# Banana Waste Composting

## Sparśa Banana Fibre Factory

## Version 1

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If you have any questions, just drop messages on my Team / WhatsApp or if urgent call me!!

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# 1 Introduction

## 1.1 Background and motivation

This is a handbook for the compost production by manual turning at the Sparśa Banana Fibre Factory located at Tribeni-Susta, Nawalparasi-west district, Lumbini province, Nepal.

Banana agricultural waste is usually left on farmland to decay or burnt in the open. These habits are harmful to the surrounding environment and pose a health hazard to the local population.

The survey showed that farmers in the area rely on fertilisers imported from India, which are in short supply.

The use of banana waste in our factory to extract fibre and making compost not only adds value to the waste and helps the farmers, but also improves the surrounding environment.

The composting process is physically demanding and taking time, but I hope this background will lead to motivation.

*Figure 1. Banana waste left at the field around our factory.*

If there is something important, I put this emoji!

# 2 Compost Pile Making

## 2.1 Composting materials (factory wastes)

Below are three types of waste, and the processes required for each waste before mixing with other waste to make a composting pile.

1. Banana leaves
   - Cut into small pieces using cutting machine (chaff cutter)

2. Unusable part of banana trunks
   - Cut into small pieces using cutting machine (Chaff cutter)

3. Slurry
   - Press the water out by using press machine (dedicated press should be designed)

*Figure 2. Left) Banana leaves, Middle) Unusable trunks, Right) Slurry*

**Note**

- Unusable part of trunks is easier to cut into small pieces when it is fresh.
- The reasonable range of waste particle size for composting is 3~50mm (according to The Composting Handbook).

## 2.2 Mixing ratio of each waste to make one pile.

Each pile weighed approximately 600 kg, and the mixing ratio of each waste was created based on the Carbon to Nitrogen (C:N) ratio recommended by the Composting Handbook, range of 25:1 ~ 40:1, and the approximate amount of each waste produced from a single banana tree.

| Mixing ratio | value | Actual weight [kg] |
|---|---|---|
| Banana leaves | 40 wt.% | 240 |
| Unusable part of trunks | 35 wt.% | 210 |
| Slurry | 25 wt.% | 150 |
| 1 pile | 100 wt.% | 600 |
| C:N ratio | 39.5 | |

**Note**

At the moment, the only way to weigh each waste is to place it in a bucket and measure it on a digital scale. However, this is too time-consuming and too inefficient.

The weight of each waste does not need to be so precise, as it varies according to moisture content and other factors. So, my advice is:

In the beginning, you can weigh each waste, and develop your sense of the weight by volume of each waste. Once you are used to it, you can mix each waste by looking only at the volume. This way you can save a lot of time and effort.

Ideas of developing the sense

- Measure and note the length, width and height of the waste volume produced by weighing. Repeat this several times to get a sense of volume and weight.
- Compare the size of produced volume with something familiar or always available at the factory and get a sense.
- (not sense but) Weigh the average weight per shovel and count the number of shovels.

## 2.3 Marking each pile

After making the pile, mark the pile (at least with the date).

Example is shown below according to the provisional plan (Check 3.4.2 The provisional plan)

Examples of marks on each pile

Date :
Mixed times :
1st turning : ☐
2nd turning : ☐
3rd turning : ☐
4th turning : ☐
5th turning : ☐

According to the provisional plan of composting (see below).

e.g.) The pile was made on 20th March 2024 and now 55th day of process

Date : 2024/03/20
Mixed times : 2
1st turning / 1st mixing : ☒
2nd turning : ☒
3rd turning / 2nd mixing : ☒
4th turning : ☐
5th turning : ☐

# 3 Composting Procedure

## 3.1 Compost favoured condition.

The table shows the favourable conditions for composting as indicated by The Composting Handbook (Actually, there are more parameters - Appendix.6.1 -, but only those that can be checked and modified at the factory are shown here).

| Condition | Prefered range |
|---|---|
| Moisture Content | 50~60% |
| Carbon to Nitrogen (C:N) ratio | 25~40 |
| Temperature | 50~65℃ (120~150℉) |

## 3.2 Temperature

In our plant, temperature is the most important parameter in monitoring the composting process. However, if you don't know what the temperature indicates, you don't know what to do with the pile at the moment.

I will describe the relationship between composting process and temperature below.

### 3.2.1 Temperature range and typical temperature graph

Composting takes place mainly within two temperature ranges: mesophilic phase, (20-45℃), and thermophilic phase (45-75℃). It's important to note that different types of microorganisms thrive in environments with different temperature.

The Composting Handbook recommends a **temperature of 55℃ or higher** which is in thermophilic temperature range **for several days (e.g. three days) for sterilization of compost** (Another institute -USEPA – recommend 15days). Make sure we achieve this in our composting too!

**Our previous experiments have shown that our composting recipe exceeds 55℃ for at least three days, so if the temperature of piles you make does not exceed 55℃ for three days or more, assume that something is wrong.**

However, **above 75°C, there is a risk of ignition**, so cooling by adding water, for example, is required (see below "3.2.2.Process Monitoring Guide – temperature ").

P.S. Our waste materials are hard to degrade, so I don't think the compost will ever exceed 75°C, but just in case.

For reference, the graph below shows a typical compost temperature graph and the micro-organisms that thrive in that temperature range.

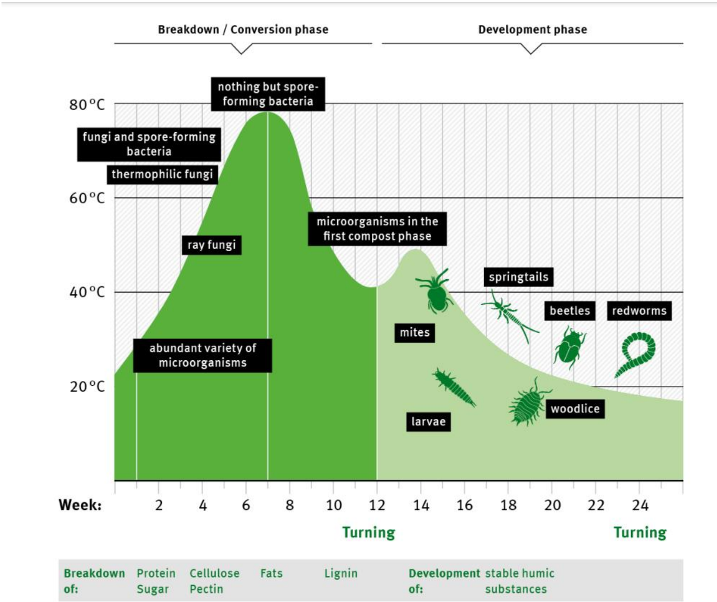



*Figure 3. Typical compost temperature changes.*

### 3.2.2 Process Monitoring Guide – temperature base.

The following is a process monitoring guide based on temperature.

| Process Indicator | Possible causes |
|---|---|
| Low temperatures at the start of composting | · Poorly degradable feedstocks<br>· Feedstocks too dense or too wet |
| Consistently lower than normal temperatures throughout | · Materials too dry<br>· Materials too wet or dense<br>· Pile is too small<br>· Insufficient aeration |
| Consistently higher than normal temperatures throughout | · Highly degradable feedstocks<br>· Low C:N ratio<br>· Moderately low moisture<br>· Large and well insulated pile |
| Highly variable temperatures reading | · Feedstocks poorly mixed<br>· Development of aeration channels |
| Large temperature difference between outer layer and inner core. Sharp drop or rise in temperature | · Pile compacted, needs turnings<br>· Possibly a mechanical problem (not biological e.g. suddenly drying of the pile |
| Very high temperature readings (>70°C or 160°F) | · Insufficient cooling due to moderately low moisture, and/or overactive process due to highly degradable feedstocks |
| Temperature above 75°C or 170°F | · The process of spontaneous combustion might have started in one or more sections of the pile. (dangerous)<br>· Pile may be too large |
| Temperature fails to increase after turning | · Moisture content is very low or very high<br>· Active composting phase is nearly ending |

When you measure the temperature and notice something unusual or feel something weird, first look at this guideline to see what the cause could be, then act.

### 3.2.3 Temperature measurement

We use the long stem thermometer (around 50cm long) to measure temperatures.

From the process monitoring guide above, **temperature should be taken at least at two different spots and depths (25cm: surface & 50cm: near to core) in the pile and record them.**

If you measure two points and feel something is wrong, you can increase the number of measurement points to assess the situation of the entire pile.

During the **first 2-3 weeks (thermophilic phase), the temperature changes must be carefully monitored to ensure the sanitization of piles**.

**For the first 2-3 weeks, you should measure temperatures at least once every 2 days** and then once every 4-7 days thereafter.

Figure 4 shows a rough image of measurement method, but you can do it your own.

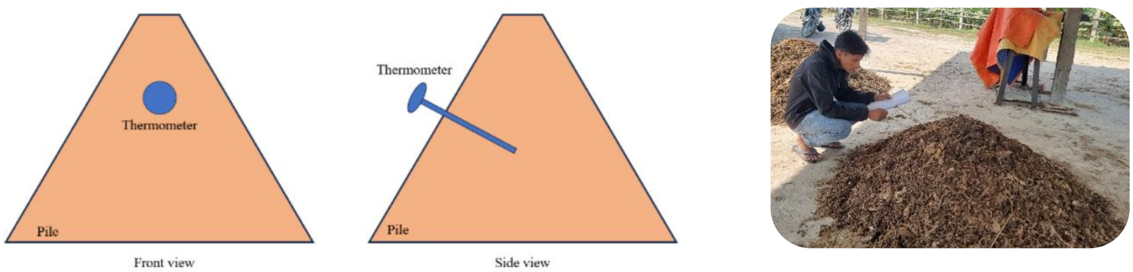



*Figure 4. Temperature measurement*

**Note**

- Temperature Monitoring Sheet is available in SharePoint. You can print them and use them for recording. (there is also an excel sheet for recording, if you need one, contact Haruto and we will arrange a call to explain how to use it)]

- Temperature measurement with analogue thermometer is simple but time consuming. So, once you get used to composting the same material, recipes and processes, you can reduce the number of temperature measurements or even eliminate them (if you are fully aware of what is going on).

## 3.3 Turning / mixing method

**In this handbook, "Turning" refers to turning to mix one pile, and "Mixing" refers to mixing two different piles.**

Turning (also Mixing) mixes the materials, facilitating movement between hotter and cooler areas of compost, thereby preventing stagnation commonly associated with static com-posting systems (our system). Thus, it is also an important process.

**When Turning or Mixing piles, try to put compost that was on the outer layer (more sensitive to outside temperatures) into the core layer (less sensitive)**.

**During Turning (Mixing), carry out a Hand-Squeeze test, explained below, to check the moisture content of the pile and add water if necessary (favoured condition: 50~60% moisture content).**

### 3.3.1 Hand-Squeeze moisture measurement

Procedures

1. Grab a handful of composing material.
2. Squeeze the material hard with your hand, check for drips.
3. Release your grip and allow the material to stay in your hand, smear some between your finger and thumb.
4. Inspect the material and your hand.
5. Use the table below to estimate the percentage of moisture content.

| Observation—description | Estimated moisture content |
|---|---|
| • Water flows freely out of your hand | Greater than 65% |
| • A few drops of water are visible between your fingers | 60%–65% |
| • You don't see any water between your fingers. When you open your hand, a sheen of moisture is clearly visible. | 55%–60% |
| • No sheen of water is visible and a ball of compost remains in your hand. If you tap the ball gently, it remains intact. | 50%–55% |
| • A ball of compost forms but break apart during tapping. | 45%–50% |
| • After squeezing, the compost does not remain in a ball when opening your hand | 40%–50% |
| • No ball forms and a dry talcum-like feel remains on your hand after discarding the material. | Less than 40% |

**Note**

- Be careful **not to add too much water**, as the hand-squeeze test is an inaccurate method for measuring moisture content. It is particularly difficult to measure when the waste particle size is large (in the first stages).
  - ➢ Too high water content inhibits temperature rise in the pile.
  - ➢ A more accurate method is the Air-dry test, but it is time-consuming. The method is described in the Appendix.6.2 for reference.

## 3.4 Factory compost area planning

Turning (mixing) is carried out usually according to the state of the pile and/or temperature situation, but as we are inexperienced at this stage, I made a **provisional plan** to use compost area effectively according to the data collected 2023/2024.

It should be noted that this is a provisional plan and we have never carried out factory composting according to this plan so far (as of 5th May 2024).

Therefore, if anyone, especially those managing composting, feels that there are improvements to be made or that this plan does not work at all, please contact Haruto (my contact in title page) with a summary of report including any comment e.g. “what the problem” “how you think it can be improved” etc.

**Note**

- It is impossible that the current plan (I would say 'version 1'), which has not yet been tried and tested, does not have areas for improvement.
  Please actively take notes and tell Haruto everything so that we can come up with a new plan that can produce high quality compost even more efficiently, which will have a great impact on several aspects.
  (e.g. NIDISI, surrounding farmers, environment, etc.)

### 3.4.1 Assumption for the provisional plan

In order to create a provisional plan, several assumptions were made. These are listed below.

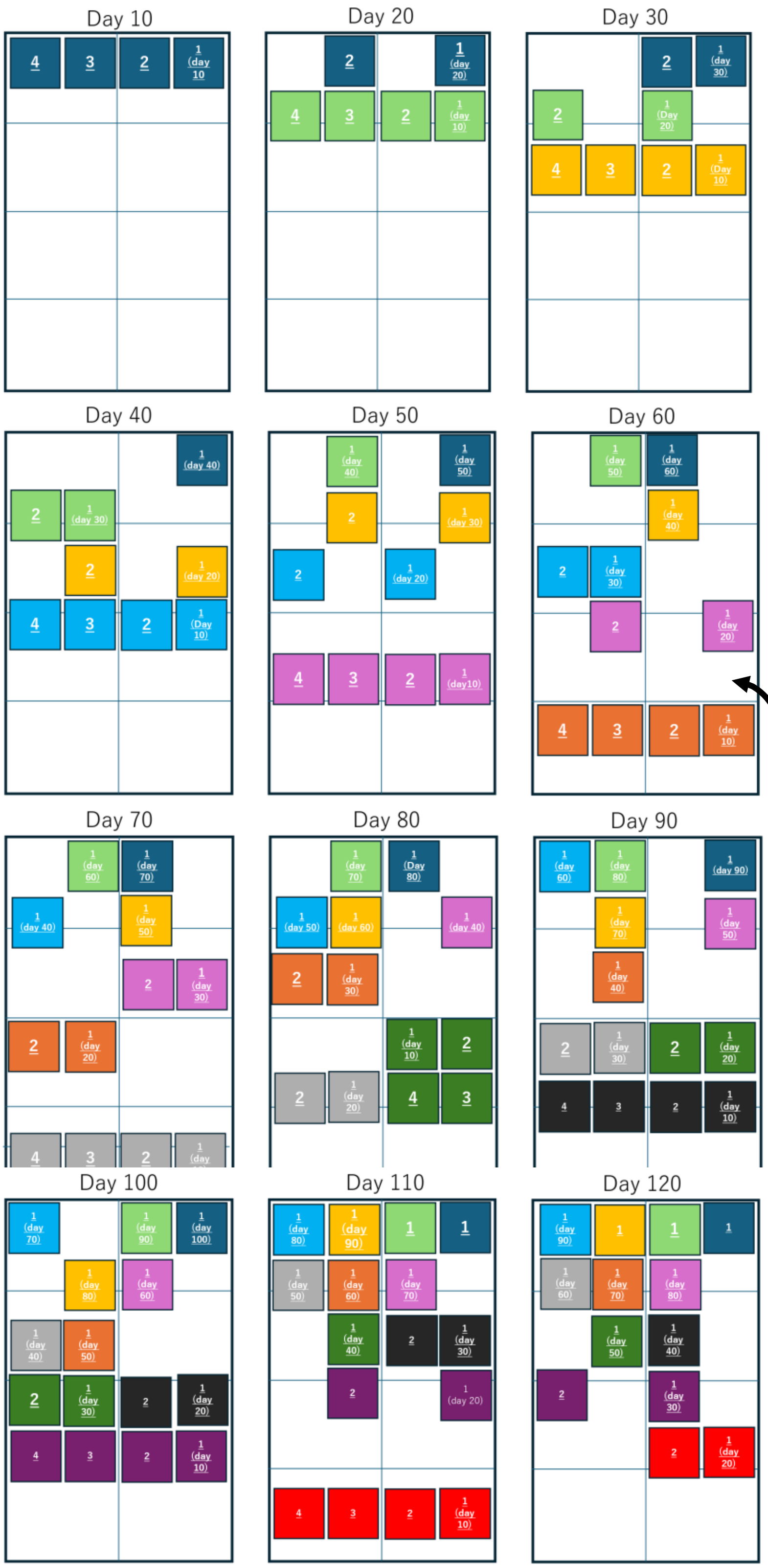
- Estimation : 4 piles per 10 days
- Pile size : 2m length, 2m width (600kg)
- Compost area : 14.5m * 9m
- Therefore 6 rows in total
- Mix all the pile after 90 days (no more Turning / Mixing, so doesn’t matter)
- Fibre extraction for 4 months (120days) – means waste production also 4 months

**Each piles composting schedule**

Day 10 - 4 piles
Day 20 – Mix 2 into 1
Day 30 – Turn
Day 40 – Mix 2 into 1 (all 4 piles made in 10days into 1)
Day 50 – stay
Day 60 – turn
Day 70 – stay
Day 80 – stay
Day 90 – last turn
From day 100 – just let them stay

### 3.4.2 The provisional plan

Schematics of the provisional plan based on the above assumptions are shown below. If you have any questions, please contact Haruto (title page). This plan is for reference only at the moment and does not have to be strictly adhered to.

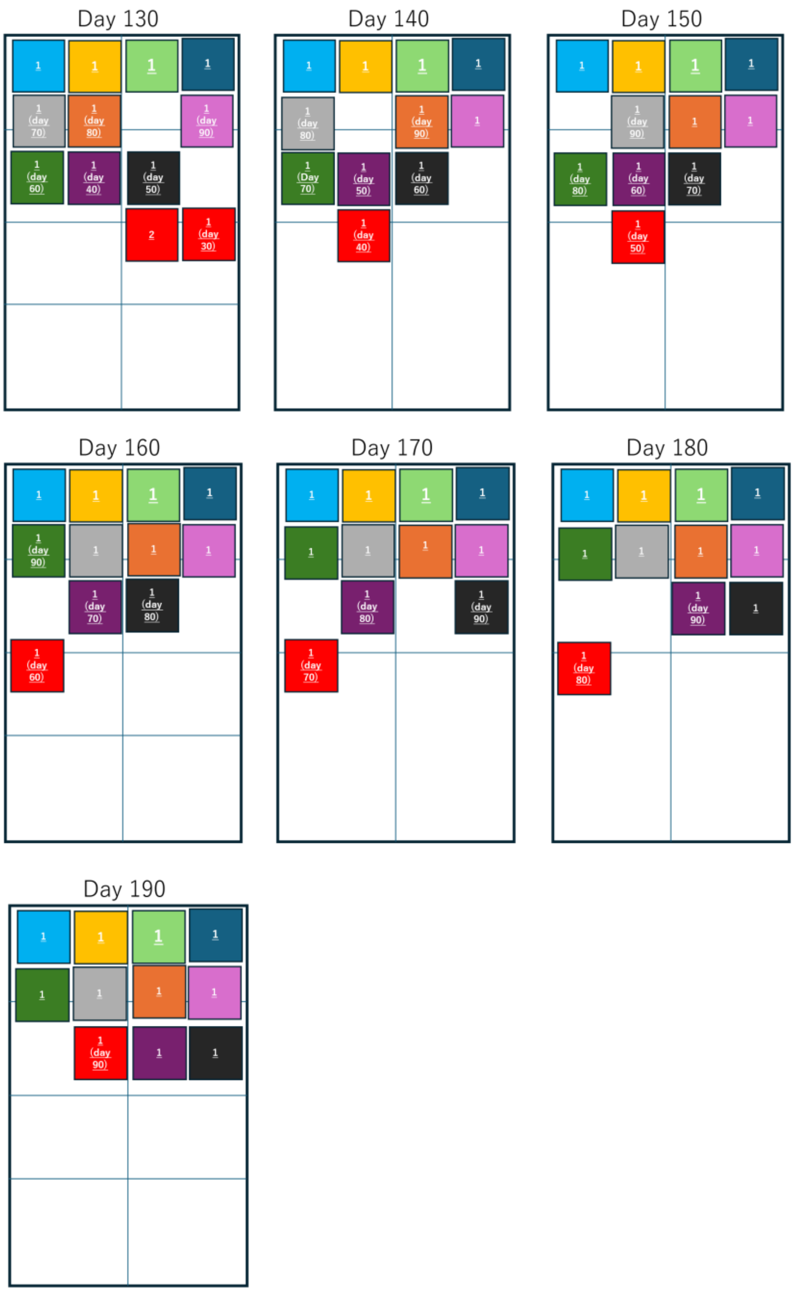



As it is not assumed that the four piles (per 10 days) will be made on the same day, the Turning (Mixing) date etc. will vary depending on the piles.

This plan, so to say, represents the state of the composting area at 10th, 20th and 30th days after the start of composting.

I assume that you start making new piles (orange here) before you move pink piles, therefore, on days 60 there is 1-row gap. (same reason for other days later)

Some piles do not move on the spot on the days of the Turning (Mixing), but this means that they are turned on the same spot.




In the schematic diagrams, the piles with 90-day and later are not mixed, but in practice they can be mixed to make more space.

<u>Possible failure of current plan</u>

- We don't know the size reduction (degradation) speed of pile.
  - Mixing period may not fit into the plan.

- Composting is highly dependent on the surrounding environment. It therefore requires a frequent monitoring and flexible response on site.

- There is no guarantee that it will not have to be turned/mixed after 90 days.

# 4 Compost Maturity Check

**The application of immature compost in the field can have a negative impact on plant growth**.

The results of our previous experiments did not show phytotoxicity in compost piles that were more than 120 days old. However, this is unreliable because the experiment could only be carried out once, and because every composting process can be different due to various influences, so you should check the maturity of compost frequently at first, and occasionally once you get used to.

## 4.1 Appearance and smell - you can do every time.

It is easy to test whether the composting process is finished just by using your eyes and nose. (once you get used to)

- If it looks dark and crumbly (as compost should).
- Smell is an excellent indicator of healthy compost. Put a good handful into a bag etc., and seal it. After 3 or 4 days open the bag and sniff.
  - If it has a pleasant earthy smell, it is matured.
  - If it smells foul or rotten or a bit like ammonia the compost is not finished.

## 4.2 Seed germination test

The test uses fast germinating seeds (e.g. radish) to determine if enough phytotoxins are left in the compost to inhibit germination.

Processes

1. Fill 2~3 flowerpots with moist compost (sample you want to test).
2. Fill 2~3 pots with commercial compost, or previous tested batch, or soil (control).
3. Plant 5 seeds for each pot.
4. Moist them when necessary.
5. After seven days, count the number of seeds that have germinated in each pot.
   - If the germination rate is significantly lower in the test sample than the control (less than 75%~80% germination), the compost is still immature.

**Note**

- I recommend you carry out both tests above at the first. Once you know the smell of mature and immature compost or looking or whatever indicator you notice, it is not necessary to perform a germination test every time.

Once this stage is complete, the compost can finally be used in the fields!!

Congratulations!!

Thank you so much for your work on this topic :)

From this chapter onwards, read only if you plan to add biochar to your compost.

# 5 Biochar Application for Compost

## 5.1 Biochar production

The production of biochar at the factory currently uses a **Metal Kon-Tiki kiln** known as **flame curtain** kiln.

The principle, briefly described, is the so-called flame curtain, which forms a flame at the top of the kiln, shielding the biochar in the lower layer from oxygen and preventing oxidation of the biochar, while at the same time allowing the pyrolysis gases generated from the feedstock to burn cleanly.

If you are producing biochar for the first time, **be sure to watch this video before** doing so.
> https://youtu.be/1o0QqePtNM4?si=-K38Os3gNQff8L07

**Important aspects of the production** include.

- Feedstock must be dry (as much as possible).
- As little smoke as possible during production.
- Be very careful about burns and fire (always have a bucket of water available).

We have produced biochar using bamboo, banana leaves and lantana so far. The general production process is the same for different feedstocks, but the feed rate varies because the rate of thermal conversion of each feedstock changes. The production process is shown below.

1. Pile the biomass in the bottom of the kiln and light the fire.
2. When the biomass begins to turn to ash (surface turns white), add another layer of biomass.
3. Repeat this process until the kiln is full or the biomass is used up.
4. When the surface of the last layer is almost completely white, end the process with spraying water, and drain water out from the drainage pipe.
5. Remove the biochar from the kiln and dry it lightly in the sun.

Process 1

Process 2 & 3

Process 4

Process 5

**Note**

- The kiln was developed by the Ithaca Institute. I have personally visited their institute in Nepal. If you wish to contact them, you can put me on cc.
  - Ithaka Institute contact:
    - Mr. Hans-Peter Schmidt – Head of Swiss - schmidt@ithaka-institut.org
    - Mr. Bishnu Hari Pandit – Head of Nepal - bhpandit29@gmail.com
    - Mr. Anand Pokhrel – Nepali Institute worker - anandpokhrel2001@gmail.com

  There are also resources below to learn more about the Kon-Tiki kiln.
  - Ithaka_Kon Tiki flame cap pyrolysis for the democratization of biochar production.pdf (Read this first! – in SharePoint)
  - https://www.ithaka-institut.org/ithaka/media/doc/1462795288103.pdf
  - https://youtu.be/lZlJSo8RNAY?si=7LsCY_H_0j3Uid8e

- A photo of a lantana I took around the factory is shown below. It was flowering in the rainy season around the factory. In winter, it is dead and dry, making it suitable for biochar production.

- I recommend the production of biochar from banana leaves (or lantana). This is because bamboo and lantana can also be used as fuel for cooking and warmth. Also, bamboo has to be bought and I don't think it is economically feasible for us.

- **High moisture content in the feedstock results in higher emissions and lower biochar yields.**

## 5.2 Biochar application to pile.

Additions of 2-10% (by volume) of biochar to compost are recommended.

Considering the results of the previous experiment and the time required to prepare the biochar, a 5% (by volume) addition is considered reasonable.

The density of our compost is roughly 600~700 $kg/m^3$ (highly depending on moisture content).

One pile is around 600 kg, so its theoretical volume is 0.86 $m^3$~1 $m^3$ (practically much bigger) and its 5 vol.% is 0.043-0.05$m^3$. Therefore, the amount of each biochar required is approximately as follows.

| Biochar | Density [kg/m3] | 5 vol.% amount [kg] (0.043-0.05m3) |
|---|---|---|
| Bamboo | 500 (maybe not dried) | 21.5 ~ 25.0 kg |
| Banana leaves | 125.5 (dried) | 5.4 ~ 6.3 kg |
| Lantana | 132.1 (dried) | 5.7 ~ 6.6 kg |

Ensure that added biochar is evenly distributed within the compost pile.

Bamboo biochar, in particular, needs to be crushed into small pieces before being mixed with piles, as the bamboo remains in its form. Simply place it in the bag and crush it with your foot.

**Note**

- The agricultural lands around the factory have alkaline soils (around pH 8.5) and the application of biochar to these agricultural lands may not be very effective.
  (Biochar is particularly effective on acidic and degraded soils).
  - We should conduct field application research.

- The C:N ratio doesn’t need to be considered by the addition of biochar.

- If you are interested in finding out more about the impact of biochar, you can start with this video!!! (Even if you are not interested, it is worth watching!)
  - https://youtu.be/p0YNFn9Dloc?si=xTS7rH8mROAQs1ob

# 6 Appendix

## 6.1 Favor Condition for Composting

**Table 3.1** Favorable conditions for composting.

| Condition | Reasonable range[a] | Preferred range |
|---|---|---|
| Moisture content | 40%–65% | 50%–60% |
| Carbon to nitrogen (C:N) ratio | 20:1–60:1[b] | 25:1–40:1 |
| Oxygen, minimum concentration within the interior pore spaces | Greater than 5% | Greater than 10% |
| Temperature[c] | 45–70°C (113–160°F) | 50–65°C (120–150°F) |
| Ph | 5.5–9.0 | 6.5–8.0 |
| Particle size | 3–50 mm (1/8 to 2 in.) | Depends on feedstocks and use for compost |
| Bulk density | Less than 700 $kg/m^3$ (1200 $lbs/yd^3$) | 400–600 $kg/m^3$ (700–1000 $lbs/yd^3$) |

## 6.2 Air-dry test for moisture content measurement

<u>Procedures</u>

1. Place the sample on the plate and weigh it (wet sample + plate).
2. Leave it to dry. (Be careful not to let the wind blow it away.)
3. Weigh after sample completely dried (dried sample + plate).
4. The difference between the weights before and after is the amount of water contained in the sample. Calculate the moisture content from this.

## 6.3 Photo gallery
















HAPPY DIWALI
Banana Fiber
Factory
NIDISI


Thank you NIDISI !!
Thank you all for this great memories!!!
Banana Fiber
Factory