Report

Mushroom farm

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Acknowledgement

Glossary

Abbreviation	Description
ANIPLA	Associação Nacional da Indústria para a proteção das Plantas
CAGR	Compound Annual Growth Rate
EPS	European Project Semester
ISEP	Instituto Superior de Engenharia do Porto
USB	Universal Serial Bus
LED	Light Emitting Diode

1 Introduction

1.1 Presentation

The team is made up of 6 interdisciplinary students from 6 different nationalities. The team has come together to be part of the European Project semester (EPS) in the spring of 2019 at Instituto Superior de Engenharia do Porto (ISEP). Over 5 months (1 semester) the team is going to use each other's knowledge from various backgrounds and strengths to work on creating a sustainable mushroom farm using coffee waste. This highly motivated and passionate team is shown in Figure 1.

Figure 1: Our lovely team

1.2 Motivation

The team's motivation behind choosing the project to build a mushroom farm using coffee waste was that although everyone comes from interdisciplinary background, none of the team members had directly worked with food production. Everyone in the team could agree that the food industry has quite destructive processes and so everyone was motivated to create a sustainable food system which encompasses sustainable social, environmental and economical practices to encourage environmentally friendly practices. The whole team was directly interested in the delicate process used to cultivate mushrooms and how it could be optimised. The idea allowed everyone to use their specific discipline/skills in a totally unique and new situation broadening their understanding in not only their field but how their field can be applied to new industries. The team also took this opportunity to develop their skills in project management, soft skills and ability to work as a team.

1.3 Problem

Coffee is a massive industry, with more and more people consuming coffee, the negative environmental effects from the industry keep growing. When coffee is made only less than 1 % of the biomass ends up in the cup. Think about this for a while… There are more than 9 billion kilograms of coffee beans per year! A huge amount of energy and resources go into producing and shipping coffee beans around the world however all the value is placed on the liquid extraction of their flavour. But the problem here is that 99 % of the biomass from the coffee is wasted [1]. This huge amount of coffee waste is still full of nutrients which are a very good growing medium for Oyster mushrooms to

grow in. The waste coffee is full of cellulose which Oyster mushrooms need to grow. The wonderful thing about mushrooms, is that they are natures natural recyclers. For example, when trees fall in a forest, it is the mushrooms which break down these complex molecules in the wood and recycle them back into the food chain for bacteria, insects and other types of fungi to return back to the soil to be consumed. Mushrooms play a crucial role in the cycling of nutrients and their ability to do this makes them perfect for recycling a wide range of organic waste streams. Oyster mushrooms, in particular, are very versatile and have shown to grow on over 200 different agricultural waste materials. **[2]**

1.4 Objectives

The main objective is to develop a sustainable service by which waste coffee is collected and used as a growing medium for oyster mushrooms. Waste from another industry is being taken and utilized to produce food. This is sustainable by definition. A system will be designed to make the process as sustainable/efficient as possible. This will be done by developing a device which allows the monitoring and optimization of the growing environment for mushrooms to thrive and grow in abundance from waste. This device will allow the cultivation of Oyster mushrooms on a large scale in order to be sold to consumers (restaurants, supermarkets etc.) However, the device will also be able to be modified in order to allow consumers to purchase the device and cultivate mushrooms on a smaller scale at home. This can be achieved through a modular design. The aim of the overall image and values of the company is to promote sustainable food production and to connect people back to the food they eat. This is to stimulate a more environmentally friendly mindset. This will be aimed at a local market whereby local economy is supported by sourcing, producing and selling within the local market. Surrounding the whole project, the team aims to develop multidisciplinary skills, as well as soft skills, such as project management and communication skills.

1.5 Requirements

The project has the following requirements:

1. Automatic monitoring and control of the chamber conditions
2. The medium or small scale of the device
3. Usage of low-cost hardware solutions (Not exceed the budget of 100 €)
4. Usage of the open source software
5. Adaptation of the International System of Units (NIST International Guide for the use of the International System of Units)
6. Comply with the following EU Directives:
   - Machine Directive (2006/42/CE 2006-05-17) **[3]**
   - Electromagnetic Compatibility Directive (2004/108/EC 2004 12 15) **[4]**
   - Low Voltage Directive (2014/35/EU 2016-04-20) **[5]**
   - Radio Equipment Directive (2014/53/EU 2014-04-16) **[6]**
   - Restriction of Hazardous Substances (ROHS) in Electrical and Electronic Equipment Directive (2002/95/EC 2003-01-27) **[7]**

1.6 Functional Tests

To ensure the proper functioning of the prototype, the sets of tests presented in Table 1 will be performed:

Table 1: Functional Tests

Test cultivation Process	Sensors/ Actuator Test	Hardware Testing	Software Testing	Material analysis
Sterilization of Coffee waste	Humidity control	Power Supply Circuit Test	Sensor Functionality	Material Simulation
Incubation period	Temperature Control	Sensor Functionality	Actuator Functionality	FEA Analysis
Fruiting Period	Airflow control	Actuator Functionality	Integration of sensors	Chemical/Aqueous resistant
Harvesting Process	Luminosity control		Full system Functionality Simulation	
Waste Management				

1.7 Project Planning

The project is coordinated according to agile project management in terms of scrum methodology. Scrum is an agile project management methodology or framework used widely for software development projects with the aim of delivering new software capability every two or four weeks. The approach articulates a set of values and principles to guide decisions on how to develop higher-quality software faster. Nowadays, not only is it used for software development but also it has spread to other projects, such as IT and marketing, where the speed of work is high in the presence of complexity and ambiguity [8].

The main advantages of this concept are:

- Higher productivity
- Better-quality products
- Better team dynamics
- Reduced time to market
- Improved customer satisfaction
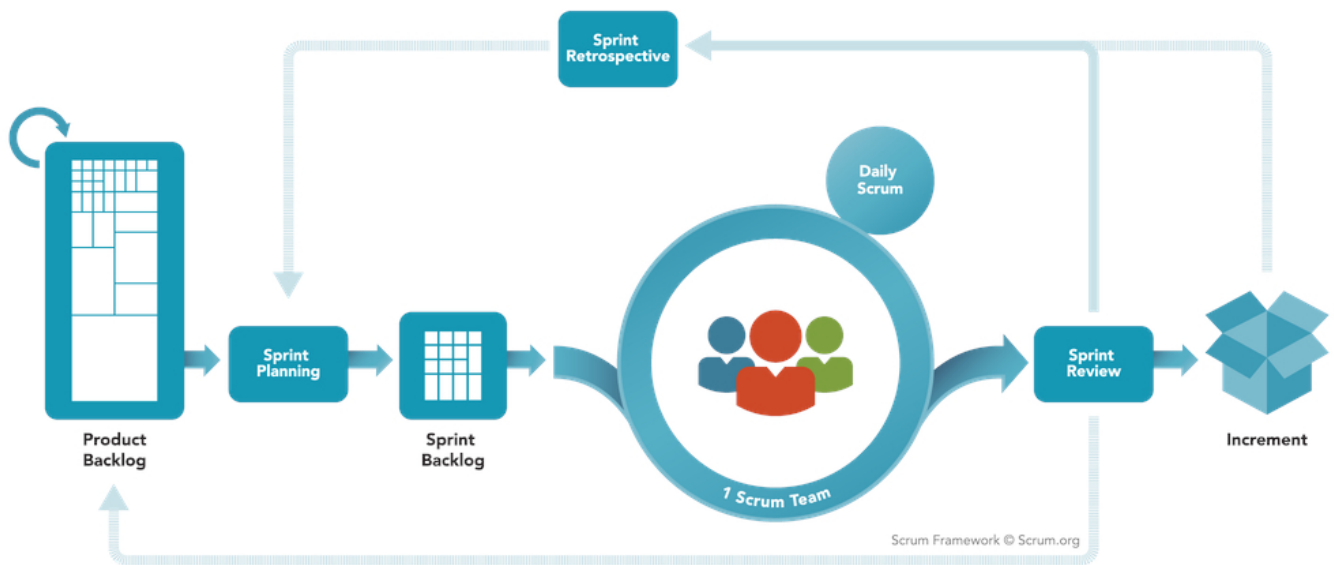
The Scrum framework is shown in Figure 2:

Figure 2: The Scrum Framework **[9]**

1.8 Report Structure

The project is structured in eight different chapters as shown in Table 2.

Table 2: Report Structure Table

Task	Title	Description
1	Introduction	General introduction of the team, the motivation and the objectives of the project
2	State of the Art	Research of existing solutions and products on the market in terms of scientific and commercial aspects
3	Project management	Documentation of the progress in accordance with the concept of the agile management method SCRUM
4	Marketing plan	The brief description of the market analysis, on what is built a marketing strategy consisting set of actions to implement it
5	Eco-effciency measures for Sustainability	Set of necessary components such as design, tests, and calculations in order to make the project sustainable
6	Ethical and Deontological Concerns	Analysis of the ethical challenges, limitations and their possible solutions
7	Project Development	The architecture, components and the functional tests of the made prototype
8	Conclusion	Summary of the results and possible future development

2 State of the Art

2.1 Introduction

In the State of the art, the natural growing process of mushroom is going to be discussed, along with

the different existing solutions, for industrial and individual purposes.

The state of the art refers to the highest level of general development, as of a device, technique, or scientific field achieved at a particular time. This is done to get ideas and solutions that could be added to the product or business plan. The cultivation process will be investigated in a lot of detail to gain a much richer understanding of the process, to see if any areas can be optimized or simplified to allow people to grow their own mushrooms as well as producing them on a more industrial scale.

By gaining a deeper understanding of not only the cultivation process but also the market allows detailed analysis of potential gaps in the market leading to a particular niche to be capitalized on.

The primary goal of a mushroom farm is to produce a consistent yield of mushrooms to be sold on the market. The goal of this report is to investigate the feasibility of creating a business surrounded by the idea of growing mushrooms using coffee waste. The output of the business needs to be investigated through market research, however the vision of the business is clear. To connect people back to their food through sustainable food production. This will either be done by creating a sustainable mushroom farm that supports the local economy, local environment and local people, or by creating a service that allows people to learn and grow their own mushrooms at home, thereby reconnecting them with the food they eat and how it is produced.

2.2 Presentation of Oyster mushroom and its growing process

2.2.1 Oyster Mushroom (Pleurotus Ostreatus)

Because the business is based around growing mushrooms in coffee waste, the mushroom best suited to do this is the Oyster mushroom. Coffee has loads of cellulose in it which is essential for the cultivation of Oyster Mushrooms. The common name Oyster refers to multiple species of mushrooms including Pleurotus pulmonarius, Pleurotus salmonostraminus, Pleurotus djamor, Pleurotus citrinopileatus, Pleurotus ostreatus, Hypsizgus ulmarius, and others. These mushrooms come ina range of colours, size and texture. Oyster mushrooms can come in pink, blue, brown and white. This allows small scale growers to cultivate 4 or 5 different products with growing oyster mushrooms. Oyster mushrooms are native to the North-eastern US. Most of the strains of Oyster mushrooms can be cultivated using the same system and growing process, all that differs is the spawn used, meaning only one method of cultivation needs to be mastered in order to produce an attractive assortment of different oyster mushrooms. In the image below you can see a large verity of different oyster mushrooms available on the market.

Figure 3: Types of Oyster Mushrrooms **[10]**

2.2.2 Mushroom growing process

Oyster mushrooms are basidiomycetes, referring to their method of sexual reproduction. The gills on an oyster mushroom contain basidia (microscopic structure). Attached to the basidia are 4 haploid spores which are released into the air at maturity. These spores germinate into mycelium. The mycelium grows through its food, in this case coffee and eventually fruits a mushroom providing the growing conditions are suitable. Oyster mushrooms are known for their heavy spore count and therefore routine cleaning in the fruiting room/environment is crucial. The goal of the mushroom is to provide a platform for sexual reproduction and release of the spores. Humans, insects and animals

are part of the chain which spread the spore of the mushroom **[11]** Mycelium continually breaks down food using an enzyme. These chemical enzymes contain antimicrobial compounds which create a protective barrier around the mycelial network. Fungi digests externally and then absorbs nutrients that have been broken down into its body. These enzymes break down food like lignin and cellulose (both found in coffee) into simple sugars which are used for continued mycelial growth. This is know as the colonization of mycelium or the incubation period after inoculation has occurred **[12]** It is crucial to have a solid understanding of mycelium because this is what mushrooms fruit from. Without healthy cultivation of mycelium, fruiting of the mushrooms will not occur. A mushroom farm firstly needs to cultivate mycelium and then through the maintenance of the right conditions (high moisture, high oxygen and the right temperature) will cause mushrooms to grow. Paying close attention to the health and growth of mycelium will help to achieve bigger yields. Mycelium needs to be cultured in a petri dish, this single petri dish is the starting point to produce large quantities of mushrooms. Different strains can be cultured to meet the needs of the growing. After the mycelium has been fully colonized and the right conditions are met for fruiting to occur, mushrooms will mature within a week. At this point, they are ready for harvesting. Each cake of block of colonized mycelium will produce between 3 to 4 flushes of mushrooms. After the 3rd or 4th flush of mushrooms, the remaining mycelium can be recycled by adding more substrate (food) and allowing it to colonize again so fruiting can occur. The Consistency of all these methods is the key to success **[13]**

Growing Mushrooms in coffee.

Mushrooms are notoriously hard to grow because of inconsistent results. This is partly due to the mass production of low-quality grow kits which give unreliable results. Even in the wild mushroom's growth is very unpredictable. However, by using the correct knowledge and relatively simple techniques it is possible to cultivate mushrooms on both an industrial and home scale. Similar to the fruits produced by a tree, mushrooms are the reproductive fruits of a dense rootlike network of cells known as mycelium. When mycelium runs out or it's put under some type of environmental stress it switches into survival mode and produces mushrooms in order to release its spores into the wind to find a better place to live. Lucky for us it is possible to recreate and manage the life cycle in order to cultivate good crops of edible mushrooms. Mushroom farming heavily relies on very strict growing conditions and minimising competition through pasteurisation **[14]**. However, this can cost quite a lot for someone who wants to grow at home. One of the aims is to make it as cheap and rewarding as possible. For this reason, Oyster mushrooms are a great place to start as they are very resilient and can grow in many types of agricultural waste. The most common materials used to grow Oyster are freshly cut hardwood logs or straw. Growing on logs can be quite difficult and can take several years before your first harvest. Growing on straw requires pasteurization to kill off any micro-organisms that will compete with mycelium. Growing in coffee has quite a big advantage as it has already been pasteurized by the brewing process meaning it is ready for inoculation, skipping out the pasteurization step. Not to mention used coffee grounds are a massive wasted resource as they are still full of nutrients which Oyster mushrooms love to grow on.

Inoculating

Firstly the mushroom spawn needs to be ordered. You will have greater levels of success if you use high spawn to coffee grounds ratio. To start 500 g of Oyster mushroom spawn to each 2.5 kg of used coffee grounds **[15]** Inoculation can be done in filter bags or buckets to provide a perfect growing environment and to prevent chances of contamination. Bags will have a filter and containers will have small holes.

Figure 4: Stages of inoculation **[16]**

Coffee collection

In order to skip out pasteurization step, the waste coffee needs to be fresh that day and therefore a service will be created to collect fresh coffee waste. Once the coffee waste is collected fresh, with very sterile conditions the coffee has to be mixed with the mushroom spawn and then added into the cultivation bag/container. Ensure there are small air holes if a container is being used instead of a filter bag.

Spawn Run

Place container in a warm (18-25°C) and dark place. During the next 3 weeks, the spawn will come to life and colonize across the coffee grounds, turning the mixture white **[17]**.

Fruiting

After about 3 to 4 weeks the whole container of coffee and spawn mix should be completely white. If you see any other colours such as green or black, then this is a competitor mold and needs to be removed. Salt can be used to kill it off without compromising the mycelium. This is why hygiene is so crucial. If you have achieved a nice white container then the mycelium is ready to enter the fruiting process by which you get mushrooms. Place the container in a pot with plenty of fresh air and a little light. Mushrooms love humid conditions so it is important to spray the mushrooms so they dont dry out **[18]** After a week or so you will see mushroom pins start to develop. Over the next 5/7 days the mushrooms will double in size every day. When the edges of the cap start turning upwards it is time to harvest. Cut the mushrooms at the base and be sure to remove the whole mushroom. You will typically get 3 or 4 flushes. The remaining mycelium can be used as spawn for the next grow.

2.3 Existing solutions for individuals

Mushroom kit

A substrate is already inoculated with mycelium and wrapped into plastic. Wrap is then placed inside the box, which is relatively small and allows to grow mushrooms anywhere in a home. Consumer has to cut an opening into the package and sprinkle it with water on a daily basis. After some time mushrooms will start to grow. After harvesting the process can be repeated twice.

Examples of existing mushroom grow kits are shown in Table 3.

Table 3: Mushroom kits available in Portugal

Name	Picture	Product	Mushroom type	Country of origin	Pricing
Resetea	[19]	mushroom growing kit	Oyster	Spain	19.90 €
CogusBox	[20]	mushroom growing kit	Oyster	Portugal	10.00 €
Kit Zás	[21]	mushroom growing kit	Oyster	Portugal	9.97 €
Siro	[22]	mushroom growing kit	Oyster	Portugal	8.83 €

Strenghts of grow kits:

- Easy to use
- Customers gain knowledge through the process

- Mushrooms are fresh
- Grow kit is easily recyclable

Weaknesses of grow kits:

- They are not designed for sustained cultivation of mushroom
- Only around 3 small flushes can be harvested

2.4 Existing industrial solutions

Aromas & Boletos

A company that focuses on the enhancement of sustainable and ecological production of wild and exotic mushrooms. Products and services for mushroom cultivation are developed and marketed. In laboratories, modern techniques are used to produce mycelium and substrate. An array of products includes mushroom spawn, grow kits, lab supplies, mushroom production equipment, and gourmet mushrooms. In the area of research, innovation and development Aromas & Boletos strives to innovate the production of mushrooms. They also do workshops for producers and aficionados, show-cookings, tastings and other activities in nature **[23]**.

Cogumelos Cultivados Lda.

A company that is specialized in the production, commercialization and distribution of exotic mushrooms. All the production is done in a biological way, focusing only on the national market. Sales are made directly to the customers such as restaurants & hotels, shops and markets, and some supermarket chains. The mission is to be an asset in the Portuguese food market and to offer high-quality biological products at affordable prices **[24]**.

Floresta Viva

Floresta Viva is responsible for the appearance of new producers, through specialized training for the activity with participants from all over Portugal and the Islands, Spain, India and France. The company is committed to being a valid partner of the producers, to be an active part in the propagation of the consumption of biological products of high-quality control. Their services include monitoring and technical support for mushroom producers, workshops on the production of mushrooms, commercialization of mushroom of different species. Other services are production and distribution of inoculated wood, as well as commercialization of specific machines and tools for shiitake trunk production **[25]**.

2.5 Conclusion

Mushrooms grow in wild and can be grown on both a domestic and an industrial scale. While farming is nothing new, people are demanding more sustainable foods. People not only want healthy food but want to know that it has been cultivated in a sustainable manner and is not having a negative effect on the environment. People are forced to pay slightly for organic and healthy produce and this is why more and more people are growing their own food at home. There are so many benefits of growing at home. Firstly, it almost eliminates the distance between the farm and the consumers plate significantly which lowers the carbon footprint of the food and guarantees freshness. Cultivating food at home can be educational and can connect people back to the food they eat. Many people do not have access to growing spaces and are sometimes unable to grow at home, but this is what makes

growing mushrooms so great. Growing mushrooms do not require a lot of space and can easily be done inside. Domestic cultivation of fungi has been popularized by grow kits, they are easy to use, take little space and after using are easily recyclable, however, there is a major disadvantage, these kits only produce three flushes and are not normally very big. After this, a new kit has to be bought or can be re-cultivated but normally can be quite time consuming and requires some specialized equipment, which can be costly for home growers. Cultivating mycelium can be difficult at home because it needs very sterile conditions. People want something that allows them to cultivate mushrooms in a sustainable way but does not require excessive effort or money. A potential solution could be to establish a service that collects fresh coffee waste and inoculates it with mushroom spawn, people would be able to buy cultivated mycelium in coffee waste allowing them to grow mushrooms on a decent scale. Remaining process will be relatively easy. The company, could supply customers with a monitoring device to make growing as simple as possible, as well as providing all the resources and information needed. The company could also provide courses to teach people about cultivating mushrooms and sustainable foods. Other option could be to build a mushroom farm by which the company provides consumers and restaurants with fresh organic mushrooms grown from coffee waste. As there are already existing farms, which have a strong position in the market, it would be extremely difficult for an EPS team to compete with established competitors. The Team decided somewhat to combine the two ideas and build a device, while also providing service mentioned above. Service would also include collecting coffee waste.

3 Project Management

3.1 Scope

The first step of successful project management is the creation of scope in order to define and organize the work that has to be executed by the project team. The best idea is to use a simple hierarchical decomposed structure of all tasks and deliverables which are essential to accomplish the final project outcome. One of the widely use structures is a Work Breakdown Structure (WBS), which visually divides the scope into sections, where each of them provides further definition and detail. In Figure 5 it is presented a brief WBS structure of mushroom farm project.
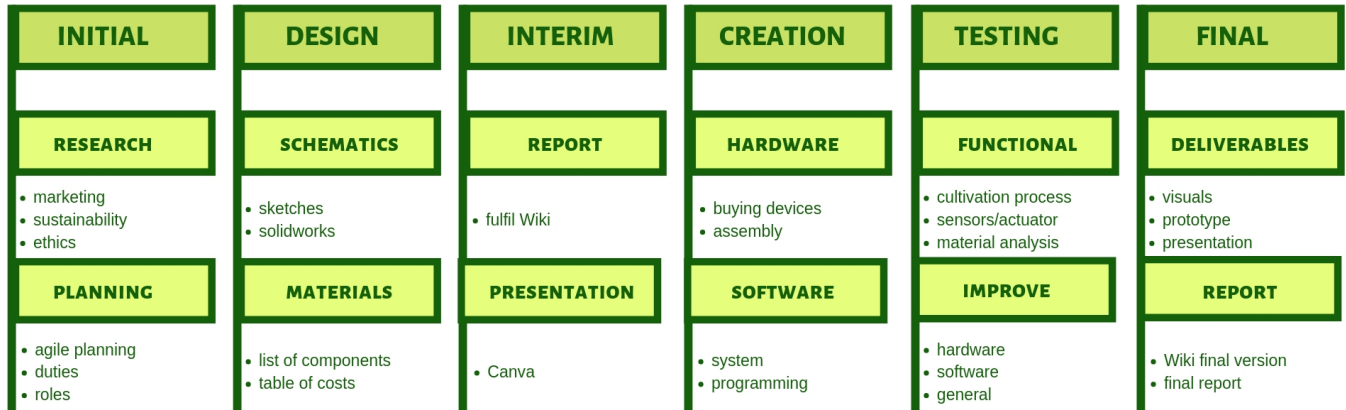
INITIAL	DESIGN	INTERIM	CREATION	TESTING	FINAL
RESEARCH	**SCHEMATICS**	**REPORT**	**HARDWARE**	**FUNCTIONAL**	**DELIVERABLES**
• marketing • sustainability • ethics	• sketches • solidworks	• fulfil Wiki	• buying devices • assembly	• cultivation process • sensors/actuator • material analysis	• visuals • prototype • presentation
PLANNING	**MATERIALS**	**PRESENTATION**	**SOFTWARE**	**IMPROVE**	**REPORT**
• agile planning • duties • roles	• list of components • table of costs	• Canva	• system • programming	• hardware • software • general	• Wiki final version • final report

Figure 5: Work Breakdown Structure (WBS)

3.2 Time

After making scope, the second step of planning is managing work time. The project is coordinated according to agile project management in terms of scrum methodology but is always better to prepare general overview with milestones and phases in the project, that is why the Gantt chart has been created. The Gantt chart is divided into phases based on project scope. The chart is a more classical tool for monitoring the course of events and tasks completion, but it could be helpful in terms of monitoring and preparing sprint backlog. The Gantt chart of mushroom farm project is shown in Figure 6
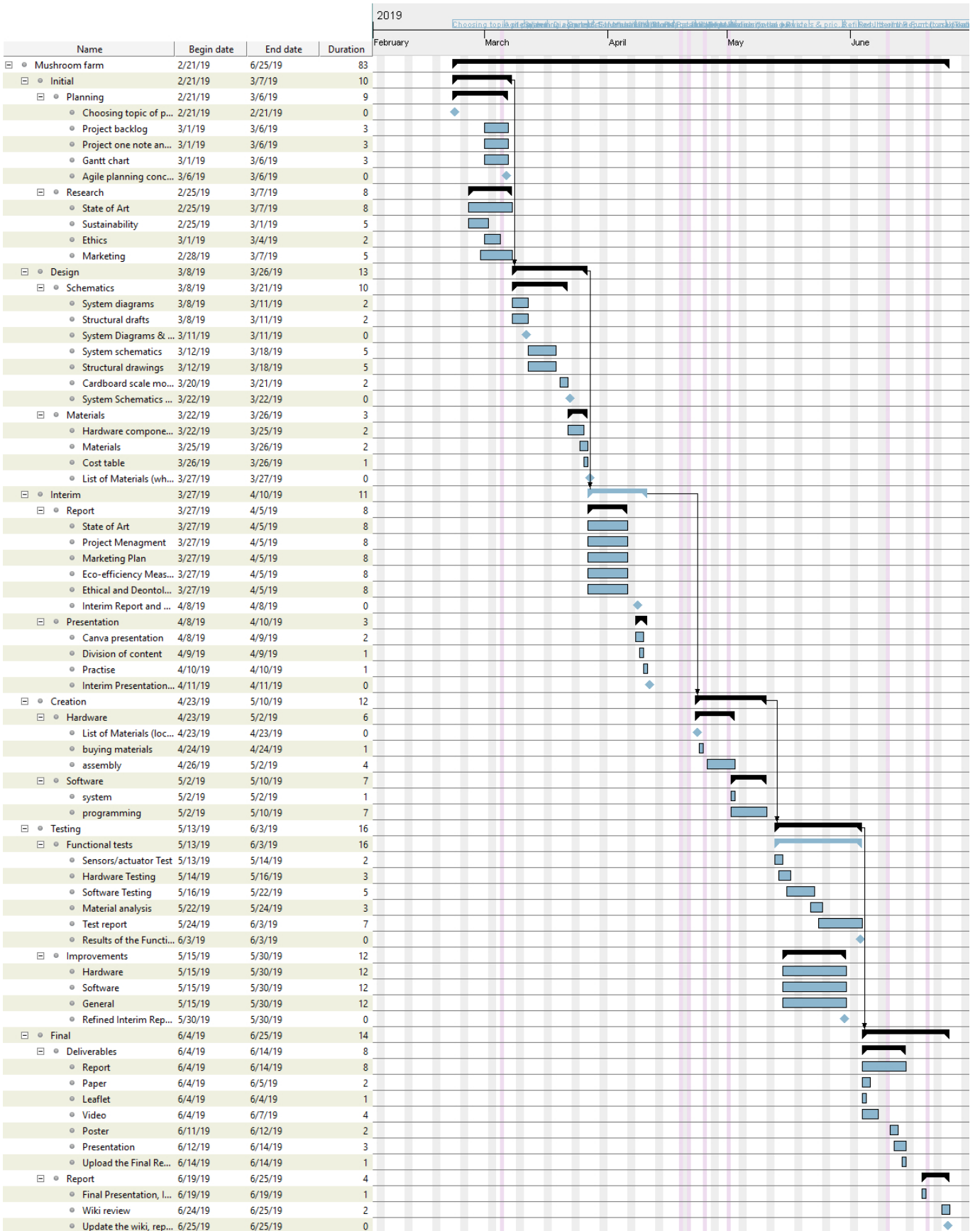
Figure 6: The Gantt Chart

3.3 Cost

Component	Quantity	Price (€)
Oyster Mushroom Spawn	1	~10
Breadboard	1	6
Resistor (10 kΩ)	1	0.05
LED Multicolor	1	0.14
Microcontroler	1	24.90
Pop-up Garden Bag (spring)	1	6
Bucket	3	-
Sensor		
Temperature and Humidity	1	12.30
Material		
PVC Transparent Fabric	1 m²	~3
Zipper	2	~4
Sewing thread	1	~2
Scratch	1m	5
Fan	2	-
Total		**~73.39**

3.4 Quality

As waste to Fungi is a business based around food production, quality has a very important role to play as the final product will be consumed. When it comes to food there are certain health regulations that need to be met.

Food quality: To minimize the risk of serious health consequence or even death from consumption of contaminated produce, the Food and Drug Administration (FDA) have established a science-based minimum standard for safe growing conditions, harvesting, packing and holding of produce for fruits and vegetables grown for human consumption. FDA is proposing these standards of the FDA Food Modernization Act (FSMA) [26].

Usage Quality: Before going to market the grow kits and surrounding procedures need to be functionally tested and optimized to ensure high-quality yields. The benefits of growing at home must practices. subside the befits from buying directly from supermarkets. The procedure must guarantee freshness, cost-effective yields and simplicity in the cultivation process. Quality of procedure will be monitored with sensors to ensure the highest quality of growth is achieved.

Service Quality: Service quality surrounding the sale of the grow kits is crucial. Besides providing information for the maintenance of the grow kit at home the business intends to provide a coffee collection service. Business must ensure that there is good communication between suppliers of coffee waste and ensure the proper care and treatment of waste coffee is conducted to avoid any contamination before the cultivation process can begin. The business aims to reconnect people back to the food they eat by supplying educational workshops and information around the idea of cultivating mushrooms and circular economy. Information and workshops must be of high quality in order to spread awareness of safe and good

3.5 People

Responsibility Assignment Matrix is used to identify roles of members in a project team. Matrix is a table that provides an overview of what tasks should be done by whom, while also pointing out responsible person for each task [27]. The companies task allocation is shown in Table 4.

Description of symbols used in a table:

- R = Responsible (Person who is mainly working on the assigned task and bears responsibility of completing it)
- P = Participant (Person who has the supporting role in assigned task)
- A = Accountable (The one who ensures that prerequisites of the task are met and who delegates the work to those responsible)
- C = Consultant (Subject matter experts, whose opinions are sought) [28]

Table 4: Responsibility Assignment Matrix

Task/People	Eren	Alex	Julia	Julien	Maike	Ronald	Supervisors
Task identification and allocation			R				A,C
Gantt chart			R				A,C
Blackbox diagram	P					R	A,C
Technical research	P	P				P	A,C
Market research, existing products	P					R	A,C
Initial budget planning						R	A,C
Specific plan			R				A,C
Business plan			R				A,C
Final schemes, diagrams	R					P	A,C
List of materials	P			P		P	A,C
Interim presentation	P	P	P	P	P	P	A,C
Interim report	P	P	P	P	P	P	A,C
Prototype construction hardware	P			P		R	A,C
Prototype construction software	R					P	A,C
Prototype assembly	P	P		P		P	A,C
Prototype functional tests	P	P	P	P	P	P	A,C
Final report	P	P	P	P	P	P	A,C
Video					R		A,C
Poster		R	P				A,C
Manual							A,C

3.7 Communications

Such a multidisciplinary and diverse project as this one would be impossible without good communication. It is necessary both to ensure that all members have the opportunity to express their convictions, thereby increasing positive discussions and diversity of opinions, or to ensure that problems that arise are dealt with appropriately. On the other hand, poor communication can worsen time management, deteriorate the team's relationship among many other problems. Communication is one of the pillars of a good project.

In order to promote good communication in the team, a policy of transparency and honesty has been adopted that allows each member to express their opinion in a judgment-free manner, but subject to constructive criticism, so no problem is left under the rag and the discussion of ideas is encouraged.

In terms of direct communication (in person), meetings are held every day to find out the progress made so far, as well as weekly meetings where a situation is made, and a reassessment to the team's planning and objectives. Moreover, on Thursday of each week, a meeting with a supervisor is organized that allows the Team to have an external opinion, to improve research, find new solutions and better organize.

As direct communication is not always possible, alternative communication channels have been created in social networks where it is possible to maintain contact, share documents or any other type of relevant information to the project. The great disadvantage of these means is that compared to direct communication, it is more difficult to ensure that the messages are not being misunderstood, so as to mitigate that effect was agreed between the team that very important matters relating the project would only be discussed in person. The great advantage of these means of communication is that they are easy to reach, very practical and allow the contact to be maintained even when the team is far away.

The main alternative communication channels used are:

1. Facebook Messenger
2. Whatsapp
3. Google Drive
4. Gmail

The communication matrix is displayed in Table 5 .

Table 5: Communication matrix

What	Why	Who	When	To whom
Deliverables	Development of the project	Team member in charge of the task	On the deadlines	Supervisors and the Team
Daily Stand-ups	Have an overview of what each group member has done so far, what were the biggest difficulties, and what is going as planned, as well as implement strategies to solve the problems faced.	The Team	Every weekday	The Team
Agenda	Informing the supervisors about the content of the meeting	Team member in charge of the task	24h before the meeting	Supervisors
Weekly meeting with the supervisors	Evaluating the progress of the project and having counseling on the ideias propozed	Supervisors and the Team	Every Thursday	Supervisors and the Team
Weekly team meetings	Make an analysis of the progress made and make a reassessment of the planning so far	The Team	Every week (on the most convinent day for every member)	The Team

3.8 Risk

Managing risk is a useful tool for measuring the impacts of tasks, measuring project fissibility, and generally planning more carefully. Without good risk management, there is no good way to come up with good alternatives for problems that may arise, so there is no way to control the impact that the tasks have on the project.
Good risk management requires identifying, analyzing and assessing all the possible risks.

In Table 6 is presented a description of the risk, its causes and effects, control mechanisms, the response strategy, and the rank.

Note:
Low = 1, Medium = 2, Strong = 3.
The Rank number comes from the multiplication of the impact and the probability.

Explanation of strategies:
Accept: Accepting the risk and do nothing.
Transfer: Transfer the risk to someone else.
Avoid: Eliminate the risk.
Mitigate: Decreasing probability or impact.

Table 6: Risk Management

Description	Cause	Effect	Trigger	Response strategy	Impact	Probability	Rank
Internal risk							
Teamwork disagreements	Misunderstanding. Problem of communication.	**[Time]** Efficacy of the work. Delay of work	Differences of opinions. Bad communication	**[Mitigate]** Try better comunication practises. **[Accept]**	1	2	2
Team member missing	Sickness, irresponsability, accident	**[Time]** Less working capacity, less diversity of opinions	Lack of commitment / sense of responsability	**[Mitigate]** Encourage/Motivate team members for the project. **[Mitigate]** Promote organization and responsability **[Transfer]** Change the responsibility of the tasks to another team member.	2	1	2
External risk							
Late delivery of materials	Suppliers didn't hold the delivery time. Transportation strike. No stock.	**[Time]** Impact on the time delay and the development of the product	Tracking the transportation online	**[Avoid]** Order components as soon as possible and verify transportation	3	2	6
Incorrect components are delivered	Suppliers behaviour, verification	**[Time]/[Costs]** Increase time delay in the development of the prototype, and costs.	Checking the feedback of suppliers and order acknowledgement of receipt	**[Mitigate]** Send back and order new components.	3	1	3
Technical risk							
Non-functional components	Bad component quality, Broken component	**[Scope]/[Time]/[Costs]** The product will not work. Impact on the time delay and costs	Checking the history/reliability/reviews of the suppliers	**[Mitigate]** Negotiate with supplier and claim the guarantee to replace the defective component. **[Transfer]** Have alternative suppliers.	3	2	6

Description	Cause	Effect	Trigger	Response strategy	Impact	Probability	Rank
Software not working	Bad algorithm selection. Bug. Lack of knowledge.	**[Time]** Programming again. Impact on the time delay	Not testing constinuosly the code.	**[Avoid]** Change programme. Testing constinuosly the code. Redesign code.	3	2	6
Growing process not working properly	Bad implementation of the process. Process selected not apropriated	**[Time]/[Costs]** Time delay (deadlines). Delay or inviabilitate of prove of concept. Mushroom not eatable	Not testing process carefully. Not selecting the right process.	**[Avoid]** Test the process several times before implementing in the device. Change process	3	1	3
Final prototype not working	Software problems. Hardware problems, Wrong implementation	**[Scope]/[Time]/[Costs]** Time delay (deadlines). Final device does not work, can't be tested.	Not testing continuosly the device in each stage	**[Avoid]** Make several tests during the development, and test each sensor and actuator separetly. Buy other components, redesign the device.	3	1	3

3.6 Procurement

Managing Procurement properly can support purchasing goods and services from external suppliers in the most efficient way. Quality and costs of goods as well as costs related to postage are crucial aspects to keep in mind while developing a procurement strategy. As there is a variety of potential suppliers in the market, materials could come from any website or local shop.

For the project to be efficient and successful, use of the supplier relationship management will be made, also known as SRM. This is a strategic and segmented approach, executed on the entire supply base, to maximize value and minimize risks **[29]**.

The SRM method contains the following five steps:

- **Step 1** – Supplier identification: The first step in the SRM method is supplier identification. The company must sort out and identify all its suppliers, to whom they paid invoices over a certain period.
- **Step 2** – Supplier segmentation: This is an important step. The long list of suppliers to whom invoices have been paid must be segmented. Segmentation helps to find those suppliers that are capable of contributing to the business strategy. Only these, limited number of suppliers are worth the time and effort to build a close relationship and partnership, with.
- **Step 3** – Relationship analysis: Mainly for the top segment of suppliers classified as interesting to build a partnership with, the company must determine the existing relationship type. This is realized by using the supplier relationship analysis tool.
- **Step 4** – Relationship management: Mainly for the top segment of suppliers the existing relationship type needs to be managed towards the ideal relationship type, which is the leverage-core relationship type.
- **Step 5**: – Evaluation: On a regular basis the SRM results and lessons learned need to be documented and evaluated. This will lead to a series of recommendations towards the business like integrating the top segment suppliers for new research and development activities or proposing to restart step 2, the supplier segmentation **[30]**.

3.7 Stakeholders Management

Stakeholders are independent parties which have an interest or concern about something. In this case an interest for the project of creating a mushroom related business.
In order to manage them, a stakeholders management analysis through two different tools has been made:

- A stakeholders analysis table represented in Table 7
- A stakeholders analysis matrix represented in Figure 7

Table 7: Stakeholders Analysis Table

N°	Who	Role	Influence	Interest
1	Team	Developers	High	High
2	Supervisors	Controllers	High	High
3	ISEP	Sponsor	High	Low
4	INESC TEC	Sponsor	High	High
5	I3S	Sponsor	Medium	Medium
6	Suppliers	Providing materials	Low	Low
7	Competitors	Competition	Low	Low
8	Consumers	Buying the product	Low	Low

Figure 7: Stakeholders Analysis Matrix
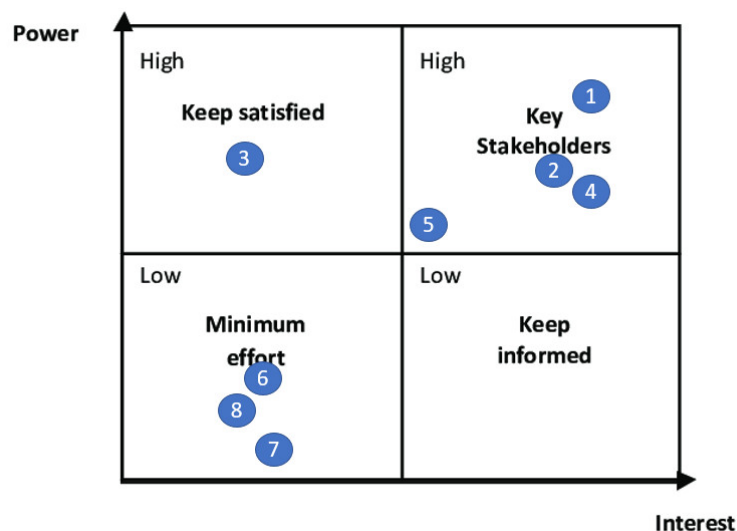
With the help of these tools, more effort needs to be put in informing the sponsors and supervisors on the evolution of the project since they are the Key Stakeholders. Adapting to communication concerning other stakeholders depending on the evolution of the project and of their place and interest in our product is also important.

3.8 Sprint Outcomes

In this section, the sprint outcomes is put available through the Table 8, which details the tasks

completed throughout the sprints and the velocity achieved. Sprints and their outputs and reviews are an essential part of the scrum project management method that will be used for this project.

Table 8: 3rd Sprint -21/03 - 27/03

PBI	Assignee	Planned Effort	Completed	Not Completed
Sprint 3 - 21/03 to 27/03				
ID009 List of Materials (what & quantity)	Julien,Erendiro	5hx2=10	X	
ID010 Improve leaflet	Julia,Alexander	1hx2=2	X	
ID011 cardboard scale model	team	2hx6=12	X	
ID012 Classes	team	25hx6=150	X	
ID013 Structural Drawings	Julien,Alexander	2hx2=4	X	
ID014 Dokuwiki References	team	5hx6=30	X	
ID015 System Schematics	Erendiro	3h	X	
Writing Marketing, Ethics, Sustainability chapters	team	24hx64=144		X
	Work capacity	85		
	Velocity	61		
Sprint 4 - 28/03 to 03/04				
ID016 Communication Presentation	Alexander,Eren,Julien,Maïke	4×1=4	X	
ID017 Eco efficiency chapter	Alexander,Ronald	2×4=8	X	
ID020 Pitch Presentation	Alexander	2	X	
ID024 Classes	team	22×6=132	X	
ID021 Ethics	Julien,Maïke	2×4=8	X	
ID018 Improve schematics and list of materials	Erendiro,Ronald	2×5=10		X
ID022 Marketing chapter	Julia	4		X
	Work capacity	108		
	Velocity	36		

3.9 Sprint Evaluations

Sprint retrospective is a meeting where a project team discusses what went well in a completed sprint and what could be improved. Team should also think of how to improve. Retrospective takes place after sprint review and before next sprint planning **[31]**. Our sprint retrospectives are shown in Table 9.

Table 9: Sprint retrospectives

Sprints	Positive	Negative	Start doing	Keep doing	Stop doing
1	Important work was done	Project planning was poor	Improve project planning	Focus on research	
2	Team has a better understanding of how to divide tasks and write them down in Planner, Brand logo and leaflet were created	Team was falling behind on writing wiki report	Provide teammates with an update of how task completion is going and ask for advice if needed	Writing report	
3	Wiki report was improved	Work was piling up and some tasks were moved to next sprint	Research on remaining report chapters	Writing remaining report chapters	
4	Ethics and Eco-efficiency chapters were completed in report, Team had a meeting with potential sponsors	Project Planning chapter was not done	Project Planning chapter	Refining report	

3.10 Conclusion

By properly defining project management has allowed the team to define a logical timescale for the project as well as addressing any potential risks and limits. It has determined an optimal management strategy in order to achieve all objectives. By defining sprints and through previous sprint analysis helps the team analyse their workflow and measure how well they work as a multidisciplinary team and adjust work ethics accordingly. Through risk analysis the team was able to analyse and overcome any potential setbacks. The team's success will be determined by how well they can manage their time and how well they can stick to the optimal project management strategy.

The next chapter the team will begin to develop their marketing plan and defining potential marketing strategies based on market research.

4 Marketing Plan

4.1 Introduction

Marketing is a complex process, that is why there are many definitions of it. One of the most popular was defined by Philip Kotler, who is the main authority of modern marketing. Marketing is described by him as the process by which companies create value for customers and build strong customer relationship in order to capture value from customers in return [32]. In this chapter, it will be briefly described many activities such as marketing research, product development, distribution, pricing, advertising, personal selling, and others – designed to sense, serve, and satisfy consumer needs,

while meeting the team's goals.

The product is providing a service with all the needed resources and information to grow mushrooms at home. In the offer, it is included fully colonized mycelium grow-kit, which gives the customer fresh organic oyster mushrooms in one to two weeks with minimal effort. After the kit stops producing mushrooms, the customer can simply return it to the store and replace it with a new one. In order to give customers the choice the kits are planned to come in a range of sizes to satisfy all needs, not only a hobbyist and industrial but also an educational one.

4.2 Market Analysis

Coffee Market

According to "Statista" the coffee market worldwide is worth over 79 Billion € in 2019 and has an expected annual growth of 4.8 % (CAGR 2019-2023) **[33]**, being the European market worth over 31 Billion € in 2019, with an expected annual growth of 3.1 % (CAGR 2019-2023) **[34]**, and furthermore the Portuguese market is worth over 816 Million € in 2019 with an expected annual growth of 2.1 % (CAGR 2019-2023) **[35]**.

1000 kg of fresh berry gives about 400 kg of wet waste pulp **[36]**. Portugal has an annual coffee consumption of about 40 tons of coffee which accounts for 16 tons of coffee waste every year **[37]**.

Portugal is the third country that pays the most for coffee **[38]**.

Mushroom Market

The worldwide mushroom market was evaluated in about 35 billion USD according to "FreshPlaza" in a recent study dated to 2015, between 2016 and 2021 is expected an overall growth on the market of about 9.2 % **[39]**. Some sources even state that the market is expected to be worth 50 billion by the end of 2019 **[40]**.

The biggest growth is expected in the Asian countries. Mushroom consumption in China, Japan and India is quite large. Partly because of the growing focus on healthy and organic foods, demand in these countries will continue to grow. Europe is the largest market for cultivated mushrooms, accounting for more than 35 percent of the global market. Moreover, demand is on the rise in North America, and South America is also recording an explosive growth. Meanwhile, Africa and the Middle East recorded a reasonable growth **[41]**.

The main species of mushrooms consumed in Portugal are white mushroom (Agaricus bisporus), brown mushroom (agaricus subrufescens), shiitake (Lentinula edodes), black mushroom from Japan (Hypsizygus tessellatus), and wild mushrooms **[42]**.

The domestic market is made mostly through hypermarkets, supply markets, hotels and restaurants. According to data from the GPP (Planning, Policy and General Administration Office), about half of the production is disposed of outside the country, namely for the Spanish and French markets **[43]**.

Through an inquiry made by **[44]** it was possible to conclude that one of the major obstacles in the commercialization of mushrooms is the establishment of distribution channels,followed by the difficulty of financing and thirdly the culinary culture **[45]**.

Sustainable foods market

Growth in Healthy Eating in Europe Across all four types of wellness food, shoppers are buying more now compared to 2-3 years ago, healthy food has increased by 41 %, organic by a third (34 %) and vegetarian and free-from foods by a quarter (26 % and 24 % respectively).

What's more interesting though is that this sector still has far to go. When asked in the next six months whether they intended to spend more, just under a fifth were going to increase their spending across the four different categories **[46]**.

Growth in Healthy Eating in Portugal As shown in a study conducted by the Center for Applied Studies of Catholic-Lisbon, School of Business & Economics in partnership with ANIPLA regarding Portuguese dietary habits 65 % of respondents prefer to consume only organic foods **[47]**. To further support this growth, the Portuguese Association of Distribution Companies (APED) confirms that "the category of organic products is in full development" and cites the "Target Group Index" study, published in 2018 by Marktest, according to which 47,7 % of Portuguese buy organic products **[48]**, and this growth has been followed by a strong commitment by most of the big supermarkets in their own biological array of products, making them no longer a niche market, occupying more and more space on the shelves, and at more affordable prices. Pingo Doce, which already commercialized organic fresh products, recently launched a new brand of its own, "Go Bio", with processed products, joining Aldi, Continente, El Corte Inglés, E. Leclerc, Intermarché, Jumbo and Lidl **[49]**.

4.3 SWOT Analysis

SWOT analysis stands for: strengths, weaknesses, opportunities and threats. The purpose of this extremely useful framework is identifying and analyzing the internal and external factors that can have an impact on the viability of a project, product, place or person. A SWOT analysis is often used as a strategic planning exercise at the very beginning of the project. The framework is considered as a powerful support for decision-making because it enables an entity to uncover opportunities for success that were previously unarticulated or to highlight threats before they become overly burdensome.**[50]**

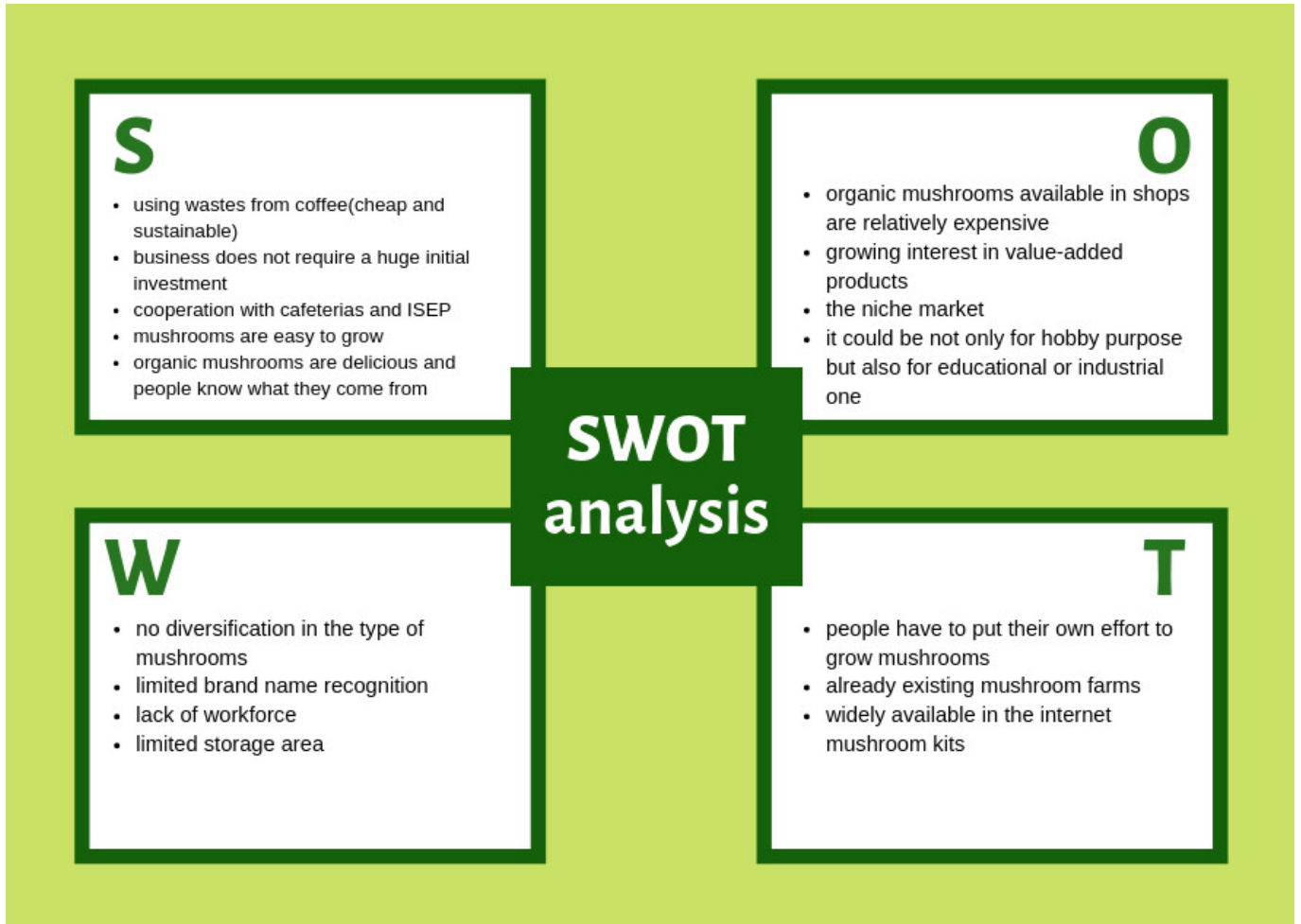SWOT analisis is presented in the Figure 8:

Figure 8: SWOT analysis

4.4 Strategic Objectives

Strategic objectives are the steps and accomplishments, which are established by an organization in order to realize the ultimate goal. Objectives help across the team to understand the goals and to determine whether the strategy is effective and the tactics are being well executed. While setting the objectives it is important to specify measurable outcomes that will be achieved within a particular time frame [51]. To state them it is used the SMART criteria approach, which has several different variations, which can be used to provide a more comprehensive definition of goal setting [52]:

Table 10: Smart goals

Letter	Variations
S	specific, significant, stretching
M	measurable, meaningful, motivational
A	agreed upon, attainable, achievable, acceptable, action-oriented
R	realistic, relevant, reasonable, rewarding, results-oriented
T	time-based, time-bound, timely, tangible, trackable
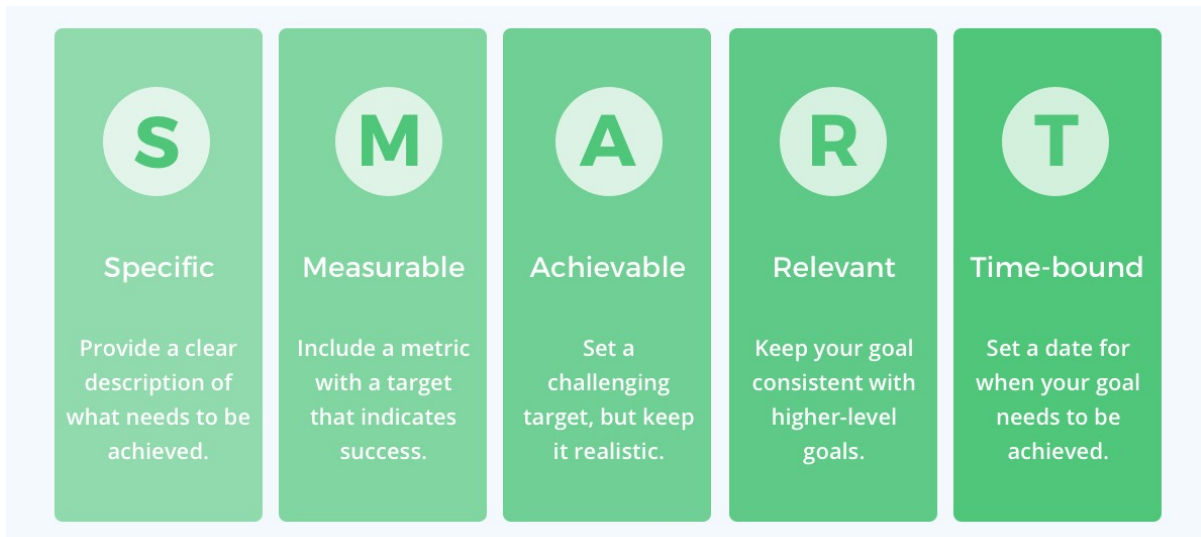
Figure 9: SMART Goals [53]

General mission and vision strategic objectives:

Economical strategic objectives

- Develop a Business based around mushroom cultivation which is both profitable and economically sustainable.
- Maintain growth for the first 5 years of operation.

Customer/Learning strategic objectives

- Introduce an innovative solution into an existing market.
- Build customer database by introducing a high-quality product and service.
- Provide high-quality training and workshops for customers. To encourage customers to live in a more sustainable way.
- To continuously learn and adopt current best practices.

Environmental Strategic objectives

- To adopt a circular approach to waste.
- To adapt processes to be efficient as possible to reduce carbon footprint.
- To continually adapt to best environmental practices.
- To spread awareness to encourage more environmentally friendly practices.

Measurable and time-framed objectives in terms of mushroom project farm:

- Conduct the potential customer survey till 15-05-2019
- Finish testing phase till 24-05-2019;
- Create a website and social media accounts till 31-05-2019
- Generate more than 150 likes and 50 comments on our website and social media before 14-06-2019
- Build a working prototype before 10-06-2019;
- Finish the project report before 14-06-2019;

4.5 Segmentation

The team must decide to exactly what market they are going to target. Despite the Global production of mushrooms increasing and an increase in global imports and exports of mushrooms [54]the team must decide what segment they want to focus their efforts on. Since the whole idea of the business is to bring low carbon food to consumers the team wants to focus on local markets. The team must decide exactly where they fit in along with all potential competitors. To do this they must establish segments in the market that they should focus in order to product segment specific marketing strategies. The segmentation is split into geographic, demographic, behavioural and psychological.

Geographic

World mushroom production in continuously increasing from 0.30 to 3.41 million tons roughly over the last 50 years from 1961 to 2010 (Fig 9) Also export and import trend lines show that mushroom exports/imports have continuously increased over the last 40 years (Fig 10). Trade of mushrooms in the European Union is significant and is reflected in table. The European Union mushroom production is about 27% of the total worlds production in 2010. Netherlands is the largest producer and consumers; Poland is the largest exporter and UK is the biggest importer. France and spain are also large producers and consumers [55]. There is not a lot of information for Portugal which may indicate the mushroom market in Portugal may not be very big. This may be due too poor marketing and may be lacking though and investment. Therefore, it is important to consider the marketing for success in Portugal. Fresh mushrooms have a very short shelf life, cannot be transported long distances without refrigeration and since the whole idea of the business is to bring low carbon food to consumers the team wants to focus marketing plan directly the local markets in Portugal.
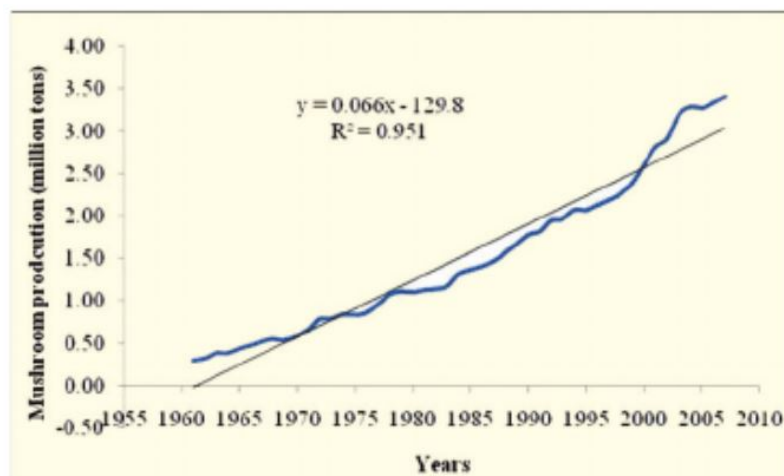

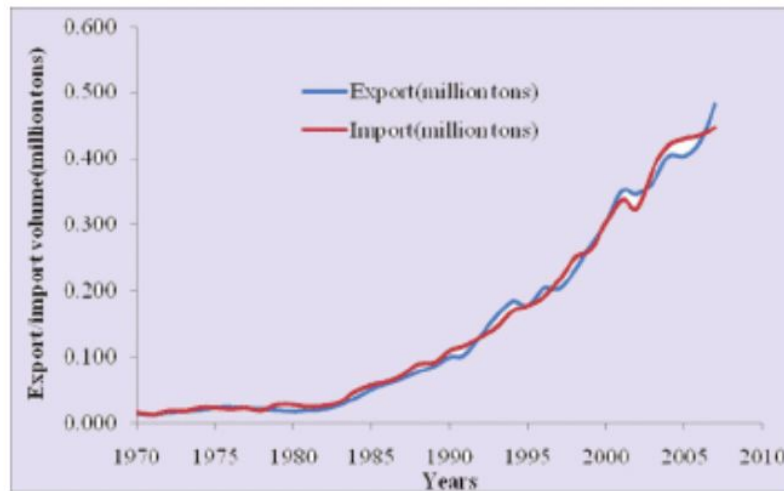Figure 10: General trend of world mushroom production(million tons) [56]

Figure 11: World mushroom export and import (million tons) **[57]**

Figure 12: Global Mushroom Production**[58]**

Demographics

- Gender: Male & Female
- Age: 21-55
- Income: Average
- Family situation: Individuals and Families
- Interest: Healthy food, Organics and environmentally friendly.

Regarding age basing on the survey**[59]** as respondents were older, they were more likely to eat fresh mushrooms therefore the team wants to have a large age range to spread awareness. According to a survey**[60]**, women were more likely to consume fresh mushrooms with higher frequency, but there is no need to create a target group basic on gender when selling the product which is dedicated for everyone. The initial plan is to divide the sales into three levels basing on the interest, in order to make it affordable for everyone. The product will be aimed at families as this targets both a young and older consumers and is most effective in spreading awareness.

Behavioral

Not only a one-off purchase of a mushroom farm, but a simple food production system designed to bring fresh low carbon mushrooms to your plate. The system is designed to appeal to a range of people due to its autonomous nature which allows different levels of involvement in the cultivation process. Cultivation of mushrooms does not require lots of space so this mushroom food system in perfect for city dwellers who do not have access to large growing spaces. Development of a customer loyalty relationship where the business will offer substantive support and provide all the necessary resources and education to along side the process. Education is aimed in spreading awareness about sustainable foods and promoting a healthy diet.

Psychographic

Psychographic target will be aimed at open minded individuals which are concerned with sustainability and are environmentally conscious. The potential customer should have some interest in the cultivation process and growing organic foods. However not much knowledge is required as product is supported with all information needed. The motive of the potential customer should be to encourage sustainable food production which naturally stimulates a healthy diet by having access to fresh and organic produce. The system has been automated to accommodate different lifestyle and

levels of interest.

4.6 Strategy/Positioning/Brand

4.6.1 Positioning Statement

For all mushroom lovers who want a high quality fresh and locally grown product, Waste to Fungi is the sustainable Oyster mushroom farm that delivers the kit which gives the possibility to grow easily ecologically from coffee wastes delicious, tasty Oyster mushrooms, unlike traditional growing kits and mushroom farms, Waste to Fungi offers the product which is simple, easy to use, supports local economy and it is eco-friendly oriented by minimizing CO2 emissions caused by logistics and what is more, transforms waste into nutritious food.

4.6.2 Benefit

The concern on product benefit should be not only living life green but also the nutrition and health aspect of eating mushrooms. Oyster Mushrooms are very healthy and nutritious. A cup of raw Oyster mushrooms provides around 28 calories and 0.35 grams of fat, 2.85 grams of protein and 2 grams of fiber. The same amount also provides 361 mg of potassium, 0.095 grams of Vitamin B6 and 33ug of Folate. Oyster mushrooms are loaded with nutrients and vitamins which make them ideal for a healthy diet. They are free from fat, cholesterol, gluten, low in calories and sodium. They have high amounts of iron compared to meats.

4.6.3 Competition

Before starting a business it is important to understand the market you are entering by analysing its strengths and weaknesses to determine the attractiveness and profitability of the potential market. Potters Five forces model acts as a framework for analysing a company's competitive environment. Potters Five Forces is a model that identifies and analyses five competitive forces that shape every industry and helps to determine these strengths and weaknesses. The number and power of a company's competitive rivals, potential new market entrants, suppliers, customers and substitute products influence a company's profitability [61]. Analysing these elements can be used to guide business strategy to increase competitive advantage.
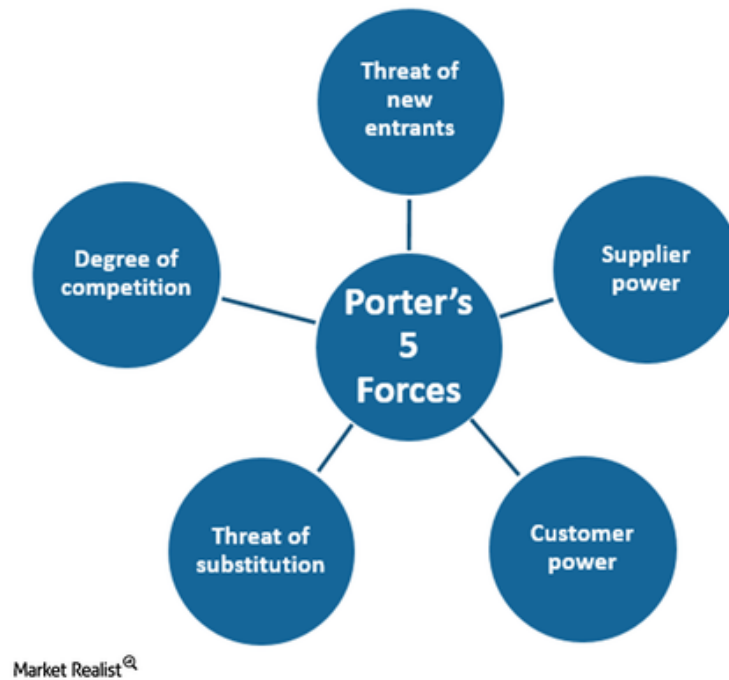
Figure 13: Potters five forces**[62]**

Competition in the industry

This Force refers to the number of competitors and their ability to undercut a company. The more competitors along with the number of equivalent products/services they offer the less power a company has in the market. Competition can drive prices down, similarly if rivalry is low then company has more power to charge higher prices. Competition drives innovation to remain competitive in the market **[63]**. Mushroom farming is nothing new and already has many competitors and therefore the team must focus on its unique selling point and makes these benefits clear to the customer. The business must differentiate itself from other mushroom farms by acting more as a supplier of resources and information rather than acting solely as a mushroom farm. By doing this the company can develop a much richer customer business relationship ensuring long term and returning customers. The customers will buy into the service rather than just a product. If competition is too similar then is reduces the profit potential of the business.

Potential of New Entrants into an industry

A business's power is also affected by the force of new entrants into its market. The less time and money it costs for a competitor to enter a competitors market and be an effective competitor, the more a companies position can be significantly weakened **[64]**. The team must take this into consideration as what makes a mushroom business so attractive is that there is no need for a massive capital investment, especially because much of the cultivation process can be done with waste from other industries. However, if the team focuses on spreading awareness about sustainable food system and work as a provider of information and resources, it will not be in direct competition with mushroom producers. The business will be based around selling the mushroom cultivation kit but by providing a service that surrounds the product it will provide multiple income streams. The aim is also to secure some funding for other organisations who want to be part of the mission in spreading awareness to encourage a change in a more environmentally conscious direction. Having multiple income stream ensures more profit potential for the business to succeed.

Power of Suppliers

This force addresses how easily suppliers can drive up the costs of inputs. It is affected by the number

of suppliers; how unique these inputs are and how much its costs to switch from one supplier to another [65]. This is where the team has quite a good advantage. Because the team wants to adopt a circular economy approach there are very few inputs which are controlled by suppliers. The business is based around the idea of reusing waste. Mushrooms will be cultivated using waste coffee and some straw. Both are another industries waste so is not only free but are also available in abundance. Once the business has established itself in the market with a positive image the team may even be able to charge cafes to pay small amounts to collect their waste as it promotes their business as supporters of a sustainable solution. Even the mushroom spawn can be recycled over and over once it has entered the system. This allows the business to operate without any fluctuation in supplies.

Power of Customers

This refers to the ability of customers to drive prices down. It is affected by the number of customers the business has, how significant each customer is and how much it would cost to new customers or markets. A company that has many smaller independent customers has much easier time charging higher prices then a smaller client base [66]. More power the customer has to more they are able to negotiate. Because the teams business is focus on local markets rather then a global market, the customer base may not be that big. However, the team wants to focus on building loyal customers and building a strong business customer relationship based which is fair to both parties. By building this sense of community rather then strictly business customers will be more willing to buy into the business. Loyal customers ensure long-term profit.

Threat of Substitutes

Substitute goods and services that cab be used in place of a company's products or services pose a potential threat. Companies that produce goods or services for which there are no close substitutes will have more power to increase prices [67]. The teams have tried to differentiate itself from other potential competitors to create a unique service. There may be a risk of substitutes outside mushroom cultivation however these are not direct competitors. As the business grows and develops with customers needs and wants the business could branch out into home cultivation kits outside of mushrooms.

Understanding all these five forces and how they can be applied to an industry can enable a business to adjust business strategy to better use its resources to generate higher earnings.

4.7 Adapted Marketing-Mix

Marketing mix is a framework for the tactical management of the customer relationship, including (the 4-Ps):

- product
- price
- place
- promotion

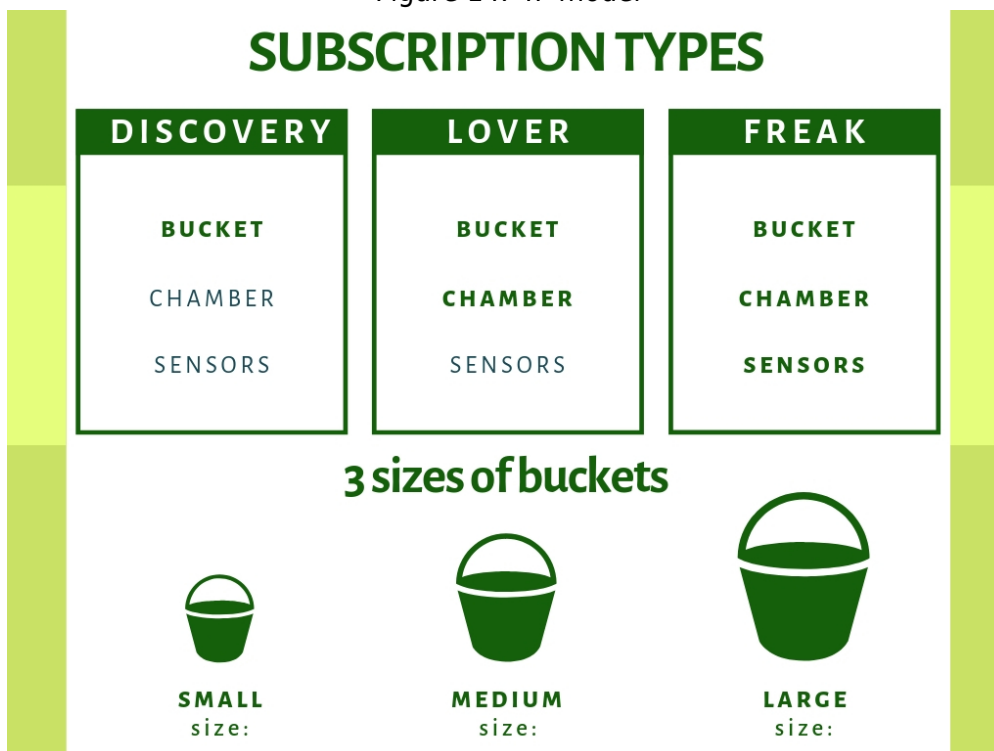4P model is presented in Figure 14 and subsription types of product in the Figure 15:

PLACE

- isep
  (main headquarters of farm)
- selling both
  (stationary at headquarters
  and by internet with delivery)
- prividing educational workshops
  at the headquarters
- colonization and storage at
  headquarters

PRODUCT

- 3 diffrent sizes of buckets
  (small, medium, large)
- chamber and sensors (optional)
- using buckets from restorants
  (recycling)
- fully colonised ready to grow
  home oyster mushrooms bucket
- 3 product options ---> 3 names:
  Discovery, Mushroom Lover,
  Mushroom Freak

PROMOTION

- creation of website
- social media marketing
- cooperation with cafeterias
  (creation of discounts)
- cooperation with local
  communities in sense of
  educational purpose (farmers,
  schools,evironmental
  organisations)

PRICE

- 3 different options of
  subscription based on interest
- possibility to return equipment
  with getting reduction
- loyal customer policy
  (discounts)
- value of product is not only
  getting mushrooms but also
  supporting environment and
  reaching educational process

Figure 14: 4P model

SUBSCRIPTION TYPES

DISCOVERY

BUCKET

CHAMBER

SENSORS

LOVER

BUCKET

CHAMBER

SENSORS

FREAK

BUCKET

CHAMBER

SENSORS

3 sizes of buckets

SMALL
size:

MEDIUM
size:

LARGE
size:

Figure 15: Subscription types

4.8 Budget

4.9 Strategy Control

To ensure the team and business is operating at full potential a Plan-do-check cycle can be integrated to ensure constant improvement and to prevent reoccurring mistakes. This is an essential part of lean manufacturing/management and encourages constant improvements in the process and service **[68]**.
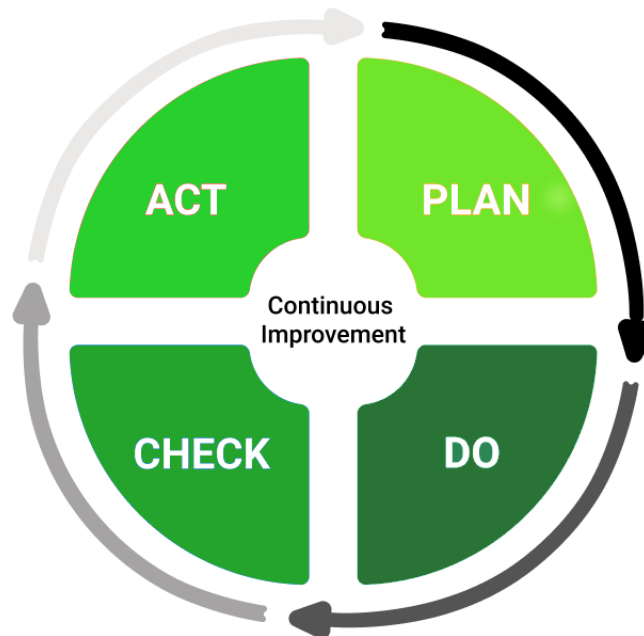
Figure 16: PDCA cycle diagram **[69]**

When should you use PDCA cycle?

- Starting a new improvement project
- Developing a new or improved design of a process, product or service
- Defining a repetitive work process
- Planning data collection and analysis in order to verify and prioritize problems or root causes
- Implementing any change
- Working toward continuous improvement

The Procedure

1. Plan: Recognize opportunity and improvement potentials and define objectives and processes for desired result.
2. Do: Test the Potential solution. Carry out a small-scale study first.
3. Check: Review the test, analyse the results and identify what you've learned and whether or not the potential solution is viable.
4. Act: Act based on what you learned in the study step. If the change has not worked, go through the cycle again with a different strategy. If potential solution is successful, incorporate what you learned from the test into wider changes. Use what you learned to plan new improvements, beginning the cycle again.

This tool is very important in ensuring a high-quality product and service. It allows the process to be adapted based on customer and market requirements. It also serves as a tool to check whether not the marketing plan has been effective and if it needs to be readjusted to better attract the intended

target group.

4.10 Conclusion

Based on this market/economic analysis, the team decided to create sustainable mushroom farm intended for mushroom lovers, which are concern about the environment. Consequently, the team decided to create a product, which uses the waste from the coffee to grow mushrooms in the buckets supplied from recycling after the usage of the food in the restaurants in order to make the product as much sustainable as possible.

The next chapter introduces briefly the Eco-efficiency Measures for Sustainability of a mushroom farm.

5 Eco-efficiency Measures for Sustainability

In this Chapter the team will be addressing any sustainable concerns by looking at the Eco-efficiency of not only the cultivation process but the business in its entirety. The team will not only look into the environmental sustainability but will also consider social and economical side as well as doing an life cycle analysis (LCA) of the concept in mind.

5.1 Introduction

With more and more pressure on businesses to be sustainable, advances in environmental management have improved drastically over the last years, however with environmental concerns becoming more and more businesses today need to take more action and responsibility to ensure a healthy and sustainable future. Businesses usually focus their efforts in environmental control on the end of the product life cycle which actually don't produce environmental solutions, but rather prolong the problem. More environmentally conscious businesses are implementing other sustainable concepts and practices that have a more significant impact on the environment, emphasizing the principles of maximum value with minimum resources. These concepts and practices include optimizing eco-efficiency, extending product responsibility and function, design for the environment, design product services and by-product synergy (one industry's waste stream is another industry's primary resource). Many of these concepts are derived from a more circular economy business model. This model aims to transform traditional linear models of production whereby raw materials enter and products and its waste exit the system into a more integrated (circular) industrial ecosystem. This model uses optimization of energy and material consumption and waste minimization, where the non-valuable outputs of one process (commonly denominated 'residual waste') serve as valuable input for other processes[70]. Businesses must analyze their product life cycle and decide what areas are best suited to implement potential solutions and optimize as much as possible. Businesses need to go above and beyond environmental regulations in order to reduce the environmental impact of their product and services rather than not making it worse. Each stage in the product life cycle must share this responsibility and implement potential solutions as best as possible. In order for these efforts to be successful, the economic and regulatory systems surrounding the development of the business must be considered to better support potential solutions and encourage better environmental practices.

5.2 Environmental

Waste to Fungi pursues the idea of being sustainable as a business. It means adopting a more circular approach by which materials are reused that would be otherwise thrown away. Coffee leftovers are used as a substrate for a mushroom to grow on. This means the service uses by-product synergy as waste from another industry is used as another primary resource. Grow kits will use plastic buckets from various food industries, thereby extending the life cycle of the buckets. The growing process will be carried out in the same containers. Waste resource collection and product distribution will all be conducted locally to minimize the negative impacts. It means less pollution created by transportation. Electrical components and mushroom spawn may have to be sourced externally, however efforts will be made to source as local as possible. This not only reduces emissions but also supports a more local economy. Process of mixing substrate with mycelium does not require energy as it can be done by the human hand. Oyster mushrooms are going to be grown domestically, which means the gap between the consumers' plate is shortened and production point, thereby reducing the foods carbon footprint. After the growing process has been completed, buckets are returned to the company for a new cycle promoting a more circular economy. Buckets have monitoring system (as an option) which allows the consumer to maximize outputs without increasing inputs. The system is modular which allows defective components to be easily replaced, rather than replacing the entire system. A full life cycle assessment could be conducted in order to point out areas of weakness in the business that can be optimized to make it as sustainable as possible. This will be done further into the chapter.

5.3 Economical

Economic sustainability are strategies for making the most out of available resources, to their best advantage. The idea is to promote the use of these resources in a way that is both efficient, responsible and likely to provide a long-term environment and economic benefits while returning a profit. The concept uses coffee waste and plastic buckets from another industry providing a suitable substrate and growing container for no cost. The deposit system is implemented into the business which uses concepts of a circular economy to not only produce less waste but to also reduce costs. It maximizes the reuse of materials but may reduce profits but also reduces waste. The company adapts to return policy to be as sustainable as possible but must make sure it generates enough profit to maintain the business.

5.4 Social

With the concept of sustainability, people mostly think of the environmental and economic side of it. But more attention is now being put on the idea of social sustainability, where by before was neglected. Social sustainability refers to the well being of all. By definition, it is the ability of a community to develop processes and structures which not only meet the needs of its current members but also support the ability of future generations to maintain a healthy community **[71]**. Industries are recognizing that social justice and social rights are an integral part of sustainability. It is truly an international effort, as the groups creating the international set of social standards for all members are called the Fair Trade Labeling Organization International. They are researching aspects of labor welfare and rights, making recommendations, and hoping soon to implement new standards through developing guiding documents **[72]**. The goal as a company is to provide people with access to fresh, healthy and organic food which in terms adds to their quality of life. Surrounding the business there is an educational aspect by which the service hopes to provide information and courses that teach people and families about the process and benefits of growing mushrooms at

home. This is not only an enriching and rewarding process but expands people awareness and knowledge in sustainable food systems as well as providing food security. The company will also encourage the fair trade of local resources to stimulate the development of sustainable communities.

5.5 Life Cycle Analysis

Life cycle assessment:

The life cycle assessment of a product (LCA) is a great tool to calculate the environmental emissions at each point during the life cycle of the specific product or industry, starting from extraction, manufacturing, use and distribution all the way to disposal [73]. It looks at a product from cradle to grave. As people demand more sustainable foods this tool becomes more necessary to consumers as this information can effect their purchasing decisions. The objective in this section is to analyse the environmental impacts of waste within the coffee production and see if there are any week areas within the cultivation process which can be optimised to be made more environmentally friendly.

Raw material extraction

In order to cultivate the mushrooms, a substrate for the mycelium to colonise onis needed. In this case, the waste coffee ground is being used. By using another industries waste as one of the main resources in the production of the mushrooms is a big sustainable advantage as it not only gives value to waste which would otherwise be thrown away but also uses more of the coffee grounds potential by using the remaining 99% of the nutrients still in the coffee grounds after extraction to grow mushrooms. Another big advantage is that by providing a service of waste management for the waste coffee ground makes the resource free making it more economically sustainable. Other resources such as plastic using in the production process need to be taken into account too, however if the business is able to repurpose even recycle buckets as grow containers instead of using single-use grow bags. Then again, the business is adding value to recycled material and extending the life of the buckets too. Production process/Use of Product. The actual production of the mushrooms has almost no negative effect on the environment. Despite the small control unit for the grow chamber which requires small amounts of power to use, the process requires very little resources. Small amounts of light and water to optimise the conditions of the grow chamber but this is all.

Post Harvest

Once the mushrooms have been harvested the waste coffee ground will no longer have any nutrients left in it. This can now be used into compost and other growing mediums for plants. The grow buckets can be reused over and over to a certain point, therefore, extending the life cycle of it. Sterilization of the bucket is required but can be done with rubbing alcohol which does not require high amounts of energy nor does it have any negative effects on the environment if used appropriately. By introducing a deposit system for the buckets and the growing chamber it encourages as much reuse as possible.

The whole cultivation process all the way from resource extraction to post-harvest tries to adopt a more circular approach by which resources are fed back into the process to maximize their use and extend the life as much as possible and by not using any single-use plastics. Because production is done at home is also heavily reduces the foods carbon footprint as it does not have to travel to reach the customers plate.

5.6 Conclusion

As people become more aware of sustainability practices, businesses will try to adopt a more circular economy approach. Whereby waste is filtered back into production, therefore, less extracted resource is used in a production process. Products are made of reused materials. When a lifetime of a product is exceeded, materials and parts are recycled. Waste to Fungi aims to be sustainable through reusing coffee waste and plastic buckets, this adds value to another industries waste and so their life is extended. There is the added benefit that these materials are free and will not generate much costs for the business. Furthermore, energy consumption is minimized by avoiding sterilization process as coffee is already sterilized through the brewing process. In addition to that, process of mixing substrate and mushroom spawn can be done by human hand, again saving energy. The circular economy concept will be achieved by establishing a cycle for the product. Once the customer has harvested mushrooms from the grow kit, it is returned, cleaned and reused as a growing container. A small low-power monitoring system is added to the grow kit making it easier for the customer to track the humidity and temperature levels to maximize yields and efficiency of the kits. Process of growing mushrooms at home is educational as well as rewarding, providing fresh, healthy and tasty food. This not only promotes a healthy diet but also promotes good environmental practices. The business aims to be sustainable not only through its practices and techniques but by spreading awareness and promoting sustainability by connecting people back to healthy, organic and low carbon food.

6 Ethical and Deontological Concerns

6.1 Introduction

Ethics regarding business is not simply about regulatory compliance and legal protection. When talking about ethics, it includes a commitment to quality products, attentive customer service, and taking care of employees and the local community. As a company, it is very important to take care of ethical concerns as it shapes its image and market position as well as it contributes to its trustworthiness. It ensures stable development and should, therefore, be the basis for the functioning.

As ethical behavior is of utmost importance while designing a new product, this chapter will cover all different aspects such as Engineering, Environmental and Sales and Marketing Ethics. In Figure 17 the most important ethical values are represented.
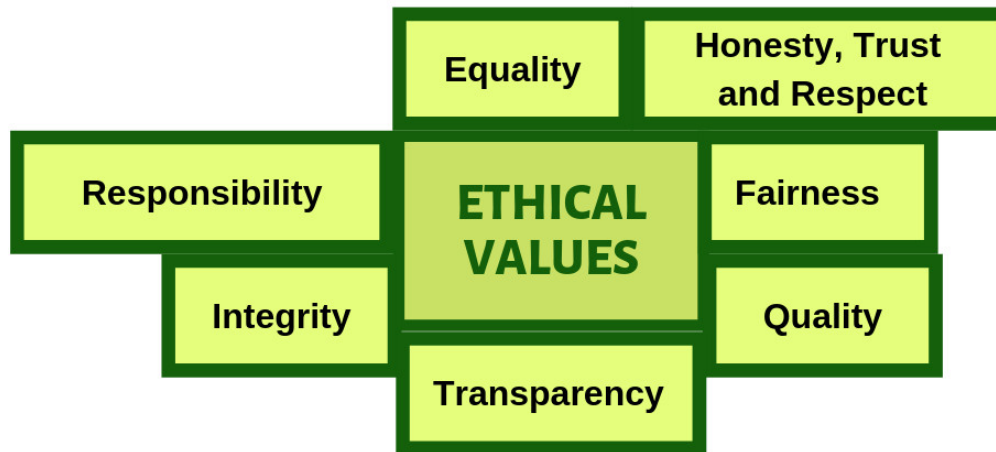
Figure 17: Ethical Values

6.2 Engineering Ethics

Engineers through their position in the industry, and the creation and development of new products have a really important role, it is therefore really important for those professionals to behave in a good ethical and moral way.
Indeed, engineers play a major role in today's society, through three main different ways:

Human: Engineers should be developing and creating products in accordance with safety, health and welfare of the public.

Environment: Engineers should be developing and creating products that are not, or as less harmful as possible to the environment. By studying the life cycle of the product in order to achieve it. This is one of this century biggest challenge as our society has to face climate change.

Society: Engineers should be developing and creating products for the benefits of whole and contributing for a better society, by creating solutions to connect, or help people in a more general way.

Code of ethics was discussed in many engineering societies, the one that was the more up to date is the Code of Ethics brought by the National Society of Professional Engineers [74].

Their Code of Ethics is composed of three main things:
Fundamental canons, rules of practice, and professional obligations.

The fundamental canons being the following:

1. Hold paramount the safety, health, and welfare of the public.
2. Perform services only in areas of their competence.
3. Issue public statements only in an objective and truthful manner.
4. Act for each employer or client as faithful agents or trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

6.3 Sales and Marketing Ethics

When thinking about advertising a product, doing it ethically is less of a marketing strategy and more of a philosophy which should seek to promote fairness, honesty, and responsibility. Ethics is always a difficult subject because everyone has slightly different ideas about what is right and what is wrong. Therefore, ethical marketing is not a strict list of rules to follow, but a general set of principles which should support companies as they decide on their marketing strategies. In fact, there are 8 different principles to be aware of:

1. The common standard of truth will be observed in all forms of marketing communication.
2. Personal ethics will guide the actions of marketing professionals.
3. Advertising is set apart from entertainment and news and the line is clear.
4. Marketers will be transparent about who is paid to endorse their products.
5. Consumers will be treated fairly, depending on who the consumer is and what the product is.
6. Consumer privacy will be respected and upheld at all times.
7. Marketers will comply with standards and regulations set by professional organizations and the government
8. Ethics should be discussed in all marketing decisions in an open and honest way **[75]**

Also, since unethical advertising is not necessary against the law and is just as effective as ethical marketing, many companies use it for their advantage. But for Waste To Fungi to have a reliable and trustworthy reputation, treating customers fair and advertise the service and product in the most transparent and honest way possible is of high importance.

6.4 Environmental Ethics

As the world population increased sevenfold from 1 billion up to over 7 billion inhabitants **[76]** during the past two centuries, so did the consumption of the planet natural resources. This behavior puts major stress on the life-supporting capacities of the planet. As a result, humans became responsible for several environmental issues such as global warming and climate change as they forget about the value and the moral status of the environment and started to exploit the planet and non-human creatures for their own advantage and comfort. The main core of environmental ethics is finding the balance between social, economic and environmental aspects and try to be more sustainable in all actions **[77]**.

When designing the Mushroom Grow-Kit, Waste to Fungi is conscious about the impact on the environment – and this should be kept as low as possible. As the service strives to be a completely circular one, taking back Grow-Kits which do not grow mushrooms anymore and reusing the chamber as well as using coffee grounds as the main component of the product which would otherwise be thrown away, the company is making an effort on being as sustainable as it can be. Waste To Fungi does not want to contribute to the pollution of the planet and produce more waste. Also, because people will be able to grow their mushrooms at home the company will decrease CO2-emissions to a minimum as mushrooms won't need to travel long to finally arrive at the end-consumer. This way the company is doing its best to act as environmental ethically as possible.

6.5 Liability

Companies willing to create and sell a product will have to confront to the liability of their product at a

certain point.

Liability is the legal aspect of the product, preventing the company to be sued for damages or incidents created by their product or its use.

In order to avoid any issues concerning liability with the product, the company decided to comply with the following EU directives:

- Machine Directive (2006/42/CE 2006-05-17)
- Electromagnetic Compatibility Directive (2004/108/EC 2004 12 15)
- Low Voltage Directive (2014/35/EU 2016-04-20)
- Radio Equipment Directive (2014/53/EU 2014-04-16)
- Restriction of Hazardous Substances (ROHS) in Electrical and Electronic Equipment Directive (2002/95/EC 2003-01-27)

Since Waste To Fungi delivers a service allowing to grow food, that would be eaten after growth, it is necessary to make sure to comply with existing food directives in Portugal in order to avoid any case of food poisoning.

Waste To Fungi decided to create a manual explaining how to properly use the product, protecting itself from incidents caused by wrongful use of the product. The decision has been made to choose trustful suppliers in order to minimize the risks of failures and potential liability issues.

6.6 Conclusion

After precisely dealing with the ethical challenges, Waste To Fungi is even more determined to respect all the aspects mentioned regarding ethical behavior. While further developing the product the company will be conscious about treating employees and customers as well as the environment as ethical as possible. The main concern is the environmental ethics as Waste To Fungi strives to provide a completely circular service in which almost no waste will be produced and the local economy will be supported. The company will even go further and use "waste" as the main component of the product. This way it won't only be avoided to produce any waste but also contributed to making a new purpose out of someone else's.

In the following chapter, Project Development is presented.

7 Project Development

7.1 Introduction

With a better understanding of the available solutions to the problem and the scientific field in which the organization is inserted (State of Art), the Market Analysis as well as all ethical and sustainability considerations, it is necessary to develop a functional prototype as proof of the concept, as well as an analysis of the feasibility of the service proposed. This chapter aims to provide a better understanding of the entire development process of this project, going from an overview of the structure of the system to the closest of the final product/service as possible.

In that sense, the development of this project can be divided into two sections:

1. Development of the product
2. Development of the service

7.2 Drafts and Initial Sketches

The design proposed in this chapter is a result of an analysis of different approaches to better solve the problem in question, starting with a "map of concept" (Figure 18) relating all relevant ideas, in that way facilitating the understanding of which solutions are the most efficient and effective.
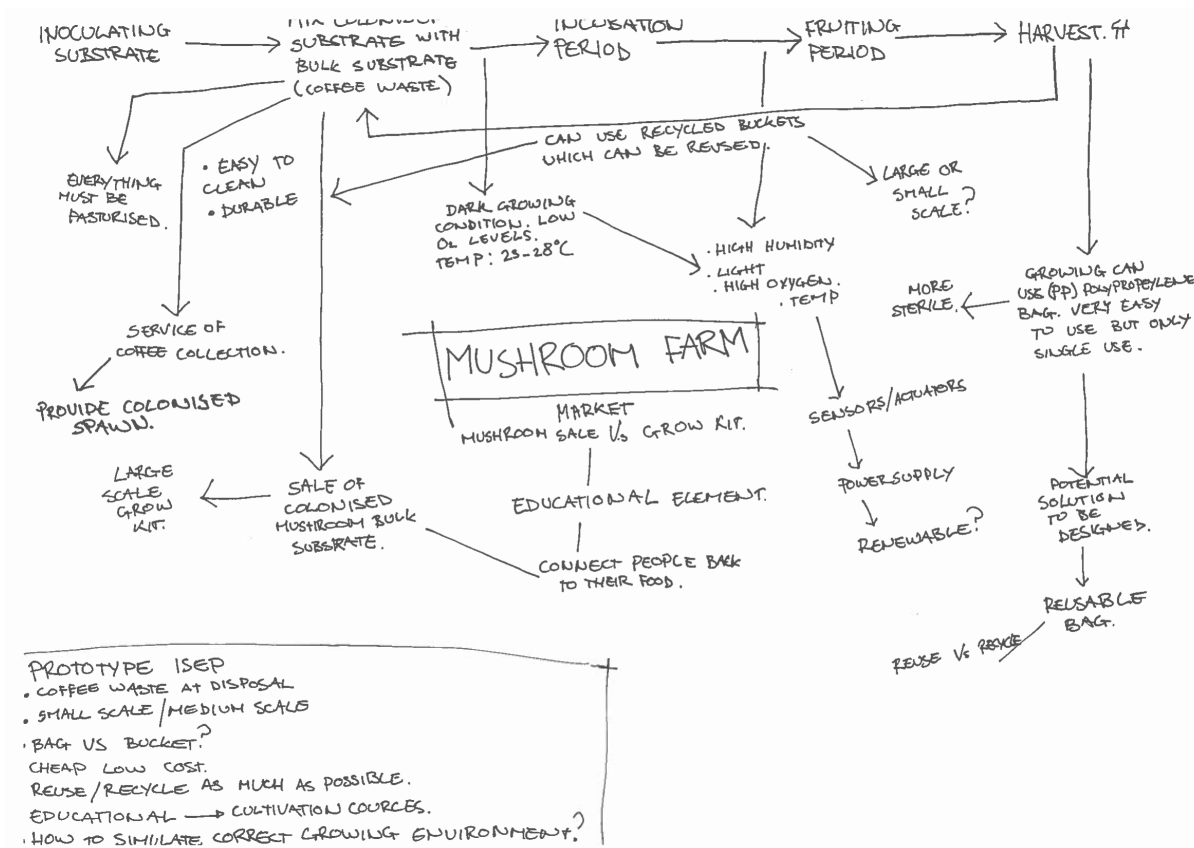

Figure 18: Map of concepts

After breaking the cultivation process into stages, the team looked for areas within the process that could be optimized to be made either more efficient or more environmentally friendly by reducing waste. Another area that was looked into was if the process could be simplified for growers at home. Despite a mushroom farm being quite sustainable as it is, there were key areas that let the process down. There seemed to be quite a lot of single-use plastics being used which could easily be substituted for more durable solutions. A conclusion was made that a low cost and simple solution was missing for users who wanted to grow at home on an adjustable scale which was not too cost and labor intensive.
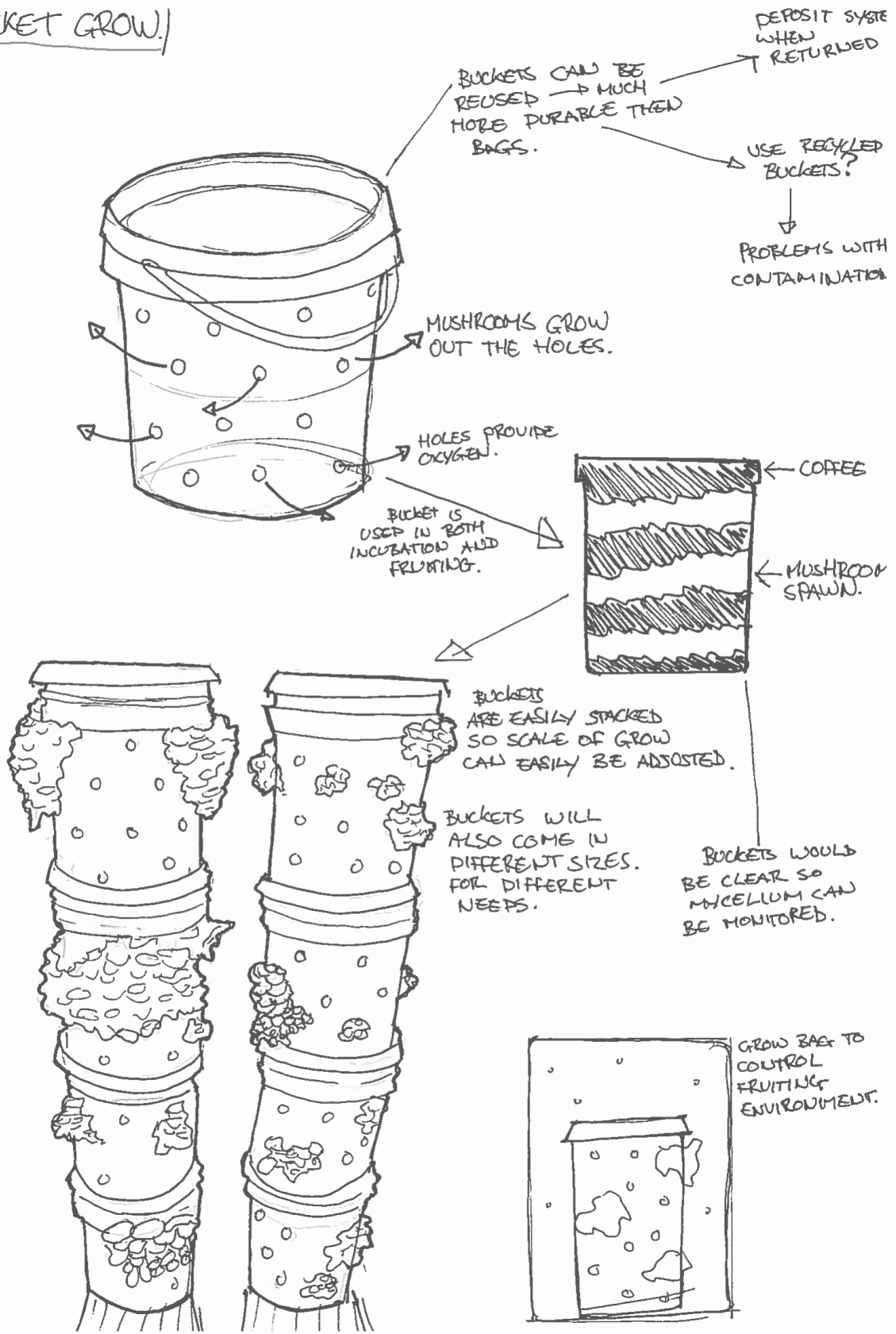
BUCKET GROW!

BUCKETS CAN BE REUSED → MUCH MORE DURABLE THEN BAGS.

DEPOSIT SYSTE WHEN RETURNED

USE RECYCLED BUCKETS?

PROBLEMS WITH CONTAMINATION

MUSHROOMS GROW OUT THE HOLES.

HOLES PROVIDE OXYGEN.

BUCKET IS USED IN BOTH INCUBATION AND FRUITING.

← COFFEE

← MUSHROOM SPAWN.

BUCKETS ARE EASILY STACKED SO SCALE OF GROW CAN EASILY BE ADJUSTED.

BUCKETS WILL ALSO COME IN DIFFERENT SIZES. FOR DIFFERENT NEEDS.

BUCKETS WOULD BE CLEAR SO MYCELIUM CAN BE MONITORED.

GROW BAG TO CONTROL FRUITING ENVIRONMENT.

Figure 19: Bucket concept

A potential solution was defined in this section. Instead of using grow bags which would only be used once, why not use buckets to grow mushrooms. Buckets are much more durable and can easily be reused. Buckets come in a range of sizes and can easily be stacked for a modular cultivation process. Recycled buckets could be used and reused to adopt a more circular approach instead of a more traditional linear process by which the grow bags are used and then disposed of. The grow buckets

can be accompanied by a modular fruiting chamber that not only allows the growing scale to be modular but allows growing conditions to be optimized and controlled to maximize harvest yields.
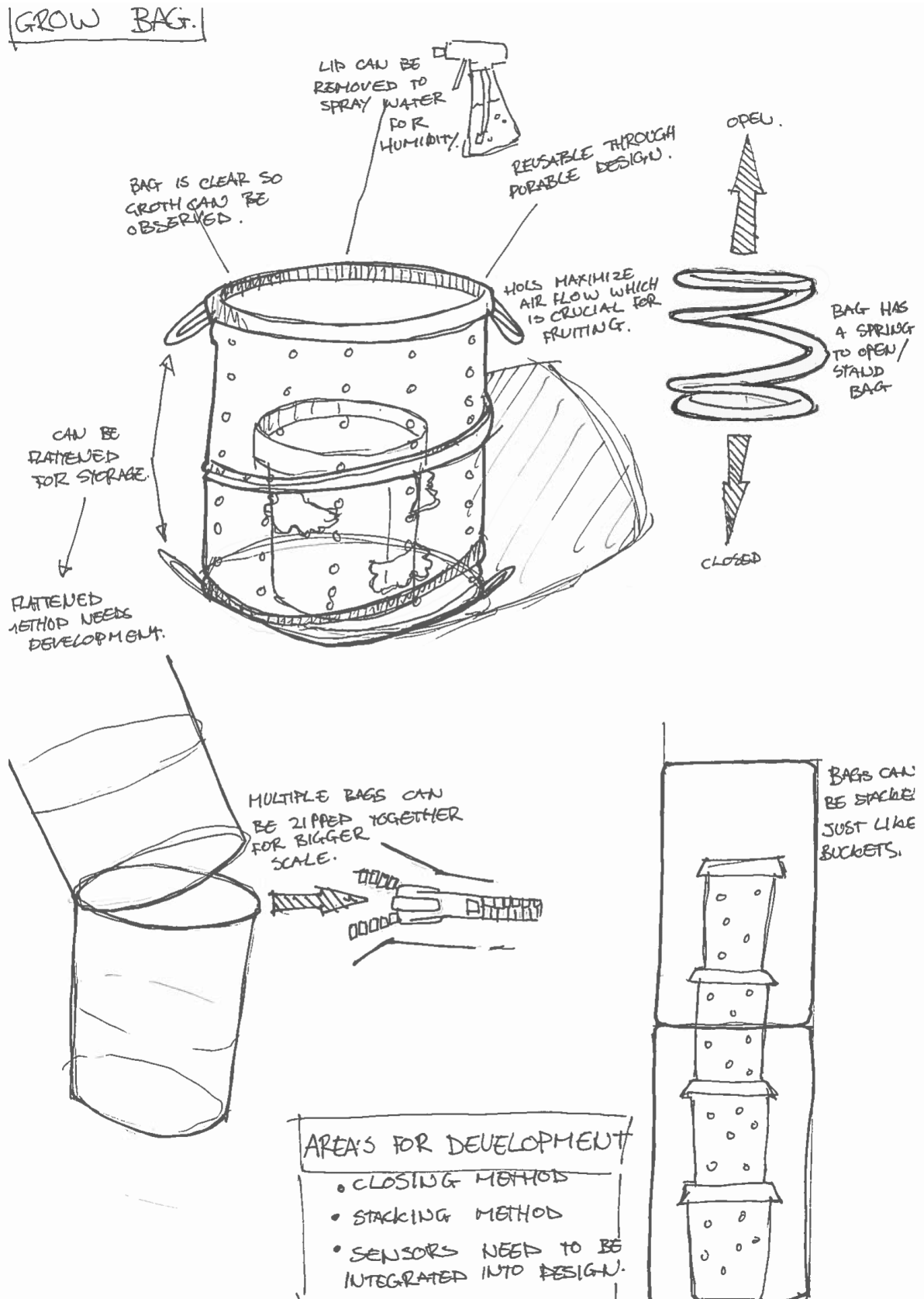

Figure 20: Chamber concept

The chamber can automate the conditioning of the buckets by means of sensors and actuators thus making the entire growing process much easier for the costumer. The design also uses a spring to mount the grow bag. This makes it very easy to fold away for storage or transportation.

7.2.1 Cardboard model

In Figure 21 a cardboard representation of the final product is presented.

Figure 21: Cardboard model

7.2.2 Solid Works model

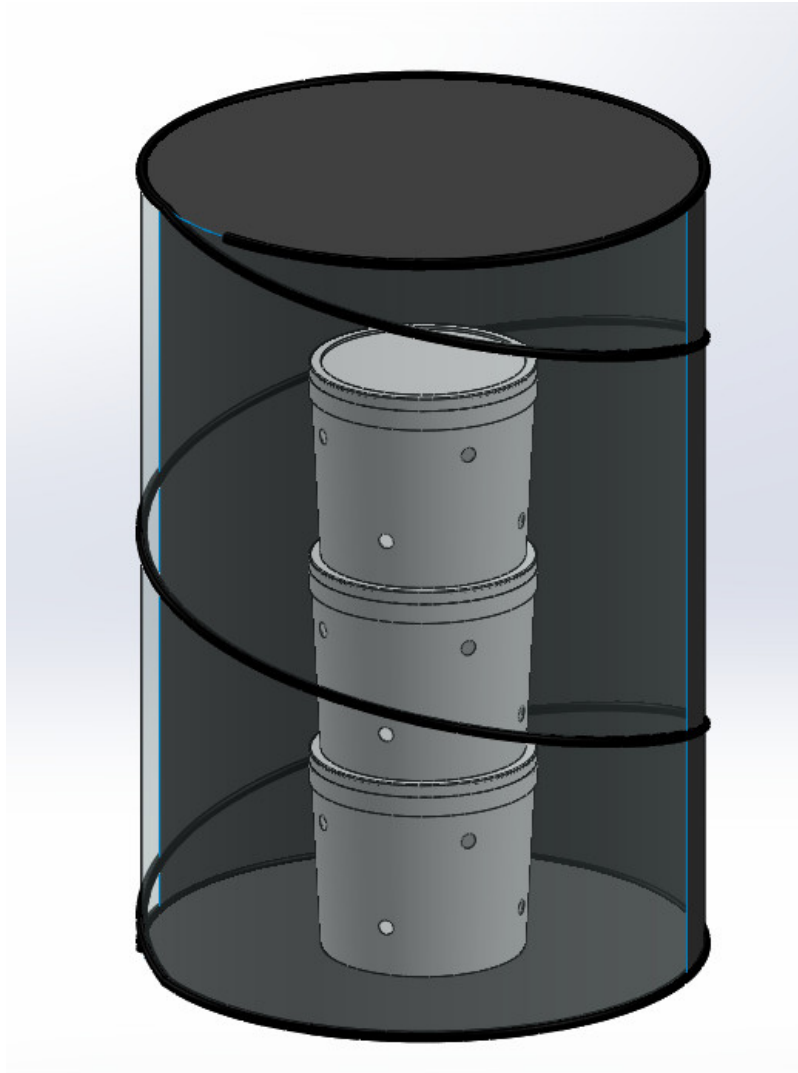In Figure 22 a rendered model of the product is presented.

Figure 22: Solid Works model

7.3 Materials

7.3.1 Materials for the buckets

The bucket that will be choosen for the colonization of the mushrooms, must have 3 features:

- The bucket must be made of a clear material to be able to track the colonization process.
- The bucket must be made of either a recyclable material or an organic material.
- The bucket must be made of a food grade material since food will be grown inside of it.

The solution found by the team consist of reusing packaging of products such as lupine seeds, or other food widely consumed in Portugal, which are usually conserved in clear buckets made out of PE or PP as shown in Figure 23.
This solution has two main benefits, on one hand it reuses someones waste, on the other hand it allows to diminish the costs.
The collection of such buckets could be made in restaurants and cafeterias, in order to have buckets of a sufficient size.

Figure 23: Bucket of lupine seeds

7.3.2 Substrate mix

The substrate in which the Mycelium will be colonized to produce mushrooms will consist of 3 main components: Coffee Waste (which is free and will be collected from ISEP Cafeteria), Agricultural straw (will be collected from a private source and will also be free) and lastly the most important the mushroom spawn. The Mushroom Spawn will have to be ordered from a spore producer. The specific spawn that the team is going to use is called **Pleurotus ostreatus** grain spawn. This strain was selected because it is well known for being easy to grow in coffee waste. There are range of suppliers by which the spores can be ordered from both inside and outside Portugal. Since the team wants to be as environmentally friendly as possible while remaining economically sustainable too. The team needs to find a supplier which is as close as possible to minimize shipping costs and emissions. However team should also ensure that the price is right and that price is not compromised by choosing a supplier because they are closer. The team has decided to order from hortadomarao mushroom supplies because they are the closest while remaining price competitive with other suppliers.

Table 11: List of Substrate mix

Nr	Component	Supplier	Price per Unit [€]	Quantity	Total Price [€]
1	Spawn Pleurotus Ostreatus	hortadomarao	18.87	4.5	**20.00**
2	Agricultural Straw	Private supplier	N/A	2kg	**FREE**
Full Price : 20.00 €					

7.3.3 Materials for the chamber

The design of the chamber is made in order to have easy storage and modularity, allowing to fold the material in a minimal space when it is not being used. The chamber will be composed of the components described in this section to realize the first prototype.

7.3.3.1 Comparing spring solutions

For the spring to be built, the team would need to shape a plastic or metal tube. Taking in consideration the equipment and scale actually considered, it was decided to use something already available on the market: a pop-up garden bag.
The different pop-up garden bags available on the market are depicted in table 12

Table 12: Comparison of spring solutions

Size	Material	Supplier	Price [€]
54×66 cm (150 L)	PE	Leroy Merlin	5.99(pick up at the store)
90 L	Unspecified	Manutan	12.92
40×50 cm (60 L)	Unspecified	Planetahuerto	9.90

7.3.3.2 Comparing the transparent fabrics

In order to obtain optimal parameters for growing, the mushroom needs to receive indirect light, in order to achieve that it was decided to have half of the tent opaque and the other clear using a clear fabric.

The different clear fabrics available on the market are depicted in table 13.

Table 13: Comparison of clear fabrics solutions

Thickness	Dimensions	Material	Supplier	Price [€]
0.25 mm	1 x unspecified m	PVC	AKI	3.99(pick up at the store)
Unspecified	5×2 m	PE	Leroy Merlin	4.99(pick up at the store)

7.3.3.3 Comparing and discussing the assembling system

As modularity was an essential criteria for the team, the use of either Velcro tape or zippers came as an option. Those would allow to close and open easily the system, it would also allow us to achieve the expected modularity.

The first overview of prices and availability of products showed that Velcro would be a better option. Indeed Velcro would be easier to repair or replace, and it is more in accordance with the model of reusing tents after ones use.

The different velcro tapes available on the market are depicted in table 14.

Table 14: Comparison of velcro tape solutions

Width	Length	Material	Supplier	Price [€]
20 mm	2 m	Nylon	Printepoupe	5.78
20 mm	1.5 m	Nylon	AKI	4.49(pick up at the store)
20 mm	3 m	Nylon	Leroy Merlin	5.67(pick up at the store)

7.3.3.4 Comparing the sewing threads

To assemble the whole, the solution that appeared as the best is the use of a sewing thread, as it would enable various assembling patterns and allow an easier reparation of the product. The goal for this part is to be durable and biodegradable, a cotton thread will then be used. There is no comparison for this component as it has no need for specific features, the provider will be the supervisors.

7.3.3.5 Materials for the bag

Table 15: List of Materials for bag

Nr	Component	Supplier	Price per Unit [€]	Quantity	Total Price [€]
1	Pop up bag	Leroy Merlin	5.99	1	**5.99**
2	Velcro tape	Leroy Merlin	5.67	3 m	**5.67**

Nr	Component	Supplier	Price per Unit [€]	Quantity	Total Price [€]
3	Transparent fabric	Leroy Merlin	4.99	1	**4.99**
4	Sewing thread	Supervisors	FREE	1	**FREE**
			Full Price : 16.65 €		

7.4 Architecture

This chapter is intended to provide a conceptual description of the structure and behaviour of the system.

7.4.1 Chamber Black Box Diagram

For the chamber is idealized a system that can accurately read the temperature and humidity, and through those values, automatically maintain the chamber in the right condition for mushroom cultivation. The described system can be represented in terms of its inputs and outputs (Black Box Diagram), as shown in Figure 24.
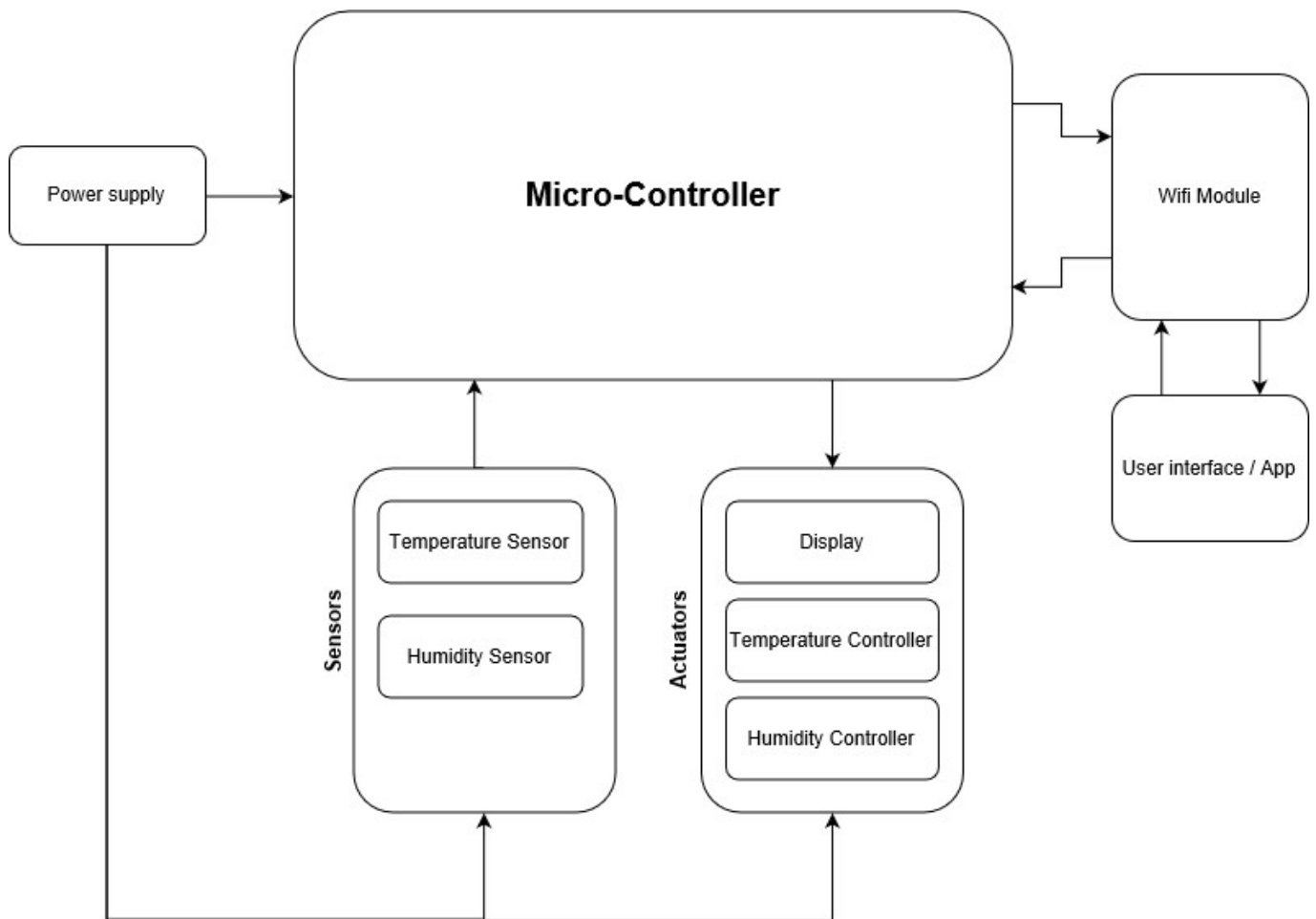
Figure 24: Black box diagram

Power supply: A power supply is a device that supplies electric power to an electrical load. The most important aspect when selecting a power supply is the provided voltage and current (power).

Sensors: A sensor is a device that can convert a specific physical/chemical stimulus into another physical quantity (for example an electrical stimulus (voltage, current, resistance, etc)) usually for

measurement and/or monitoring purposes. When selecting a sensor is important to take into consideration the accuracy and sensibility, as well the power consumption of the sensor.

Actuators: An actuator is a component responsible for controlling a mechanism or system. When selecting an actuator is important to take into consideration the effectiveness of activating the intended mechanism as well as the power consumption of the actuator.

Micro-Controller: The micro-controller is the "brain" of the system responsible for processing the signals received by the sensors and activating the actuators. There are several aspects to consider when selecting a microcontroller, from the number of pins to the processing power. For this project, in which does not require much processing capacity, the most relevant aspects to consider will be the operating voltage, and the number of pins as well as the ease to associate with modules and other peripherals.

In the following chapter, a more detailed comparison of the possible components and materials will be provided.

7.4.2 Eletronic Components for the chamber

7.4.2.1 Comparing Prototyping Boards

In Figure 16 a list of the considered prototyping boards is shown.

Table 16: Comparing prototyping boards

Prototyping Boards	Price [€]	Input Voltage [V]	Operacional Voltage [V]	Analog In/Out	Digital In/Out	USB Connection	Wi-Fi	Bluetooth	Supplier
Espressif ESP32 DevKitC [78]	**8.73**	3.3 to 5	3.3	16	32	Micro	Yes	Yes	Mouser
Arduino Nano V3.0 [79]	**12.90**	7 to 12	5	8	14	Mini	No	No	Eletrofun
Wemos D1 R2 ESP8266 [80]	**18,70**	9 to 24	3.3	1	11	Micro	Yes	No	Eletrofun

Prototyping Boards	Price [€]	Input Voltage [V]	Operacional Voltage [V]	Analog In/Out	Digital In/Out	USB Connection	Wi-Fi	Bluetooth	Supplier
LoRa SX1278 display OLED 0.96 ESP32 [81]	24.90	7 to 12	5	18	28	Micro	Yes	Yes	BotnRoll

In case of using a micro-controller without a wireless connection integrated, a external wifi/bluetooth module is necessary. In table 17 some options for those modules are presented.

Table 17: Wifi modules

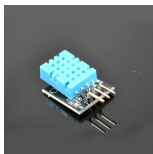| Module	Price [€]	Input Voltage [V]	Current [mA]	Supplier
Wifi ESP8266	4.25	3.3 to 3.6	40	BotnRoll
Bluetooth Module HC-06	6.80	3.6 to 6	170	Eletrofun

When selecting a prototyping board there are several aspects that should be taken into account such as: internal memory, clock speed, processing speed, among others, but due to the simplicity of the project control system presented here, these will not be the factors more relevant to be taken into consideration during the comparison (all boards presented meet these minimum requirements), instead, they will be mainly valued by their operational voltage, ease of association with other peripherals and price, the latter having the biggest influence in the decision.

With that said the prototyping board "Espressif ESP32 DevKitC " was selected. The team believes that this is the best choice for its easy integration with external peripherals, the huge amount of online resources about its funcionalities, the fact that it already has an integrated wifi module and most importantly for having the best cost / benefit ratio of all solutions presented.

7.4.2.2 Comparing temperature and humidity sensors

Temperature and humidity sensor comparison in Table 18.

Table 18: Temperature and Humidity Sensors options

Model	Price [€]	Input Voltage [V]	Current [mA]	Temperature Range [°C]	Temperature Accuracy [°C]	Humidity [%]	Humidity Accuracy [%]	Supplier
DHT11 [82]	**4,15**	3.3-5	3-4	0-50	+-2.0	20 - 90	+-4	Eletrofun
DHT22 AM2302 [83]	**12,30**	3.3-5	2.5	-40 - +80	+-0.5	0 - 100	+-3	Eletrofun
HTU21D-F [/]	**13,93**	1.5-3.6	± 0.5	-30 - +90	+-1	5 - 95	+-2	Mouser

With the purpose of delivering the most quality for the client, the team selected the temperature and humidity sensor HTU21D-F because despite being the most expensive sensor is also the most accurate one (the price difference is not very significant) and also uses the same operacional voltage as the previous selected prototyping board.

7.4.2.3 Comparing Servo Motors

Servo motors comparison in Table 19.

Table 19: Servo Motor options

Model	Price [€]	Input Voltage [V]	Stall Current [mA]	Stall Torque [Kg/cm]	Supplier
SG90	**3,75**	4.8-6	800	1.6	Eletrofun
MG90S	**7,10**	4.8-6	1200	2.2	Eletrofun

Model	Price [€]	Input Voltage [V]	Stall Current [mA]	Stall Torque [Kg/cm]	Supplier
MG996R	**8,95**	4.8-6	2500	11	Eletrofun

7.4.2.4 Power supply calculation

In **Table** 20 the power calculations are being shown.

Table 20: Power calculations for major power consuming elements

Component	Quantity	Voltage [V]	Current [mA]	Power Consumption [mW]
Servo	1	5	2500 (max)	12500 (max)
Prototyping board	1	5	200(absolute max)	1000
Fan	1	12	???	???
Temperature and Humidity Sensor	1	3.3	0.5	1.65
Heater	2	12	214	5143
Total Power consumption: 18 644.65 + Fan Power consumption mW				

By this calculation any power supply with a 17 000 or higher power is sufficent to power the entire circuit.
Power supply selected is in **Table** 21:

Table 21: Power source

Component	Price [€]	Supplier	Voltage [V]	Current [mA]	Max power provided [mW]
Adaptor/Charger AC/DC 12V	**6.30**	Eletrofun	12	3000 (max)	36000 (max)

7.4.2.5 Complementary components

In addition to the components already mentioned above, some control elements are still necessary, which do not require much comparison (the cheapest one that meets the needs is chosen), but are very important for the proper functioning of the circuit. Listed below are some of these elements:

- Resistors
- Transistors
- Capacitors
- Diodes
- LED
- Wires
- ON/OFF Switch
- Voltage Regulator

7.4.2.6 Full eletronic Components list

In Table 22 the full electronic component list is shown.

Table 22: Full electronic components list

Nr	Component	Supplier	Price per Unit [€]	Quantity	Total Price [€]
1	Temperature and Humidity Sensor HTU21D-F	Eletrofun	13.90	1	**13.90**
2	Breadboards	Eletrofun	6.00	2	**12.00**
3	MG996R Servo Motor	Eletrofun	8.95	1	**8.95**
4	Espressif ESP32 DevKitC	Mouser	8.73	1	**8.73**
5	Adaptor/Charger AC/DC 12V	Eletrofun	6.30	1	**6.30**
6	Wires male-male	Eletrofun	N/A	65	**4.10**
7	DC Power Cable Female Jack 25cm ProK	Eletrofun	1.50	1	**1.50**
8	Transistor TIP120 NPN	Eletrofun	0.49	3	**1.47**
9	56 Ω / 5 W Ceramic Resistor 588-TUW5J56RE	Mouser	0.66	2	**1.32**
10	2 Pins buttons for painels SPST ON-OFF 15mm	Eletrofun	0.95	1	**0.95**
11	Mosfet channel P - 5LP01SP	Eletrofun	0.85	1	**0.85**
12	Voltage regulator 7805 5V	Eletrofun	0.50	1	**0.50**
13	100 nF Capacitor	Eletrofun	0.10	3	**0.30**
14	Diode 1N4007	Eletrofun	0.10	2	**0.20**
15	680 Ω Resistor	Eletrofun	0.05	3	**0.15**
16	Red LED	Eletrofun	0.14	1	**0.14**
17	1 uF / 50 V Capacitor	Eletrofun	0.10	1	**0.10**
18	8.2k Ω Resistor	Eletrofun	0.05	1	**0.05**
19	10k Ω Resistor	Eletrofun	0.05	1	**0.05**
20	Fan	Supervisors	FREE	2	**FREE**
		Full Price : 61.56 €			

After all the considerations already presented the project will have a final budget of:

Final Price of the prototype : 98.21 €

7.5 Detailed Schematic

The schematics is represented in figure 25.

Figure 25: Schematic

7.6 Funtionalities

7.7 Tests and Results

7.8 Service Development

7.9 Conclusion

Provide here the conclusions of this chapter and introduce the next chapter.

8 Conclusions

8.1 Discussion

Provide here what was achieved (related with the initial objectives) and what is missing (related with the initial objectives) of the project.

8.2 Future Development

Provide here your recommendations for future work.

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Appendices

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