

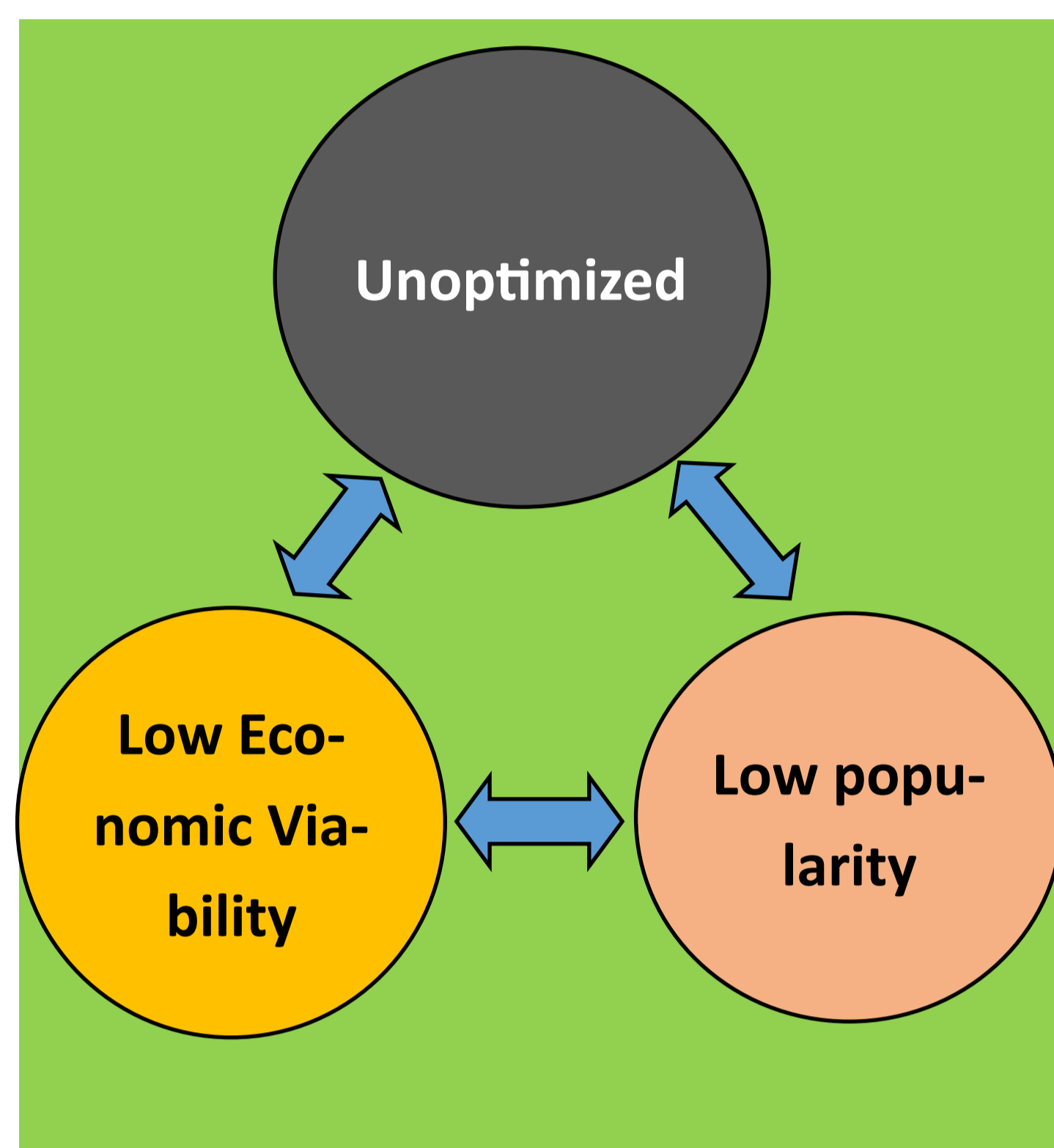
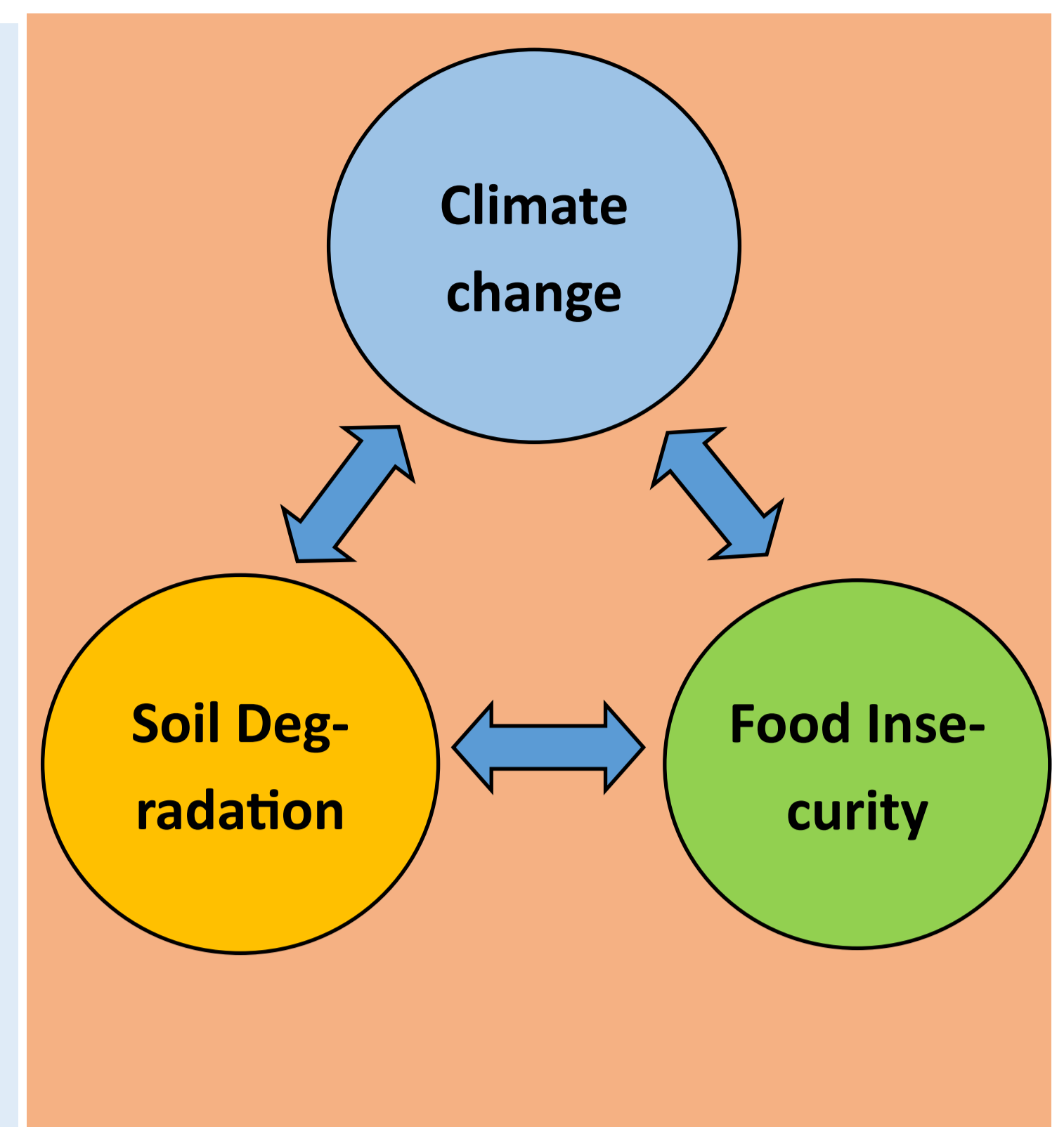


TRANSFORMING HKUST INTO AN ORGANIC "EDEN" GARDEN: DEVELOPMENT OF A NOVEL EFFICIENT COMPOSTING METHOD AND ITS APPLICATION

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INTRODUCTION

We all have witnessed it. A garbage bin full of rotting food waste, whole walkways covered in fallen leaves, bags full of coffee grounds rippling fragrances in coffee shops. In a typical city dweller's mind, they all need to be sent to the landfills because that is where garbage belongs. Guess what? This mindset is exactly what is exacerbating the trio problems of climate change, soil degradation and food insecurity. In fact, these so-called "garbage" is what have sustained the terrestrial ecosystem for billions of years. Returning these organic matters to the soil has been the core part of nutrient cycling which is necessary to keep everything alive. Composting can be a way to restore this cycle because it is a process that turns "garbage" into good quality compost that can improve soil structure and productivity, while fulfilling the sacred function of carbon sequestration under climate change. However, the largely natural composting process, if not modified adequately, has a number of drawbacks which has kept it under the shadow of synthetic fertilizers.



PROBLEMS WITH COMPOSTING

- Massive leaching in the initial stage of composting which constitutes wasted resources and may contaminate groundwater^{1,2}. This problem is particularly serious if we want to compost food waste with high water content.
- Premature thermophilic phase due to opportunistic microbes consuming labile nutrients in which past studies have suggested they are not helpful for compost maturation^{3,4}
- Potentially high NH₃ emission in early stage which further contributes to nitrogen loss⁵
- Uncontrolled release of CO₂ (even worse when anaerobic condition drives CH₄ emission)
- Difficulty in obtaining mature compost as the whole pile does not mature at the same time
- It is a slow and labour-intensive process



VISIONS AND OBJECTIVES

We hope to develop a better composting method and design a hardware (composter) which allows everyone to make compost easily and in a sustainable manner. Through this, we hope to transform the landscape which we have always ignored, the soil, which will help to create a brighter future for humanity. Our key objectives include:

1. To improve the resource efficiency of composting
2. To reduce the environmental impacts associated with composting
3. To make composting faster and more user-friendly



METHODS

To achieve our vision, we first looked into the typical composting process in detail to find out the key inputs and outputs and create a system inventory. Through both evidences from literature studies and our system inventory, we identified and designed our potential solutions to the problems above. To prove our concept and exercise our creativity, we combined two approaches: 1. To conduct scientific research to evaluate and validate our methodological solutions. 2. To create a rational design to improve the functionality of a composter.

Compost Site and Preparation



We have been carrying out our composting work in the LG7 orchard. The main ingredients we used include fallen leaves (collected around campus), horse manure-straw mix, vegetable waste from "Milano Fresh" (broccoli stem+ small amount of kumquat), coffee grounds from "Starbucks" and the LG1 canteen. We made sure that the amount of water and each ingredient added to all of the compost bins were equal. We used a lawn mower to shred all the dry ingredients into fine pieces. The differential treatment involved having different levels of extraction of vegetable waste to draw useful compounds out before they are leached, gasified or consumed by opportunistic microbes inside compost. We have been monitoring the compost temperature as a general proxy of composting progress.

System Inventory

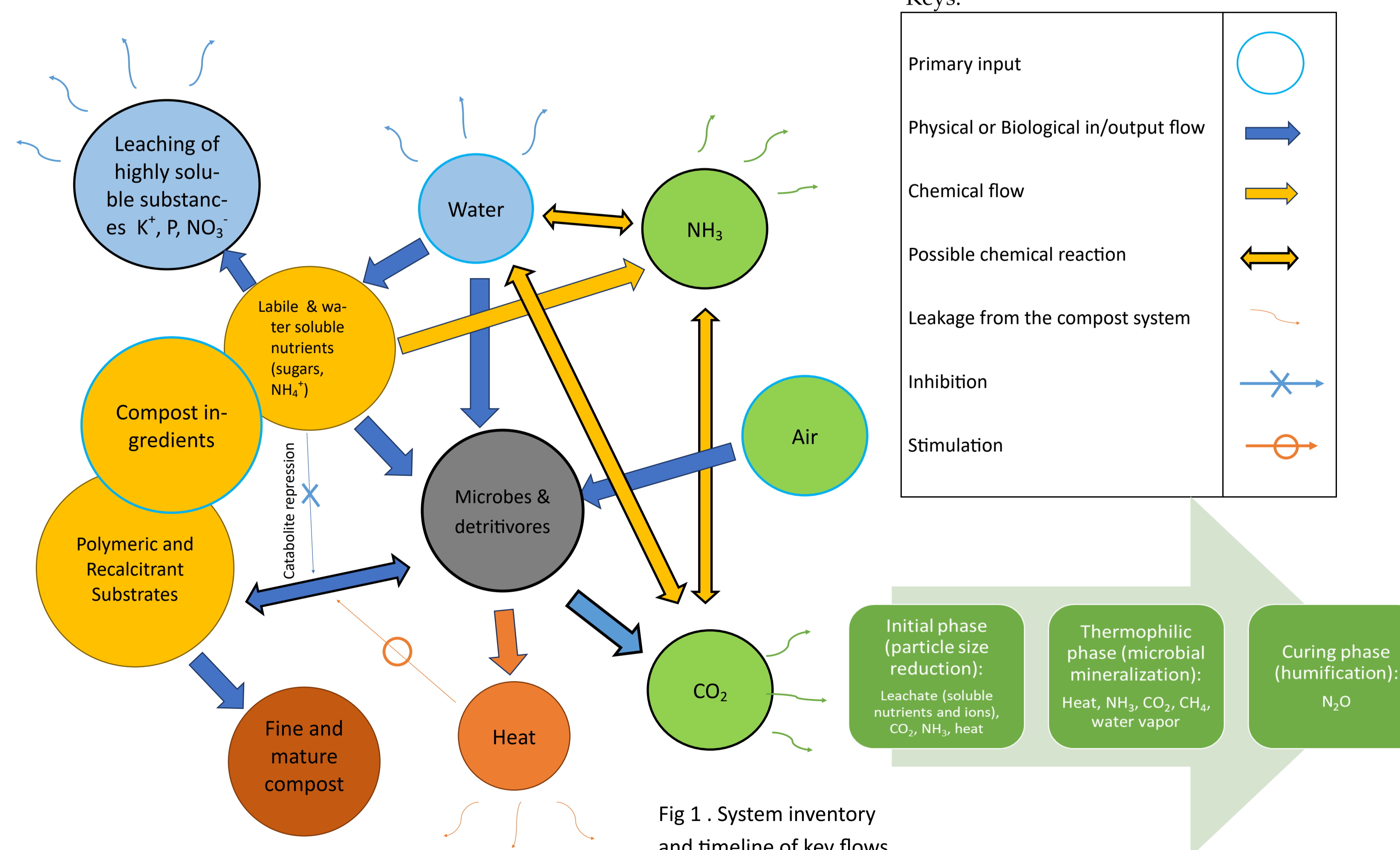


Fig 1. System inventory and timeline of key flows

Laboratory experiment

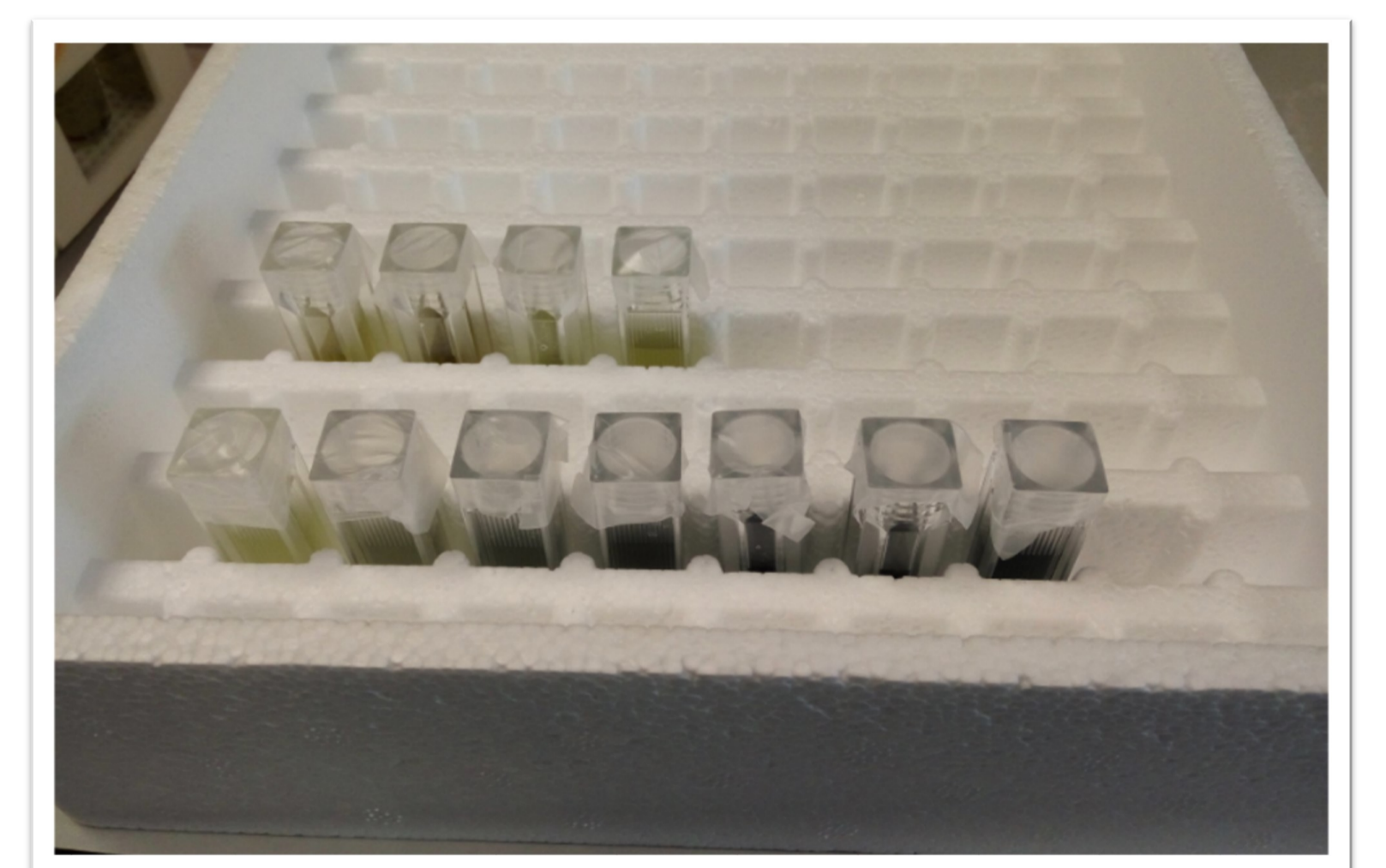


Fig 2. Cuvettes holding the vegetable extracts—anthrone mixture

Samples from the field composts were taken regularly for lab analysis. The main responses studied were 1) Total carbohydrate content in water extracts and residual solids of vegetable waste measured by Anthrone colorimetric method; 2) treatment effects on compost maturation (monitored by C/N ratio, humic acid carbon to fulvic acid carbon ratio HA/FA and NH₄⁺/NO₃⁻ changes of both samples from the field and incubation experiment. Total N will also be analysed for matured product since N is the major agronomic indicator on land. Another important quality, water retention capacity, will also be tested by gravimetric method.

The system inventory above shows the major outputs and inputs of a typical aerobic composting system. Coupled with the timeline of the major fluxes and key processes, we can design the corresponding solution for the undesirable problems encountered during composting. We identified a potential solution to reduce the loss of useful soluble nutrients and by extracting nutritious food substrates before composting or by collecting leachate during composting for later re-utilization (leaching is a type of extraction in a sense). Moreover, as the majority of N loss occurs in the first half of composting, we also hypothesized that late or split addition of N-rich substrate may improve compost end-product quality. In addition, we also designed a potential solution for emitted NH₃ to react with CO₂ given that they have a medium for effective reaction (e.g. water). More solutions will be discussed under the composter design section.

PROJECT HIGHLIGHTS

1. TOTAL CARBOHYDRATES FROM EXTRACTS



Fig 3. The simple extraction device.

We tested two extraction levels – 2hrs aqueous extraction (rotary mixing 160 rpm; solid/liquid ratio 1.1:5 w/w) and 16hrs aqueous extraction (same condition). Acid (2.5M HCl) was added to some of the extracts to hydrolyze any polysaccharide to monomers before analysis. From anthrone total carbohydrate analysis of the resultant extracts (620nm), the following results were found:

	16hrs (acid pre-treated)	16hrs (no pre-treatment)	2hrs (acid pre-treated)	2hrs (no pre-treatment)
g/L of extract (D-glucose equivalent)	0.316	0.327	0.148	0.138
g/kg of fresh mass	1.44	1.48	0.673	0.627

2. TREATMENT EFFECT ON COMPOST MATURATION

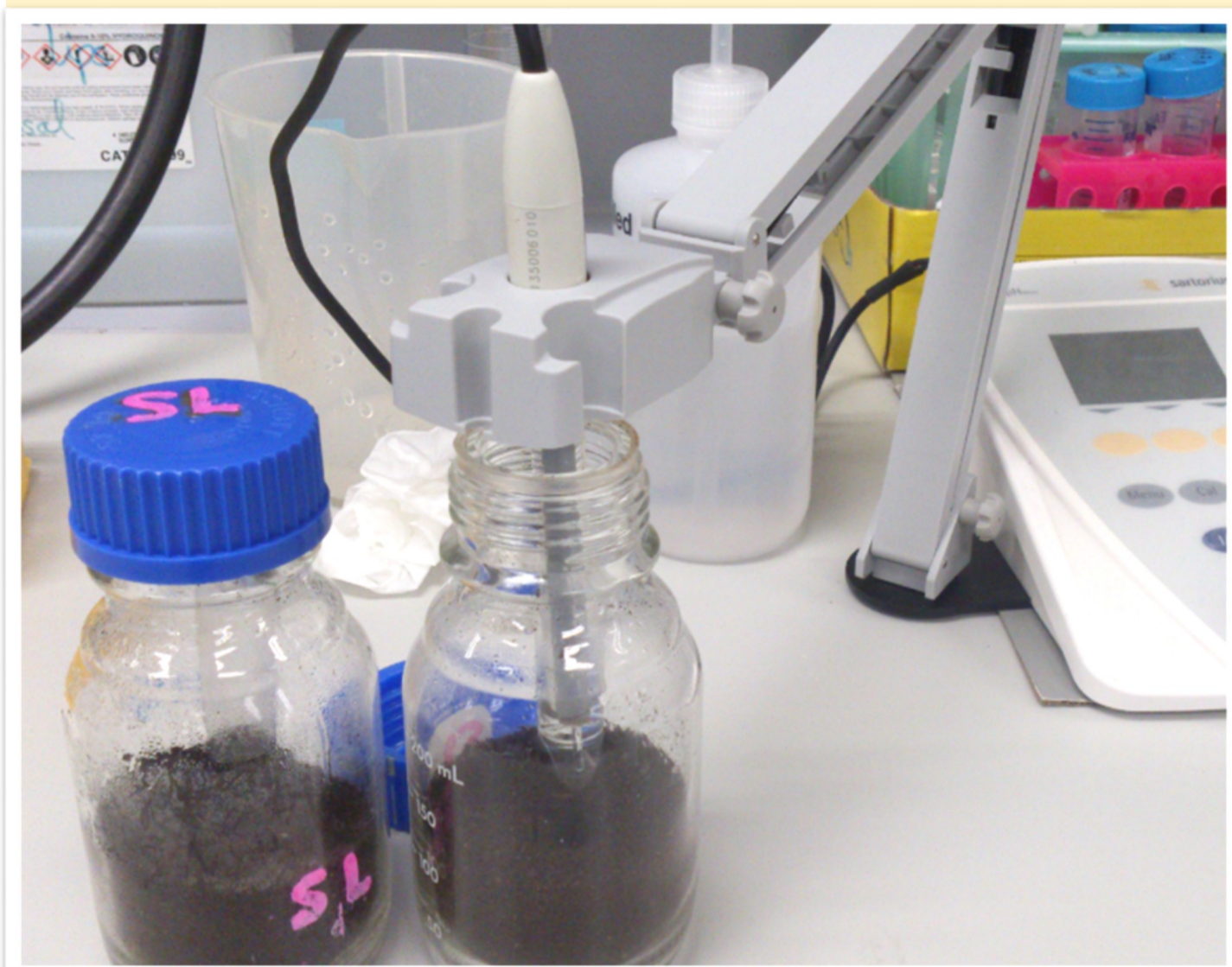


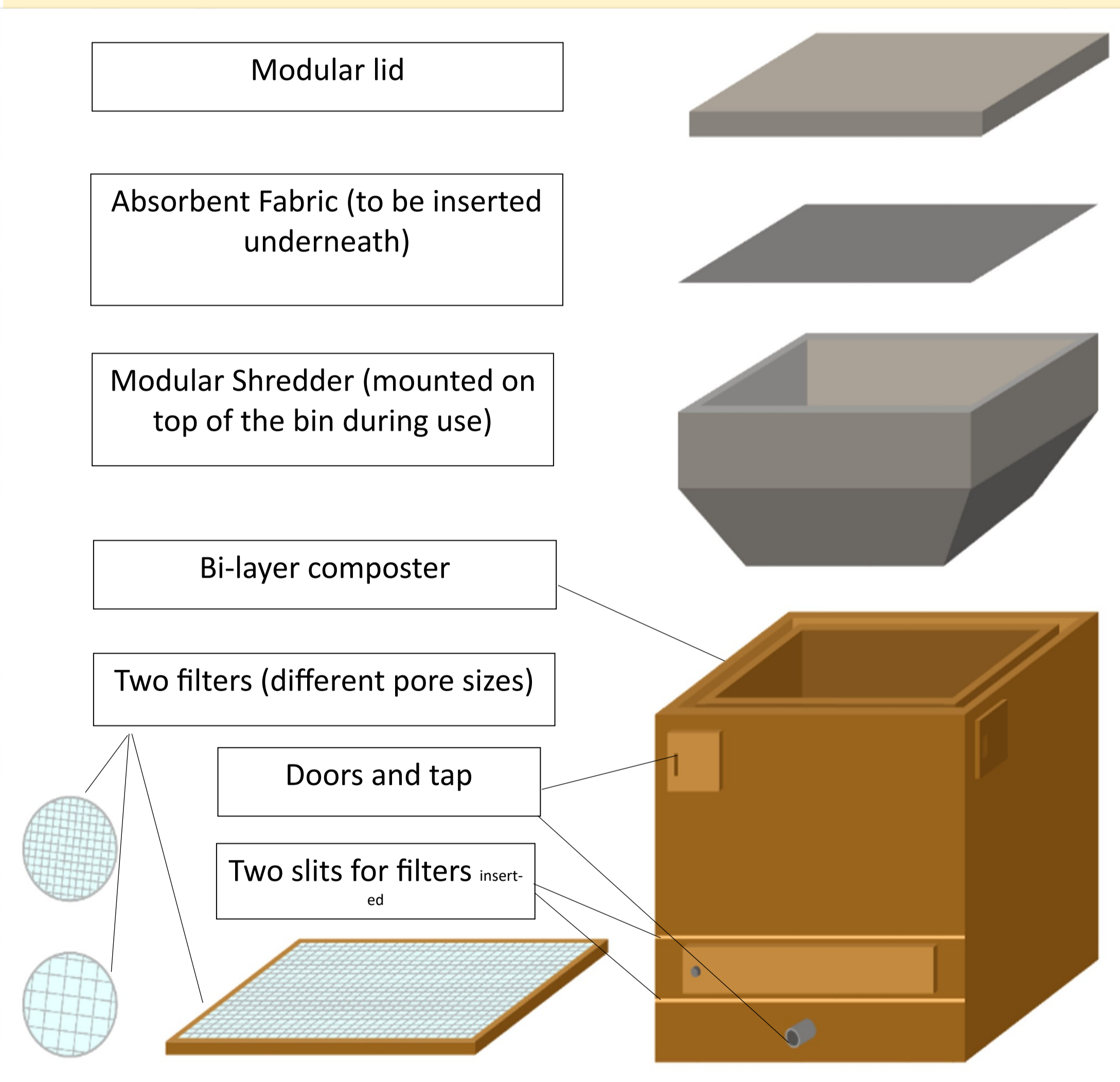
Fig 4. Lab-scale incubation.

We have an ongoing experiment to evaluate the effects of different treatments on compost maturation. Laboratory incubation experiments are used instead of field experiments because field experiment requires an unfeasibly large number of composters. Firstly, the effect of post-extraction residues (from different extraction duration in the above experiment) was being tested. Secondly, we are evaluating the effect of different timings of coffee grounds addition. Furthermore, we are also trying to study the effects of adding vegetable extracts back to the compost system at a later stage (analogous to recycling leached nutrients). However, due to the long queue of samples from lab users waiting to use the CHNS elemental combustion analyzer, we have insufficient data to compile C/N and HA/FA time profiles at the moment.

3. END PRODUCT QUALITY

We are also interested in the quality of mature end-products in terms of total N as well as water holding and infiltration characteristics as they are the key factors governing terrestrial productivity. However, due to the unexpectedly cold weather in February, composting activity was halted (the weather only started becoming permissible for composting in mid February). At the moment, no result is obtained yet since the bulk of the composts have not matured and we also have to wait for the results from the above maturation measurement to confirm maturity and make fairer comparisons between different treatments..

4. COMPOSTER DESIGN



The major components of the composter design include a two-layer composter frame, a modular shredder that can be mounted onto the top of the composter, a modular composter lid with absorbent fabric lined underneath, two filters with different pore sizes (1mm and 0.1mm) for effective separation of fine mature compost (which is very difficult normally) and leachate from the rest of the pile, several doors and a tap for easy aeration and collection of mature compost and leachate. This composter design is intended for solving the listed problems all in one as well as to maintain user-friendliness. The composter wall comprises of a two layer system which helps to trap heat when the lid and all doors are closed (sustained temperature at around 50°C can speed up compost decomposition). However, whenever any of them is opened, passive ventilation is automatically achieved as the void between the two layers is connected to the compartment holding the mature compost just below the first filter (i.e. aerating the pile from the bottom where it needs the most oxygen). The modular shredder is necessary to achieve a higher composting speed and volume reduction. Also, as it can be connected to the composter, there is no hassle to move the shredded materials from one place to another. Absorbent fabric or mesh helps to trap vapor and up-rising warm gases which mainly include CO₂ and NH₃ and the neutralization of those gases will prevent them from being emitted. The saturated fabric can be wrung to return nitrogen to the compost. Finally, since the mature compost can be taken out easily, continuous composting is allowed instead of just batch composting.

THE FUTURE

Although there are some inherent limits in the research (e.g. limited number of composters), this project can nevertheless provide a very important insight to the potential management options of organic waste for a big producer like Hong Kong. It provides insights for both innovative integrated biorefinery system (first extraction and then composting) on the industrial scale as well as the possibility of decentralized treatment of organic wastes through enhancing public participation by a user-friendly and impact-free composting approach. We hope that this project will serve as a pioneering step to transform the landscape of HKUST and Hong Kong.

Acknowledgements

We would like to take this opportunity to thank Sustainability Unit and Mr. Davis Bookhart for the continual support as well as Prof. Stanley Lau group in the Coastal Marine Lab (Mr. Chan Hong in particular) which makes the scientific research part possible. I would also like to thank some fellow students (Ms. Wong Ka Kwan and Mr. Leung Cheuk Wai in particular) who have provided crucial assistance in the field works as the project involves inevitable physical work.

DISCUSSION

1. In this part, we try to evaluate the amount of carbohydrates (one of the useful substances) in vegetable extract using simple water extraction. The results demonstrated that vegetable waste contains an appreciable quantity of carbohydrates which can be used to make valuable substances such as biofuel. However, the result neither represents the potential amount obtainable in industrial extraction nor the precise amount that would be leached in an actual compost since this simple rotary water extraction experiment is somewhat different from them.

2. Food substrates that have undergone non-destructive (enzymatic or very powerful mechanical extraction) can be conveniently put back into the compost. Preliminary results showed that extraction not only take away some of the soluble nutrients but can also affect the substrate in some other ways (e.g. increasing the porosity) which sped up its decomposition. However, this may cause premature and shortlived thermophilic phase which may not be beneficial for composting. Coffee ground is a very interesting substance because of its high surface area and N content, thus it can be used to control compost temperature precisely (to remediate the above temperature effect of extraction) which then help optimize the maturation of the bulk substrates (i.e. fallen leaves).

3. The cold weather early on appeared to have driven away compost detritivores and there was no signs of compost microbial decomposition as well. This means composting is best done outside winter and we can save winter time for collecting bulk ingredients (i.e. fallen leaves).

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