking the seeds in the planting bags

The planting bags were placed at open area next to the sheltered farm shed. The bags were moved into the sheltered farm shed temporarily in days of poor weather such as typhoons. Since there were many birds and wild creatures nearby, to prevent the turnip seedlings from damage, the planting bags were protected with insect net.

Photo 16. Protecting the planting bags with nets

Photo 17. Turnip seedlings of bag A

Photo 18. Turnip seedlings of bag E

During the planting period, the pH value, temperature and the humidity of each bag of soil were measured. Besides, the germination rate, growth of plants, and length and taste of the turnip were recorded and compared.

	A	B	C	D	E
Germination rate	90%	90%	90%	80%	100%

Table 5. Germination rate of A to E

	A			B			C			D			E		
	pH	°C	RH	pH	°C	RH	pH	°C	RH	pH	°C	RH	pH	°C	RH
Week 9 (17/10)	5.3	29	75%	5.2	29	75%	5.2	29	75%	5.2	29	75%	6.4	29	75%
Week 10 (24/10)	6.4	26	75%	6.2	27	75%	6.4	26	75%	6	26	78%	6.3	26	75%
Week 11 (31/10)	6.0	30	77%	6.4	30	76%	6.1	29	76%	6.2	28	77%	6.1	28	77%
Week 12 (7/11)	6.8	23	76%	6.5	24	75%	6.3	24	76%	6.4	24	77%	6.3	24	77%
Week 13 (14/11)	6.7	22	75%	6.4	22	75%	6.7	21	76%	6.8	21	76%	6.5	21	74%
Week 14 (21/11)	6.0	21	74%	6.5	20	75%	6.4	20	75%	6.7	20	76%	6.8	20	72%
Week 15 (28/11)	6.1	23	72%	6.6	22	76%	6.3	22	75%	6.3	22	75%	7.0	21	75%
Week 16 (5/12)	6.3	20	66%	6.8	20	62%	6.4	19	73%	6.7	19	56%	6.8	19	65%

Table 6. pH, temperature and relative humidity of soil of A to E

	A	B	C	D	E
Average leaf length cm Ranking	34.0cm 1st	26.2cm 3rd	30.1cm 2nd	25.8cm 4th	18.5cm 5th
Average root length cm Ranking	17.5cm 3rd	21.3cm 1st	14.2cm 4th	20.2cm 2nd	13.5cm 5th
Average total length cm Ranking	51.5cm 1st	47.5cm 2nd	44.3cm 4th	46.0cm 3rd	32.0cm 5th
Average diameter cm Ranking	2.4cm 4th	3.8cm 1st	3.6cm 2nd	3.2cm 3rd	1.6cm 5th
% of “Black-heart” (infected by fungal or bacterial pathogen)	0%	0%	0%	0%	0%

Taste (e.g. sweet or bitter) Ranking: 1st is the best, 5th is the worst.	3rd	1st	4th	2nd	5th
Texture (e.g. smooth or rough, much or less fiber) Ranking: 1st is the best, 5th is the worst.	3rd	1st	4th	2nd	5th
Average ranking score (Smaller the amount, the better the average performance is.)	2.5	1.5	3.3	2.7	5.0
Overall performance ranking	2nd	1st	4th	3rd	5th

Table 7. Turnip growth performance of A to E

*Remarks: Around half of the turnips were bitten or damaged by rats 1 week before harvesting. The number of turnips of each bag and the weight of the turnips were not counted as turnip growth results. The taste and the texture of the turnips were evaluated by 5 farmers and villagers and the rankings of “Taste” and “Texture” were summarized by evaluators’ comments.

Photo 19. Turnips from bags A to E

Recapping the setting of the experiment, there were 3 kg, 2kg and 1kg portions of Bokashi bran in “A”, “B” and “C” and there was no Bokashi bran in “D” and “E”. For “E”, there was no compost materials and only soil from the farm.

There were some observations from the experiment. This pilot study would provide some insights for further investigations regarding composting.

1. The turnip growth conditions of A to E were compared in the experiment. In terms of gemination rates, conditions of different stages, size and taste of the turnips, A to D performed similarly, but E performed obviously differently. The sample size was relatively small. At this stage, there was no evidence to support the correlation between the amount of EM (from the Bokashi bran) and the productivity of the compost soil or the amount of nutrients released by the food waste and the plant residues.
2. Although no Bokashi bran was used for sample D, the overall growth conditions of the turnips in D were similar to those of A to C. It could be possibly related to the digestion activity of the EM from the soil which was put on top of each layer of raw compost materials in the anaerobic composting stage. There are many sources of EM for composting. Because of limited time, to ensure there would be a certain amount of EM, Bokashi bran from KFBG was chosen. In future study, the amount of the EM in the soil can be monitored. The tests can be conducted again without using Bokashi bran, but directly the native EM from the farm soil or make the bran by leftover rice from the village.
3. Compared with E, the turnips of A to D were much bigger in length and diameter. By inference, the plants grew better in the soil with compost materials. It was possibly accounted for the enhancement of the soil texture and the nutrients released from the compost materials.
4. Aforementioned, the EM for composting was not only from the Bokashi bran. There were unknown amounts of EM and other living organisms in the natural environment. Nevertheless, adding Bokashi bran which was from a reliable source would provide a certain amount of EM to decompose the composting materials. The optimal ratio of the amount of EM and the raw materials was not figured out in this stage.
5. Recording the root part of the turnips, the average root length of B was the greatest. Theoretically, nitrogen, phosphorus, and potassium are the three primary nutrients essential to plant growth. Potassium is important to root growth. It could be accounted for the richest content of potassium in soil of B according to the laboratory test of chemical analysis. However, the raw materials were evenly distributed to each bucket to the greatest extent. The ratio and the types of the raw materials and the nutrient releasing rate of the compost materials are also worth to be analyzed in the future.
6. According to farm records, there were around 10-15% of turnips of each crop with a “black-heart”, infected by fungal or bacterial pathogens”. In this experiment, no turnip was found with a “black-heart” in the root part. It hardly reflected whether there was a relationship between using compost materials and the pathogen infection of turnips.
7. Recording the leaf part of the turnips, the average leaf length of A was the greatest. Nitrogen is important to leaf growth of plants. However, referring to the total nitrogen content test, A was not the highest among the sample. For the other two primary nutrients of plants, the contents of potassium and phosphorus in soil of A were not the highest. There would be other factors influencing the plant growth which could be investigated further.
8. It is suggested to use more plants, such as leafy vegetables to compare in future study to see if there are any differences between the growth conditions of the leaf, root and other parts.
9. Compared with aerobic composting, the duration for anaerobic composting would be longer. Moreover, it took around 1 more month to cure the semi-product from the composting bucket. However, it was observed that the anaerobic composting method required less effort to store and turn the materials. During the experiment period, there were several typhoons and heavy rainstorms and floods in the area. The composting materials were inside the buckets with lids. Therefore, they could be kept successfully and not easily washed away by heavy rain and strong wind.

Limitations and Recommendations

During the experiment, the water loss due to evaporation was relatively serious and around 2L of water was added to each bucket in the curing process. The water loss varied according to the weather and the evaporation rate. The refilled water needed by the EM in the buckets would theoretically vary. The constant water refilling process would possibly influence the EM activities in the buckets.

Photo 20. Low water content of soil

Due to limited resources, the sample size of the experiment was relatively small. It would be a pilot study of Bokashi compost operation in the remote rural village farm. It is suggested to conduct the experiment more times to see if there is any relation between the nutrient content of the compost product and the amount of EM from Bokashi bran to carry out the anaerobic decomposition of the raw materials from domestic food waste and farm waste.

Aforementioned, there were many birds and wild creatures nearby. Although the net could to a certain extent protect the turnips from being attacked by birds, the net could not prevent the turnips from being eaten by insects and rats. The rats could break through the net and climb into the planting bags, especially when the turnips were close to be mature for harvest.

Although rat traps were placed around the experiment zone after realizing the rats' activities, some of the turnips were bitten in early December. In the future, if there will be similar experiments, more protection methods should be implemented.


Photo 21. Turnip leaves bitten by insects


Photo 22. Turnips eaten by rats of bag B


Photo 23. Turnips eaten by rats of bag C

If there would be more time and resources, the EM materials can be generated in the village with leftover rice which can be collected from the villagers and the stores nearby, and no need to order $50/2kg Bokashi bran from outside.


Photo 24. Fungal activities inside the composting buckets

Conclusion

This was a pilot compost study in remote villages. It reflected the impacts on compost to the soil and the plant to certain extent by comparing the results of turnip planting with and without compost materials. It provided insights on how to manage the food waste and plant residues in the village and the farm. It has demonstrated how to recycle local nutrients and reuse the resources. There was no evidence to support the correlation between the quantity of effective microorganisms and the productivity of the compost soil or the quantity of nutrients released by the food waste and the plant residues. The optimal ratio of EM and raw materials was not figured out. Despite these, the plants grew better in soil with compost material. It was possibly accounted for the enhancement of the soil texture and the nutrients released from the compost materials. The need for more future research in this area, as well as the development of sustainable management of food waste and farm waste is recommended.