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FOOD WASTE RECIPES
for growing bacterial cellulose

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Introduction

Scope:
Acknowledging the large amounts of food becoming waste every day, the project investigates the circularity and potential of using food waste as a resource for biomaterial creation, in order to expand the scale, production and use of bacterial cellulose (BC) in uncontrolled diy settings.

Context:
Research and use of bacterial cellulose has been growing exponentially over the last years with applications in fields of biomedicine, packaging, art, product, fashion design and emerging prototypes for architectural uses. Although a bio-based and biodegradeable material synthesised by bacteria, if grown in pure form it involves an expensive process, or if domestically grown, through Kombucha fermentation, it is still using 'raw' ingredients (tea and sugar) that pose constraints for scaling up its production for potential wider use in the built environment.

Research Questions and Aims

1. Can we grow bacterial cellulose from food waste?
investigate whether various food wastes can become part of the growing medium for bacterial cellulose synthesis, and if yes, test working ingredients, ratios and methods that offer more consistent growth

2. How resilient is the process?
test whether the process can be achieved in a domestic uncontrolled and unsterile space rather than a laboratory setting, and observe patterns, working methods and techniques

3. What are the properties of the grown materials?
observe growing and drying behaviours and how these may differ and influence a different type of bacterial cellulose pellicle with different or similar properties to the one grown through the Kombucha recipe

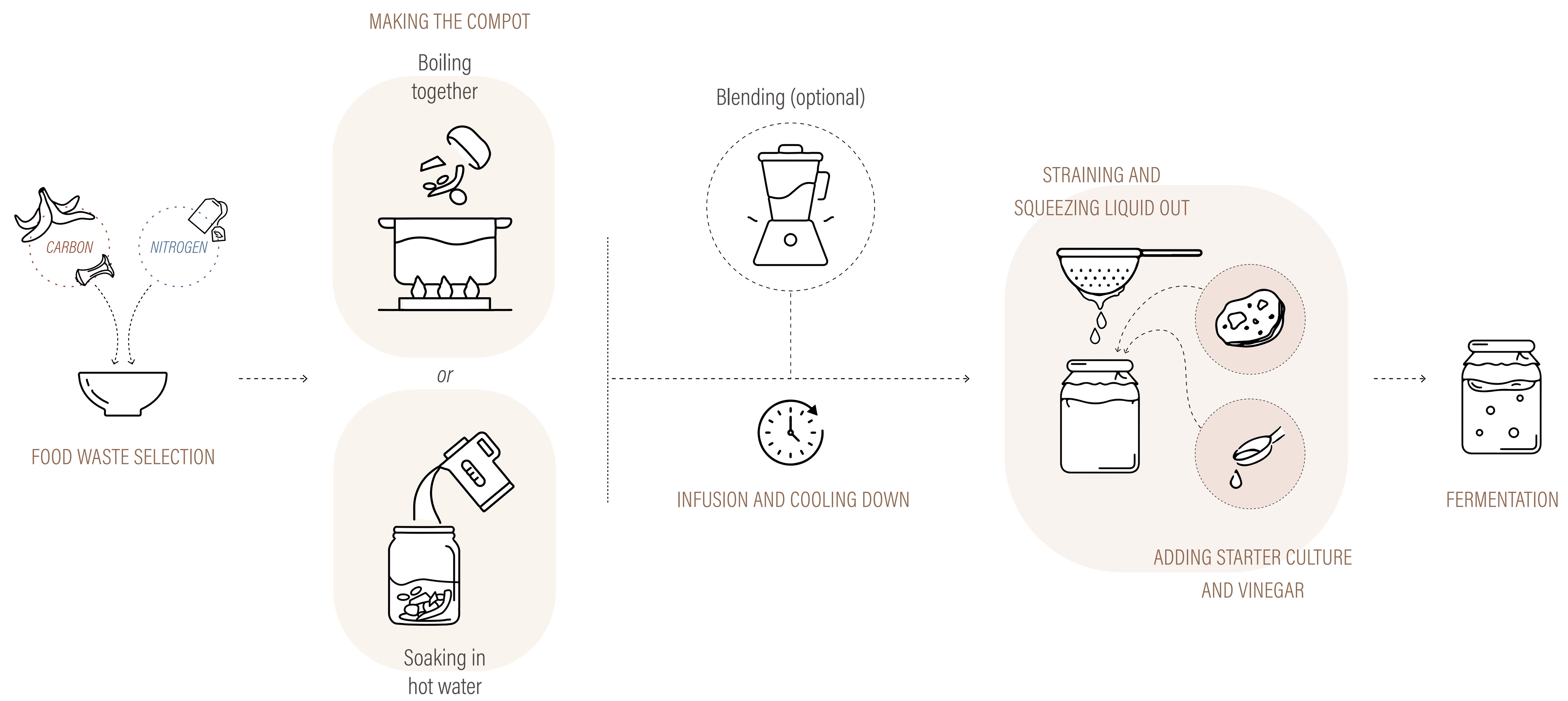
Methodology

The research had an experimental approach with iterative testing that combined anecdotal and exploratory approaches with methodical planning and literature review research. Initial review of existing literature on bacterial cellulose growth from waste and their tested methods was undertaken. Together with precedents on diy experiments, they informed the development of initial test recipes. The preliminary tests were followed by sets of experiments looking at improving recipes and outcomes.

The preparation of the growing media from food wastes is showed in the middle-top diagram; this summarises the different methods used and the learning outcomes emerged from repeating the preparation multiple times and observing best practices.

Photographic monitoring was used along with written observations and findings, these were logged into experiment tables with detailed information about used ingredients, preparation method, growing behaviour, and material properties, both at harvesting and when dried.

*Poster edges show some pellicles at harvest time (left) and in dried form (right)
Top to bottom: apple, banana, orange, watermelon, pineapple, banana and orange.



Storage
Food waste can be either used fresh, air or oven dried, or stored in the freezer. The type of storage preceding the process may affect the structure of the waste and therefore its infusion for the fermentation.

Decontamination
In some cases, such as apple, thorough decontamination may not be necessary as the waste comes from the core, however it plays a crucial role in processing waste in the form of peels or skins.

Breaking down the components
Making the compot already starts breaking down the structure of the waste, allowing sugars and other nutrients to be infused in the water. Blending can also add to this aim increasing the sugar content of the liquid, however it can lead to fine pulp that passes through the filter.

Separating liquid from solid
Removing solid matter to leave the liquid as free of pulp and bits as possible is crucial to avoid its interference with the fermentation process and its risk of making it prone to contamination.

Acidic media
Apple cider vinegar helps give a microbial boost whilst also dropping the PH under 4.5 for fermenting.
For banana peel which is more alkaline, higher content of vinegar, or starter culture is advisable.

*Diagram above summarises the used method for media preparation with information about each step and important observations underneath.

Apple waste BC

Recipe
The process of preparing the growing media proves the most straight-forward and easy to be performed.

Growth
In comparison to Kombucha pellicles, the apple waste produces similar growth in the same amount of days when nitrogen source is introduced.

Wet properties
Consistent, smooth texture
#A1 - 3mm (28 days)
#A2 - 10-12mm (28 days)

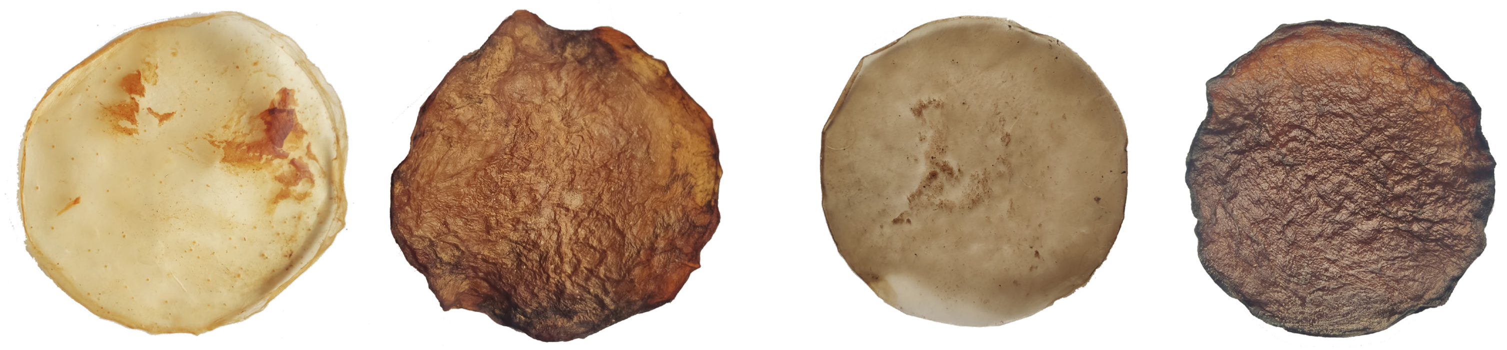
Dry properties
Comparable elasticity and texture to Kombucha pellicle
#A1 - semi-transparent, smooth
#A2 - opaque, wrinkled texture
Smell - hints of vinegar, fruity

#A1 - Apple waste
28 days fermentation

#A2 - Apple and tea waste
28 days fermentation

#B1 - Banana peel
7 days fermentation

#B2 - Banana peel
28 days fermentation



*Columns show each pellicle from fermentation stage, to harvested form (top and side views of the disk) and to dried form (top view of disk).

Banana peel BC

Recipe
The process of preparing the growing media can prove timely when blending because of the step of straining fine pulp.

Growth
The growth can vary, especially with the amount of banana peel introduced in the growing media. Depending on method, texture can also be affected, bubble formations appearing.

Wet properties
Consistent, smooth texture
#B1 - 1mm (7 days)
#B2 - 8-10mm (28 days)

Dry properties
Brittle texture, more fragile than Kombucha or apple waste pellicles
#B1 - semi-transparent, smooth
#B2 - opaque, wrinkled texture
Smell - almost odorless, faded hints of banana peel

Results

Preliminary tests showed that bacterial cellulose can be grown with nutrients coming entirely from wastes, without addition of sugar, from a wide variety of fruit wastes such as banana peel, apple and pear cores, orange peel, pineapple skin and watermelon rind.

Further experiments focusing on the most common fruits available in UK, apples, bananas and oranges, showed various fermentation behaviours, such as not all being influenced by a nitrogen source (tea waste), that banana peels in higher quantities gave a thicker pellicle, and that orange peel fermentations were more prone to contamination. Therefore, as orange peels were also the most covered waste type in existing research on wastes used for bacterial cellulose growth, apple and banana wastes were analysed in more detail.

Apple waste showed consistent results in growth and material properties, whilst further experiments of banana peel fermentations showed inconclusive results. More testing is needed to understand the behaviours of these fermentations and analyse the impacts different factors (preparation method, ratios of peels, fruit ripeness and ratios of starter culture) have on the pellicle growth.

Conclusion and future investigations

This project found that bacterial cellulose (BC) can be synthesised from nutrients contained in a variety of food wastes, with some working ratios and methods being identified (1). In comparison to the Kombucha BC pellicle, the process appeared less resilient (as it seemed more prone to contamination depending on the cleanliness of the wastes), however the uncontrolled setting did not seem to affect the success of the growth differently than it would influence it in the Kombucha process (2). Finally, a variety of fascinating properties emerged from various wastes, some similar to the Kombucha samples, others entirely different. The method as well as the period of growth are believed to influence the material properties along with the nutrients given by the waste (3).

This research uncovered many new potential avenues of investigation including further exploration of working recipes for growing larger scale BC, and studies on the potential of banana peel BC - how it changes properties (colour, texture) when drying, and its lack of vinegary smell that may make it more appealing to users as opposed to the Kombucha pellicles. In addition, the potential of expanding this process could inform future research that investigates smaller to larger scale design and infrastructure implications, related to collection and processing of wastes, domestic arrangements, and other considerations needed in order to create systems that use local waste to grow local materials.

Bibliography

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