Insect Farming – An EPS@ISEP 2022 Project

Abstract. Human activities contribute to environmental changes that affect the quality of life on the planet. This is the case of meat production with the direct emission of greenhouse gases and the indirect contamination of soil and water caused by intensive cattle feed farming. The public awareness towards this issue is growing in western cultures, leading to the stagnation of meat consumption and to the willingness to adopt alternative sustainable sources of protein. A possible solution is to farm insects as they present a reduced environmental impact and constitute a well-known source of protein. However, for westerners, eating insects implies a cultural change as they are still seen as dirty and disgusting. In 2022, a team of five EPS@ISEP students chose to design a solution for this problem followed by the assembly and test of the corresponding proof-of-concept prototype. They decided to design a home farming kit to grow mealworms driven by ethical, sustainable and the market needs. By exploring the insect life-cycle, the kit provides protein for humans and animals, chitin for soil bacteria and frass for plants. In addition, it can be used as an educational tool for children to learn about sustainability, social responsibility and insect life-cycles, helping to overtake the cultural barrier against insect eating from a young age.

Keywords: Engineering Education · European Project Semester · Insect farming · Environmental change · Proteins.

1 Introduction

European Project Semester (EPS) is a programme for engineering students, but students of other fields of study are welcome as well. It is offered by universities all around Europe and is intends to prepare engineering students to face the challenges of the contemporary world [12].

TeamOnesect developed throughout the EPS the INFAKIT, a mealworm-farming kit to produce protein and fertiliser at home, a partly self-regulating setup with sensors and microcontrollers to control the ideal conditions. Moreover, TeamOnesect developed a small website, which allows the user to regulate and monitor its INFAKIT from distance. Ethical, sustainable and modular aspects played a major role and guided as a red line throughout the process. This Scientific Report will summarise the approach, research and the strategies of the whole project.

2 Preliminary Studies

2.1 Related Work

This chapter addresses similar projects as the one of Team Onesect, in the form of various research studies. For this purpose, three studies were set up. Starting with a commercial state of the art, where similar companies and products that also revolve around insect breeding are compared. In a second study, a scientific study, a closer look at the (environmental) possibilities and the impacts is taken. In the final study the regulations concerning the breeding of insects will be gone through.

The commercial research shows that insects are used for various purposes such as human diet, pet food, soil fertiliser, dye and many other. Big farms use sophisticated insect technologies to farm a large scale of insects and sell them, or their frass and exuviae, for commercial use. Most of these companies use technology-driven, sustainable, circular, and innovative techniques such as special storage systems, industrial washing machines, control software, and smart measuring tools [8].

In addition to these large companies and sophisticated techniques, there are also companies that offer consumers the opportunity to grow their own insects. For example, there are some companies that offer kits to grow mealworms indoors [14, 2]. They use a layered structure to separate the mealworms from the frass and exuviae.

The scientific state of the art shows that eating insects do provide us a rich source of animal protein, even more than conventional meat [13]. But not only the level of proteins, but also the amounts of fat, vitamins, and minerals are comparable to those of meat [1].

The environmental benefits of breeding insects cannot be omitted either. Their large numbers in population and diversity provides food security (without having to import nonnative species) [6]. Furthermore, Lars-Henrik Lau Heckmann, a Biologist and Ph.D. from The Danish Technological Institute and also an expert in insect farming says that he usually assumes that rearing insects is 100 times more environmentally friendly than raising cattle [10].

Besides the more positive effect on the environment, even insect waste can be reused. Debris are made up of frass, basically a mix of the excretions and unconsumed food, and exuviae, the exoskeletons left behind after molting. This waste can be used as a highly effective fertiliser [9].

For the legislation and regulation in insect farming, the EU distinguishes two types of insect farming, namely a law for commercial purposes and a law for non-commercial purposes [5]. The product will be a kit to grow insects in the home, so the law for non-commercial purposes will be used. This one states that you can farm insects and do with them whatever you want if they are not sold or promoted as food in any other way. The product provides customers with mealworms, not necessarily to eat because they decide what they want to do with them.

2.2 Ethics

Deontology is a term used to describe a philosophy that proposes whether acts are good or bad based on a set of principles. Actions that follow these criteria are considered ethical. As a result, ethical and deontological considerations are extremely important and have a significant impact on today's society. To prosper and maintain a favorable image, businesses must address each of these problems.

Engineering Ethics - engineers' services must be based on honesty, impartiality, fairness, and equity, as well as a commitment to the public's health, safety, welfare and rules of practice and obligations.

Sales and Marketing Ethics - Markets are characterized by a clash of interests among multiple stakeholders. There is rivalry for resources, consumers, and pricing, among other things, which creates fertile ground for actions that may not be ethical. To manage markets and marketing, a specific code of behavior, regulations, and procedures known as ethics are essential. TeamOnesect's sales ethics may propel it to new heights and also paving the way for client loyalty, improved morale among the sales staff (based on the quality of the product) and marketing team, and even sustainable growth by incorporating ethical culture into the company.

Environmental Ethics - In order to provide a product that is environmentally friendly, the team will focus on these points:

1) Maximize the efficiency with minimal energy consumption by choosing the best ratio between the quality of the components and their energy consumption.

2) Using recycled or recyclable materials in the product.

3) The product is focused on the „zero waste" set of principles.

Liability - For the EPS project, the team must comply with the following EU Directives to avoid product liability issues: Machine Directive (2006/42/CE 2006-05-17), Electromagnetic Compatibility (EMC) Directive (2004/108/EC 2004-12-15), Low Voltage Directive (LVD) (2014/35/EU 2016-04-20), Radio Equipment Directive (RED) (2014/53/EU 2014-04-16), Restriction of Hazardous Substances (ROHS) in Electrical and Electronic Equipment Directive (2002/95/EC 2003-01-27).

The team will always be honest and follow an environmentally responsible path to build a product that does not harm the environment, uses as little energy as possible, as well as a transparent and honest customer service, because this is the only way for us to grow as a company.

2.3 Marketing

Being able to communicate and analyse about the evolution of the business is essential. A market analysis allows the company to extract the best possible strategy to carry out our project.

When we speak about insect market, we need to precise the one we speak about. A company can be specialise in producing insect for breeding them and also sell them like that but also to sell them as ingredients or food for human consumption which is our case with our product. Regarding this market, of edible

insect, it was estimate at 500 million of dollars in 2019 and is expected to grow in the future.This food market appears to be an excellent alternative to meet the growing population [11].

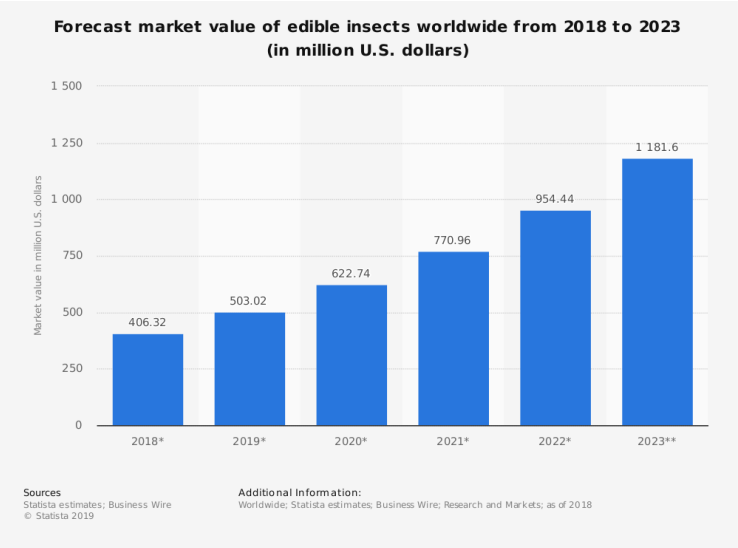

Fig. 1. Graph showing the potential evolution of the insect market in million of dollars

In order to complete this graph, we can take a look at the data collected by Statista presented [16].

In fact, one of the largest increases is in the European market. We have chosen to exclude the Asian market from our target because it is already present and well established as we can see. Thus, concerning the market that seems to be the most promising for the development of our product, Europe seems to be a perfect candidate.

Survey In order to confirm our choice concerning our market and provide the best product, we decided to conduct a study. This was conducted online. We have shared this link with many people as possible, from different backgrounds. The fact of carrying out this study online firstly, allowed us to simplify its analysis. Secondly, it allowed us to have opinions coming from people from very different backgrounds with non-similar living conditions. Studying this data helps to understand how consumers think and act. This can affect purchasing decisions in the market. All of this data is used to divide consumers into segments and to predict what consumer behaviour will look like. As markets evolve, consumer analysis becomes a more complex process. This is because new needs emerge and must be met, new trends emerge. With that consumer interests and desires

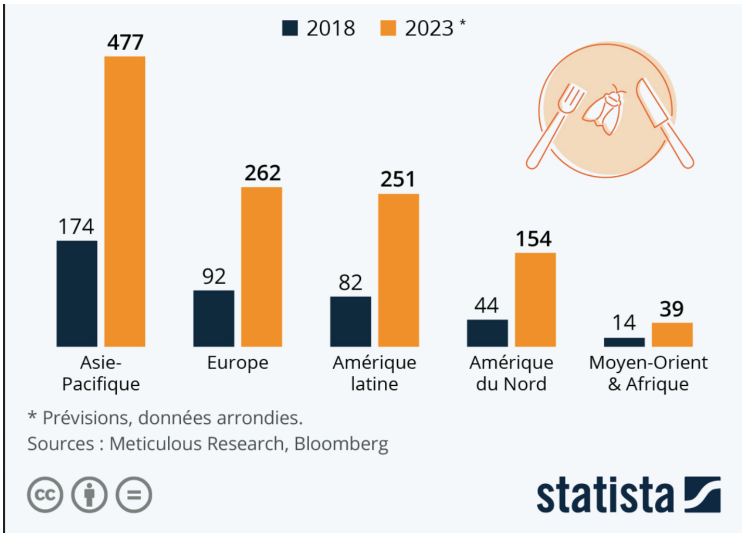

Fig. 2. Graph showing the potential evolution of the insect market in million of dollars

change. Our study concerned people from Europe because as the Asian market already existed it was more relevant for us to focus on this part of the world. Having answers from people coming from different countries and social backgrounds is a very good way to get a global opinion on the state of mind of a consumer towards insects and our future product. The most relevant values we got came from the following questions:

« Have you ever tried some kind of processed insects? » and « Do you have a freezer and blender/grinder at home? »

Fig. 3. Result of the two questions ask in the survey

This allowed us, out of a total sample of almost a hundred people, to realise that even this growing market remains young and inexperienced. In addition to helping us to identify our potential consumers, this study also provided us with technical information. Indeed, a large majority of the people who took part in this study already own some of the technical equipment that we had planned to

integrate into the INFAKIT. Knowing this gives us the opportunity to rethink our design and in particular the possibility to restructure our budget.

Market competitor After looking for competitors, we realised that the market of insect already exist. Regarding there is already competition, we were able to classify them into two categories. The direct one and the indirect one. A direct competitor will be someone or a company that provides the same offers as us. In this case, someone that offers the possibility to, breed insect, to provide eatable insect, to create fertiliser. Instead of that an indirect competitor is someone or a company that provides you a product or a service that can be different as ours but could satisfy the same need and reach the same goal. For example, only selling eatable insect satisfy one of our main goal and can be considered as an indirect concurrent. But another farming home kit would be consider as a direct competitor because our main goal is to allow people to achieve this result by their own.

All this information gives us essential information that we have taken into account when developing our product. However, it is important to add some precision. In particular with regard to our survey. It is important to keep in mind, however, that this study is based on a hundred people. To further analyse this market, and to ensure the relevance of our choices, we have used tools. From these tools like PESTEL analysis, SWOT analysis, we defined the strengths and weaknesses of our product and our company in relation to the market. Other tools were used such as strategic objective, target segmentation strategic positioning, marketing mix, budget and strategy control. This will allow us to detail our analysis of the consumer of INFAKIT, always with the aim of avoiding making a wrong decision and therefore direction.

Communicate our production In view of this competition and the number of other companies on the market, actions was necessary. For doing that we had to promote our product.

For that we decided with the whole team to access our communication around physical support, poster and flyer, and digital support, by social networks.

We also realized two posters. One eye-catcher, more commercial and one more technical presenting our product. The interest of this communication is to make people aware of our product and its benefits.

Communicating about our product also allows us to promote our environmental aspect and its importance compared to INFAKIT

2.4 Sustainability

Introduction With growing awareness of the dangers and problems coming with non-sustainability and a change in many companies' corporate culture and objectives, sustainability is nowadays one of the most important factors for, on the one hand, economical success and on the other hand, satisfied and motivated employees. Sustainability or sustainable development is defined by the

Fig. 4. Commercial and scientific Poster

"UN World Commission on Environment and Development" better known as the "Brundtland Conference" as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [3]. In this conference the participants also defined three different pillars onto which sustainability development builds. These pillars are social pillar, environmental pillar, and economical pillar (see Figure 5).

In the following chapters, how the team took all these into account is explained.

Social The social pillar is regarding the people respectively the stakeholders. As a company, Team Onesect wants to fight injustice, such as discrimination and sexism and strengthen values that promote fairness and respect for individual rights. To fight injustice all genders are paid equally for the same job they do and support gender equality, combat social exclusion inside the company and its structures and promote training and workshops for employees and superimposed. Furthermore, transparency to the internal and external stakeholders is a serious concern, therefore the team wanted to find a clear and easy way to communicate inside and outside the company, shared information with the persons or groups to which they are relevant, and explained and rationale every one of our important decisions made. Also, benefits and additional services such as the possibility of working from home or at flexible times, the opportunity to gain bonuses and special payments, or a company's pension plan will all boost the feeling of appreciation, motivate our employees and rise social sustainability. Without

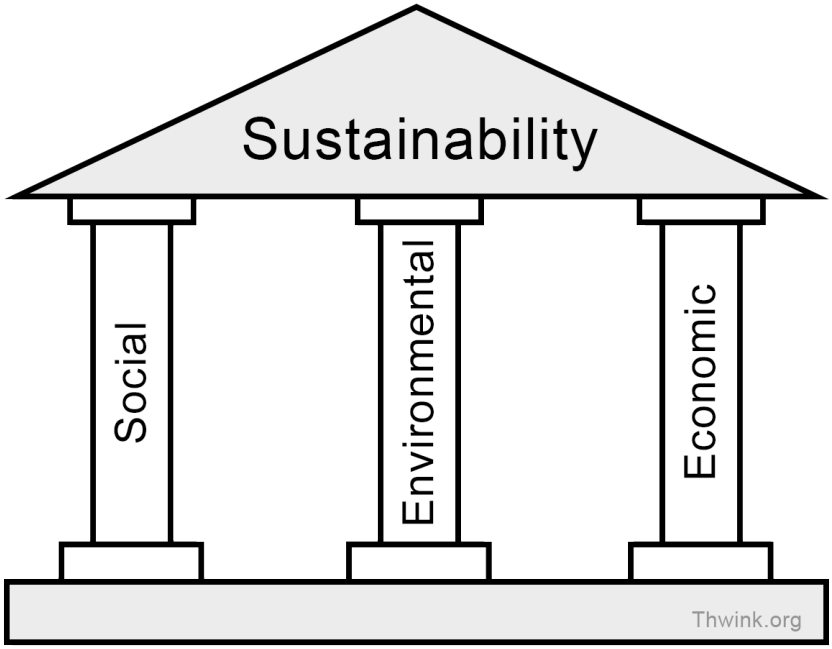

Fig. 5. Three Pillars of Sustainability [15].

saying it goes that the company respects all laws regarding social aspects and will not contribute to for example such things as exploiting the workers, supporting child labour, or providing insufficient working conditions.

Economical Economical sustainability refers to an economical system inside a company that does not affect either the environmental or the social sustainability in any negative way and also allows long-term economic development. It describes the concept of generating profits without causing long-term damage to the resources needed to do so. Therefore, regarding economical sustainability, profit is not the only goal to focus on, but an important one as costs and risks also need to be covered. Besides that, the company wanted to focus on fair trade, environmental protection, and social justice which all go hand in hand with economical sustainability. Even if economical sustainability and sustainable development, in general, are key factors in the corporate culture there are many advantages coming with these concepts. Many studies, for example, one carried out by "Deloitte" in 2020, show, that people nowadays take sustainability and the insert for sustainability into account very strongly when making new purchase decisions [4]. Furthermore, the sustainable mindset will lead to a good reputation, a more loyal customer base, and better and more highly motivated employees, who identify with the company. To achieve these goals it is very important to use the required resources as efficiently and mindful as pos-

sible, wherever an improvement can help reduce the use of resources it should be implemented and done by all employees. In addition, the supplier is chosen and managed very precisely and taken many sustainable factors, for example, delivery distance and materials, into consideration very carefully. Also, the production and the warehouses will be kept close to the potential market in order to reduce long-distance deliveries and first exploit the close market.

Ecological Environmental sustainability calls for the protection of the environment, including natural resources. Companies should work for a conscious use of water, energy, and finite raw materials. It also stands for only removing as many non-renewable raw materials from the earth as can be replaced by renewable raw materials. This is to avoid damage to the ecosystem and instead promote biodiversity. This also means that emissions must be so low that they can be offset or cause no damage. In order to do that the team wants to minimise the use of non-renewable resources and energies and support those with renewables. If the use of non-renewables is necessary, the resources should be recyclable easily and with only little emissions or should have already been recycled before. Also, the use of toxic or harmful resources to humans or to nature, in general, will not be allowed. Furthermore, the products are designed as long-lasting as possible and with an easy to repair modular design. If pieces break the costs and emissions to fix the INFAKIT should be kept as low as possible, and a fast repair should be guaranteed. But not only the processes in the company and for the suppliers should be ecologically sustainable, but also the product itself should have a positive impact on the environment. The INFAKIT will not only reduce the consumption of cattle meat, which is in basically in every important environmental aspect and almost every nutritional aspect less recommendable than the mealworms (see Figure 6)

Besides that it will also help to make a change in people's minds, away from conventional meat consumption and towards a new and more eco-friendly way of eating. Eating insects will become more normal. In addition, it can be used as an educational tool for children to raise awareness of natural life cycles and teach them responsibility, and also as a garbage dumpster for food to avoid food waste.

Conclusion To conclude, meal worms present a promising alternative as protein source which is more sustainable than the common protein sources like cattle farming from an ecological, environmental and also social perspective. The following chapter will provide a proposed solution on using home breed insects as a protein source.

3 Proposed Solution

3.1 Concept

The INFAKIT is an insect- farming kit designed for the usage at home. The main component is its insects: in this case the Tenebrio molitor, which is better

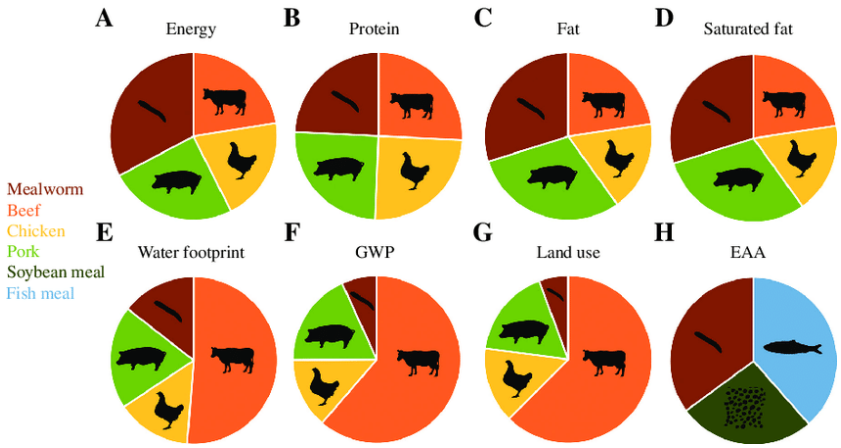

Fig. 6. Nutritional values and sustainability of mealworms and conventional food/feed. (A-D): The nutritional value of a 100-g edible portion of mealworms compared with various livestock meats. (E-G): The comparative effect of mealworms and livestock on the environment, presented as water footprint per edible ton, global warming potential (GWP) for each 1 kg edible portion, and land use for each 1 kg edible portion. (H): Essential amino acid (EAA) comparison of mealworms and classic feeds such as soybean and fish meal. [7]

known as mealworms. The INFAKIT allows its users to follow the entire life cycle of the insects and obtain in addition valuable resources generated in the process: fertiliser for houseplants and human edible protein.

The fertiliser can be generated by composting the frass and excuvae, while the protein powder can be produced by collecting around 70 percent of the current mealworms and further freezing and then grinding them.

3.2 Design

Structure The INFAKIT's design which can be seen in Figure 6 is going for simplicity and modularity. It ensures that all components have a different shape so that there is only one possibility to put the design together correctly. This avoids confusion and increases the ease of use. Its main parts are the mealworm layer, which ends in a little ramp on top of the frass and excuviae drawer. On top a dispenser can be found, which allows the feeding of the mealworms and the beetles in an automatically and periodically timed manner, controllable from distance - the user only needs to fill the dispenser with enough food. Modularity ensures easy adaption and changing of its drawers and sections, which makes cleaning extremely easy. Moreover, the electronics are collected compactly in an own box, which can be easily opened and removed if broken parts need to be exchanged.

The different functions are indicated by colors to increase convenience. For example, all drawers that are used frequently are indicated with a bright orange

colour. Those who have animals are indicated by a dark green colour. The electrical drawer and dispenser are given a neutral colour. This is because they need to be used/disconnected less. Neutral colours block unnecessary user interactions.

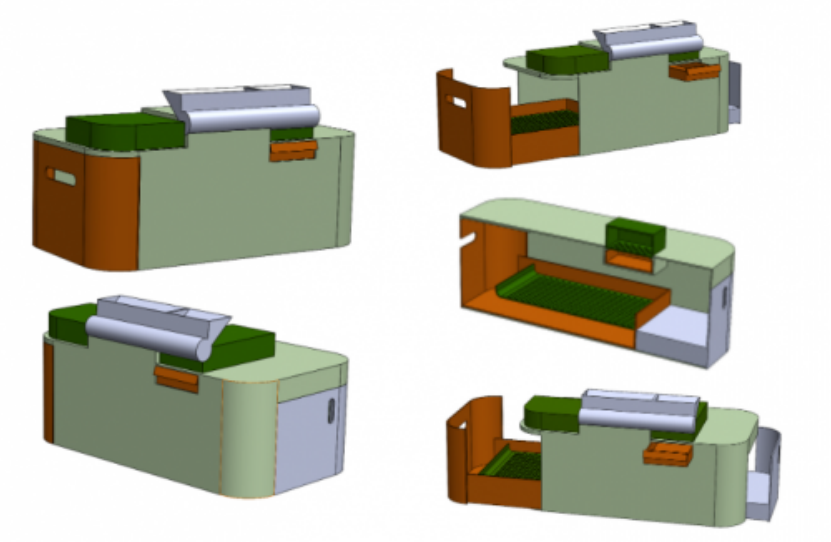

Fig. 7. INFAKIT Design

Control The INFAKIT distinguishes between manually vs. automatically controlled actions that enables the setup to work in all its functionality. Moreover, with the help of a website, some of the manually tasks can be done by the user remotely.

To separate the different stages of the Tenebrio molitor throughout the lifecycle, the user can use tweezers (will be delivered) or their hands – however the preferences are.

Web/Mobile Application The main reason for designing and implementing a web page – INFAKIT Web – is to be able to control the environmental conditions of INFAKIT even remotely. With INFAKIT Web it is possible to feed the mealworms and adjust the temperature and humidity of the INFAKIT. The web server can be accessed with any device that has a browser on the local network.

4 Prototype Development

The prototype itself is very similar to the proposed product. The main functionalities are the same, however the used components and the design differ. Focus

of the prototype is to develop a kit with which can test the main and basic functionalities like testing the separation of frass and excuviae via fan, the ability of providing different breeding sections with food through a remote-controlled dispenser and moreover the interactions between reading humidity and temperature sensor input with a micro-controller, further leading to an automatic control of the fan to improve the living situation for the insects again.

4.1 Assembly

Structure The prototype is based on an assembly of different plastic boxes in different shapes and sizes stacked on each other to provide subsections for each stage of the life-cycle:

- Beetle and Egg Tower (separated through small sieve)
- Pupae Box
- Mealworm Layer (with ramp)

Further Boxes or Layers are:

- Frass Collector
- Electronical Box
- Food Dispenser Layer (with Output to Beetle Box and Mealworm Layer)

The box containing the mealworm state of the Tenebrio molitor build the main layer of the INFAKIT – Prototype. It is off medium length and is built with a little plastic ramp at the end. The ramp assures that the frass and excuviae but not the mealworms will get blown over in the separation process. The side products will be collected in the underlying box which is called the "frass collector". The ramp needs to consist out of plastic, since the mealworms can climb cardboard but not plastic.

The electronical box contains the breadboard with all the needed connections between microcontroller, temperature and humidity sensor and fan. The sensor as well as the fan is applied to the inside of the mealworm layer trough tape. For its connection wires a hole is drilled into the backside of the plastic box.

For the prototype a plastic organiser is adapted as shown in Figure 8 below. The different layers are shortened with a saw and further boxes inserted or applied with tape and glue accordingly.

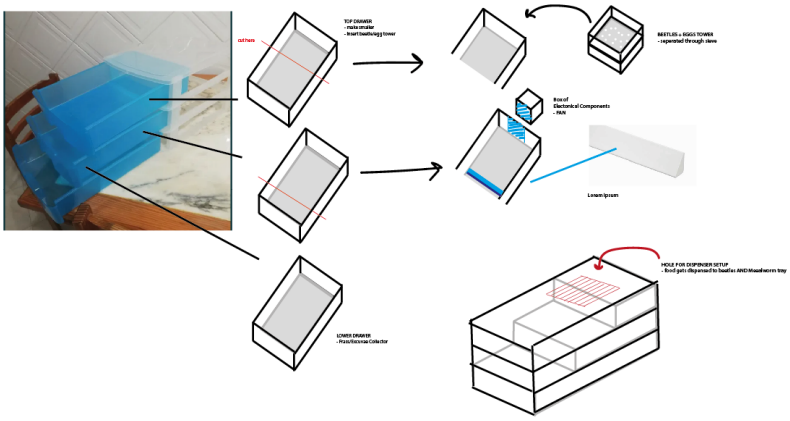

Fig. 8. INFAKIT Prototype Setup

Control The control of the prototype in general does not differ from the product presented in section 3 - proposed solution. The electronic components used stay the same, as well as the proposed functionalities. For separating the different life-cycle stages, the users use their hands or a Tweezer. The fan is controlled by the microcontroller and can be started through the website or through sensor input. Similar is true for the servomotor which serves as a gate opener for the dispenser. It can be triggered manually through the application or will be activated periodically once a day.

The breadboard connections for all electrical components are displayed in Figure 9.

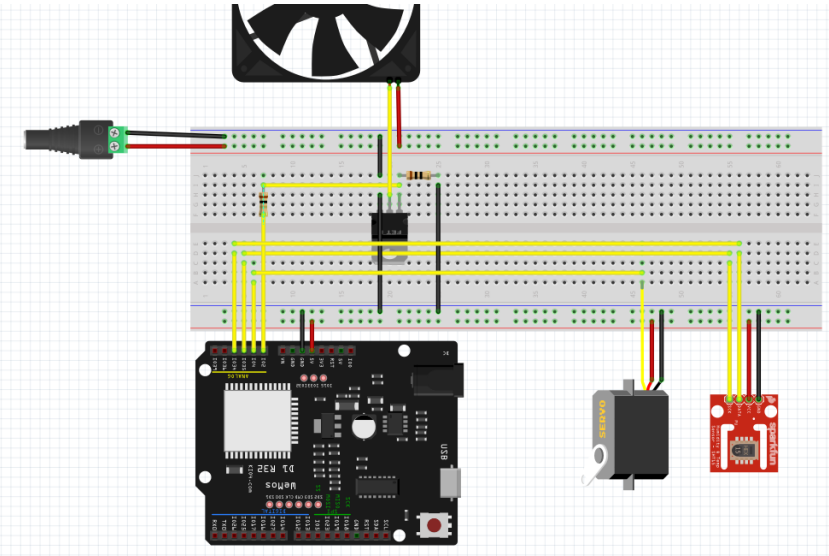

Fig. 9. Breadboard connections

Web/Mobile Application The web server controls the servomotor connected to the ESP32 GPIO 21, as well as the fan that is connected to GPIO 23. On the web server, the temperature and humidity sensor (DHT 22 – connected to GPIO 18) displays live values of the environmental conditions.

INFAKIT Web can be accessed by typing the ESP32 IP address on a browser in the local network.

The ESP receives an HTTP request from a new client (browser). For example, when the button „Turn ON" (Fan) is pressed, ESP32 receives a request on the /23/on URL. Then it turns on the fan that is attached to GPIO 23 and updates the state of ventilator on the web page. Creating the web page is done by ESP32 by sending a response to the browser with HTML code to build the web page. The web page is sent to the client using client.println(). All the HTML, CSS, Javascript and AJAX are sent to the client as an argument of this function. AJAX allows web pages to be updated asynchronously by exchanging data with a web server. This means that it is possible to update parts of a web page, without reloading the whole page. In Listing 1.1. it is shown the way INFAKIT connects to the local Wi-Fi Network.

Listing 1.1. Connecting to Wi-Fi/ Initializing variables

```
void setup() {
  Serial.begin(115200);
  dht.begin();

  myservo.attach(servoPin); // attaches the servo on the servoPin to the servo object
  pinMode(output23, OUTPUT); // Initialize the output variable as output
  digitalWrite(output23, LOW); // Set outputs to LOW

    // Connect to Wi—Fi network with SSID and password
  Serial.print("Connecting to ");
  Serial.println(ssid);
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  // Print local IP address and start web server
  Serial.println("");
  Serial.println("WiFi connected.");
  Serial.println("IP address: ");
  Serial.println(WiFi.localIP());
  server.begin();
}
```

Listing 1.2. contains 1 button that can switch the outputs of the microcontroller from LOW (fan is OFF) to HIGH (fan is ON).

Listing 1.2. Fan

```
                // turns the GPIOs on and off
              if (header.indexOf("GET /23/on") >= 0) {
                Serial.println("GPIO 23 on");
                output23State = "on";
                digitalWrite(output23, HIGH);
              } else if (header.indexOf("GET /23/off") >= 0) {
                Serial.println("GPIO 23 off");
                output23State = "off";
                digitalWrite(output23, LOW);

              }
```

Listing 1.3. contains a slider from 0 to 180 of the servomotor, that can be adjusted to control the servo's shaft position. The current slider value is automatically updated in the web page, as well as the shaft position, without the need to refresh the web page. For this, AJAX is used to send HTTP requests to the ESP32 on the background. Therefore, refreshing the web page doesn't change the slider value, neither the shaft position. When the ESP32 receives the GET

request from the URL/? Value = [SLIDER-POSITION], it can retrieve the value parameter in the URL and move the servo motor to the right position.

Listing 1.3. Servomotor

```
            if(header.indexOf("GET /?value=")>=0) {
              pos1 = header.indexOf('=');
              pos2 = header.indexOf('&');
              valueString = header.substring(pos1+1, pos2);

              //Rotate the servo
              myservo.write(valueString.toInt());
              Serial.println(valueString);
```

Listing 1.4. shows how the datas are read from DHT22, which is updating asynchronously (there is no need to refresh the page to see the changes) the values of Humidity and Temperature on the webpage.

Listing 1.4. Sensor

```
            float h = dht.readHumidity();
            // Read temperature as Celsius (the default)
            float t = dht.readTemperature();
            // Read temperature as Fahrenheit (isFahrenheit = true)
            float f = dht.readTemperature(true);
      if (isnan(h) || isnan(t) || isnan(f)) {
              Serial.println("Failed to read from DHT sensor!");
              strcpy(celsiusTemp,"Failed");
              strcpy(fahrenheitTemp, "Failed");
              strcpy(humidityTemp, "Failed");
            }
            else{
              // Computes temperature values in Celsius + Fahrenheit and Humidity
              float hic = dht.computeHeatIndex(t, h, false);
              dtostrf(hic, 6, 2, celsiusTemp);
              float hif = dht.computeHeatIndex(f, h);
              dtostrf(hif, 6, 2, fahrenheitTemp);
              dtostrf(h, 6, 2, humidityTemp);
```

4.2 Tests & Results

The prototype and its purpose can be divided into different applications that need to be tested: design and functionality of the prototype and moreover the processing of the meal worms.

Regarding the functionality it can be concluded that a more powerful fan is needed to blow the exuviae over the ramp into the under laying collector or the size of the drawer is recommended to be reduced. With the setup used in this survey, the separation process does work, but a quicker, more efficient way should be aimed at.

In concern of processing the insects into human edible protein, the following setup has been tested and is recommended. Freezing the insects for at least 48 hours in a normal kitchen freezer is sufficient to kill them in a pain free way. Further storage in the freezer is recommended until the actual processing.

For grinding the worms into protein powder, baking the worms for 25-30 minutes at 100 degrees, two-sided heat turns out to work best before grinding. As a side-dish the worms can be easily fried in a pan with oil and spices. Their taste is not very intense and their consistency reminds of chips.

4.3 Discussion

The discussion of the project is separated into two pieces. In the first part the general idea is discussed, the main idea that is developed at the beginning, and what is followed the whole time. Team Onesect wanted to spread awareness about the sufficient life cycles and vulnerable ecosystems which are there in nature by helping people to start their own life cycles at home. Furthermore, and just as important, the goal is to make insect eating more common in today's society and to help change people's opinion about insects as a food source. The INFAKIT can provide you with proteins and mealworms to eat, closing the life cycle is easily possible and, speaking from our point of view, it is so much fun but also so interesting to see how nature works and the development from egg to beetle. In the second part, the way how the final design of the INFAKIT turned out and how it differs from the first idea is discussed. The first draft of the INFAKIT contained a heater to dry the mealworms, a blender to process the dried mealworms, and a phone app to control the INFAKIT remotely. The final design of the INFAKIT does not contain any of this. The blending unit and the heater could be left out as most people have an oven and a blender or grinder at home, furthermore, it would lower the production costs and of course the final price. In addition, the phone application is changed to a web application due to programming problems and time pressure. All in all, it can be said that the team achieved to fulfil the main goal by providing the INFAKIT and encouraging people to look beyond the horizon. The INFAKIT itself turned out a little bit different and less automated than planned in the beginning, mostly due to practical reasons and to keep it affordable for a fair price.

5 Conclusion

5.1 Achievements

Project Outcomes Regarding the project outcome it can happily be said, that an actual product which full fills the initial requirements could be developed. Through gaining more knowledge, ideas and first drafts were created, further adapted and changed throughout the process. The INFAKIT offers a kit to grow mealworms at home, providing human edible protein in an sustainable way - allowing its users to rethink their nutritional behaviours.

Personal Outcomes From an personal perspective it can be concluded that every single participant in this group gained a lot of experiances and further broadend their horizons and knowledge in social skills like teamwork, product development and english skills. Moreover, the intercultural exchange allowed gaining new perspectives and communication skills, since those differ slighlty in cultural backgrounds.

5.2 Future Development

The next step for the INFAKIT is creatinga community for users of the INFAKIT. Also for people who do not own an INFAKIT, but have an interest in eating insects, there will be room within this community. By expanding the website, there is a space created for weekly blog posts and recipes.The website will also be expanded for better remote management. The site can also be supplemented with an app to make it easier to use for mobile users.

The product can be upgraded by adding additional components. The electric drawer is modular in nature, so that modifications or improved components can be easily applied. If necessary, there is room for minor modification to make the design even more modular. This allows the user to expand the design and grow larger populations.

In terms of marketing, Team Onesect would like to sell the product outside of Portugal and eventually beyond the European borders. Finally, expand the business and possibly offer other insects. This still requires a lot of research and development.

The main goal of the INFAKIT is still to create a better world and make the human diet more ecological by eating insects. Team Onesect will therefore mainly focus on spreading awareness and acceptance of eating insects.

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References

1. Baiano, A.: Edible insects: An overview on nutritional characteristics, safety, farming, production technologies, regulatory framework, and socio-economic and ethical implications. Trends in Food Science & Technology **100** (2020). https://doi.org/10.1016/j.tifs.2020.03.040
2. BeoBia: Pet Food | BeoBia - The future of pet feed | England. https://www.beobia.com/ (2022), [Accessed in March 2022]
3. Brundtlandconference: Report of the World Commission on Environment and Development: Our Common Future. https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf (1987), [Accessed in May 2022]

4. Deloitte: Shifting sands: How consumer behaviour is embracing sustainability. https://www2.deloitte.com/ch/en/pages/consumer-business/articles/shifting-sands-sustainable-consumer.html (2021), [Accessed in May 2022]
5. European Comission: Small insects – Big impact! EU authorises insects as food. https://ec.europa.eu/newsroom/sante/items/712990/en (2021), [Accessed in May 2022]
6. Gahukar, R.: Edible Insects Farming: Efficiency and Impact on Family Livelihood, Food Security, and Environment Compared With Livestock and Crops, pp. 85–111. Elsevier (2016). https://doi.org/10.1016/B978-0-12-802856-8.00004-1
7. Grau, T., Vilcinskas, A., Joop, G.: Sustainable farming of the mealworm tenebrio molitor for the production of food and feed. Zeitschrift fur Naturforschung C **72** (2017). https://doi.org/10.1515/znc-2017-0033
8. Group, V.: Insect farming technology (black soldier fly, mealworm) (2022), https://viscongroup.eu/markets/insects/, [Accessed in March 2022]
9. Houben, D., Daoulas, G., Faucon, M.P., Dulaurent, A.M.: Potential use of mealworm frass as a fertilizer: Impact on crop growth and soil properties. Scientific Reports **10** (2020). https://doi.org/10.1038/s41598-020-61765-x
10. Kristian Sjøgren: sciencenordic: How much more environmentally friendly is it to eat insects? https://sciencenordic.com/agriculture--fisheries-climate-climate-solutions/how-much-more-environmentally-friendly-is-it-to-eat-insects/1445691 (2017), [Accessed in May 2017]
11. M. Shahbandeh: Global edible insects market size 2018-2023 . https://www.statista.com/statistics/882321/edible-insects-market-size-global/ (2021), [Accessed in May 2022]
12. Semester, E.P.: Welcome: European project semester (2022), http://europeanprojectsemester.eu/, [Accessed in March 2022]
13. Tang, C., Yang, D., Liao, H., Sun, H., Liu, C., Wei, L., Li, F.: Edible insects as a food source: a review. Food Production, Processing and Nutrition **1**, 8 (2019). https://doi.org/10.1186/s43014-019-0008-1
14. The Hive Explorer: MODULAR EDIBLE INSECT FARM. https://thehiveexplorer.com/pages/mealworm-life-cycle (2022), [Accessed in March 2022]
15. Threepillars: Threepillars. https://ecoabode.com.au/3-pillars-sustainability/ (2022), [Accessed in May 2022]
16. Tristan Gaudiaut: Les insectes arrivent dans nos assiettes . https://fr.statista.com/infographie/23148/croissance-chiffre-affaires-marche-insectes-comestibles-par-region/ (2021), [Accessed in May 2022]