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Composting and Compost Use: Practices by Small Rural-Urban Farms, Communities and Families

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Abbreviations

CAU	China Agricultural University
EC	Electric Conductivity
FiBL	Research Institute of Organic Agriculture (www.fibl.org) at Frick, Switzerland
MARA	Ministry of Agriculture and Rural Affairs
MoHurd	Ministry of Housing and Urban-Rural Development
NDRC	National Development and Reform Commission
SDC	Swiss Agency for Development and Cooperation (www.deza.ch)

1. Introduction

Since 2004, China has become the largest waste producing country in the world. Now it generates 400 million tons of solid waste every day with annual increasing rate of 8%. At global level, the World Bank warns that the global waste will increase by 70% reaching 3.4 billion tons by 2050 in a business-as-usual scenario (Silpa Kaza, 2018).

Figure 1: Urban waste increase in Beijing and China

With the rapid economic development and the rising consumption level, the amount of urban solid waste is increasing dramatically in China, as showed in Figure 1. In terms of the content of the urban solid waste, organic waste accounts for over 50% in mid-income developing countries as China and India, while this figure is about 30 to 40% in developed countries as Switzerland. China statics show that the major methods dealing with the organic waste at present is landfill (about 52%) and combustion (about 45%), without any information about organic waste composting.

Recognizing the urgency to address the issue, in 2017, the State Council of the People's Republic of China reposted the Action Plan on Household Waste Classification Mechanism (AP on Waste) that was co-proposed by the National Development and Reform Commission (NDRC) and the Ministry of Housing and Urban-Rural Development (MoHurd). The AP on Waste stated the principles and objectives of household waste management that are Reduction, Resourcing and Bio-safety Disposal.

Despite above regulations, in reality, the organic waste, particularly the large amount of household organic waste are not disposed in an environmentally friendly manner. Main reasons are lack of operational regulations that encourage the bio-safety waste disposing. Public awareness is very low. General public and communities are lack of knowledge with regard to waste classification and waste compost. The organic waste is part of the nature, and shall be recovered as resources returned to the soil. There are various resource recovery technologies, for instance composting, is regarded as the best solution that transform the organic waste into humus. Composting reduces the final amount of waste disposal for burning or landfill.

In recent years, Chinese government attaches high attention to the development of ecological agriculture by defining the goal of zero increase of chemical fertilizer and pesticide by 2020. Promoting the resourcing and reuse of agricultural waste, substituting chemical fertilizers for organic fertilizers has received strong government support. Composting is regarded as an effective measure to reduce agricultural waste, transforming straws and livestock manures into organic fertilizers and soil improver.

In the long history of China agriculture development, composting was quite common for small farmers. In recent three to four decades, traditional composting in agriculture production has been lost, giving the way to chemical fertilizers for pursuing yields. The results are degraded soil quality and high occurrence of plant diseases and wide use of pesticides. Having recognized the negative environmental and ecological impacts of excessive chemical inputs, farmers turned to organic fertilizers and compost to improve the soil health substantially from long term perspective.

Taking into account the high amount of urban organic waste generated, and the agricultural waste generated by small to medium sized farms, the Swiss Agency for Development and Cooperation (SDC) initiated the small action on organic waste composting, aiming to reduce total waste generation, reuse and resource them as useful waste through composting.

2. Composting practices by farms, communities and families

2.1 Background of SDC funded small action on organic waste composting

Recognized the issues of household kitchen waste in Chinese cities and resourcing opportunity at the large number of small to medium sized peri-urban farms, SDC initiated the small action on organic waste composting to **Reduce** the waste generation by **Resourcing** the organic part, thus improving the soil health. The small action has below two outcomes:

Outcome 1: select communities and farms to pilot the organic waste compost

Outcome 2: communication for public awareness raising and policy influencing

To achieve above objectives, SDC cooperated with the Yifendi farm (see profile below) practicing various composting techniques, which constitutes the major content of this report. In addition, SDC partnered with the Friend of Nature launching the composting at Beijing Qiming kindergarten, where fresh kitchen waste generated by the kindergarten, and the garden waste as tree branches available at kindergarten were input materials for composting. Similar composting method was practiced at the Swiss Embassy also with the results tested. Due to various reasons, household kitchen waste composting at one community was not able to be carried out as planned. However, Dr. Liyan WANG of SDC practiced the Bokashi digestating method since 2018, and influenced her Swiss colleagues. Test results of the liquid digestate from one Bokashi bin are included in this report.

Figure 2: Mr. Yan at the composting event at Yifendi farm

Figure 3: Mr.Fuchs gave training to international students of CAU

With the progressing of the project, below three expert groups provided substantial guidance to the project, which has made this small action solid and fruitful:

Mr. YAN Jiacheng, a permaculture lecture was first invited to Yifendi farm in May 2019. He visited two times the Yifendi farm and farms near Yifendi, and provided valuable field guidance not only to composting, but also to the greenhouse plantation and disease suppression in general.

Mr. Jacques Fuchs, a composting expert from the Research Institute of Organic Agriculture in Switzerland (FiBL), delivered the master courses on composting at the China Agricultural University (CAU). Taking the opportunity of his mission to China in October 2019, Mr. Fuchs was invited by SDC to visit Yifendi farm. Mr. Fuchs guided the Yifendi farmers on all practical issues confronting them in composting, in terms of the input materials and ratios, attention in turning the compost piles, control of temperature and moisture of the pile, compost use, places for composting and compost storage etc.,

Prof. QIAO Yuhui and her team at the CAU were mandated by SDC to follow Yifendi composting practice, taking samples of compost and soil before and after compost use, and made laboratory tests and analysis. Work of CAU is the basis of the core of this report.

2.2 Profile of Yifendi farm

Located in the north Changping suburb, Yifendi farm has 120 Mu (1 ha=15Mu) rose garden, 50 Mu greenhouses planting vegetables, and 50 Mu land planting maize mainly. In the six suburbs round Beijing, there are about 600 such 50 to 200 Mu small to medium sized farms that produce vegetables and fruits supplying mainly citizens in Beijing.

Figure 4: A small tiller machine at Yifendi farm

Yifendi farm has 20 cold plastic greenhouses and 15 warm greenhouses with brick walls. Each greenhouse is about 1 mu in size. The cold greenhouses rotate the operation through the year, producing major Chinese vegetables as eggplant, cucumbers, tomatoes and various leafy vegetables through the year. The warm greenhouses produce vegetables in the autumn-winter cold season only. In summer month of July and August, temperature in the warm greenhouses is too high for the plant to grow. Yifendi makes good use of the two months. After harvest in May, corn seeds are sowed randomly in the warm greenhouses. In two months, they grow to over 1 meter high, then mixed with chicken manure and lime, and sealed by mulch. The soil temperature can increase to over 60 degree through July and August, that will kill the insect eggs in the soil. This operation of "sealed heating" is widely used by Yifendi to keep the soil health. Such sealed heating operation is also implemented for the cold greenhouses in a rotate manner in the summer. In addition, the low winter temperature in Beijing can also help kill some insect eggs left in the cold greenhouses.

Yifendi farm pursues organic plantation since its foundation in 2012. About 800Kg chicken manure and 400Kg sheep manure is outsourced for each greenhouse annually. Each ton of chicken manure costs 700 CNY, and each ton of sheep manure costs 400 CNY. This cost includes the transportation, which is actually the major cost. The sheep manure is from Innermongolia, 600 kilometers from the farm, and the chicken manure is from Hebei province, ca. 200 kilometers from the farm.

Figure 5: Composting experience sharing at Yifendi farm

Graduated from China Agricultural University, the General Manager RUAN Zheng has never stopped looking for the eco-plantation techniques through his career in this farm. Inspired by the initiative of SDC, RUAN decided to practice composting in his farm. Since the project started in May 2019, four knowledge and experience sharing events were organized at Yifendi farm, including the two visits of the permaculture lecturer YAN and visit of Swiss composting expert, Mr. Jacques Fuchs in October 2019.

2.3 Composting practices at Yifendi farm

What is composting?
Composting is a biological process that microorganisms decomposes the organic matter in the input materials for composting, transforming them into humus, that can improve soil structure and biological activity, thus making both the soil and the plants more resilient to diseases.

There are many factors influencing the quality of final compost: a suitable carbon-nitrogen ratio of the input materials ensuring the natural starting of the composting, composting process management, i.e, the control of temperature and moisture, as well as the storage of the matured compost.

Yifendi farm has attempted to use various input materials that are available for composting.

Figure 6: Rice husk (left), shredded tree branches (middle) and mushroom stick waste (right)

The carbon-rich input materials include:

a) Rice husk with 20% horse manure is mostly used composting material. The husk is from a horse farm, which generates rice husk regularly. The horse farm is thus happy to provide freely the used dirty husk to Yifendi farm, who has to cover the transportation cost of about 300 CNY per ton;
b) Corn straws that are generated in the farm;
c) Tree branches in the farm that are shredded into 2~3 centimeters short. Swiss expert Jacques Fuchs suggested to buy another type of machine that can crush the branches into thin pieces other than only cutting, to increase the surface area which is beneficial for the composting process.

The nitrogen-rich materials include:

d) Chicken manure outsourced from Hebei province. Poultry or livestock is banned in Beijing;
e) Vegetable seedlings, residues or waste generated in the farm through the year;
f) Urea was also added for testing purpose.

In summary of the input materials, the accessibility and price are the two most important factors that support the composting practice economically sustainable. The best C:N ratio of starting materials for composting is 30, but it is hard to control precisely. In practice, farmers shall try to obtain a suitable range of 25~35 C:N ratio, and learn to adjust the C:N ratio by adding carbon rich or nitrogen rich materials according to the decomposition process.

Composting skills could and will be improved through practices. In Yifendi farm, the composting is mainly implemented during winter season when the farm work load is relatively less. In other seasons, farmers are too busy with the plantation work. At the beginning, for test purpose, the size of the compost is only 4 cubic meters, which were too small to produce good quality compost produce. After the guidance given by the Swiss experts, size of the later piles are about 2 meters wide, 1.8 meters high and 5 to 6 meters long, meaning 15 to 20 cubic meters. The composting is usually done in the open air between two greenhouses.

Temperature and moisture of the pile are the two main factors that affect the decomposition process. The temperature rose to over 60 ℃ in 2-3 days after piling up, and could maintain for a couple of days, then decrease slowly. Turning operation shall be carried out normally when the temperature dropped to 40℃. After turning, the temperature would increase again. It happened also that the temperature increased over 65℃, even hit 70℃, which shall be avoided through turning operation or adding water. Depending on the input materials, the whole composting process needs normally 3 to 4 months for the bio-waste to degrade completely.

Figure 7: Composting process management

Figure 8: Turning compost by forklift

Moisture shall be well controlled that no water drops when clenching the compost in the fist, and the compost stays together after open the fingers. The bio-decomposition process may stop under low moisture, and high moisture may create anaerobic environment that doesn't favor the composting process and releases unpleasant smell of ammonia. Turning compost is very important. Due to the heavy work of compost turning, after several months, Yifendi farm decided to rent a forklift, which saved the labor hour and proved to be more efficient.

In addition to normal open air composting, for the purpose of comparison and accumulating experience, Yifendi also made below attempts:

a) Upon request of a private composting partner, Yifendi attempted to do the compost within the greenhouse. The advantage of this operation is that the vegetable seedlings can be used immediately after harvesting. The compost period was however only one month because on one side the private company requested the compost product urgently; on the other side, Yifendi farm didn't want the followed plantation was delayed. (corresponding to Pile 2 in below chapter)
b) A pile of rice husk with and without urea, left in the open air for about one year, to check how good the composting process can happen naturally and with some urea, which corresponds to Pile 6 and 7 in this report。

Details of each composting pile in terms of the size, input materials and their ratios, and the composting period can be found in Table 1 in the next chapter.

2.4 Composting practices at the Swiss Embassy

As the initiator, advocator and coordinator propagating the organic waste composting practices, the Swiss Embassy made efforts to practice two composting methods.

2.4.1 Bokashi digestate - a test for urban household kitchen waste

Bokashi digestating method was introduced from Japan and Taiwan to China, and gained popularity by some civilian environmental enthusiasts in cities. Bokashi means in Japanese "fermentation of organic matter". Strictly speaking, this is not aerobic composting, but anaerobic digestating. The input materials are better household fresh vegetable and fruit waste. The fresh bio-waste is put into the so-called Bokashi bin. EM (Effective Microorganisms) bacteria is often added each time the green waste is put into the bin to help creating the favorite anaerobic environment. Depending on the amount of fresh organic waste generated, it may take 1 to 2 months to fill a 20-liter bin. During this period, the "liquid fertilizer" is produced, which is yellow to brown color with light taste of fermentation. 2 weeks after the Bokashi bin is full, the semi-degraded waste that is often covered with a layer of white hair can be buried in the garden or farm land. The composting process will continue in the soil. Semi-degraded waste was added to the compost Pile # 8, and was proved to be good starter to accelerate the composting process in the winter season when the input materials were mainly carbon rich materials from fallen leaves. Session 2.4.2 describes in more details.

Figure 9: Liyan Wang introduced Bokashi digestating

There are a few Bokashi bin manufactures, providing 10 and 20 liter size bins, along with EM in the market. Observing the popularity of and enthusiasm to this special composting method, Dr.Liyan WANG, initiator of this small action, purchased herself two bins and has been practicing at home since 2018. Under her influence, colleagues at the Swiss Embassy bought bins of different manufacture and did similar exercise. In order to know the level of nutrients and organic matter in the liquid fertilizer, samples were brought to CAU for test, which correspond to Pile # 10 in this report.

It has to be recognized that quality of the Bokashi bin and EM play critical role in the success of this digestating method. Even so, its wide application at communities is hindered by several factors: a) most urban dwellers are not willing to invest on the bin and EM; b) Using the Bokashi bin at home is demanding because it requires separating the fresh green waste from other kitchen waste strictly; c) there isn't place to further handle the semi-degraded fresh waste for urban households without own gardens. More pilots are needed for this method to sustain and develop in the communities, in combination with good community waste management.

With the implementation of urban solid waste sorting in Beijing since 2020, kitchen waste has been separated from other wastes. Cities need well designed urban solid waste management system to deal with the large amount of kitchen waste.

2.4.2 1-cubic meter small size composting

Figure 10: Compost box at Swiss Embassy

The Swiss Embassy also attempted another composting method which is suitable to be implemented in communities, kindergartens or schools, where fallen leaves and branches are easily accessible. The fallen leaves and small branches were collected and piled in a 1m^3 wood frame. The compost was done in late autumn, beginning of the winter in November 2019. Composting process didn't start due to unattended situation in late November, followed by Christmas and New Year holiday season. After 2 full bins of organic waste from Bokashi digestating were added in the January 2020, as well as water content to increase the moisture of the compost, the temperature started to increase and reached 60-65℃. A second temperature increase to nearly 60℃ was monitored after turning the compost. After the third time pile turning operation, the temperature stayed around 40℃. No further turning was done. The compost was also tested to check the result, corresponding to Pile # 8.

3. Analysis of composts and digestates

3.1 Compost sampling and test methods

In order to understand the quality of the compost and make improvement in the future, as well as to be confident for Yifendi farm to apply the compost, SDC mandated the China Agricultural University (CAU) to take samples of the composts and make laboratory tests.

3 to 5 samples were taken for Pile #1 to 7. Sample of Pile #8 and the liquid fertilizer sample #10 generated from Bokashi digestate were taken by the Swiss Embassy and brought to CAU. Compost produce sample from Pile #9 was given to CAU for test only. The input material of compost #9 is the kitchen waste from the company canteen through certain anaerobic digesting device. Exact period and method of digestating is unfortunately unknown. Requested by the company, the company name is not disclosed in the report.

Table 1 indicates the details of each composting/digestating pile, which was sampled and tested.

Table 1: Details of each composting/digestating pile

Pile #	Input materials	Ratio	Volume (m^3)	No. of days between start of operation and sampling
1	Rick husk, corn straw, chicken manure	1:1:1	4	75
2	Rick husk, corn straw, chicken manure composted within the greenhouse to use the tomato seedlings immediately after harvest	1:1:1	4	55
3	Rick husk, corn straw, chicken manure +tree branches	1:1:1:1	4	40
4	Tree branches, chicken manure	5:2	4	45
5	Tree branches, Urea	50:1	4	45
6	Rice husk, Urea left in the air for 1 year period	50:1	16	380
7	Rice husk left in the air for 1 year period	1	16	380
8	Fallen leaves, small tree branches + semi-fermented family fresh food waste	10:1	1	210
9	Kitchen waste from company canteen	-	-	-
10	Bokashi digestate, fresh vegetables and fruits	1:2	0.02	7~15

There isn't national standard specially for evaluating the quality of compost produce from organic waste generated by farms and family food waste in China yet. CAU followed below existing standards for the laboratory testing:

For compost produce Number 1 to 8, NY/T3442-2019: Technical Specifications for Livestock Manure Composting is used. Below group parameters are tested as indicators to evaluate the quality, maturity and stability of the compost. These parameters are categorized in below 4 groups following their functions to soil other than physical or chemical characteristics though academically might not be correct:

1) Physiochemical parameters: Water content, Electrical Conductivity (EC), salt content and pH value. These parameters are relatively simple and can reflect the quality of the compost from different perspectives. These group parameters are mainly affected by the starting input materials for composting.
2) Parameters related to nitrogen transformation: Total Nitrogen and Available Nitrogen as Ammonium NH_4-N and Nitrate NO_3-N, Total Phosphorous and Available Phosphorous are put here also as nutrient. Compost process management affects the nitrogen transformation, i.e. the nitrification and denitrification. Ratio of NO_3-N/NH_4-N indicates the maturity of composting and stability of the compost produce.
3) Parameters affecting soil health: organic matter and humus are distinguished from other parameters for their particular function in improving soil structure and health for mid and long-term. Fulvic acid, humic acid, humin and the ratio between humic acid and fulvic acid are further analyzed.

4) Germination rate (GI), as a parameter indicating phytotoxicity of compost, was also tested to be sure that the compost can be applied safely.

The sampling and tests were carried out in two times. The sampled composting pile #1 to 5 for the first round was at the beginning of exploring period, the volume of the composting piles was about 4 m^3 only. Second time the composting pile # 6 and 7 at Yifendi farm was only 1 m^3 as Yifendi simply wanted to know how the compost may process if the rice husk was placed in the air for one year with and without urea. In addition, composting pile #8 from the Swiss Embassy, compost produce #9 from canteen food waste of a private company and the liquid fertilizer from Bokashi digestating bin #10 were also sent to CAU for testing and analysis. Even though following the same test standard, not exactly the same parameters were tested between the two rounds of test. The first round of testing focused more on compost nutrient indicators, so the salt content was not tested, while the second round of testing focused on phytotoxity, so water content was not tested. Major indicators were tested which allowed horizontal comparison, helping draw some preliminary conclusions. The input materials and process management definitely influence the compost, thus the test results. Furthermore, it has to be recognized that sampling moments, sampling places and the duration between sampling and testing as well as the testing methods can also influence the laboratory results to certain extent. To minimize above influencing factors, 3 samples were taken by CAU, tested and averaged, as indicated in below chapters.

For the liquid fertilizer generated from # 9 Bokashi digestate, different standards were used as there isn't a national standard yet, including:

Table 2: various standards used in testing the liquid fertilizer

Indicator	Referenced Standard
pH	NY/T 1973
Total Carbon	NY 525-2012 sectoral standard for organic manure
Total N and P	GB/T 17767.1 and 2 Testing method to organic and inorganic compound fertilizers: total N and total P
Ammonia and Nitrate Nitrogen	HJ666-2013 Testing method of water quality on ammonia nitrogen
COD	GB11914-89 Testing method of water quality on COD

3.2 Laboratory test results and implications

3.2.1 Temperature change during the composting process

Temperatures of the composting piles 1 to 5 were recorded, as indicated in Figure 11.

Temperature and moisture of the compost are the two main factors that affect the decomposition process. Temperature is the only mean that Yifendi farmers can measure, through which farmers got to know when the composting pile shall be turned. A thumb principle is when the temperature goes down, turning shall be done. Moisture can be measured, but the farmers of Yifendi mainly control the moisture through experience gained in the exercises, that is no water drops fall when clenching the material in the fist. The right moisture shall be maintained around 50% because the compost pile would be in anaerobic situation under high moisture, which shall be avoided. Microbial will not work under too low moisture, which means the composting process would stop. Both situation of too high or too low moisture shall thus be avoided in the process management.

The temperature of the composting pile would rise to over 60℃ in 2-3 days after piling up subject to well starting mix of input materials with suitable carbon-nitrogen ratio, and well controlled moisture. This is the **warming-up phase** of the composting process that the bacteria would first degrade the sugar and protein in the feedstock. Turning operation shall be carried out each time when the temperature starts to drop. After turning, the temperature would rise again. If the turning is not done uniformly and completely, next temperature increase would be influenced, which is probably the situation of Pile 1 that the turning operation shall be done earlier. Outside air temperature has little influence than normally imagined. The Pile 1 to 5 were all done in winter 2019 to 2020 though starting dates were different. This is the **thermophilic phase (55-65℃)** during which the pathogens will be eradicated, as well as the weed seeds. After 4 to 5 turning operation in the first 2 months, the temperature would decline when the semi-fiber and fiber started to be decomposed. This is the

cooling phase. It still takes another 2 months for the wood fiber be degraded and decomposed completely, the so-called **curing phase** (André W.G. et al, 2016). During this period, turning operation every 2 weeks is necessary, which is the experience of Yifendi farm.

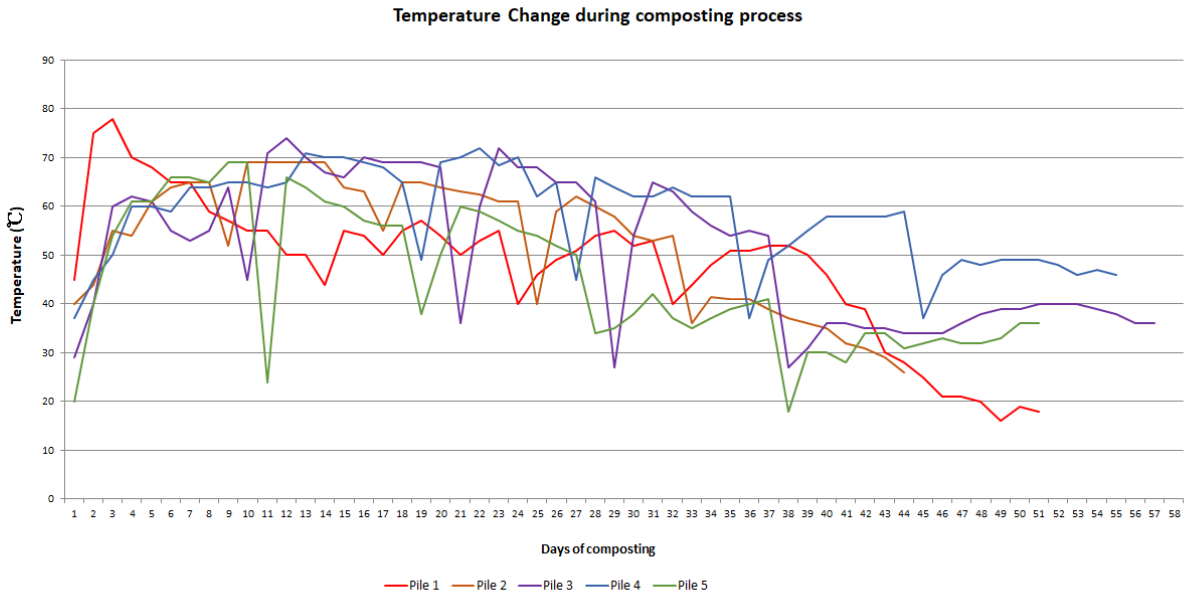

Figure 11: Temperature change during the composting process

3.2.2 Physicochemical indicators

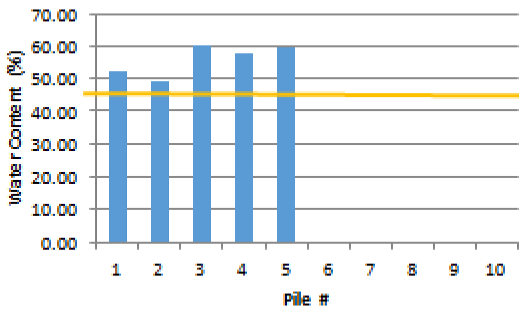

Figure 12: Water Content of the compost produce

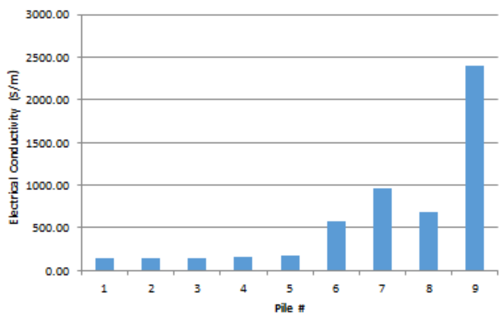

Figure 13: Electrical Conductivity of the compost

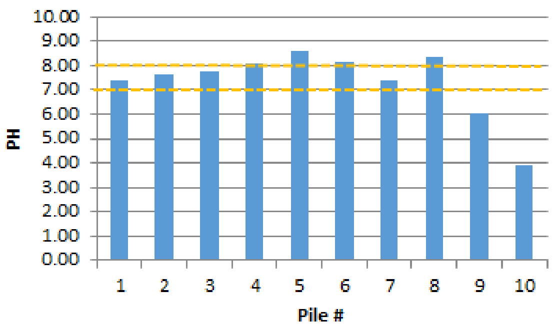

Figure 14: pH value of the compost

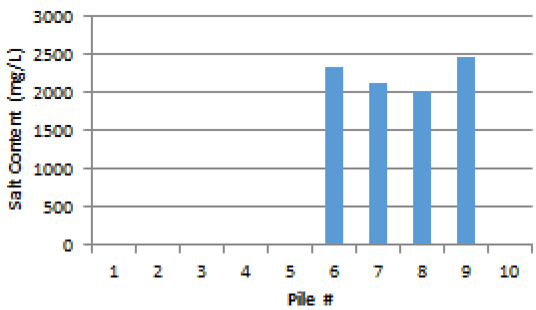

Figure 15: Salt content of the compost

Water content and Electrical Conductivity of the composts were tested, see Figure12 and 13. The yellow line indicates the reference value specified in the Standard. Water Content for completely matured compost shall have the water content below 45%. Since the samples #Pile 1 to #5 were taken 1 to 2 months after the composting started, the composting process haven't completely finished yet, the water content of these composts were thus still higher than the reference level.

The EC reflects the activity of ions of chloride, nitrate, ammonium and sulfate. The EC level of Pile #1 to #5 is also low compared to Pile #6 to #9 that the composts were relatively more matured when sampling. EC of the private company is too high for unknown reason.

pH value and salt content are shown in Figures 14 and 15. Yellow line in the Figure shows the reference range specified in the Standard that the pH value shall be weakly alkaline between 7 to 8. pH value of Pile # 5 is 8.5. This is probably because of the urea added to the compost. Results show that the compost produce from private company doesn't meet the Standard. Salt content of #9 was also the highest, which is probably because of the kitchen waste with high salt content.

pH value of the liquid fertilizer from Bokashi digestate is lower than 4, meaning that the liquid fertilizer has to be diluted 50 to 100 times before applying to any plant, which confirms the recommendations of Bokashi bin manufactures. Minimum diluting times, however, is not certain.

3.2.3 Parameters related to nitrogen transformation

Nutrient contents of all compost produce were measured as shown in Figure 16. Total phosphorous, available phosphorous were not measured for the second time. Results show that nutrient contents of all compost samples are all rich without big difference except the extreme high level of total nitrogen for Pile #9 from the private company. Two points need to be noted here:

1) The levels of compost nutrients are related to the feedstock for composting. The composting process management affects the maturity of the compost. The percentage of NO_3-N is more important in the Available Nitrogen because nitrate-nitrogen is the form that crops can absorb. The higher percentage of nitrate, the more matured the composting and the better storage management afterwards. The ammonium nitrogen was not low for all in the second round of tests, indicating possible denitrification occurred due to improper storage of the compost.
2) The value of compost is not its absolute level of nutrient contents, but its biological functions that will be discussed in the next section, because that is what other organic or inorganic fertilizers doesn't provide.

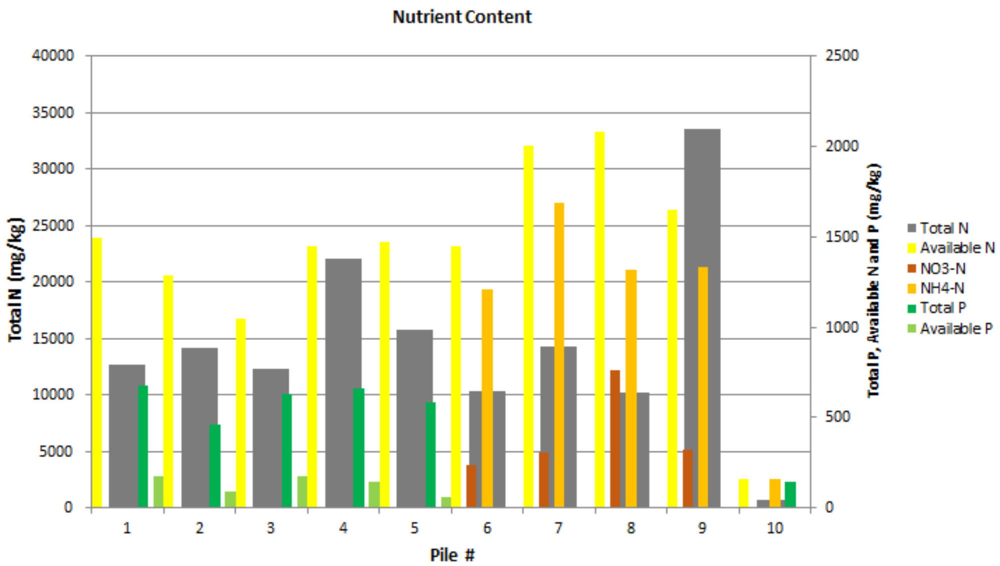

Figure 16: Nutrient Content of compost produce

The nutrient content levels of liquid fertilizer are listed here also, but they are not comparable because of different standards and solid-liquid difference. What can be found is that liquid fertilizer is rich in available nitrogen and total phosphorous, i.e. the nutrients that can be easily absorbed by plants. See section3. 2.6 for more test indicators for liquid fertilizer.

3.2.4 Parameters affecting soil health

Compost can produce rich organic matter and humus which chemical fertilizer can't provide. Organic matter and humus can improve not only the soil fertility, but also the soil health that soil and plants can better resist disease. The maturity of the compost may influence the humus content and share of its composition. Test results show that the organic matter and humus of all compost produces exceed the reference level of 30% and 20% specified in the standard respectively, indicating the good bioactivity of the compost produces. The samples of Pile #1 to 3 haven't fully decomposed. Results could be better if the tests were carried out after the composts were matured. Pile #8 has relatively low level of organic matter. This is because that the input material is mainly fallen leaves.

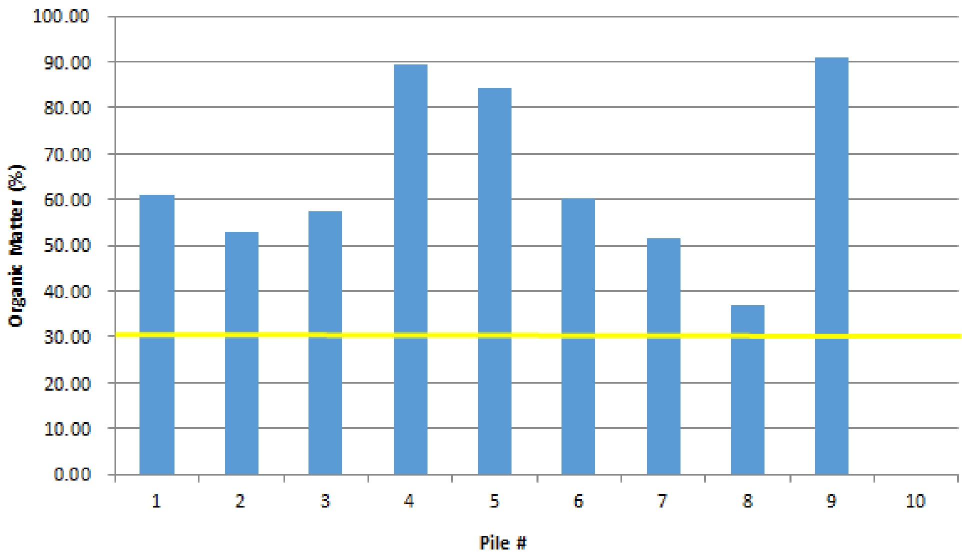

Figure 17: Organic matter of compost samples

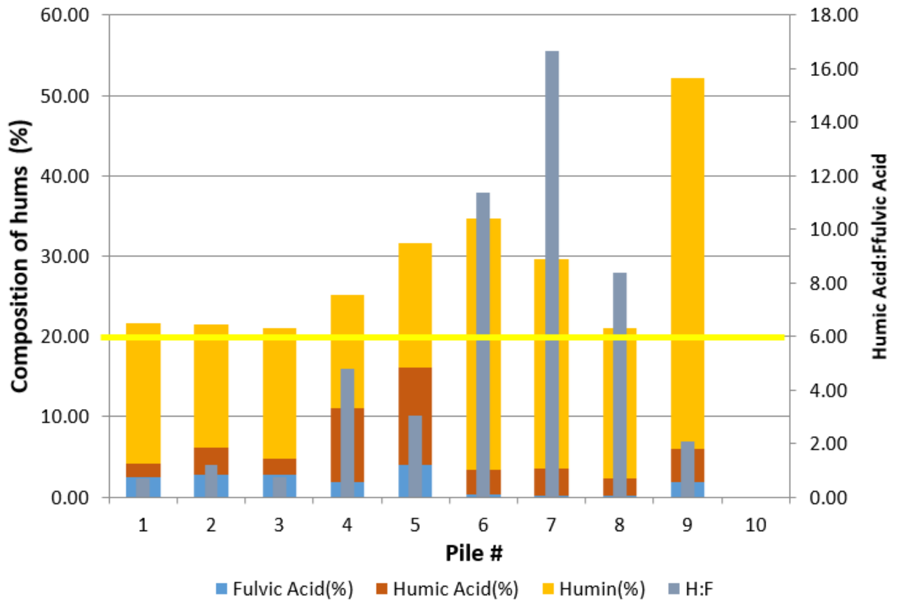

Figure 18: Composition of humus and ratio between humic acid and fulvic acid

Composition of fulvic acid, humic acid and humin in the humus were further analyzed. The ratio between humic acid and fulvic acid (H:F ratio) implies more the quality of the compost produce, the higher the value, the better quality of the compost. The low H:F ratio of compost Pile #1 to #3 implies the immaturity of the compost. The fully matured Pile #6 to #8 have comparatively high H:F ratio. It is important to note that even though the compost produce of the private company has high content of nutrients, organic matter and humus, its H:F ratio is very low indicating the poor composting process.

3.2.5 Other indicators

The germination rate (GI) is one important indicator to test the quality and safety of the compost produce. GI of all solid compost produces were tested, as shown in Figure 9. Compost pile #8 has the best germination rate over 80%, meaning compost Pile #8 can be applied safely. This is probably because it is over 200 days when Pile #8 was tested, which means the composting process had basically finished. Germination rate for Pile #9 is less than 40%, meaning it shall not be applied directly to the soil. Taking into account its acid pH value and high salt content, #9 compost produce is not recommended to use.

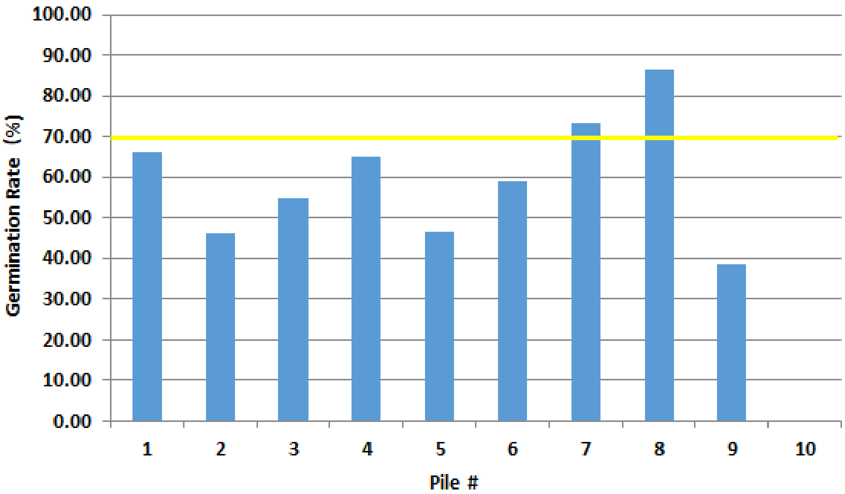

Figure 19: Germination Rate of the compost

3.2.6 Test results of the liquid fertilizer from Bokashi digestating bin

Liquid fertilizer from Bokashi digestating bin follows different laboratory test standards, with below test results:

Table 3: Test results of liquid fertilizer from Bokashi digestat

Total Carbon g/L	COD	pH	EC us/cm	Total N mg/L	Ammonia N mg/L	Nitrate N	Total P mg/L
18.36±0.04	358862±30	3.93±0.01	1283±167	758±30	163.23±0.50	1.00±0.07	148±4

The liquid fertilizer obtained from Bokashi digestating is quite rich in nutrients, especially the content of total phosphorus and available nitrogen are relatively high. The chemical oxygen demand (COD) is very high, indicating that the microflora is active, but not sure if they are flora beneficial to soil.

However the low pH value of liquid fertilizer is only 3.93, and needs to be diluted 50 to 100 times before applying to any plant. In this small action, only one sample of liquid fertilizer was collected. Quality of the Bokashi bin where the liquid was taken is not satisfactory. Liquid fertilizers from other Bokashi bins need to be tested to draw convincing conclusions.

3.3 Some Recommendations

Few takeaways from limited exercises under SDC funded small action:

1) The compost shall ensure certain period of high temperature phase that is over 55℃ for 3 weeks or 65℃ for one week (André W.G. et al, 2016), to kill various insect eggs, pathogens and weed seeds. Temperature of the composting piles shall be controlled not exceeding 70℃ through turning, watering or aeration.
2) Depending on the feedstock and process management, it may take 2 to 4 months to get matured compost produce. Compared to nutrient contents, humus and its composition, germination rate define more the maturity of the compost, thus its quality.
3) Compost from nitrogen rich input materials has high nutrient content that can improve soil fertility in a short term. Carbon rich input materials, however, can stay in the soil much longer, thus is good for the health of the soil. Therefore, it is suggested that Yifendi farm continue to explore using tree branches as feedstock for composting for its long-term carbon sequestration.
4) Carbon-to-nitrogen ratio of input materials is important for the composting. The composting would be very slow with the fallen leaves alone. Mixed with fresh green waste, as the case for Pile #8, is beneficial. Pile #8 has good comprehensive indicators, which is worthy of further promoting at schools, companies, organization and communities with gardens.
5) Pile #9 performs the worst among all compost produces. The wish of this private company to collect and compost the canteen food waste shall be encouraged. However, its composting equipment may only be, in essence, a heating equipment that only dry the food waste, not the real composting, because decomposition by microorganisms needs much longer period of 2 to 4 months.
6) In terms of input materials for composting, chicken manure is good for its high content of nitrogen, phosphorous and potassium. Corn straws are rich in carbon. Taking into account the availability and cost of these materials, it is suggested that Yifendi farm continue use rice husk, straws and chicken manure at ratio of 1:1:1, or attempt to use corn straws and chicken at 2:1 to 3:1.

4. Compost use

4.1 Compost use at the Swiss Embassy

Figure 20: Plants in SDC's garden

SDC has a small garden of about 100 square meters. In the Spring 2020, SDC staff planted tomatoes, eggplants, peppers, and lettuce in the garden. Diluted liquid fertilizer from Bokashi bin was the only fertilizer applied to the soils. The harvest is not so bad. This joyful exercise shed light on the possibility to develop urban agriculture, and is a useful attempt to improve the urban living environment and change the lifestyle of urban dwellers.

4.2 Compost use at Yifendi Farm

The compost produced in the farm is mainly applied as basic fertilizer and added amendment to the greenhouses. Before composting, about 800 kilograms of chicken manure and 2 tons of sheep manure were used in the farm for each greenhouse averagely every year. After applying the compost, no sheep manure was applied. The same amount of chicken manure was used but not directly to soil in the form of organic fertilizer. Instead, the chicken mature was the major feedstock for composting and finally returned to the soil in the form of compost. By roughly estimation, about 300 tons of compost was applied to the greenhouses in year 2020.

To measure the effectiveness after applying the compost, 5 samples from soils in the greenhouse, and 2 samples outside the greenhouse were taken for test. The greenhouse where compost was used just harvested tomatoes. The soil outside the greenhouse, as reference, has never applied any fertilizer. The test results were averaged and show in Table 4.

Table 4: Comparison of nutrient content of soils in and outside the greenhouse after compost application (green, lake blue, yellow and red represents high, moderate to high, moderate and low level respectively according to the soil fertility grading standard)

	Water Content %	pH	OM %	TN mg/kg	Available N mg/kg	Nitrate N mg/kg	Ammonia N mg/kg	Available. P mg/kg	Available. K mg/kg
Outside greenhouse	8.08	7.36	2.82	1460.5	48.06	40.33	7.73	25.71	103.36
Inside greenhouse	7.87	7.4	3.08	2323.0	315.02	307.6	7.35	56.59	174.25

The test results are delightful:

- Difference of water content and pH value before and after compost application was not significant. Both were neutral soils;
- Soil organic matter level in the greenhouse was higher than outside the greenhouse, even after growing the tomatoes, and both were in the moderate to high level;
- Total nitrogen levels in and outside the greenhouse were both very high, and total nitrogen in the greenhouse was 1.6 times higher than outside the greenhouse. The nitrate nitrogen in the greenhouse was nearly 8 times higher than outside the greenhouse, showing the high available nitrogen level in the greenhouse even after growing the tomatoes;
- Available phosphorous and available potassium level in the greenhouse was 2.2 and 1.7 times higher than outside the greenhouse respectively;

In conclusion, the organic matter, total nitrogen and nitrate nitrogen, available phosphorous and potassium are all largely increased after applying compost, indicating that the compost can improve the soil quality in terms of the nutrient contents and organic matter. This may also be related to the long term application of organic fertilizer to the soil in the greenhouse. Unfortunately, the soil sample before applying the compost was not tested. As mentioned in previous chapters, soil improvement by compost is a medium to long-term process.

4.3 Cost-benefit analysis of the composting practice at Yifendi farm

Yifendi farm has been composting Since 2019. Before a cost-benefit analysis was done, Yifendi thought that the farm's operating cost must have increased because of extra outsourced input materials for composting, doubled laboring due to composting, renting a forklift turning the compost, and nearly 10'000CNY to purchase the tree branch shredding machine. Upon request of SDC, a rough estimation of the actual operating cost before and after the composting was made, and the result is surprising.

Before composting, Yifendi spent about 1760CNY per greenhouse per year, which included 400CNY labor cost and 1360CNY purchasing chicken and sheep manure. After composting, the annual cost for chicken manure is the same. An additional 120CNY is spent to purchase the rick husk from a cooperative horse farm. Another 100CNY is spent to buy some wood chips to increase the carbon material in the compost. Labor costs are doubled. It costs 4800CNY per year to rent a forklift to turn the compost, which is averaged to about 140CNY per greenhouse per year. At first glance, it feels like operating cost should increase. But don't forget, after composting, the farm no longer applies sheep manure, which saves 800CNY per greenhouse per year. Considering a 5-year depreciation period of the tree branch shredding machine, the investment is apportioned to about 50CNY per greenhouse per year. In this way, **the running costs of the farm after composting did not increase, being the same as before the composting.**

Table 5: Running cost before and after composting (in CNY per greenhouse per year)

Before composting	Chicken manure	Sheep manure	Labor				
1760	560	800	400				
After composting	Chicken manure	Rick husk from horse farm	Labor	Wood chips	Corn straws	Forklift renting	Tree branch shredding machine
1770	560	120	800	100	0	140	50

Benefits after compost application in the farm are multifaceted:

- From mid to long term, soil organic matter and nutrients will increase, soil health will be improved contributing to strong resistance to soil or crop disease;
- Improved soil health will produce high quality products, which can make more profits for the farm from long-term perspective.

These benefits are not so obvious in the short term, but already sufficient for Yifendi farm to make determination to continue the composting practice in the future.

5. The way forward

Chinese government has defined its long-term strategy promoting the development of green and ecological agriculture. Since the January 1 2019, “the Soil Pollution Prevention and Control Law of the People's Republic of China” has been enacted. The Law stipulates that every organization and individual has the obligation to protect the soil and prevent soil pollution. To achieve the goal of “Zero growth of Chemical Fertilizer and Pesticide by 2020”, the government provides subsidies to encourage the substitution of chemical fertilizers for organic fertilizers. Although composting was once common in the long history of the Chinese agricultural production, it is far from being a mainstream practice and solution for improving Agroecology in the modern agricultural development today.

In China, there are large amount of small to medium sized farms in the peri-urban region, which produce large amount of agricultural waste. In places with intensive livestock and poultry industry, manure produced by animals has negative impacts on the environment and ecology. Composting from agricultural waste and animal manure can make good use of agricultural waste, increase the resourcing, recycling and reuse of the agricultural waste, thus reducing their pollution on the environment and ecology.

A recognized institution as FiBL in Switzerland is also needed for China, who can provide guidance to the composting, assuring the quality of the compost produce for safe and suitable use. A national or sectoral guideline is needed to specify the composting in terms of feedstock, suitable carbon-nitrogen ratio, process management, as well as the use of the compost.

It would be meaningful to analyze the effects of relevant policies in China, for instance, to assess the improvements to the water body and ecology in the region of Lake Tai after resourcing and reuse the agricultural waste round Lake Tai under the goal of zero grow of chemical fertilizers and pesticides.

In year 2019, Chinese government announced the national strategy to enforce garbage sorting nationwide, with the first batch of piloting cities as Shanghai, Beijing, Hangzhou, Xi’an etc. Ministry of Housing and Rural Development (MoHurD) further stressed in its “Government Notice on Promoting Household Waste Classification in Key Cities” that the classification of kitchen waste is compulsory. Dealing with urban solid waste, particularly the large share of kitchen waste is challenging, and demand system approach to design an efficient urban solid waste management system.

The effectiveness and safety of Bokashi digestating still need further study and practice. CAU adopted various standards for different purposes that can only get test results of some physical and chemical parameters. The biological characteristics, which are deemed the most outstanding feature of Bokashi digestating were unfortunately not able to be measured. Efficacy after the semi-decomposed green food waste was buried in the soil needs also assessment for drawing confident conclusion and promotion. Furthermore, Bokashi digestating method demands high public environmental awareness and social recognition. Similar methods have been successfully applied in Spain, India and Taiwan, and are worthy of further experimentation in the Chinese community.

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