

Improving the print quality of Print pastes made from nutshell waste

project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 04 - 04 - 2023

22 - 09 - 2023

end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

The need to reduce our reliance on fossil fuel energy and non-renewable resources, along with a growing awareness of the environmental impact of our energy and materials, has increased interest in bio-based materials that utilise biomass, and avoid melting plastic. In the world of additive manufacturing, these materials have gained popularity as a sustainable approach for reducing print energy and material footprint. Traditional materials used in additive manufacturing, such as ABS and PET, require significant amounts of energy to melt, are derived from non-renewable sources (petroleum), and are not biodegradable, creating a need for more sustainable alternatives. The commonly used biopolymer PLA already is an improvement, as it is made from renewable resources. However, it still has some sustainability challenges:

(1.) PLA is still a thermoplastic and thus requires significant energy to melt. This is the great majority of the energy use of FDM printers. (2.) PLA is produced using valuable food sources (e.g. corn), causing competition with food production and land use. (3.) Although PLA is technically biodegradable, the process is very slow (> 100 years) under normal conditions (e.g. when landfilled). Only in a controlled (industrial) composting environment can PLA degrade within 3 months. Thus when not disposed of correctly, PLA can still contribute to plastic pollution. (4.) Due to the specific recycling and composting demands, there are not yet reliable sorting and composting systems in place. Therefore, PLA often still ends up in a landfill or the ocean. (Ghomi et al., 2021).

One way researchers are finding better alternatives is by using biomass waste streams that harden at ambient temperature, with no need for melting; creating 3D printable materials made from e.g. Oyster & mussel shells, eggshells, olive pomace and mica. Their development can reduce waste and carbon footprint; material cost compared to virgin materials; offer unique properties and textures; and contribute to a more circular economy. However, the current limitations of these materials are that they show inconsistency in quality and processing, making it difficult to control properties and achieve consistent printing quality. In addition, most of these materials are water-soluble. Though this allows for easy re-printability, it does decrease their durability.

The main aim of this project is to increase the print quality and consistency of nut shell-based materials. the goal is to test multiple recipes and printer settings on their ability to produce consistent prints with high quality. to compare, samples will be evaluated using the following criteria (Figure 1):

1. Extrudability; consistent flow rate, minimal nozzle clogging, good layer adhesion, prevention of stringing
2. Surface finish; the smoothness and consistency of the printed surface
3. Dimensional accuracy; how closely a print matches the intended dimensions.
4. Detail resolution; primarily influenced by layer height
5. Overhang & bridging capability; maximum overhang and ability to bridge gaps without support

To show the potential of the material, its print quality will be compared to that of PLA prints. Additionally, when time allows it, the aim is to look into the end-of-life of the material and potentially experiment with ways to make the material re-printable without it being water soluble during its use phase. By doing this I hope to create a more durable material.

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introduction (continued): space for images

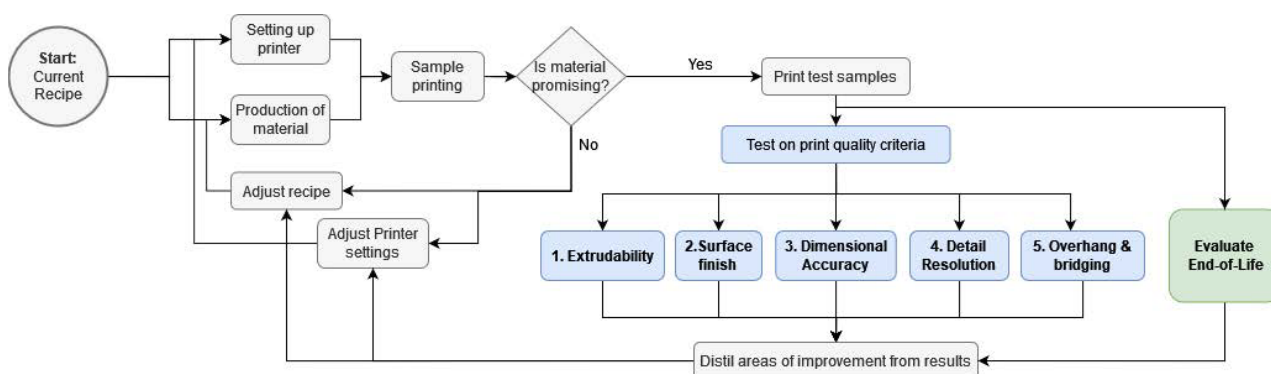


image / figure 1: Flow Diagram Procedure & Criteria

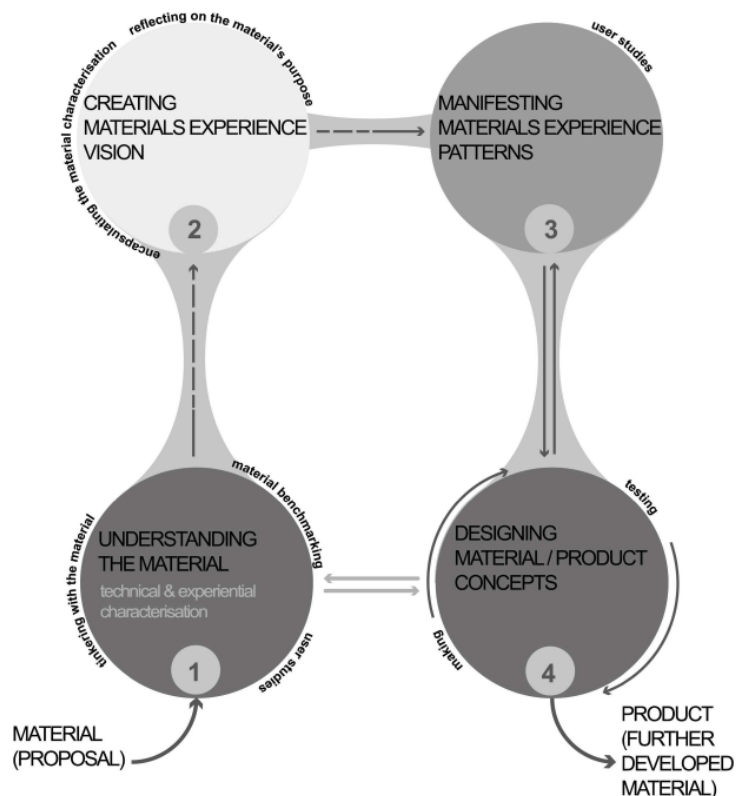


image / figure 2: The Material Driven Design Method (Karana et al., 2015)

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

The main issue this project addresses is the lower FDM print quality of Bio-based materials made from biomass waste streams compared to that of PLA and other commonly used 3d print filaments. To compare results, prints made with the developed material mixes will be evaluated on the already mentioned criteria (see introduction); Extrudability; Surface finish; Dimensional accuracy; Detail resolution; and overhang & bridging capability. Though the mechanical properties of the material are important, they will be largely left out of the scope of this project. This is done to allow for enough time to perfect the print quality as much as possible.

Another issue that will be addressed in this project is the durability and end-of-life scenario of the material. Currently, many similar materials are made with water-based binders. This allows for easy re-printability at end-of-life, but it does decrease the material's durability and limits the applications. Part of the project will therefore be spent on finding alternative binders or methods that prevent the material from dissolving in water, while also taking into account the end-of-life scenario. Testing all aspects of material durability would be a project in its own right. Therefore, This project will focus on two specific factors: the material's water resistance during use and its reprintability. Water resistance can be assessed through a simple water immersion test. Testing the reprintability, will require a more experimental approach to find ways to restore the material to its initial viscous state. When a viscous state is reached, reprinting the material using the same print file will help compare the reprinted samples on the determined quality criteria (see introduction)

A Eazio Bio printer will be bought for this project to prevent time spent on modifying a desktop FDM printer . the hardware design of the printer thus falls out of the scope of this project. Adjusting printer settings to achieve optimal print quality does fall into the scope.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

The main goal of this research is to develop a recipe for bio-based material made from nutshell waste that can be extruded using FDM with a print quality equal to or better than the currently available PLA filament. The sub-goal is to improve the durability of the material by looking into ways to make the product non-water-soluble during use.

The aim is to create a nutshell-based recipe that can deliver high-quality print results on an FDM food printer. To showcase the recipe, I aim to deliver multiple printed prototypes that showcase the capabilities and qualities of the printed material, especially regarding the visual qualities.

Though not the focus of this project, I do aim to do some mechanical test on the final material recipe so future research on improving the properties can have reference data.

Furthermore, I intend to produce a prototype that demonstrates the material's attempted insolubility and water resistance during use, as well as its reprintability. (If I manage to find a presentable solution)

Near the end of the project, some time will be spent on exploring possible use cases/applications for the developed material.

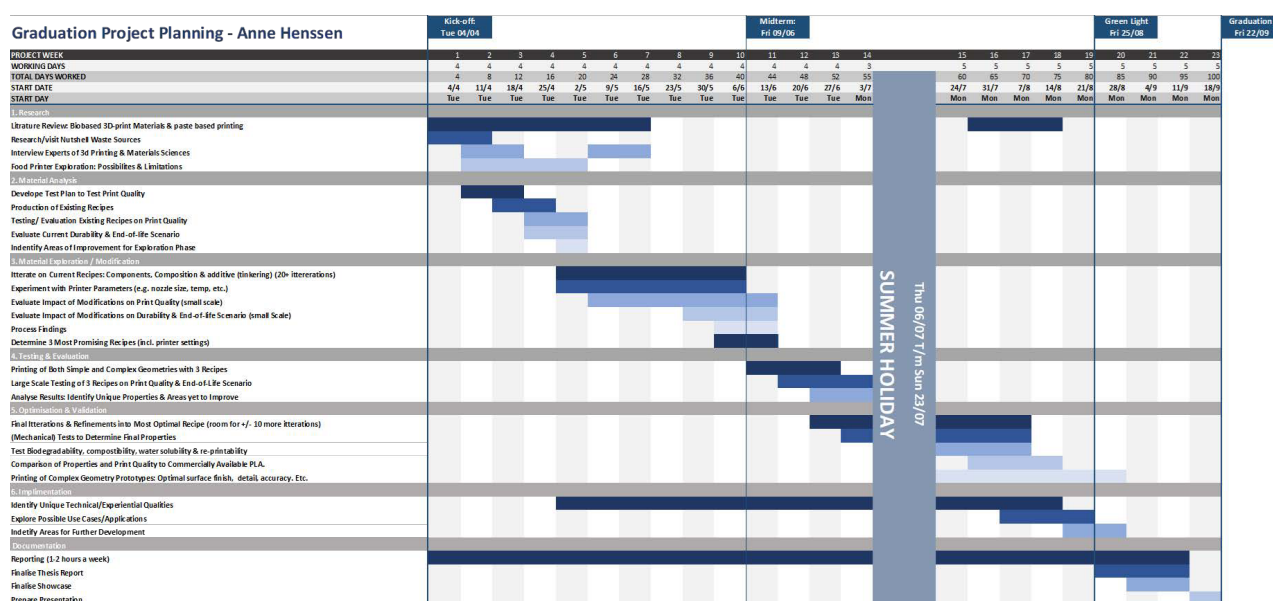
PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 4 - 4 - 2023

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end date



I have divided my project into six phases:

- (1)Preliminary Research: gathering of information on current (nutshell) bio-based materials, their properties, and their current/potential applications in 3D printing. Gathering information on the properties of nut shells and their waste stream. Understanding the working of a paste printer.
- (2)Material Analysis: analyse the current walnut shell-based 3D printing material to identify areas for improvement
- (3)Exploration & Modification: Iterate on current recipes based on identified areas of improvement; modification of material's composition and printing parameters.
- (4)Testing & Evaluation: Test the modified walnut shell-based 3D printing material to evaluate print quality, durability and end-of-life.
- (5)Optimisation & validation: Refine the material based on test results, determine final properties and print complex prototypes to showcase qualities.
- (6)Implementation: Determine possible applications and necessary future improvements

Throughout the project, the MDD method (see Figure 2) will be used as a reference (Karana et al., 2015). The project's main focus is on the "material exploration" step of the method. Up until my holiday, I will work part-time (4 days), I decided to do this to allow myself a day a week to further develop myself in woodworking. After my holiday I will work full-time on the project.

Since reporting is an activity which I usually spend more time on than the average student, I have scheduled a few hours of reporting each week. I will have one hour meetings once a week with my mentor.

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, Stick to no more than five ambitions.

This project perfectly combines 3 of my main interests; Design for sustainability, Material Development and Additive manufacturing. During my studies, I have spent considerable time on projects involving 3D printing (for 10XL and 3DRobotPrinting) and Material development of bio-based materials (MDD & PEM courses). However, never have I had the possibility to combine both of these skills. This graduation project appeared to be an excellent chance for me to address some concerns I've been having lately regarding the sustainability of my 3D printing projects. While using recycled plastics to create items is a positive step towards reducing waste, it is not without drawbacks. For instance replacing durable, non-plastic outdoor benches with recycled plastic ones will lead to the release of more microplastics into the environment.

To conclude, the need to find better alternatives to plastics is increasing and I'm passionate about contributing to this. This project is a great starting point.

Another reason for setting up this project is that I think my strengths lay in being precise and detail-oriented.

I think focussing on perfecting/optimising the print quality of the purposed material fits this approach well.

Additionally, during my bachelor's and master's, I have always enjoyed prototyping most. Choosing a prototype-heavy project is hence a logical choice.

Competences I want to prove and develop further:

- Knowledge of additive manufacturing, gained during my minor in advanced prototyping, my elective "digital materials" and my Internship.
- Knowledge of Material Driven Design, gained during the PEM course of Advanced prototyping and the MDD elective.
- Knowledge of design for sustainability, gained during bachelor courses and my elective "towards circular product design".

Personal learning ambitions for this project:

- Improve Academic writing skills
- Gain in depth-knowledge on (bio-based) material development
- Improve my presentation skills
- Better understand/ experiment with G-codes
- Work on/ Improve my scientific/technical debate and discussion skills

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

SOURCES:

Ghomi, E. R., Khosravi, F., Ardahaei, A. S., Dai, Y., Khorasani, S. N., Foroughi, F., Wu, M., Das, O., & Ramakrishna, S. (2021). The Life Cycle Assessment for Polylactic Acid (PLA) to Make It a Low-Carbon Material. *Polymers*, 13(11), 1854.

<https://doi.org/10.3390/polym13111854>

Karana, E., Barati, B., Rognoli, V., & Zeeuw van der Laan, A. (2015). Material driven design (MDD): A method to design for