'Products Design and Systems Engineering in a Team'
Microengineering Section, Master Phase
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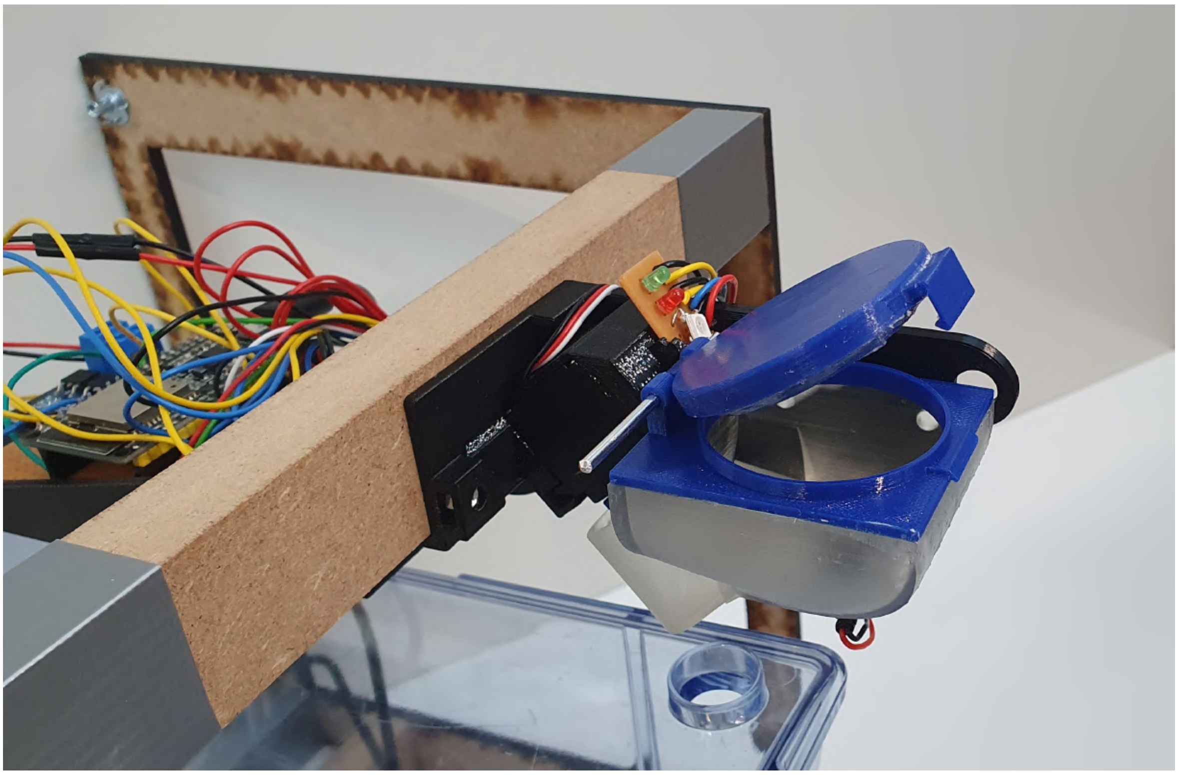

Fish&Feed

By Arthur Lettermann, Ilana Schürmeyer, Irène Andres, Melissa Kundert, Paul-Antoine Croux, Vadim Cladien

Group 4

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Teaching assistant : Guillaume Hueber
Professors Yves Bellouard / Edoardo Charbon

Executive summary

The Fish&Feed system addresses the critical need for automated, precise, and reliable feeding in zebrafish research laboratories. Designed for academic labs, biotech companies, and aquaculture facilities, the product significantly reduces the manual effort required for fish feeding, ensuring consistent care and minimizing human error. Its innovative approach is tailored to support research scalability and efficiency.

Our system offers a ray of **key technical solutions** combining precision engineering and a user-centric design:

- At its core is a modified Archimedes screw mechanism with an integrated piston, enabling milligram-level accuracy in dispensing granulated fish food. The mechanism uses a helical groove and gravity-assisted motion to ensure smooth food delivery without clogging or compacting the granules, a critical advantage over existing solutions.
- A vibratory element enhances food flow, overcoming challenges with granulated material behavior in humid conditions.
- The Fish&Feed is compact, fitting perfectly into standard lab rack configurations. It features a modular structure for easy disassembly and cleaning, with intuitive components that minimize maintenance downtime.
- Real-time status updates are provided via LEDs and a WiFi connected interface, allowing users to monitor the feeding schedule and address issues like low food levels and possible errors.

Compared to competitors, Fish&Feed is able to balance affordability, precision and adaptability. Positioned between high-cost robotic systems and manual tools, it provides robust automation designed specifically for zebrafish labs. It is focused on granulated food and has a compact design setting it apart from other products, meeting a niche need in the expanding lab automation market.

Our **prototype** demonstrates the above mentioned key functionalities, including high-precise dispensing, real-time monitoring and a user-friendly assembly. Managing to fit it into the limited space between fish tank and rack, the prototype was done with low-cost materials like PMMA and PETG.

The project was a **collaborative effort**, structured with clearly defined roles across mechanical design, electronics, software development and management. Weekly meetings, iterative prototyping and constant communication were instrumental in tackling challenges like limited space constraints and ensuring compatibility with lab environments.

Future steps include refining the prototype based on further testing in lab situations, enhancing the user interface through customer feedback and scaling production with additional sponsorship. Protecting intellectual property and optimizing manufacturing processes will also be crucial in preparing the product for the market.

The Fish&Feed has shown promising as an innovative, practical solution for automated zebrafish feeding. While further development is required, its current performance and scalability potential make it a worthwhile investment. With improvement on the prototype and our business strategy, Fish&Feed has the potential to set new standards in automated zebrafish care, revolutionizing lab workflows globally.

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1 Product Concept

1.1 General description

The Fish&Feed system is designed to streamline feeding in zebrafish facilities through automation. After extensive lab observations and discussions, we identified the need for a consistent, adaptable feeding solution for standardized lab structures.

The system operates on a programmable schedule, feeding up to five times a day. Users enter tank data into a computer dashboard, and the system dispenses precise food amounts. This ensures efficient, time-saving care for the fish.

Real-time error notifications are provided via RGB LEDs and dashboard alerts:

- **Red LED:** "Empty Groove" for critical food depletion.
- **Green LED:** "Food Almost Empty" for low food levels.

Further two LEDs indicate if the device is powered and connected to the user interface.

User-friendly controls include a reset button for errors and a tank release button for safe handling. Fish&Feed offers reliable feeding, error detection, and intuitive controls, making it indispensable for zebrafish labs.

1.2 Brief market analysis

The product targets laboratories, biotech companies, and aquaculture facilities. With over 8,000 labs globally, our affordable automated feeder fills the gap between costly robots and imprecise manual tools. It provides precise feeding, quick payback, and recurring revenue from replaceable parts. Leveraging partnerships and targeted marketing, the business strategy ensures scalability and growth in a competitive but expanding market.

1.3 Unique selling points of our product (USP)

Our automated zebrafish feeder stands out for its:

- **Precision and Adaptability:** Specifically designed for zebrafish, supporting up to 1,000 tanks.
- **Affordability:** Positioned between expensive robots and basic tools, offering cost-effective automation.
- **Real-Time Notifications:** RGB LED alerts and dashboard messages for smooth operation.
- **Ease of Maintenance:** Replaceable components and intuitive controls for user independence.

It combines efficiency, affordability, and scalability, ensuring optimal zebrafish care with minimal effort.

2 Technical Solution

2.1 Technical and functional requirements

ID: Project-Subsystem-Requirement Type-Number of Chapter in WBS.Numbering
D: Design, F: Functional, O: Operational, P: Performance

ID	Requirements	Priority	Status
Mechanics			
FF-M-P-2.1.1	The cylinder shall dispense at least 60 mg of zebra fish food[1].	High	✓
FF-M-O-2.1.2	The cylinder shall be removable from the container.	High	✓
FF-M-P-2.1.3	The system shall dispense a consistent quantity[2].	High	✓
FF-M-D-2.2.1	The storage container should have a volume of 26mL[3].	Medium	✓
FF-M-D-2.2.2	The lid shall seal the opening airtight.	High	✓
FF-M-D-2.2.3	Humidity containment should be done with silica gel.	Medium	✓
FF-M-O-2.2.4	The user shall be able to refill container through the lid without needing to detach it from the holding frame.	High	✓
FF-M-D-2.3.1	The servomotor shall fit within the entire device.	High	✓
FF-M-D-2.3.2	The dispensing cylinder shall be detachable from the servo motor in one continuous motion.	High	✓
FF-M-D-2.4.1	The humidity sensor shall record the humidity in the container without coming in contact with the food.	High	✗
FF-M-D-2.4.2	The humidity sensor shall be detachable from the container.	High	✗
FF-M-D-2.5.1	The system should resist to high humidity conditions[4].	Medium	✗
FF-M-D-2.5.2	The cylinder should be able to withstand dishwasher conditions.	Medium	✓
FF-M-O-2.5.3	The storage container should be cleanable in a dishwasher.	Medium	✓
FF-M-D-2.5.4	The storage container should be able to withstand dishwasher conditions.	Medium	✓
Electronics			
FF-E-D-3.1.1	The device shall have an on/off button.	High	✓
FF-E-D-3.1.2	The device shall have a reset button.	High	✓
FF-E-D-3.1.3	The device shall have a button putting the motor into the home position.	High	✓
FF-E-D-3.1.4	The device shall have one LED for errors and warnings (groove empty, refill container).	High	✓
FF-E-D-3.1.5	The device shall have one LED to indicate the state of the device (on/off).	High	✓
FF-E-D-3.1.6	The device should have one LED to indicate if the device is connected to the app.	Medium	✓
FF-E-F-3.2.1	The device shall have a motor to actuate the mechanism.	High	✓
FF-E-P-3.2.2	The motor shall be able to have a force of 0,47 Ncm[5].	High	✓
FF-E-F-3.2.3	The device shall have a vibrating entity to improve food flow.	High	✓
FF-E-F-3.3.1	The device shall have a IR sensor to detect the presence/absense of food in the groove.	High	✓
FF-E-F-3.3.2	The device shall have an IR sensor to detect when the quantity of food in the container is below a thershold[6].	High	✓
FF-E-F-3.3.3	The humidity sensor shall record the humidity in the container.	High	✗
FF-E-P-3.3.4	The humidity sensor shall record humidity in the range of 0-100%.	High	✗
FF-E-D-3.4.1	The devices shall be powered with cable.	High	✓
Software			
FF-S-P-4.1.1	The device shall dispense the food at a set time.	High	✓
FF-S-P-4.1.2	The device shall activate the vibrator when the cylinder is rotating back from the feeding position.	High	✓
FF-S-P-4.2.1	The device shall detect when humidity level in the container surpasses a threshold (tbd).	High	✗
FF-S-P-4.2.2	The device shall detect when there is no food in the groove when the cylinder rotates to the feeding position.	High	✓

[1]amount of food for a fish for a day deduced by the product sheet of Zebrafeed in chapter 7.6
[2]standard deviation of dispensed food falls below 10mg, proven by measurements in chapter 7.5
[3]calculated amount of food for 30 fish (max number of fish in a tank) for a week with product sheet in chapter 7.6
[4]see water spraying test in chapter 7.7.2
[5]value measured with a torque test (more information in chapter 7.7.1)

ID	Requirements	Priority	Status
FF-S-P-4.2.3	The device shall detect when the food level in the container has been fallen below a threshold[6].	High	✓
FF-S-O-4.3.1	The number of fish that need feeding shall be stored in the memory.	High	✓
FF-S-O-4.3.2	The device shall split the amount of food dispensed for a given number of fish over the given feeding instances.	High	✓
FF-E-F-4.4.1	The device should be connected to an interface.	Medium	✓
FF-S-O-4.4.2	The operator shall be able to set parameters (number of fish and feeding times) manually in the interface.	High	✓
FF-S-D-4.4.3	The interface should display the number of fish in the respective tank it is mounted above.	Medium	✓
FF-S-D-4.4.4	The interface shall display the humidity level in the container.	High	✗
FF-S-D-4.4.5	The device shall alert the user when there is an error with a LED on the device and a notification on the interface.	High	✓
FF-S-D-4.4.6	The device shall alert the user when the container needs to be refilled with food some time (depending on how many fish are in the tank) before it is empty.	High	✓
Integration			
FF-I-D-5.2.1	The container shall be detachable from the holding frame in one continuous motion.	High	✓
FF-I-D-5.2.2	The holding frame shall be attached to the rack by a screw.	High	✓
FF-I-D-5.3.1	The motors (servo and vibration) should be protected against water droplets.	Medium	✗
FF-I-D-5.3.2	The product shall be able to fit between the rack and the fish tank.	High	✓
FF-I-D-5.3.3	There shall be a space of minimum 1cm between the product and the fish tank (to remove the tank).	High	✓

As shown in the requirements above, we were able to incorporate most of the goals we set. Especially those concerning precision and user-friendliness, that were of great importance, have been fulfilled.

The few unfulfilled requirements can be classed into two categories, the first one being humidity monitoring. After weighing up the benefits against the drawbacks, we concluded that the added complexity in container design and software was not worth the gain of being able to monitor humidity. Having already incorporated the silica gel as a humidity containment method, the issue was taken care off. The second category concerns the water resistance of our device. This important factor will need to be addressed and solved in future developments of our product.

2.2 Design phase: solutions explored

At the initial stage of identifying the dispensing mechanism, we compiled a list of all possible methods for dispensing a powder-like product. While this list is not exhaustive, we have gathered some of the ideas below. Our aim was to remain unbiased toward obvious solutions, allowing us to explore every possibility before filtering them through our requirements.

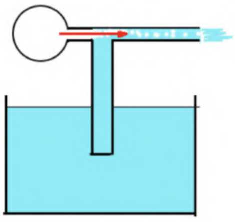
(a) Archimedes screw Cons: disassembly, precision

(b) Rotatory tumbler Cons: humidity sealing, lateral space

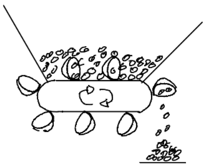
(c) Actuated trap door Cons: disassembly, cleanability, actuation

(d) Vibrating hole Cons: humidity sealing

[6] approximated amount of food left for 2 days for 30 fish, confirmed by measurements (see chapter 7.5)

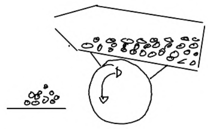


(a) Air compressor
Cons: compressor's size, precision



(b) Scooping
Cons: actuation, humidity sealing, precision

(c) Sieve
Cons: humidity sealing, actuation



(d) Shaking hole
Cons: humidity sealing, actuation, momentum, size

For most of the concepts, feasibility was not suitable due to our requirements for easy disassembly and cleanability. Many of our ideas involved actuating parts that were in direct contact with the food, which made the potential designs too complex to be practical. Additionally, some of these actuation methods required a large amount of space, either for implementing the actuator itself or to provide sufficient range of motion for the components. This was incompatible with the limited space available in the lab.

Among the options considered, the Archimedes screw emerged as the most efficient mechanism. However, it typically requires an additional actuator to trigger motion in the container, enabling the powder to fall into the screw. This solution also required careful consideration of the assembly process and the connection to the motor, particularly regarding humidity sealing and the limited space available.

After evaluating all the ideas, we quickly concluded that the most suitable mechanism had to be actuated by a rotational motion. Rotation clearly offered the most relevant approach to making the mechanism suitable for tight spaces and easy disassembly. From this conclusion, we decided to explore the Archimedes screw further, while addressing its typical shortcomings.

To overcome the drawbacks of the traditional Archimedes screw, we focused on modifying its topology. This led us to develop various designs that utilized grooves rather than a continuous screw.

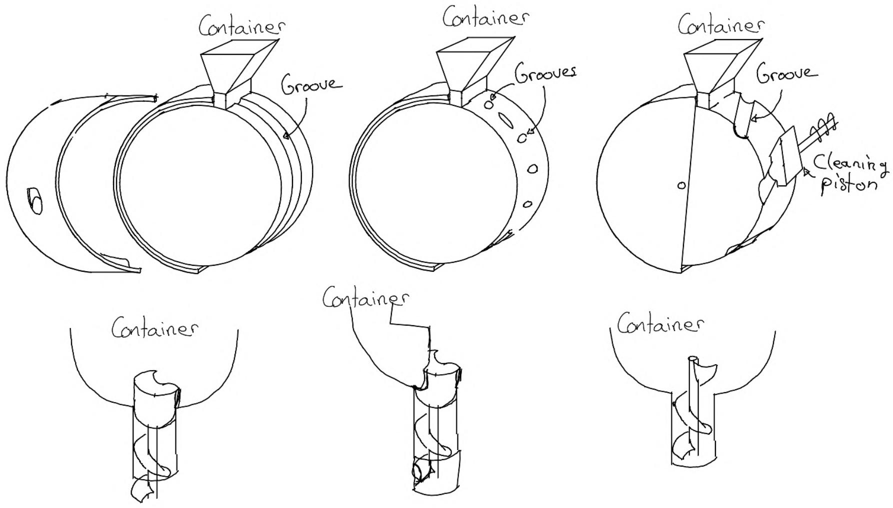


Figure 2.3: 6 ideas based on Archimedes screw's rotation

In Fig. 2.3, you can see that we experimented with different orientations for the screw's axis of revolution. The second row was not relevant enough to allow proper integration of the motor and its linkage. The first row was more suitable regarding motor placement. However, the first design in this row featured a continuous groove, which could not ensure either the precision or the non-blockage of the powder. The second design could not guarantee proper cleaning or the complete emptying of the grooves, which led us to consider the third design. However, its implementation with a cleaning piston proved unworkable.

This process ultimately led us to merge the vertical orientation of the second row with the concept from the third image of the first row to create our final design. The vertical axis proved to be the most suitable choice, as it allowed for a mechanical linkage between the cleaning piston and the rotational motion. This ensured that the mechanism remained sealed by the piston when not in use and that the grooves, aided by gravity, could reliably dispense single doses.

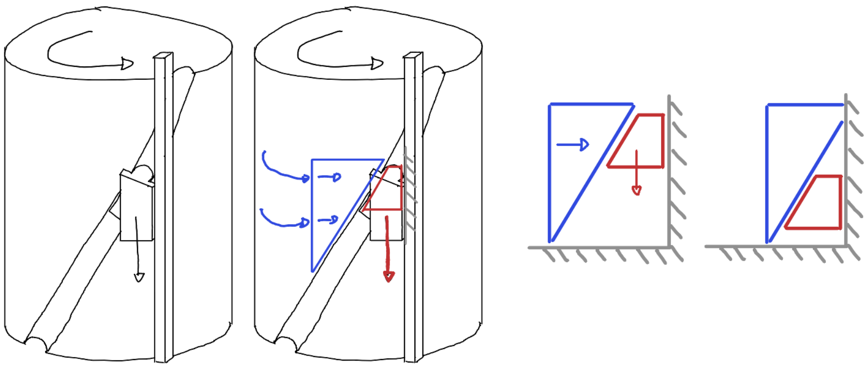


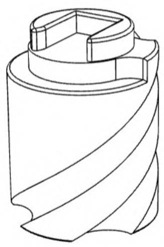
Figure 2.4: Final concept used

As shown in Fig. 2.4, it is intuitive to see that the slope causes the piston to move downward when the cylinder rotates toward the piston. This simple idea emerged as the result of converging from all the concepts discussed above. It enabled us to fulfill the requirement of working within the available space, as the mechanism operates with only one motor while ensuring that the grooves remain unblocked.

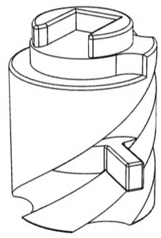
2.3 Technical choices made

2.3.1 Selected design

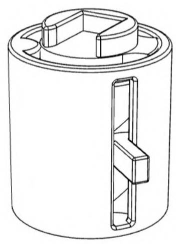
As mentioned, the concept of our final mechanism is shown in Fig. 2.4.



(a) Cylinder with the groove receiving the food to dispense



(b) Cylinder with the piston that will slide down the groove

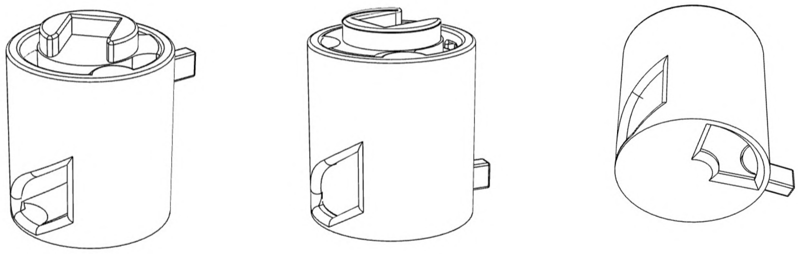


(c) Cylinder with the piston and their housing outer cylinder

Figure 2.5: Piston functionality of final mechanism

Our design begins with the three components shown in Fig. 2.5. In Fig. 2.5a, you can see the cylinder with the groove that transports and dispenses the powder-like food from the container to the fish tank. In Fig. 2.5b, the cylinder is shown with the piston, which slides downward as the cylinder rotates, ensuring that the groove is emptied, as briefly explained in Fig. 2.4. Finally, in Fig. 2.5c, you can see the previous two components assembled with the housing.

The housing serves a dual purpose: it guides the cylinder to move only rotationally and the piston to move only vertically. A key feature of this housing is the small round extrusion visible on the top of the outer cylinder. This extrusion helps keep the cylinder fixed vertically during rotation. It is only when the mechanism is in the home position (with the piston at the bottom) that this extrusion no longer constrains the cylinder vertically, allowing for easy disassembly of the mechanism.



(a) System position to allow the groove to fill up from the *container's window* (piston upmost position)

(b) System position in transit to delivery with no more food able to get in the groove (piston halfway position)

(c) System position after complete dispensing of the food, view of the *dispensing window* (piston down most position)

Figure 2.6: Different windows of final mechanism

From there we could implement the container and the other elements to make our entire design, as visible in the figure below.

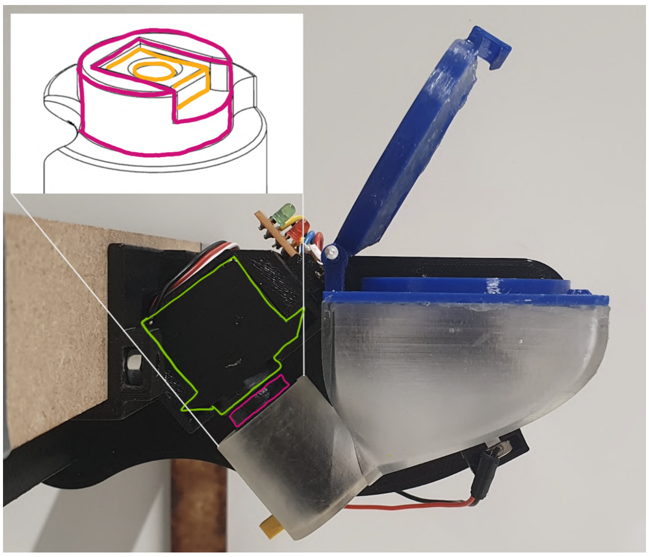


Figure 2.7: Final design of the whole mechanism

Figure 2.8: Demonstration video of the Fish&Feed

As shown in Fig. 2.7, the container is now connected to the window depicted in Fig. 2.6a. One can also see that the square housing of the cylinder is fitted onto the motor's square key, coupling the cylinder to the motor. The assembly only allows this square housing to align with the motor when the piston is in its lowest position.

Additionally, the overall design is slim, ensuring it does not exceed the height of the rack and takes up minimal space beneath the rack. This approach minimizes clutter for the user and ensures the design does not interfere with the fish tanks.

2.3.2 Concept of Operation (ConOps)

To be able to use the F&F the user first needs to install it, following the steps stated in Fig. 2.9. One must know that every holding frame will be attached previously to the racks of the labs by the F&F team.

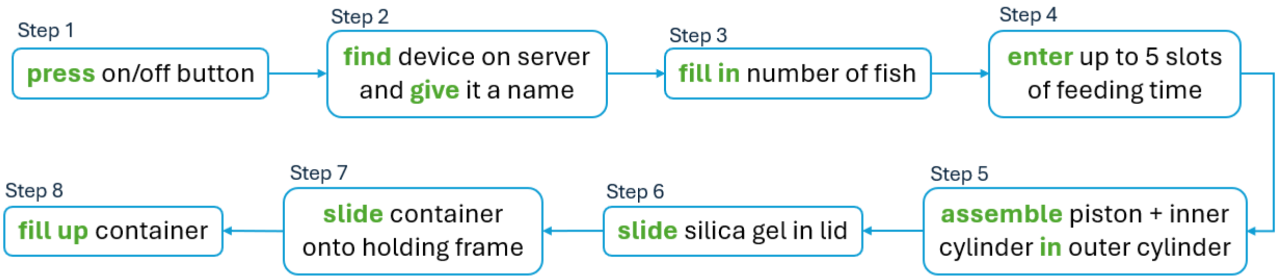


Figure 2.9: Installation steps

Once the device is ready, the user can launch the feeding process. During this process some errors might occur. Fig. 2.10 shows what can happen, when (e.g. an error when there is no food in the groove resulting in a red light on, or a warning when the food in the container has passed a certain threshold resulting in a green light on) and how to resolve the issue(s).

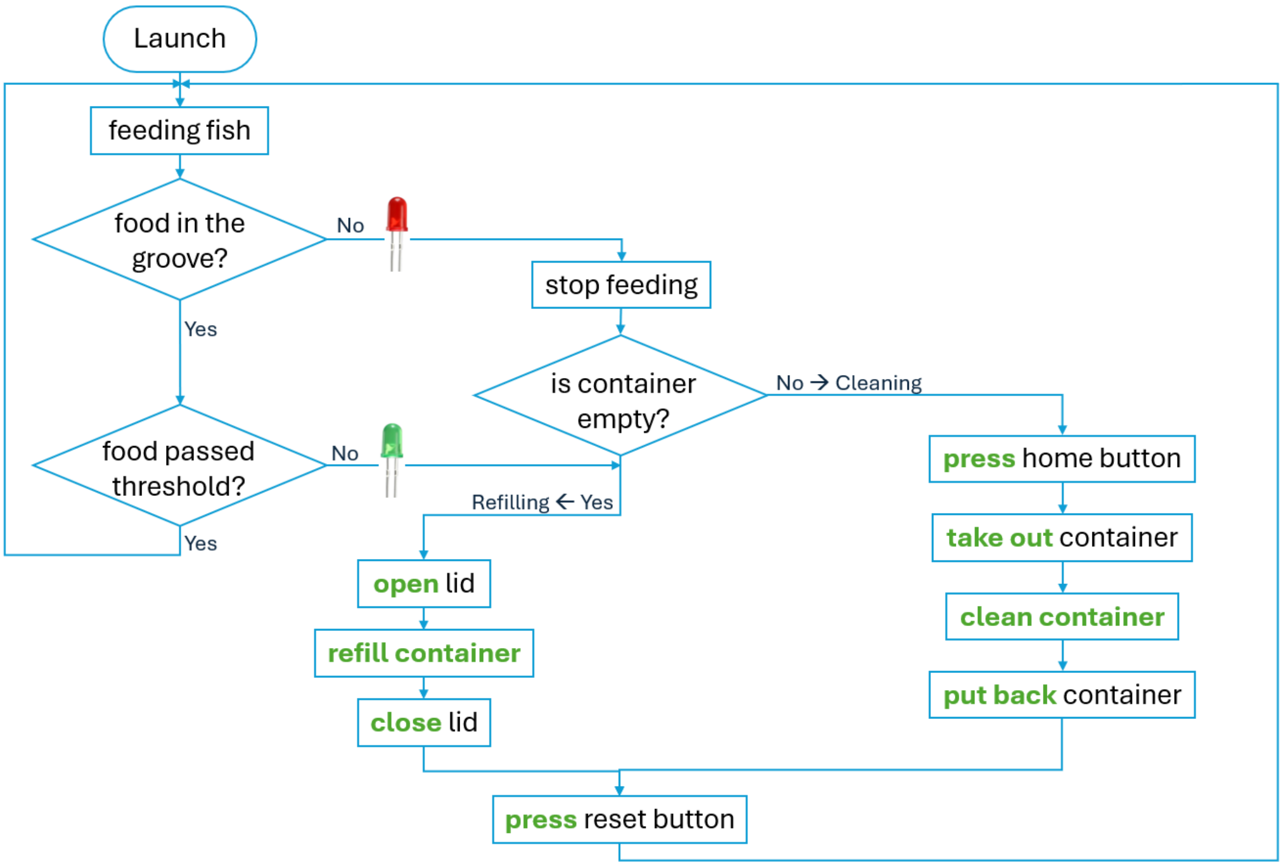


Figure 2.10: Operating principle

2.3.3 Key elements in the design related to the unique selling points of the product

The key feature of this version of an Archimedes screw is the piston. This feature requires various adjustments to ensure successful implementation. To make the piston move automatically, as mentioned earlier, the mechanism requires a helical groove with an appropriate angle.

The mechanism's three main components are the container (which also serves as the cylinder housing), the cylinder itself, and the piston. These three parts have specific shapes and dimensions to ensure the mechanism operates without jamming, failure, or loss of precision. Among these components, some critical dimensions had to be carefully implemented. For example:

- The slope of the container's base, which ensures the food consistently slides into the groove.
- The slope of the groove, which determines the friction affecting the piston's ability to move up or down.
- The angle of the cylinder axis relative to the horizontal plane, which allows the groove to fill consistently and with precision.

One key component that has not yet been discussed is the vibrating system. While the container's slope helps the food slide downward, it is insufficient for managing the behavior of powder-like products. A triggering mechanism through vibration is necessary to ensure the powder flows correctly.

This presented a challenge because the vibration's effectiveness depended on how and where the vibrator was fixed to the system. In many cases, it failed to effectively move the powder. The solution was to attach the vibrator to a beam, which altered the vibration mode to create a specific resonance that improved the powder's flow behavior. This solution was discovered empirically and will be detailed further in the next section.

2.3.4 Analysis / modelling of these *key* elements and how they could be further optimized

This section evaluates how the key components discussed above could be improved. As mentioned earlier, the angle of the helical groove significantly affects the fluidity of the piston's sliding motion. By using the same simplified 2D drawing shown in Fig. 2.4, we can analyze the system through a free-body force analysis.

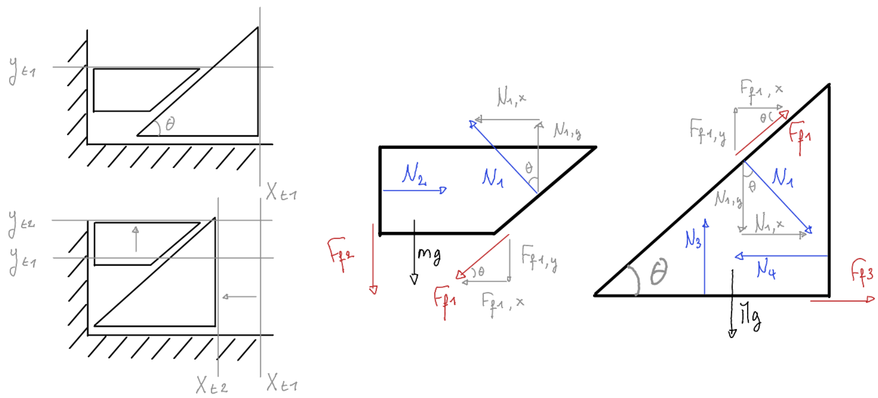


Figure 2.11: Free-body Newton analysis of the piston sliding vertically

Without delving into all the detailed calculations, two key conclusions can be drawn from Fig. 2.11:

- Vertical and Horizontal Displacement Relationship: The vertical displacement of the piston (represented by the quadrilateral shape) is directly related to the horizontal displacement of the cylinder's outer layer (represented here as a triangle) by the relation:

$$\Delta y = \Delta x \cdot \tan\theta \tag{2.1}$$

This equation shows that the angle θ directly impacts the height the cylinder must have for the same horizontal displacement Δx.

- Force N_4 and Friction Coefficients Relation: By completing the full force analysis, a relationship is established between the force N_4 and the parameters θ, μ_1, μ_2, and μ_3, which are the angle of the groove and the friction coefficients for the three contact surfaces, respectively. In this context, N_4 represents the torque the motor applies to the system, where:

$$N_4 = \frac{M_{motor}}{R_{cylinder}} \tag{2.2}$$

Ultimately, the force N_4 is given by the equation:

$$N_4 = \frac{m_{piston} g \cdot [(\mu_1 + \mu_3)\cos\theta + (1 - \mu_1\mu_3)\sin\theta]}{(1 - \mu_1\mu_2)\cos\theta + (\mu_1 + \mu_2)\sin\theta} + \mu_3 \cdot m_{cylinder} g \tag{2.3}$$

This equation applies in two cases:

  - Static case: When the system is stationary.
  - Dynamic case: When the system moves at a constant speed.

These two cases differ in the values of the three μ, as static and dynamic friction coefficients are distinct. Using Eq. (2.3), we can calculate the minimum torque required to overcome the static friction and the torque needed to move the system at constant speed.

To verify this equation, we can observe that when the friction coefficients tend to zero (i.e., no friction), the equation simplifies to:

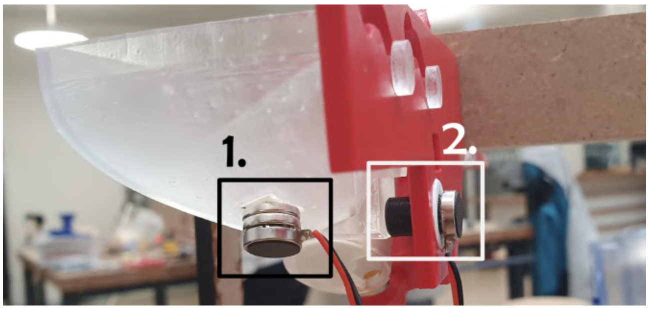
$$N_4 = m_{piston} \cdot g \cdot \tan\theta \tag{2.4}$$

This result corresponds to the force required to move the piston upward, factoring in the relationship between y and x discussed earlier.

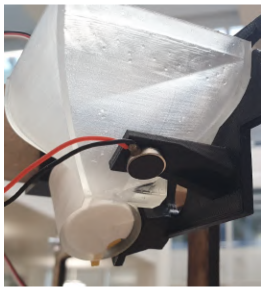
Furthermore, to optimize the mechanism and minimize friction, we could compute the partial derivatives of this function to evaluate the impact of each parameter. This optimization would allow us to identify the ideal set of parameters, reducing the required torque, minimizing the cylinder's height and dimensions, and ultimately saving space within the overall design.

Another element that could be optimized is the way the powder flows. Further research into the rheology of the food could help determine the most appropriate container shape to minimize instances where the powder fails to flow as intended. Despite the container's shape, we have introduced a vibration system to address such unwanted behavior.

The vibration system is another aspect that requires analytical optimization. So far, we have only experimented with different positioning and various methods of transmitting vibrations to the container. Conducting a more systematic analysis would help us better understand how to achieve efficient and consistent powder flow.



(a) Two different positioning of the vibrator



(b) Final positioning of the vibrator on a beam

Figure 2.12: Tryouts of vibrator positioning

In Fig. 2.12a, one can see two different positions for the vibrator that were intuitively chosen to transmit vibrations to the container. However, these two implementations did not successfully activate the food flow with this specific vibrator model. To address this issue, we attempted to alter the vibration mode of the vibrator by attaching it to a beam, as shown in Fig. 2.12b.

The beam was used to resonate at a slightly different frequency than the vibrator itself. Empirically, we found that the new vibration mode of the beam interacted much more effectively with the food, enabling it to flow correctly. To optimize this solution, further analysis of the beam's resonance modes could be conducted. The resonance mode of a beam depends on factors such as the excitation frequency, dimensions and material. By determining the optimal parameters and initial vibration excitation, we could improve the repeatability of the groove being filled, thereby enhancing the system's precision.

Once the repeatability is improved through optimizing the vibration mode, we could focus on enhancing accuracy. This could be achieved by empirically determining the relationship between certain dimensions and the doses served. Using a dataset, we could derive a function that predicts a specific dose of food (in milligrams) based on parameters such as the window size, cylinder angle, groove angle and groove size.

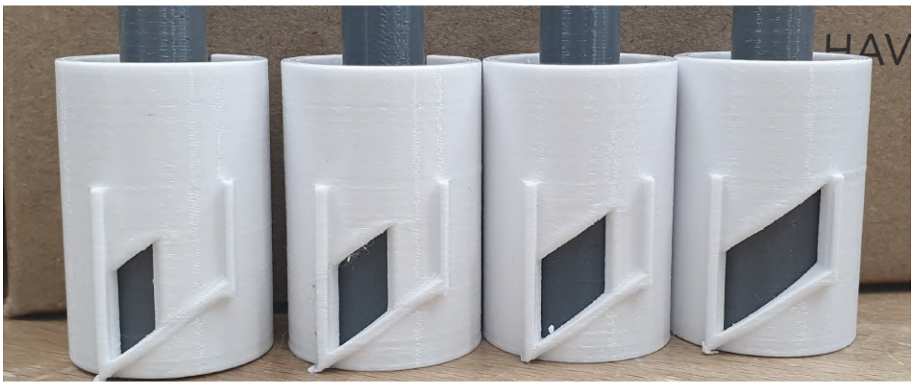


Figure 2.13: Different window sizes to modulate the dose dispensed

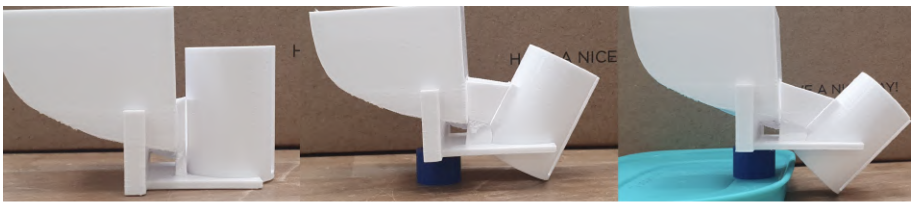


Figure 2.14: Different angles of the cylinder axis

From our data, the angle shown in Fig. 2.14 affects how the groove fills up. The steeper the angle, the lower the precision becomes, although this results in only a slight improvement in accuracy. Conversely, as shown in Fig. 2.13, the window size does not directly influence precision but instead affects the dose dispensed, thereby impacting the precision-to-dose ratio.

With a larger dataset, we could perform a multidimensional interpolation to analyze the combined effects of these parameters. This would allow us to estimate the optimal set of parameters for delivering a specific dose of food while maintaining or even improving the precision. Currently, with our existing parameters, as illustrated in a graph included in the annexes, we achieve a precision of 2.83mg (see chapter 7.5) for a 40mg serving. By refining this process, we could further enhance both accuracy and precision.

2.4 Manufacturing choices and proposals for future production

2.4.1 Prototype fabrication

The main fabrication tool we used for our dispensing system was 3D printing using PETG filament and the MK4 printers at SPOT. It allowed fast feedback and quite high precision, even for small parts. The main reason for using it was the high geometric complexity of our parts. In particular, the support frame and the container would have been difficult to produce otherwise. For the latter, we used resin as the material. One reason was the need for transparency so that the IR sensor could see how much food was left in the container. The other reason was the surface finish of the outer cylinder, which needed to be as smooth as possible to allow the smallest possible tolerance to the inner cylinder.

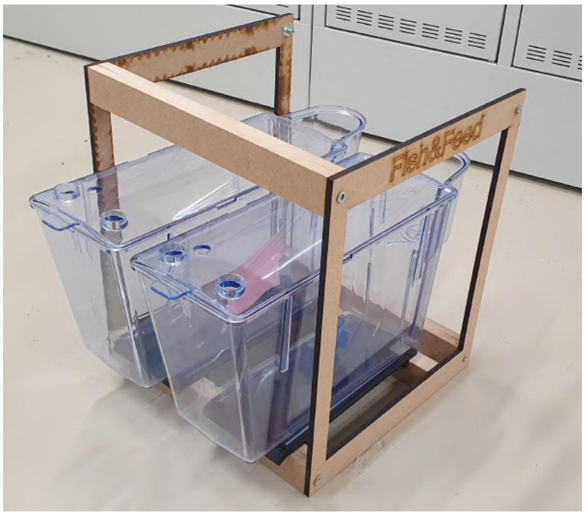


Figure 2.15: Rack model with two fish tanks

The electronic parts - buttons, LEDs, sensors and motors - were soldered onto a strip grid board.

To verify and test that our prototype would fit into the space available in the fish labs, a rack model was made. This was done by cutting PMMA with the laser cutter and plunge saw at the SKILL. The 4 beams were then screwed to the two side pieces, creating a rack model that would fit two fish tanks, as shown in Fig. 2.15.

2.4.2 Final product (Estimated costs for manufacturing)

For our Fish&Feed we estimate a price of 50 CHF per unit since it shall cover all costs plus a profit margin and also be accessible to medium and large-sized laboratories.

For the final product, we target injection molding of all parts that were 3D-printed in the prototype due to its precise, reliable and long-term cost-effective nature. The Fish&Feed mechanism consists of 4 parts, excluding the casing which is still in development. In this estimation, we will therefore calculate with 5 small to medium sized pieces.

1. Injection mold: The injection molds are the most expensive part of the manufacturing process. It is a one-time cost which will pay out through turnover. The preferred steel for our mold is the DAIDO S-STAR steel due to its "high purity with fine microstructure" (LKM Mold Steel Grade Chart, see Appendix) which helps retain the high precision requirement of our design. It is food-grade approved and thus will not cause health concerns for the fish. The online estimates indicate a range of $1000 to $6000 per mold. The upper end of this estimate will be used to allow accounting for price fluctuations.

This would result in a total injection mold cost of 24000$ for all parts. These molds can be used for up to 1 million times.

2. Unit price: According to an estimate by Shanghai Sourcing the unit cost would be around 50 ct (US $). This would be reduced with bulk orders. The required material is polycarbonate due to its food safety and structural integrity over time. We were explained that it is the standardized material for the element the fish are in contact with. The unit price includes labour and material costs. It is difficult to estimate an assembly price at this early stage.

3. Shipping: A rough estimate for shipping from China to Switzerland is 1000 US $ for $<$ 300kg shipments via train which would be preferable due to its comparatively small carbon footprint and short travel times.

Turnover: A reliable estimate for the first year is the supply of two medium-sized fish labs with each around 250 tanks, selling 250 units. This would result in a turnover of 12,500 $. The total initial and fix cost in that first year would be 25,125 US $, not counting employee wages and assembly costs. The employee wages are not factored in since like in a lot of startups we expect to not hire additional employees until the break-even point and also do not plan to deduct our own wages until that time.

With all these costs and estimations applied it can be estimated that the Fish&Feed company would break even in 2,5 years. We also expect a rise in sales after the first year accelerating the process.

Of course these are only rough estimates and the costs could be about 20% lower or higher than estimated. We have reached out to injection molding companies to receive more precise quotes but have not yet gotten reliable answers.

2.4.3 Quality analysis and control

To deliver a reliable and safe product for both users and zebrafish, we are committed to implementing rigorous quality control measures throughout the production process. Key areas of focus include:

- **Precision and Material Flow Testing:** The polycarbonate container and cylinder, shaped through precision molding, will be tested to ensure consistent and accurate dispensing of fish food. This guarantees precise feeding for optimal care of the zebrafish.
- **Toxicology Testing:** As the Fish&Feed comes into contact with livestock feed - in this case, zebrafish food - it is critical to ensure no harmful chemicals leach into the water. Comprehensive toxicology testing will confirm the safety and compliance of all materials.
- **Humidity Testing:** Operating in a humid environment requires that both the electronic casing and the dispensing mechanism perform reliably. These components will undergo rigorous humidity tests to simulate real-world conditions.
- **Seal Integrity and Electronic Testing:** The electronic casing will be subjected to additional seal integrity assessments to confirm water-tightness, and electronic testing will verify safe and reliable performance even in high-moisture settings.

By addressing these critical factors, we aim to produce a Fish&Feed device that meets the highest standards of safety, durability and precision, ensuring peace of mind for researchers and optimal care for zebrafish.

3 Intellectual Property (IP) Analysis

3.1 Prior art search (before patenting)

In our product development, a thorough research of prior art was needed. We are adamant that this process was done meticulously as to provide a responsible intellectual property and avoid any infringement on existing designs. Having compared feeding devices for aquatic life in pet supply shops and having gone through different patent databases, we conclude that none of the private household devices on the market are comparable to our product. There are however some patents that show remarkable similarities with the Fish&Feed dispensing mechanism. Both the *Powder dosing device* and the *Apparatus for dispensing powder* have attributes that can be found in our product, like the idea of using an Archimedes screw for the former or the use of a piston for the latter.

We will take a closer look at those two patents in the following chapter.

3.2 Patent search (freedom to operate)

Our main research has been done with the EPO (European Patent Office) website, where we have found two existing patents that share many features with our feeding device. It is interesting to note that both existing patents are mainly aimed at dispensing powder in the medical sector, where high precision and low volume are of great importance.

3.2.1 Powder dosing device (US2004155069A1) [2]

With its endless screw and a vibrating feature that helps dislodge powder that could get stuck upon entry in the screw, it seems quite similar to our system. However there is no piston involved pushing the food along. Furthermore the endless rotation of this device provides a continuous flow of powder and lies in contrast to our method of dispensing fixed quantities.
Although relying on a similar concepts with a screw as the key element of powder distribution, ou product differs to this patent in that it is precisely tailored to the dispensing of fish food. It is therefore sufficiently different as to not pose any problems in future attempts to patent our dispensing mechanism

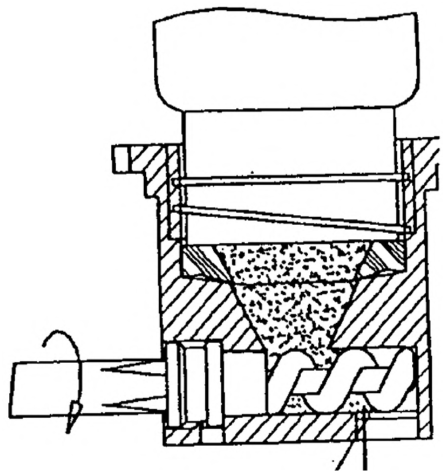


Figure 3.1: Powder dosing device

Similarities	Differences
• archimedes screw • vibration to help dislodge powder	• no piston • endless rotation -> continuous flow

3.2.2 Apparatus for dispensing powder (US2013248563A1) [1]

Unlike the first patent 3.2.1, this one shares the predetermined packages and the piston element with our product (number 24 in Fig. 3.2). And contrary to the endless screw, it also rotates between the filling and dispensing position back and forth. But our system does so in a much simpler and cleaner manner. The device in this patent 3.2.2 steers the piston with the help of a carrier and only so when it is in the dispensing position (stationary). The piston in our device is moved by the rotation of the screw, therefore constantly in motion between the two positions and dispenses throughout the rotation.

Besides, the pistons in the apparatus do push the powder into their compartments (number 25 in Fig. 4.1), which is something our system doesn't do. When handling fish food, which comes in form of granules and not powder, it is very important not to compact it otherwise it will start sticking together and precise dosing will become impossible. This is where our product has a clear advantage over the device in this patent. It is designed for granules (not powder) and handles them in a simple yet delicate way to ensure a smooth flow of granules.

Similarities	Differences
• has piston • predetermined dosage of powder • rotary motion between two positions (filling and dispensing)	• stationary dispensing • piston compacts powder • dispenser for powder

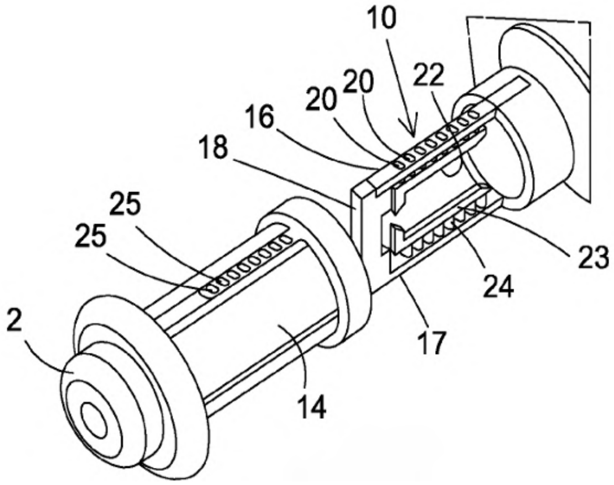


Figure 3.2: Apparatus for dispensing powder

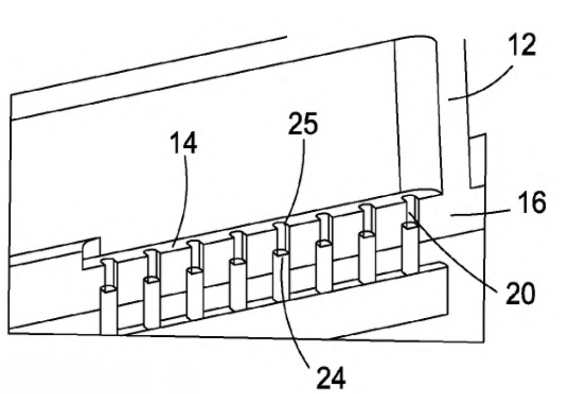


Figure 3.3: Pistons in apparatus for dispensing powder

3.3 Discussion on opportunities for IP and possible IP strategy

There are multiple ways to protect our product, two of them are described in greater detail in the following paragraph:

a. **Trademark:** A trademark may be "a sign used within economic activities by a producer or vendor to identify a particular product or service" [3]. It may be interesting to trademark the name "Fish & Feed" and its possible iterations (e.g. F&F, Fish and Feed, F and F) to facilitate differentiation of our offering.

b. **Patent:** To patent means to protect a creator's invention. The invention must be new, useful and unique. Our invention is, according to the IP analysis, applicable for a patent. The patent's most impactful locations are Switzerland (our entrance market), China (production) and the location of assembly. In the future, more locations shall be considered.

Although it is possible to protect the whole dispensing unit, the truly innovative part is our dispensing mechanism. Therefore, we decided to protect the mechanism and not the device as a whole in the form of a patent.

3.3.1 First claim

A dispensing apparatus suitable for dispensing substances, including but not limited to fluids, granulates or powder, having an apparatus body, consisting of a circumferential side wall (1) with a side opening (13) acting as the connection to the substance storage compartment, a bottom dispensing opening

(14) and a half-cylindrical protrusion (3), wherein the apparatus body encloses an apparatus core (12), characterized in that it is of a cylindrical shape with multiple grooves (4,5) where at least one groove is of a different diameter than the other grooves which slides onto the protrusion aiding in the alignment of the apparatus body and apparatus core and at least one other groove through which a piston (11) slides, wherein the apparatus body and the apparatus core are slid into each other and can rotate around the same axis but independently from the other connected by the piston, wherein a motor first positions the piston so that the side opening is aligned with the substance storage compartment opening and the substance fills the groove up to the followed by the motor-initiated movement of the piston downwards so that the bottom opening aligns with the bottom of the groove and the substance is dispensed.

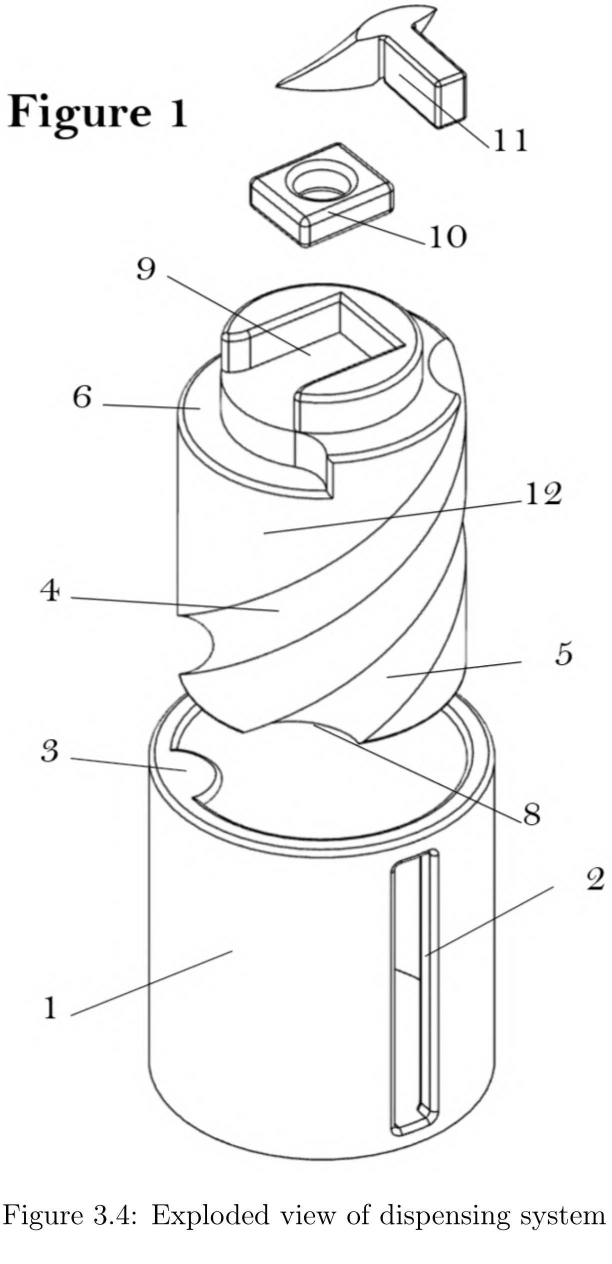


Figure 3.4: Exploded view of dispensing system

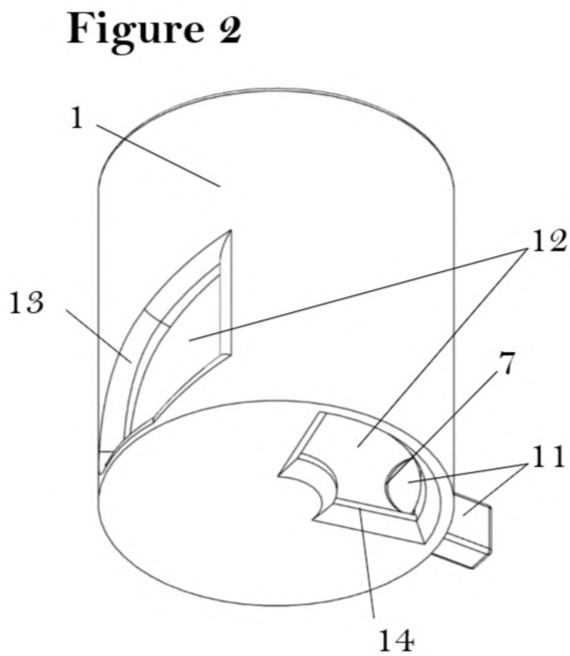


Figure 3.5: Bottom view of dispensing system

4 Aspects of a pre-Business Plan

4.1 Market

Our automated zebrafish feeder targets academic labs, pharmaceutical and biotech companies, marine biology centers, and aquaculture facilities, which commonly use zebrafish for research in genetics, pharmacology, and behavioral studies. Secondary markets include educational centers and aquariums. With around 1,500 labs in Europe and over 8,000 globally using zebrafish, this market is growing rapidly, with a projected CAGR of 15.37% by 2030. Current challenges like inefficient manual feeding and human error highlight the demand for automated, precise solutions. Positioned as a premium product, our feeder addresses these needs while aligning with trends toward lab automation and optimization, making it a compelling option in this expanding market.

4.2 Strategy towards commercialization

The commercialization strategy rests on several pillars: the creation of strong partnerships with research institutions, biotech companies and aquaculture facilities to establish a base of trust and direct access to the market; targeted marketing campaigns via social networks and specialized platforms to raise awareness among researchers and laboratory managers; and the organization of practical demonstrations, such as workshops and on-site trials, to enable potential users to experience the product's benefits at first hand. Distribution agreements with laboratory equipment suppliers will be essential to extend the product's geographical reach. Finally, discussions with insurers or financing institutions could facilitate the integration of the product into laboratory budgets.

4.3 Our organization

Melissa, as Project Manager, oversees the project, ensuring objectives and deadlines are met. Arthur handles IT, developing algorithms for a smooth user interface. Irène manages electronics, ensuring reliability and durability. Paul-Antoine and Vadim, mechanical engineers, focus on robust and functional design. Illana handles finances, partnerships, and regulatory compliance. To strengthen the project, we plan to involve a manufacturing engineer for cost-efficient production, a quality assurance specialist for safety and reliability, a regulatory expert for compliance, and a customer service representative to support users. This structure ensures a strong foundation for market success.

4.4 Planning

The company will start as a Limited Liability Company (LLC), which is ideal for launching our zebrafish vending machine project. This structure offers benefits such as low minimum capital (CHF 20,000), management flexibility, and limited founder liability, allowing us to focus on design, prototyping, and validation with minimal administrative burden. As the project grows and gains adoption in laboratories and research centers, we plan to transition into a Limited Company (LC). This shift will enable capital raising through share issuance, attract investors for industrialization and global expansion, and enhance credibility with partners. With a minimum capital of CHF 100,000, the LC structure will position us for market penetration and long-term growth.

4.5 SWOT analysis (Strengths, Weaknesses, Opportunities, Threats)

The product benefits from a lack of direct competitors in the market for automated feeding solutions for zebrafish, and offers customized options tailored to users' specific needs. However, the market remains small and requires expertise to integrate the device into existing infrastructures. Opportunities include the growing adoption of zebrafish in research and complementary products such as automated water quality monitoring. However, the entry of major players and regulatory changes represent potential threats.

- **Strengths:** Lack of direct competitors in automated feeding solutions. Unique precision and customizable options, catering to zebrafish-specific needs.
- **Weaknesses:** Initial reliance on niche markets. Requires expertise for potential integration with existing lab setups.
- **Opportunities:** Expanding market with increasing zebrafish adoption in research. Potential for ancillary products, such as automated water quality monitoring.
- **Threats:** Entry of larger competitors leveraging economies of scale. Regulatory changes impacting device compatibility or usage in labs.

4.6 Pricing analysis / competition

Our automated laboratory zebrafish feeder is positioned between existing solutions like the Triton robot, which costs hundreds of thousands of CHF and is overbuilt for most labs, and the fish gun, priced at 1,500–2,000 CHF but lacking precision and requiring manual intervention.

Compared to other laboratory fish feeding solutions, our feeder offers a balanced solution with full automation, precision, and the capacity to manage up to 1,000 tanks. This ensures a rapid return on investment compared to a full-time employee (approx. 65,000 CHF/year in Switzerland). Recurring revenue from spare parts, such as cylinders, ensures long-term client support and system durability. Positioned as a robust and affordable alternative, our feeder meets market demands for cost, performance, and ease of use, enabling us to capture significant market share.

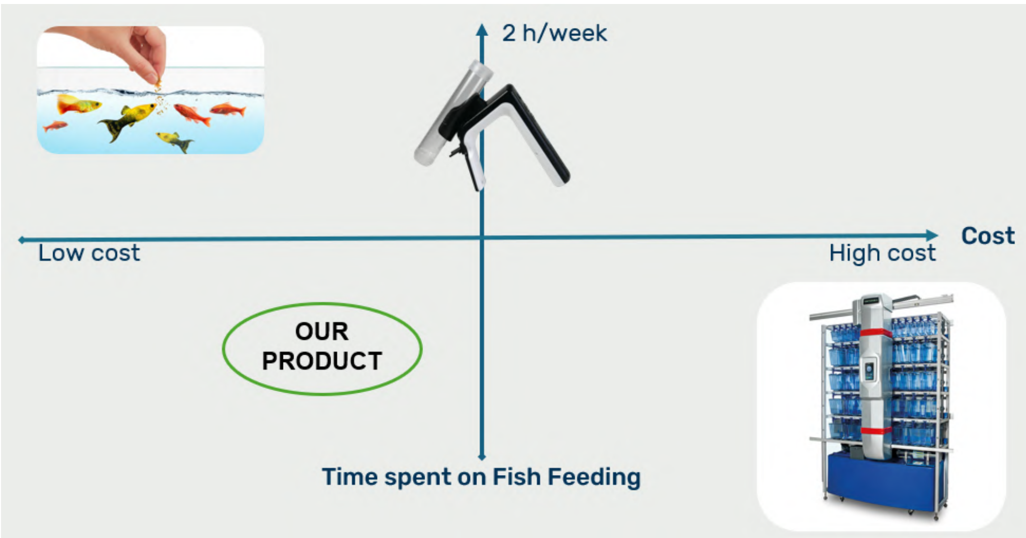


Figure 4.1: Qualitative comparison of our product and the other competitors

5 Project Management

5.1 General strategy

The work for this project was done by a team of six people. In order to achieve an efficient work distribution, we split into smaller groups that were responsible for different aspects of the product. Paul-Antoine and Vadim were responsible for the mechanics, more precisely developing and prototyping the dispensing mechanism and food container with 3D prints. Irène, working on the electronics, identifying the correct actuators and sensors, equipping the device with power was later joined by Vadim helping her with soldering. Arthur was head of software, creating a user-friendly interface and allowing a WiFi-based communication between the interface and the dispensing system. Last but not least, Melissa and Ilana were responsible for the management aspects, researching and documenting our progress. In the early stages of the project those roles stayed quite rigid. But towards the end it was common to work interactively, especially in the assembly and testing phase.

5.2 Work breakdown structure

After multiple iterations and rephrasing of the project, the following structure helped us split up our workload into achievable goals. Furthermore it allowed a good distribution of workload among the team and assisted us in managing our time throughout the semester (see 5.3).

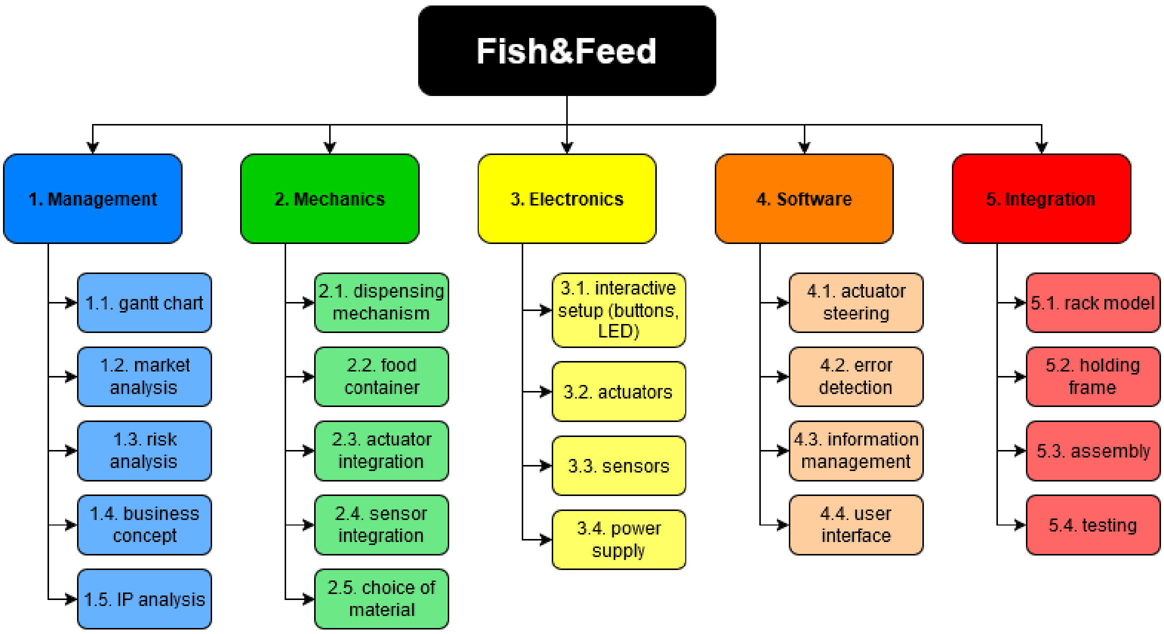


Figure 5.1: work breakdown structure

5.3 Stakeholder analysis

The development and selling of our product relies on many different stakeholders, our group being the main actor. We designed and created the prototype for the Fish&Feed supported by the teaching staff and the different workshops (SPOT and SKILL). They provided us with knowledge, experience and utilities heavily influencing the successful development of our product. The funding for the prototyping came from EPFL, although further investment will be needed by sponsors and shareholders. In order to start shifting our product on the market, different agencies and retailers will need to by payed to produce, promote and sell the Fish&Feed. Our target customers are Zebrafish Laboratories and eventually private households. We also intend to uphold a constant line of communication between the customers, more precisely lab assistants directly working with our product, and our group to have a steady feedback. This will help to continuously improve and further develop our design.

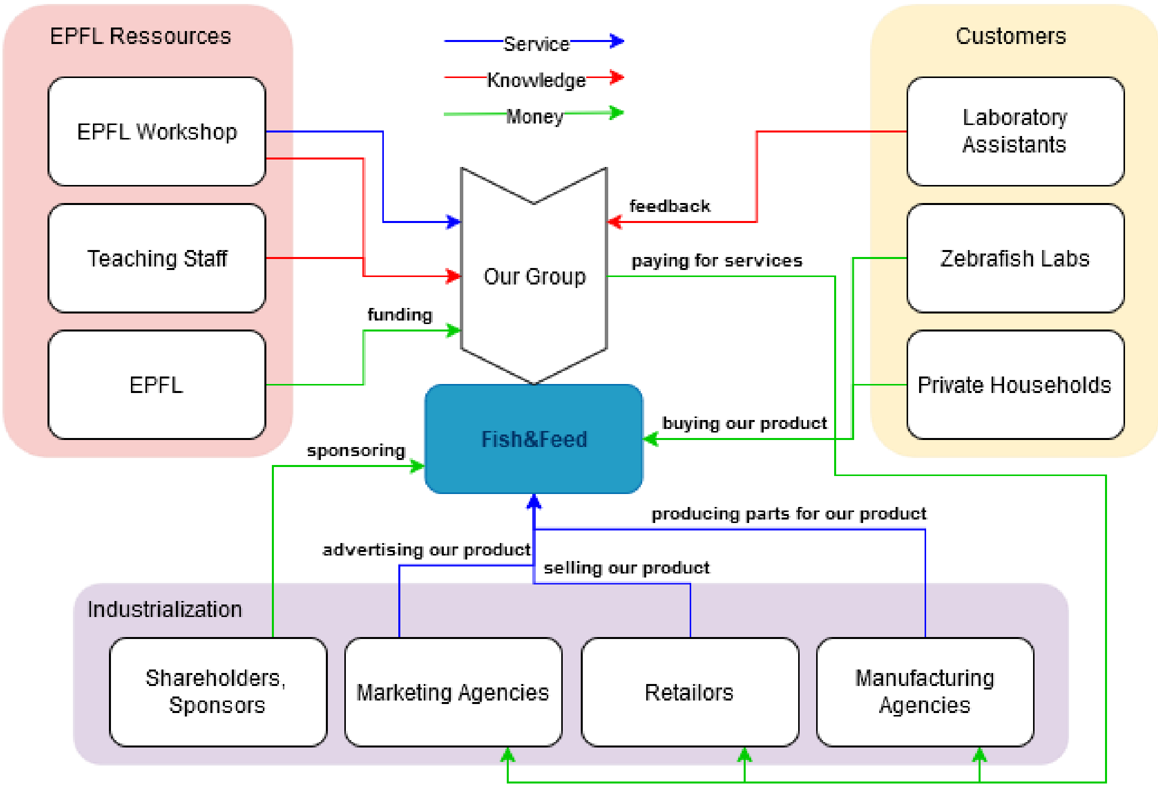


Figure 5.2: stakeholder analysis

Important stakeholders	**Their needs**
Zebrafish Labs	Repetitive and precise feeding of fish with small tolerance for errors, fish need to be fed multiple times a day, cheaper solution for feeding many fish
Laboratory Assistants	Reduction of feeding time (refill in bulk rather than small quantities), easy surveillance of feeding situation, device that can easily be fixed in case of errors
Sponsors (from the medical or biological field)	Increase the capacity of zebrafish laboratories for further optimization of medical research

5.4 Gantt chart

5.4.1 Initial plan

The initial plan was to develop both the dispensing mechanism and container in time for the CDR, so that they could be combined with the holding frame afterwards. The thought was that they would be developed fairly independent from one another. Furthermore we planned on incorporating the sensors and actuators as soon as preliminary designs of the dispensing mechanism and container were available. Everything concerning software (WiFi-communication, motor steering and information management) was to start one week before the CDR.

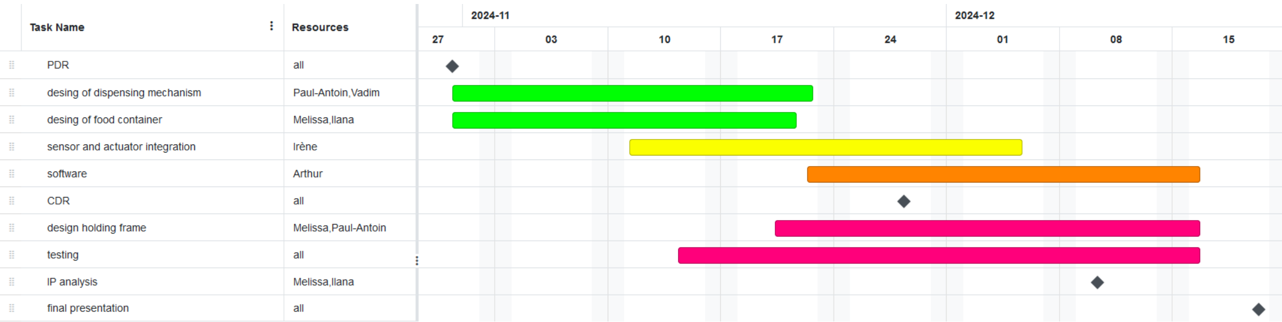


Figure 5.3: Initial Gantt Chart

5.4.2 Deviation from the original planning

Fairly quickly, we discovered that because of the limited space between the rack and the fish tank, the assembled components of our device (dispensing mechanism, container, actuators and sensors) didn't fit into the given space. We had to change the designs and positioning of the motors which lead to more collaborative work earlier than anticipated. The design of the container had to be adapted and its development ended up tightly linked to the dispensing mechanism. Moreover, a team member responsible for the mechanics went on to support the people on electronics and software. And the final design of the container could only start after extensive testing of the ideal orientation between the dispensing mechanism and container. This meant the prototyping of the holding frame was done weeks later than planned. Luckily we had little to no problems with the electronics so we caught up with our schedule.

5.4.3 Reflection on how the project went: difficulties encountered and remedies

One problem encountered during the project was the placement of the vibrating motor. Crucial for a consistent powder flow in the container and a repetitively precise dispensing of food, it was essential to our product. On the one hand, the vibrator only worked reliably when it was directly in contact with the container. On the other hand, it couldn't be incorporated in the container, because that needed to be easily retractable and dishwasher resistant. Many tests were done and multiple iterations of different solutions were proposed before a satisfactory end product was achieved.

Another issue was more of managerial nature. Especially in the beginning of the project there were some misunderstandings and miscommunication happening which resulted in meetings, where only half of the team was present. This lead to additional work in organizing zoom meetings in order to get people up to date on the progress made and decisions taken in those meetings. By introducing weekly meetings with regular hours and using a system of cake based absence fines, we managed to avoid those problems for the rest of the semester.

5.5 Work distribution - Who did what?

- Arthur Lettermann

  I worked on the coding part and established the connection with the server. I also contributed my expertise in the field of fish feeding, as I am currently working as an assistant in a zebrafish lab. This expertise helped me guide my colleagues with the specific requirements and enabled us to visit two different zebrafish labs in preparation for the development of our product.

- Ilana Schürmeyer

  My task within Fish&Feed was assisting Melissa in the management and systems engineering thanks to my prior knowledge in this field. In addition, I was responsible for the design and contents of the presentations. In the beginning I also assisted the mechanical design process by determining the amount and placement of the silica gel for a dry storage environment.

- Irène Andres

  At the start of the project I was assigned to do some research on software and hardware. I rapidly focused on the hardware when I had to familiarize myself with a humidity sensor (which we did not use in the end). Then I had to figure out how to implement all our electronics components with our ESP32. After that, I drew up the circuit diagram so that assembly went smoothly when we had to solder our components to the copper plate. I also took measurements with Melissa to see how accurate our device is.

- Melissa Kundert

  In the beginning of the project I was responsible for doing research on customers needs and conducted interviews with multiple lab assistants. Apart from taking care of the management, I helped with the mechanical design of the container. I further developed the system enabling a smooth assembly of the container onto the holding frame and the humidity containment system in the container. Together with Irène and Vadim we conducted many measurements with the micro scale to ensure the dispensed amount of our system was in the milligram range.

- Paul-Antoine Croux

  I contributed to the mechanical design and analytical optimization of dimensions. Additionally, I participated in the physical prototyping process, focusing on the manufacturing and implementation of all components to ensure the proper assembly of the final prototype. I also assisted in implementing the sensors and verifying that they functioned correctly within the physical system, meeting the requirements we had established.

- Vadim Cladien

  I contributed to the design of the mechanism, collaborating with Paul-Antoine to develop a functional and suitable solution. I also selected the appropriate motor and vibrator for our system, while writing the code to ensure their operation with the ESP32. Finally, I performed the soldering of various components to guarantee reliable and durable connections within our circuit.

6 Conclusions

In this project we have managed to create an inventive product that achieves milligram-level precision in dispensing fish food. This level of accuracy, combined with the compact design and fulfillment of most of our initial requirements, shows the significant progress made in addressing the needs of zebrafish research labs.

While we are proud of what we have achieved, there are areas where improvements could enhance the product further. With additional time, we would have liked to develop a humidity protection system and refine the dispensing mechanism, particularly addressing the looseness of the piston after disassembly. Especially creating a humidity-sealed electronics casing remains a critical improvement on our prototype for future work to ensure long-term reliability in the humid environments of fish labs.

Looking ahead, our focus will shift to enhancing the user experience. We plan to invest in developing an intuitive, user-friendly interface, using customer surveys to better understand the specific needs of lab assistants and researchers. In order to prepare our product for the market, expanding our sponsor network, improving the prototype and conducting more rigorous testing in fish labs will be essential.

In its current state, Fish&Feed has demonstrated great promise and even sparked interest in a zebrafish lab at EPFL, PhenoGenomics, which is a strong foundation for future development. Despite the remaining challenges, the progress so far has shown that this product is worth further investment, that we are interested to take. With continued effort and support, Fish&Feed has the potential to set new standards in automated zebrafish feeding in laboratory environments.

Figure 6.1: the team

7 Annexes / supporting Documentation

7.1 Bill of Materials

ID	Object	Quantity	Price [CHF]	PriceTot [CHF]	Supplier	Material	Bought or made
			Electronics				
1	ESP32 wroom 32	1	4	4	Spot		Bought
2	Servo S-7361	1	6	6	Spot		Bought
3	Vibrator	1	1,27	1,27	Conrade		Bought
4	Power amplifier	1	0,2	0,2	Spot		Bought
5	CNY70	2	0,3	0,6	Spot		Bought
6	Button	2	0,2	0,4	Spot		Bought
7	Switch button	1	0,15	0,15	Spot		Bought
8	LED	2	0,5	1	Spot		Bought
9	RGB LED	1	0,6	0,6	Spot		Bought
10	Cable mini-USB	1	2	2	Spot		Bought
11	Electronic perforated plate	1	6,5	6,5	Spot		Bought
12	Straight bar connector	2	0,2	0,4	Spot		Bought
13	Resistor	9	0,1	0,9	Spot		Bought
14	Connection cables	4	1,5	6	Spot		Bought
			Mechanical parts				
15	Container	1	7,22	7,22	Spot	Resin	Manufactured
16	(inner) Cylinder	1	0,24	0,24	Spot	PETG	Manufactured
17	Piston	1	0,01	0,01	Spot	PETG	Manufactured
18	Motor square key	1	0,01	0,01	Spot	PETG	Manufactured
19	Front holding frame	1	1,52	1,52	Spot	PETG	Manufactured
20	Back holding frame	1	1,9	1,9	Spot	PETG	Manufactured
21	Screw for electronics	4	0,04	0,16	Spot		Bought
22	Hexagonal threded sleeve	4	0,03	0,12	Spot		Bought
23	Container top	1	0,2	0,2	Spot	PETG	Manufactured
24	Container lid	1	0,2	0,2	Spot	PETG	Manufactured
25	Container clip	1	0,01	0,01	Spot	PETG	Manufactured
			Rack parts				
26	Side part	2	0,85	1,7	Skil	PMMA	Manufactured
27	Beam	4	0,5	2	Skil	PMMA	Manufactured
28	Screw for rack	8	0,1	0,8	Skil		Bought
29	Screw for assembly	3	0,05	0,15	Spot		Bought
			Others				
30	Silica gel	1	0	0	Pheno...		Sponsored
31	Fish food	1	0	0	Pheno...		Sponsored
			Total price	45,85			

Figure 7.1: BoM (Bill of Material)

7.2 Circuit diagram

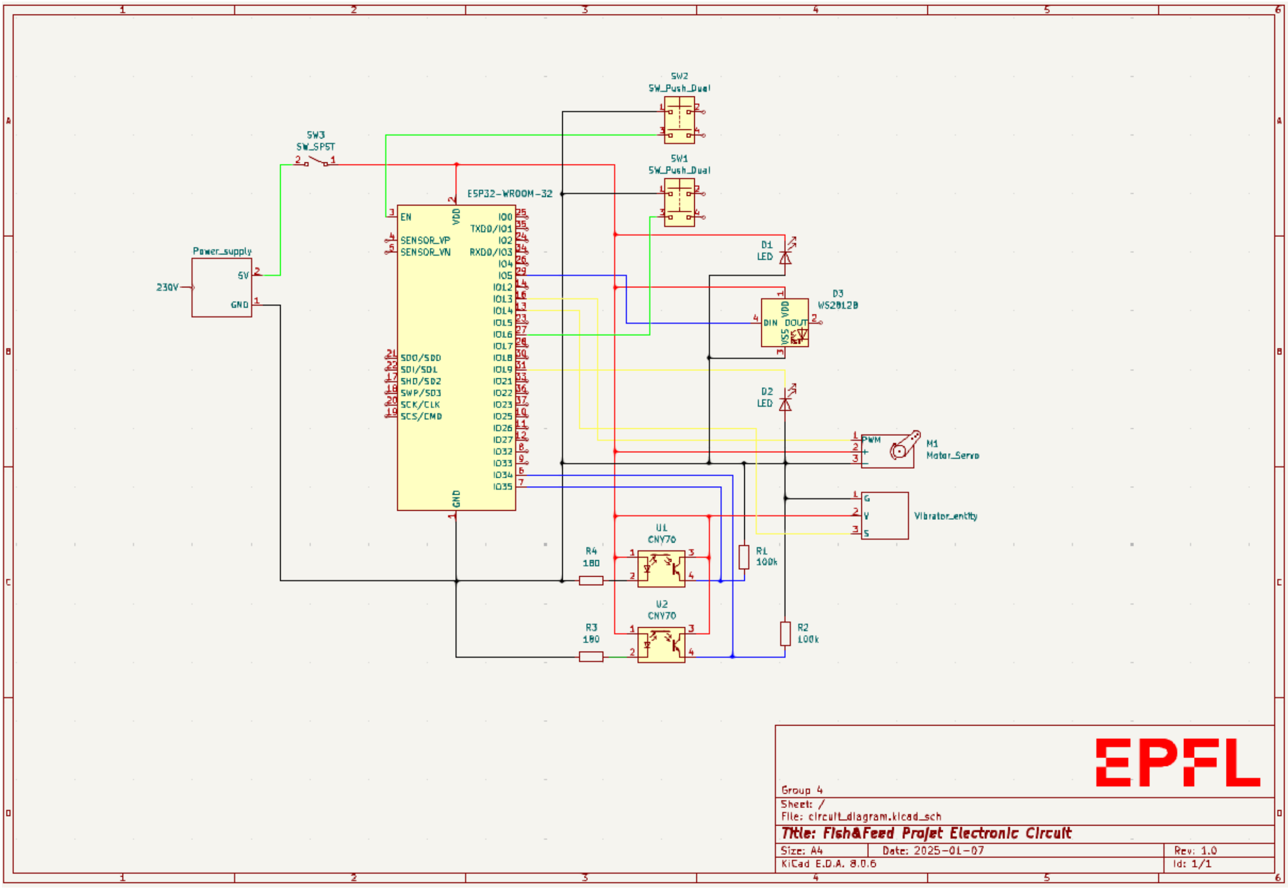


Figure 7.2: Electronic circuit

7.3 Code

```cpp
#include <WiFi.h>
#include <PubSubClient.h>
#include <Wire.h>
#include <time.h>
#include <Adafruit_NeoPixel.h>
#include <ESP32Servo.h>

// Définition des broches et paramètres matériels
#define VIBRATOR_PIN    14
#define servoPin        13
#define CAPTORGROOVE    34
#define CAPTORUP        35
#define PIN             5  // Broche de sortie pour les LEDs WS2812B
#define NUMPIXELS       1  // Nombre de LEDs WS2812B utilisées
#define PIN_BUTTON      16
#define LED_CO          19

// Variables liées à l'alimentation des poissons
int nbFoodPerFishPerDayMg = 60;  // Quantité de nourriture par poisson par jour en mg
int OneTurnMg = 40;  // Quantité de nourriture délivrée par un tour du moteur en mg

// Variables pour le nourrissage
int sensorValue = 0;
float groove_error = 0;  // Erreur liée au capteur de nourriture
int buttonState = 0;
int captorUp = 0;

// Positions du moteur servo
int pos_max = 160;         // Position maximale
int pos_min = 10;          // Position minimale
int pos_min_vib = 135;     // Position pour la vibration
int pos_groove = 95;       // Position pour l'alignement de la nourriture

// Initialisation de la bibliothèque NeoPixel pour les LEDs
Adafruit_NeoPixel pixels(NUMPIXELS, PIN, NEO_GRB + NEO_KHZ800);
```

```
// Initialisation du moteur servo
Servo servo1;

// Informations Wi-Fi
const char* ssid = "OMEN16-C0990NZ 4976"; // Nom du réseau Wi-Fi
const char* password = "#943E4c2";         // Mot de passe Wi-Fi

// Serveur MQTT
const char* mqtt_server = "broker.emqx.io";

// Client Wi-Fi et MQTT
WiFiClient espClient;
PubSubClient client(espClient);

// Variables pour MQTT
long lastMsg = 0;
char msg[50];
int value = 0;

// Configuration du serveur NTP pour l'heure
const char* ntpServer = "pool.ntp.org";  // Serveur NTP
const long gmtOffset_sec = 3600;        // Décalage horaire GMT+1
const int daylightOffset_sec = 3600;    // Heure d'été

// Variables pour les données du MQTT
String error = "error";
String nbFish = "3";  // Nombre de poissons par défaut
String timeFeed[5];   // Tableau pour stocker les horaires d'alimentation
```

```
// ------------------------------------- Fonctions ---------------------------------------

// Calcul du nombre de tours nécessaires pour distribuer la nourriture
int NbTurn() {
  int fish = nbFish.toInt();
  int quantityDayMg = fish * nbFoodPerFishPerDayMg;  // Quantité totale nécessaire par jour
  int nbFeeding = 5;  // Nombre de nourrissages par jour
  int nbTurn;

  // Vérifie les horaires de nourrissage configurés
  for (int i = 0; i < 5; i++) {
    if (timeFeed[i] == "00:00") {
      nbFeeding--;
    }
  }

  // Calcul du nombre de tours
  nbTurn = (quantityDayMg / nbFeeding) / OneTurnMg;

  // S'assure qu'au moins un tour est effectué si des poissons et des nourrissages existent
  if (nbTurn == 0 && nbFeeding != 0 && fish != 0) {
    nbTurn = 1;
  }

  Serial.println(nbTurn);
  return nbTurn;
}

// Initialisation des composants pour la distribution de nourriture
void setup_serving() {
  servo1.attach(servoPin);
  pinMode(VIBRATOR_PIN, OUTPUT);
```

```
  pinMode(CAPTORGROOVE, INPUT);
  pixels.begin();  // Initialisation des LEDs
  pinMode(CAPTORUP, INPUT);
}

// Fonction pour un tour de distribution de nourriture
void one_turn() {
  unsigned long startTime = millis();
  vibrate();  // Active la vibration pour faciliter le mouvement des grains

  // Mouvement du servo pour aligner la nourriture
  for (int posDegrees = pos_max; posDegrees >= pos_groove; posDegrees--) {
    servo1.write(posDegrees);
    delay(10);
    sensorValue = analogRead(CAPTORGROOVE);
    Serial.print("Voltage = ");
    Serial.println(sensorValue);
  }

  // Vérifie si le capteur détecte que la nourriture est disponible
  sensorValue = analogRead(CAPTORGROOVE);
  if (sensorValue < 1500) {
    String groove = "groove empty";  // Indique que la nourriture est absente
    pixels.setPixelColor(0, pixels.Color(255, 0, 0)); // Rouge
    pixels.show();
    delay(500);
    groove_error += 0.5;
    client.publish("esp32/error_321", groove.c_str());

    // Attend que l'utilisateur appuie sur le bouton pour réaligner
    while (1) {
      buttonState = digitalRead(PIN_BUTTON);
      if (buttonState == LOW) {
        for (int posDegrees = pos_groove; posDegrees >= pos_min; posDegrees--) {
          servo1.write(posDegrees);
```

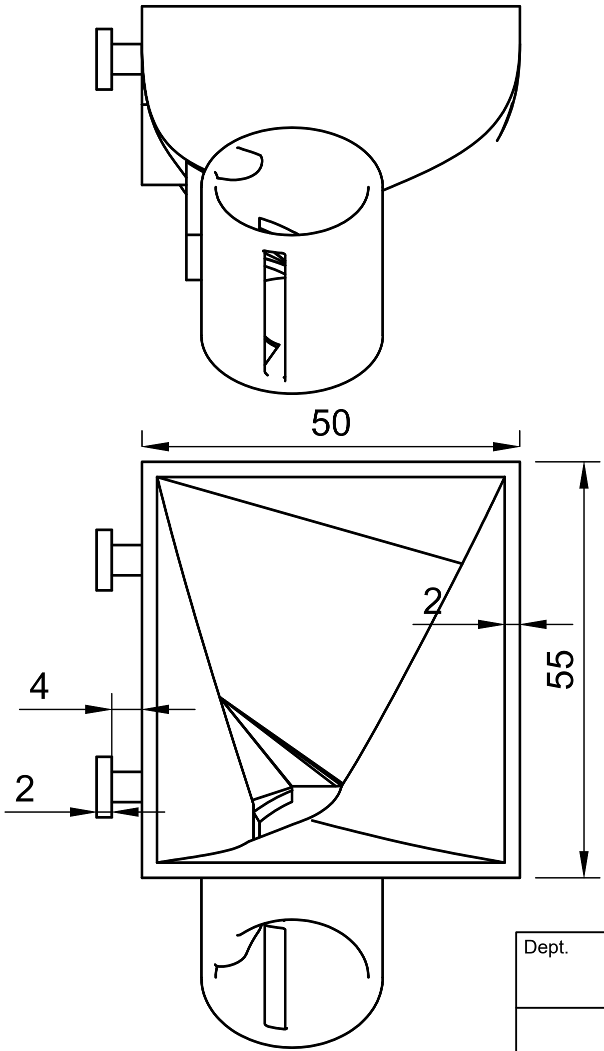
```
          delay(10);
        }
        delay(1000);
      }
    }
  }

  // Retour au point de départ
  for (int posDegrees = pos_min; posDegrees <= pos_groove; posDegrees++) {
    servo1.write(posDegrees);
    delay(10);
  }

  unsigned long endTime = millis();
  Serial.print("Temps écoulé pour one_turn(): ");
  Serial.print(endTime - startTime);
  Serial.println(" ms");
}

// Vibration pour faciliter le mouvement des grains
void vibrate() {
  digitalWrite(VIBRATOR_PIN, HIGH);
  for (int i = 0; i <= 20; i++) {
    for (int posDegrees = pos_max; posDegrees >= pos_min_vib; posDegrees--) {
      servo1.write(posDegrees);
      delay(8);
    }
    for (int posDegrees = pos_min_vib; posDegrees <= pos_max; posDegrees++) {
      servo1.write(posDegrees);
      delay(8);
    }
  }
  digitalWrite(VIBRATOR_PIN, LOW);
```

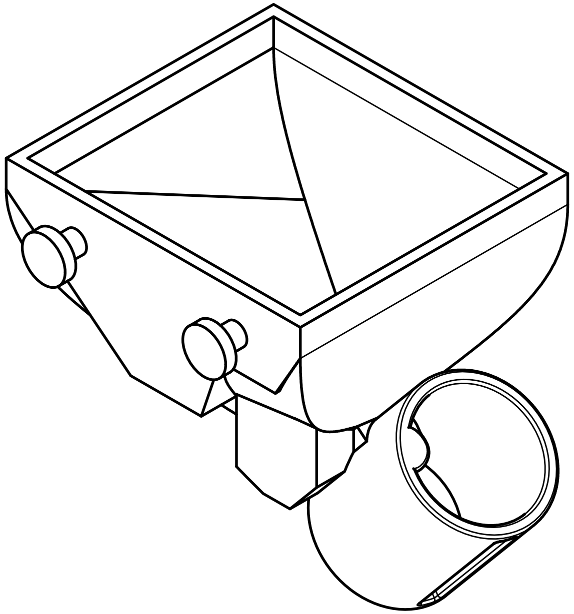
```
  }
  digitalWrite(VIBRATOR_PIN, LOW);
}

// Fonction principale de distribution de nourriture
void serving(String nb) {
  int number = NbTurn();  // Nombre de tours nécessaires
  for (int i = 1; i <= number; ++i) {
    one_turn();
  }
  checkIRUP();
}

// Nourrissage manuel
void nourishFish() {
  Serial.println("NOURRISSAGE!");
}

// Vérification du capteur pour indiquer si le réservoir est vide
void checkIRUP() {
  captorUp = analogRead(CAPTORUP);
  if (captorUp < 1000) {
    String message = "tank almost empty";
    client.publish("esp32/error_321", message.c_str());
    pixels.setPixelColor(0, pixels.Color(0, 100, 0)); // Vert
    pixels.show();
  }
}

```

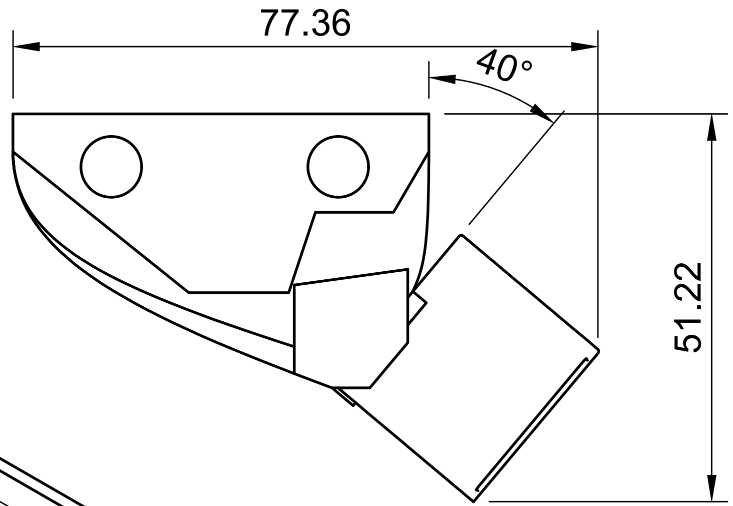
```
// -------------------------------------- Reste du code --------------------------------------


void setup() {
  Serial.begin(115200);  // Initialise la communication série à 115200 bauds pour le débogage.

  setup_serving();       // Configure le servo, la LED NeoPixel, les capteurs, et d'autres périphériques matériels.
  setup_wifi();          // Connecte l'ESP32 au réseau Wi-Fi spécifié.

  client.setServer(mqtt_server, 1883); // Configure le serveur MQTT (broker) pour l'échange de messages.

  // Configure le fuseau horaire et synchronise l'heure via un serveur NTP.
  configTime(gmtOffset_sec, daylightOffset_sec, ntpServer);
  Serial.println("Synchronisation avec le serveur NTP...");

  client.setCallback(callback); // Définit la fonction de rappel qui traite les messages MQTT entrants.

  // Éteint la LED NeoPixel au démarrage.
  pixels.setPixelColor(0, pixels.Color(0, 0, 0));
  pixels.show();

  pinMode(PIN_BUTTON, INPUT_PULLUP); // Configure le bouton comme entrée avec une résistance pull-up.
  pinMode(LED_CO, OUTPUT);           // Configure la LED comme une sortie.

  servo1.write(pos_groove); // Place le servo à la position initiale.
}


void loop() {

  // Si le client MQTT n'est pas connecté, tente de se reconnecter.
  if (!client.connected()) {
    reconnect();
  }
```

```

  // Lit l'état du bouton pour des interactions manuelles.
  buttonState = digitalRead(PIN_BUTTON);

  // Fait tourner la boucle MQTT pour traiter les messages entrants et maintenir la connexion.
  client.loop();

  // Affiche les données pour débogage.
  Serial.println(nbFish);          // Nombre de poissons.
  Serial.println(timeFeed[0]);     // Premier horaire de nourrissage.

  // Parcourt les 5 horaires de nourrissage définis.
  for(int i = 0; i < 5; i++) {
    // Si l'heure actuelle correspond à l'un des horaires définis, exécute le nourrissage.
    if (compareTimeWithCurrent(timeFeed[i])) {
      serving(nbFish);        // Distribue la nourriture.
      nourishFish();          // Logique supplémentaire pour le nourrissage.
      delay(60000);           // Attend 1 minute pour éviter une répétition immédiate.
    }
  }

  // Si le bouton est pressé, réaligne le servo pour permettre l'accès manuel à la "cup".
  if (buttonState == LOW) {
    for (int posDegrees = pos_groove; posDegrees >= pos_min; posDegrees--) {
      servo1.write(posDegrees); // Déplace progressivement le servo vers la position minimale.
      delay(10);                // Petite pause pour éviter un mouvement brusque.
    }
  }

  delay(1000); // Pause d'une seconde avant la prochaine itération de la boucle.
}
```

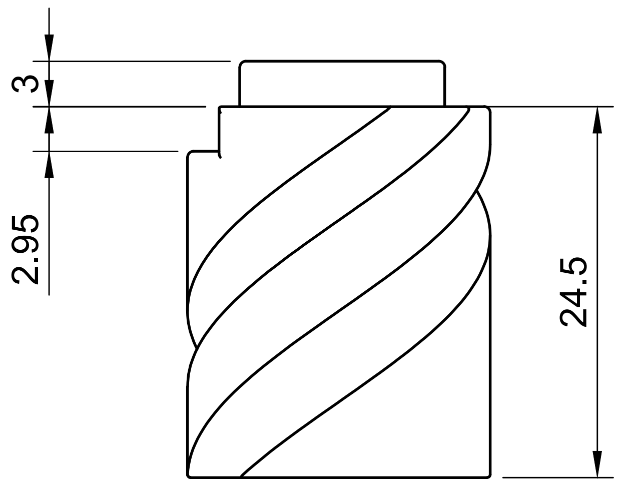
7.4 Technical Drawings

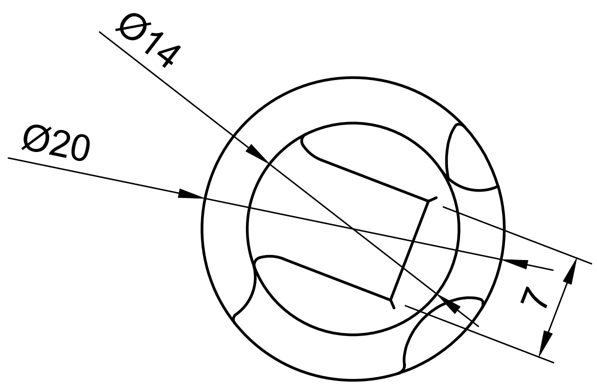


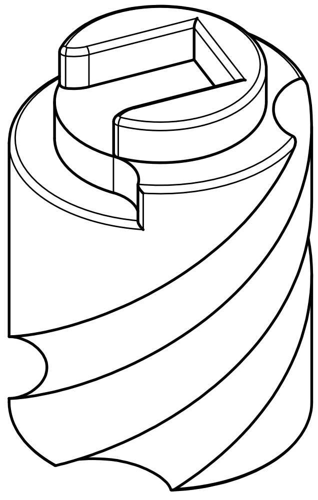




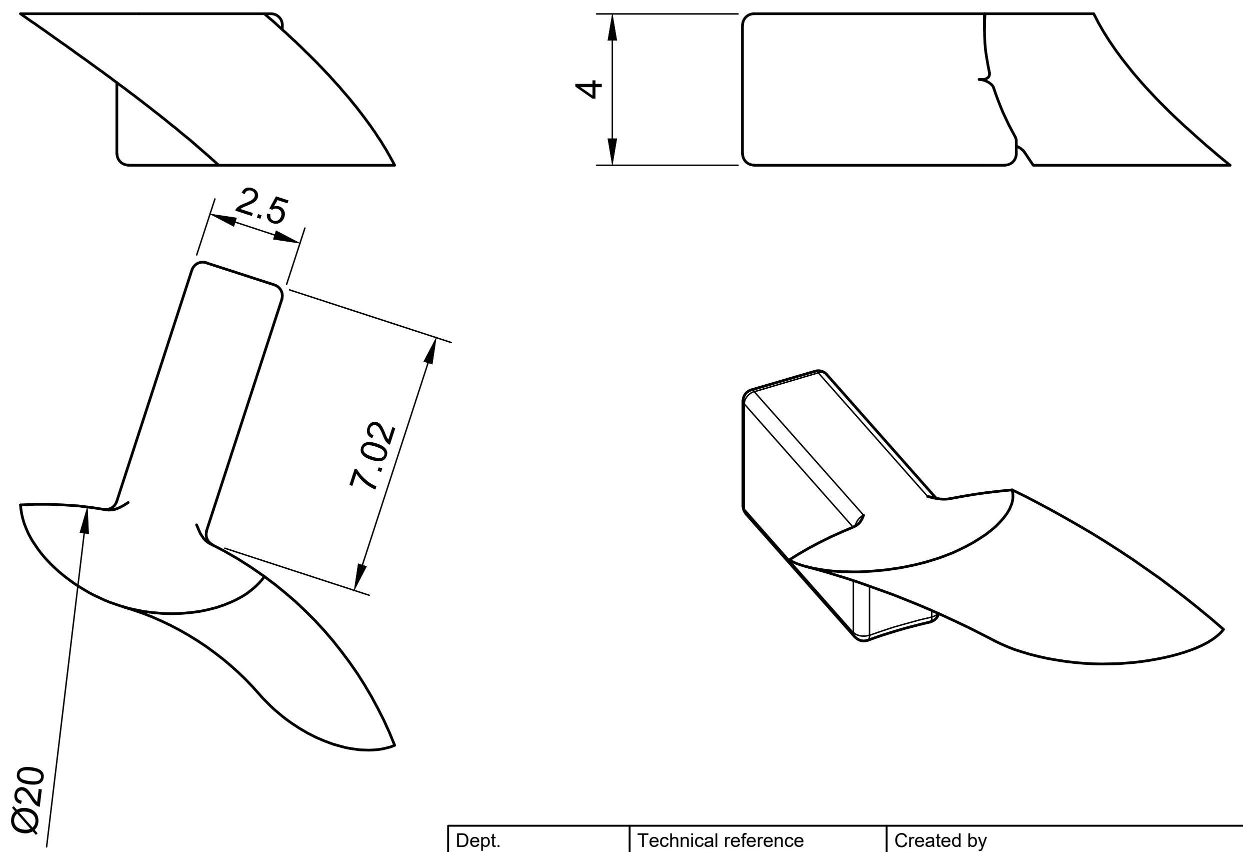
Dept.	Technical reference	Created by	Approved by
	15	Paul-Antoine Croux 2024-25	
EPFL		Document type	Document status
		Title	DWG No.
		Container	
			Rev. / Date of issue / Sheet 1/1



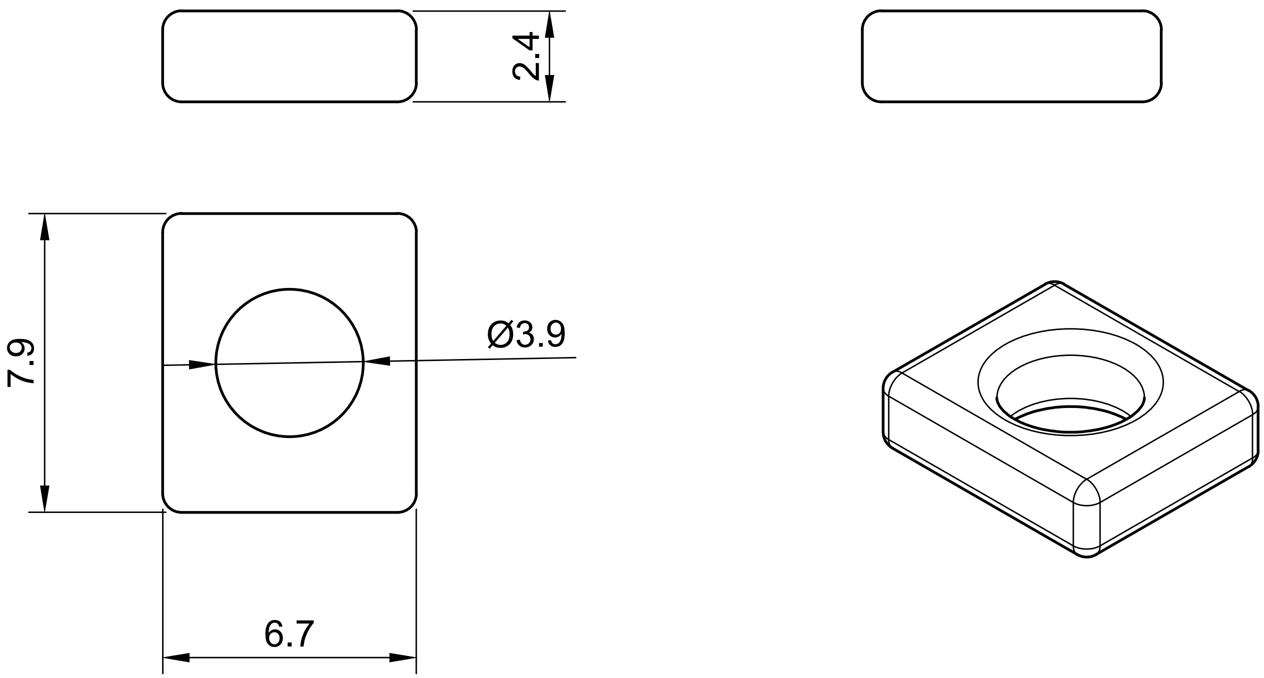




Dept.	Technical reference	Created by	Approved by
	16	Paul-Antoine Croux 2024-25	
EPFL		Document type	Document status
		Title	DWG No.
		Cylinder	
			Rev. / Date of issue / Sheet 2/1



Dept.	Technical reference	Created by	Approved by
	17	Paul-Antoine Croux 2024-25	
		Document type	Document status
EPFL		Title Piston	DWG No.
			Rev. / Date of issue / Sheet 5/1

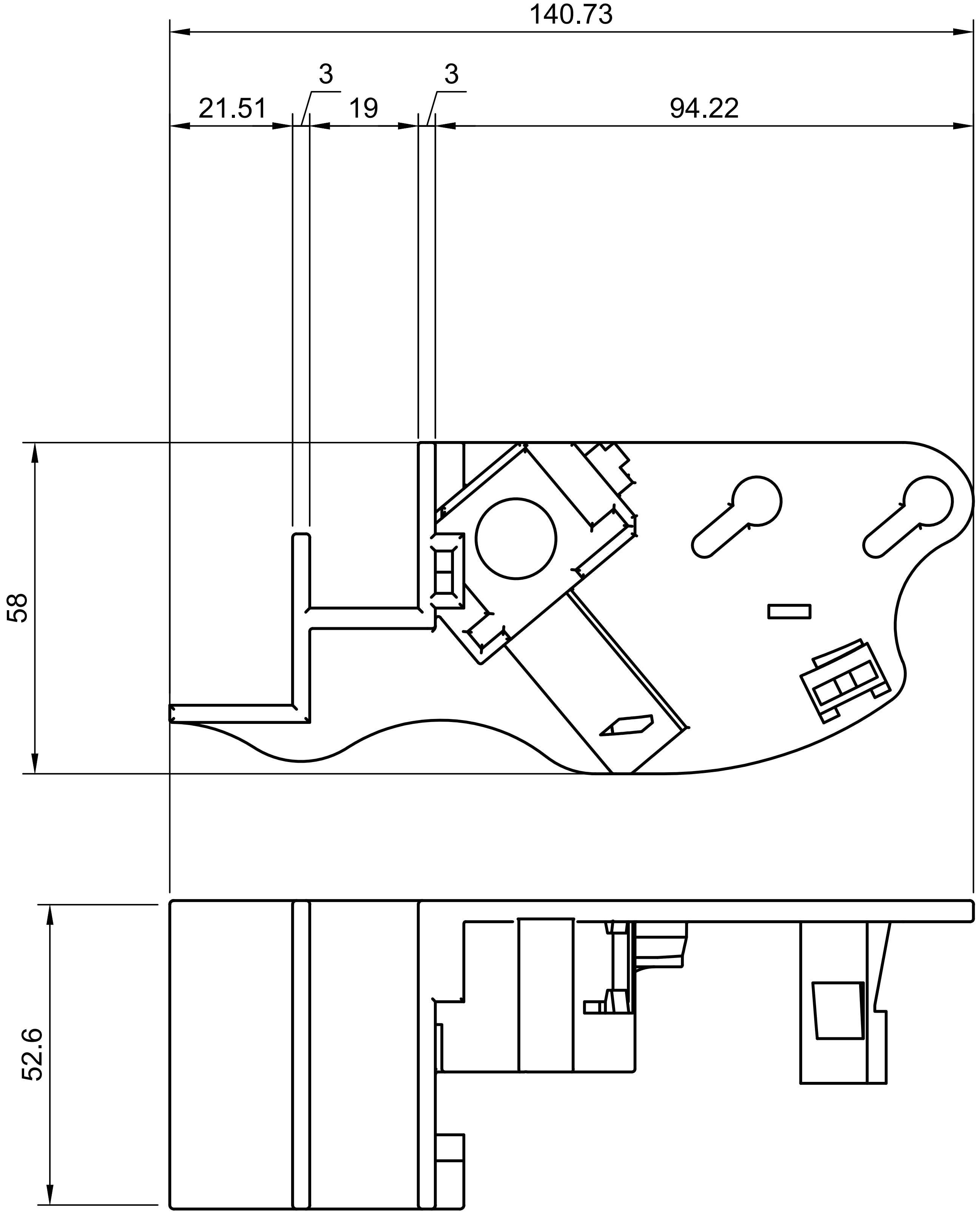


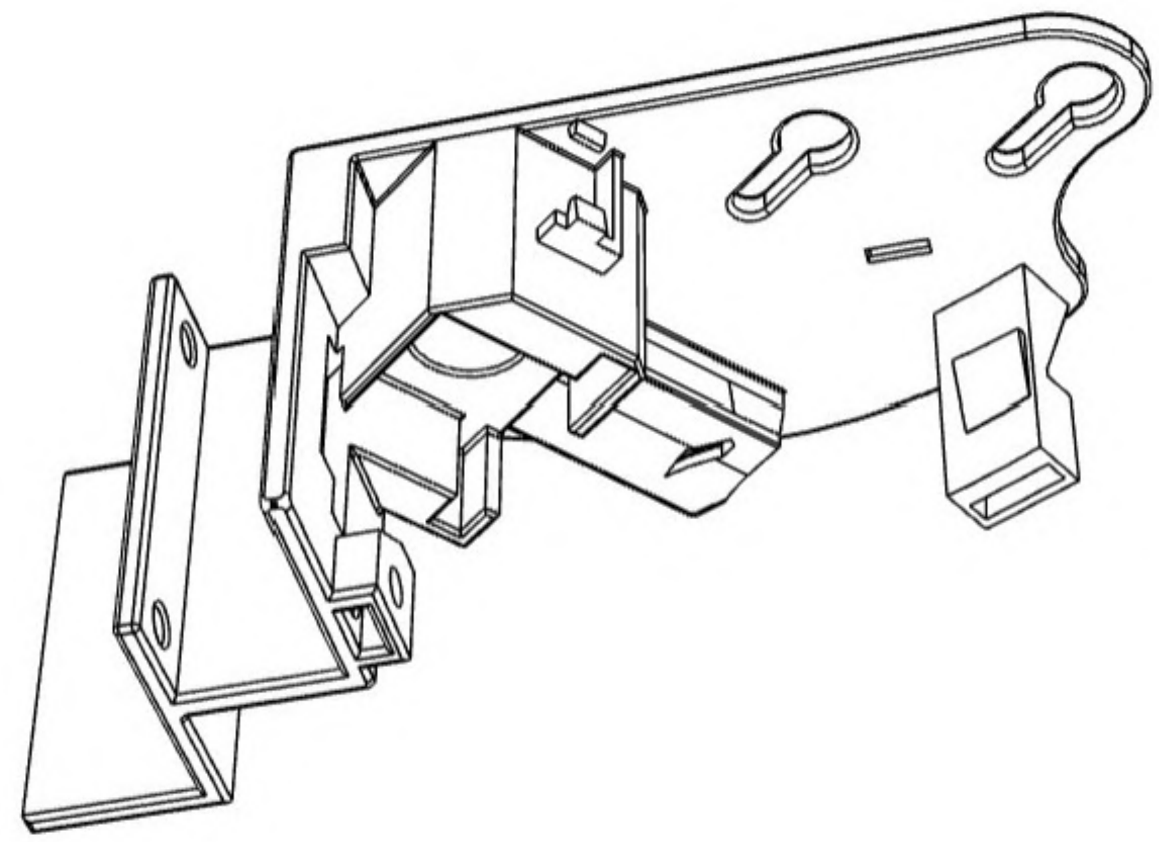
Dept.	Technical reference	Created by	Approved by
	18	Paul-Antoine Croux 2024-25	

Document type	Document status

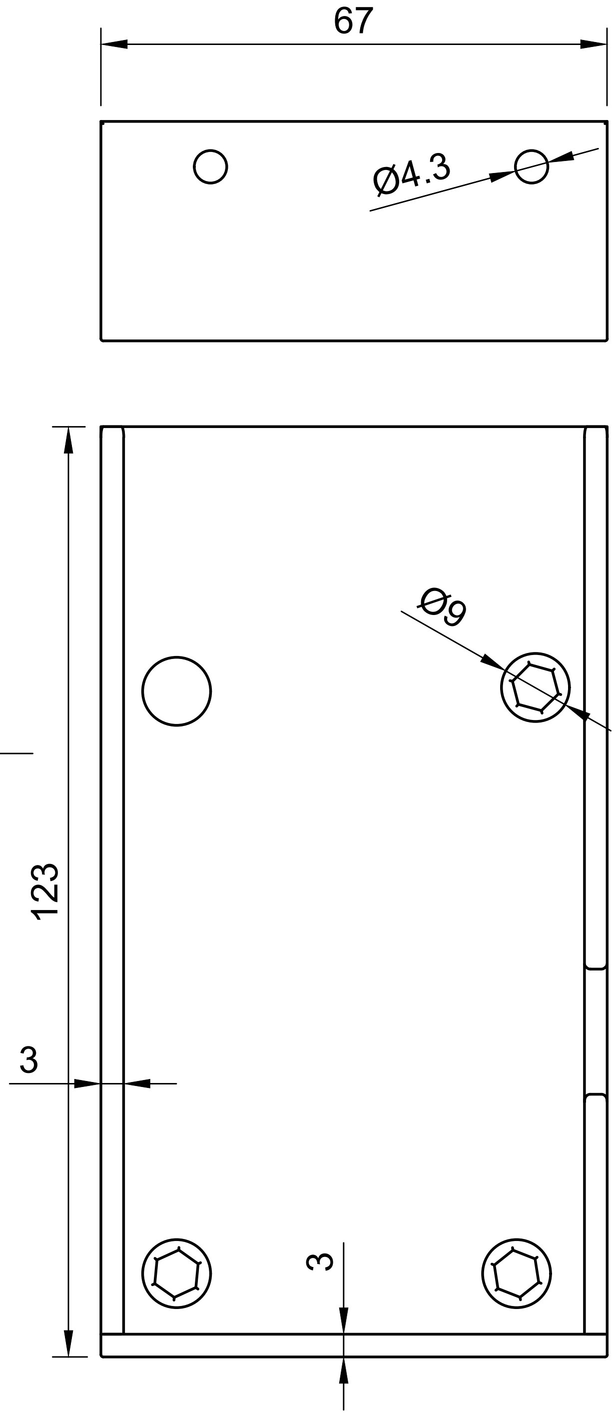
Title	DWG No.
Motor square key	

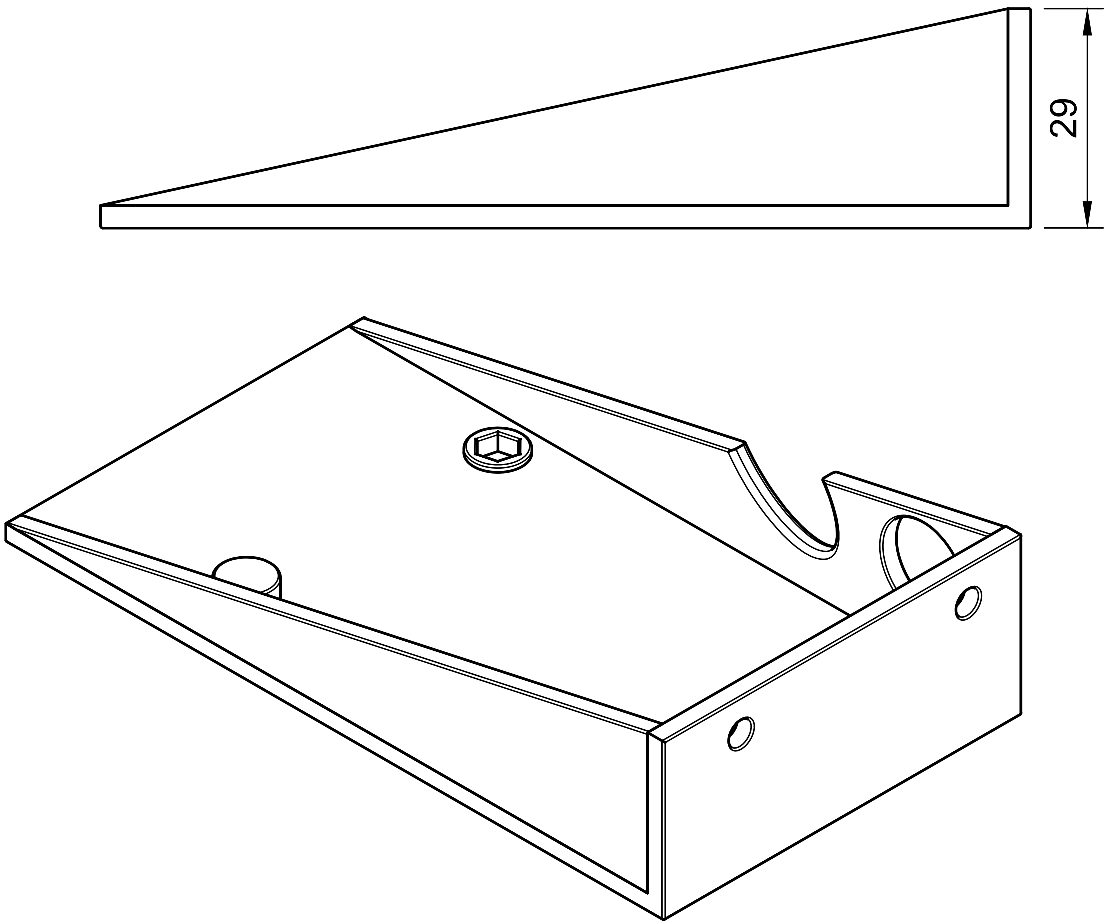
Rev.	Date of issue	Sheet
		5/1



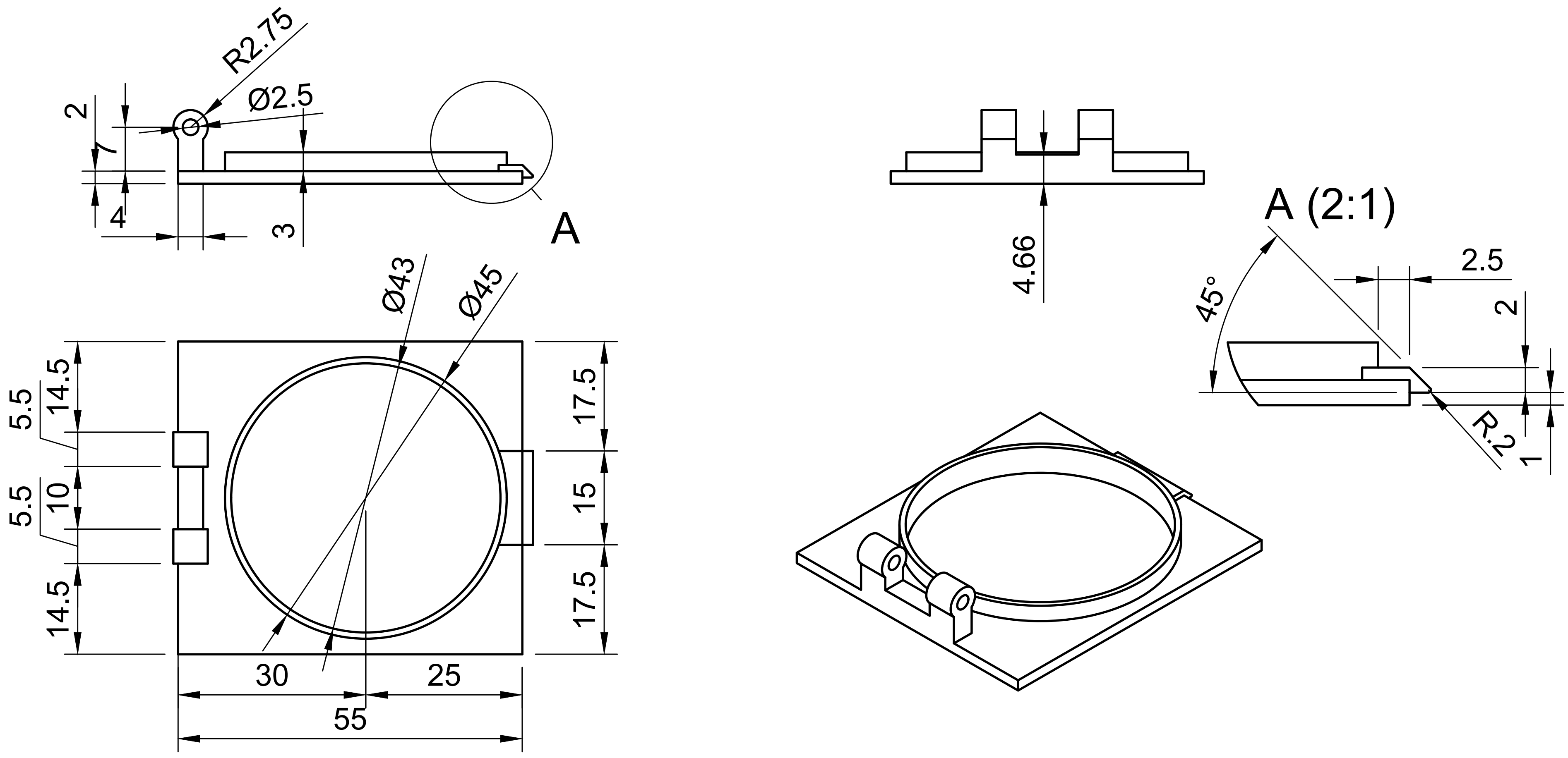


Dept.	Technical reference	Created by	Approved by		
	19	Paul-Antoine Croux 2024-25			
EPFL		Document type	Document status		
		Title Front holding frame	DWG No.		
			Rev.	Date of issue	Sheet 1/1





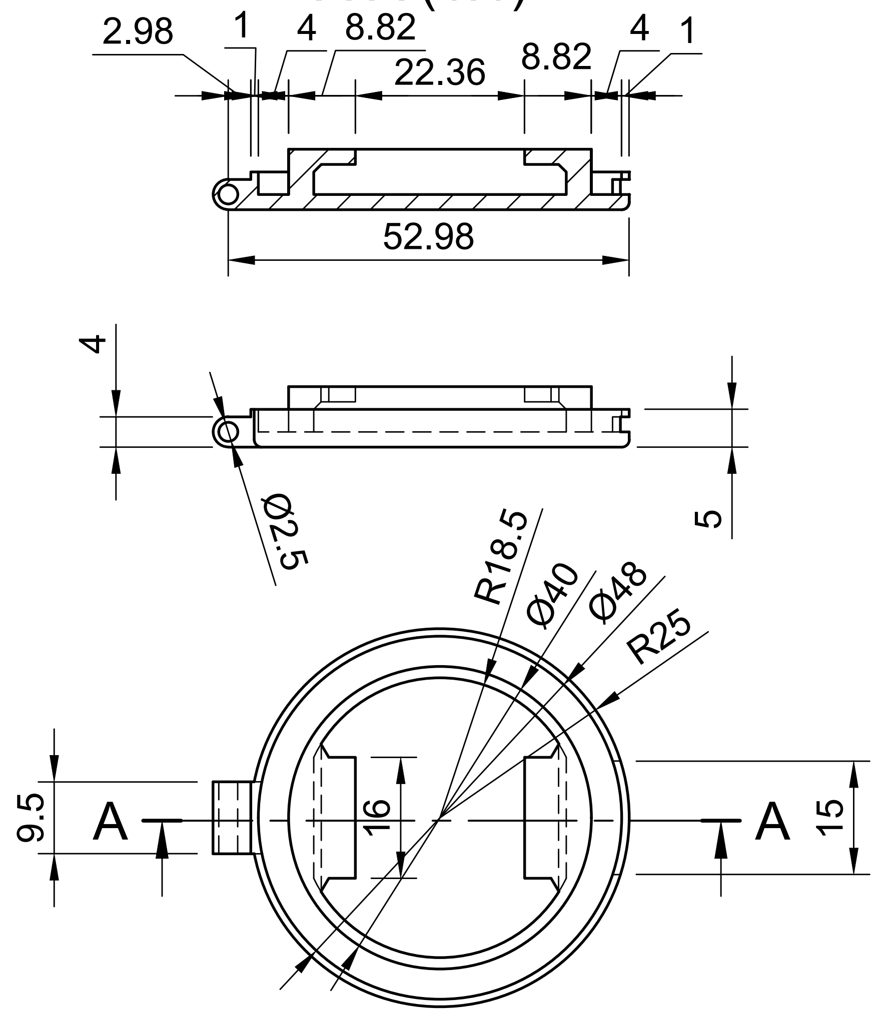
Dept.	Technical reference 20	Created by Paul-Antoine Croux 2024-25	Approved by
		Document type	Document status
		Title **Back holding frame**	DWG No.
			Rev. / Date of issue / Sheet 1/1

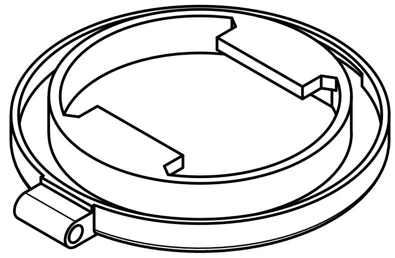


Dept.	Technical reference	Created by	Approved by
	23	Paul-Antoine Croux 2024-25	
		Document type	Document status
		Title: Container top	DWG No.
			Rev. / Date of issue / Sheet 1/1

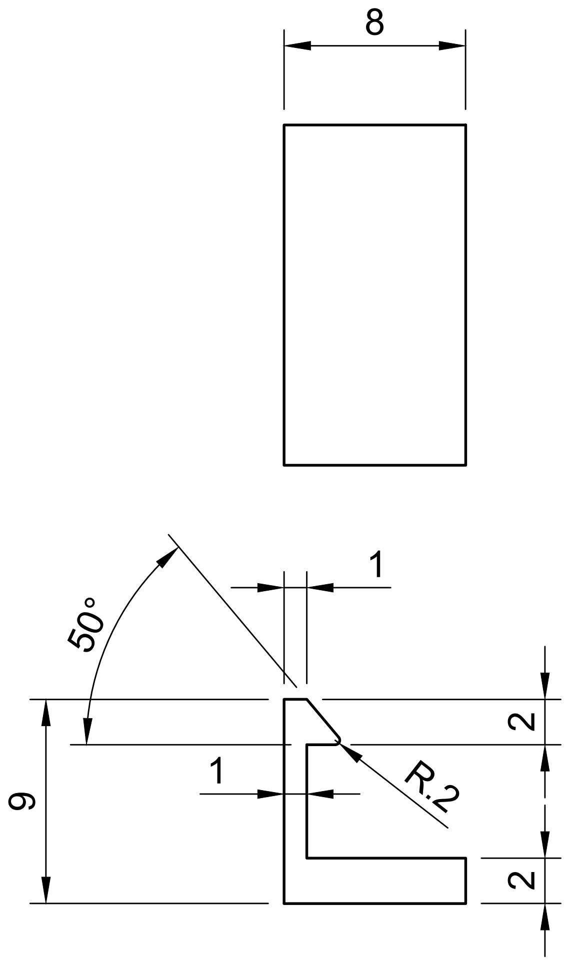
EPFL

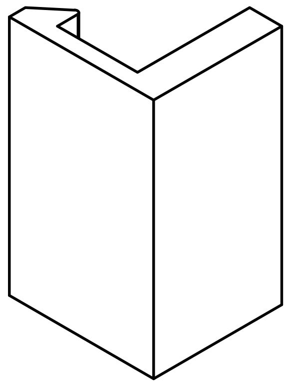
A-A (1:1)





Dept.	Technical reference	Created by	Approved by
	24	Paul-Antoine Croux 2024-25	
		Document type	Document status
EPFL		Title: Container lid	DWG No.
			Rev. / Date of issue / Sheet 1/1





Dept.	Technical reference 25	Created by Paul-Antoine Croux 2024-25	Approved by
		Document type	Document status
EPFL		Title Container clip	DWG No.
			Rev. / Date of issue / Sheet 3/1

7.5 Measurements

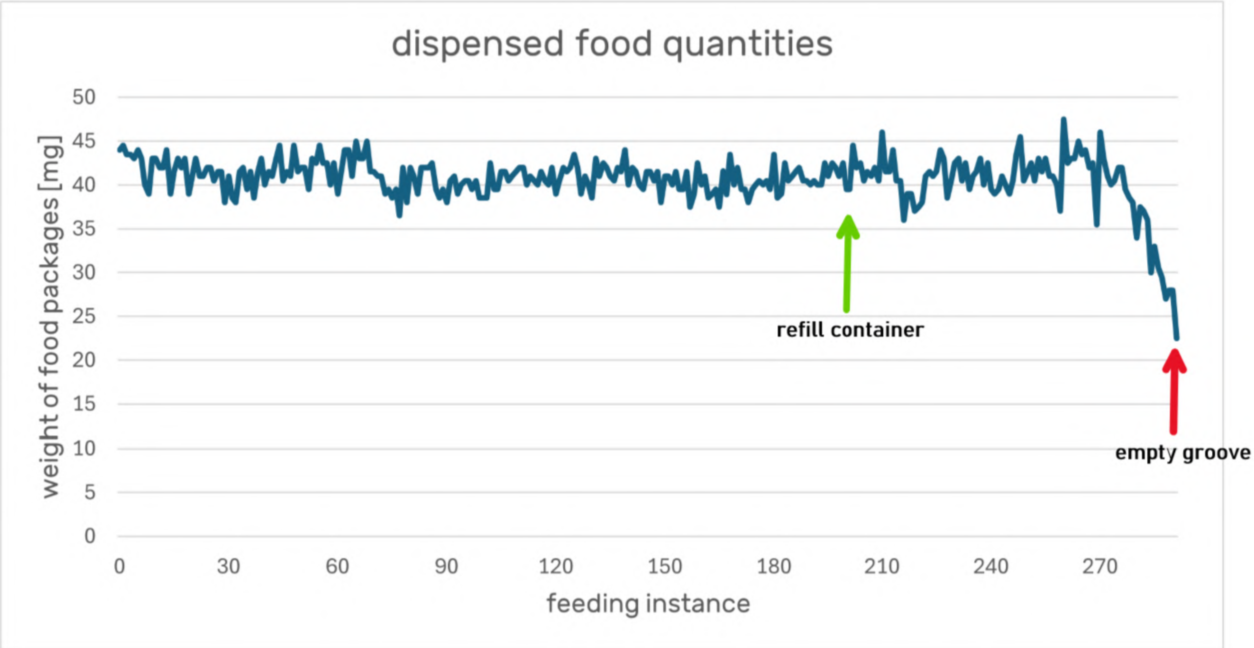


Figure 7.3: Graph of measurements of dispensed food

If one wishes to check our findings, one can find the measurement setup in chapter 7.7.3.

Nbr. of feeding instance	total amount of dispensed food [g]	food dispensed in one feeding instance [g]	food dispensed in one feeding instance [mg]	Comments
0	0,044	0,044	44	
1	0,0885	0,0445	44,5	
2	0,132	0,0435	43,5	
3	0,1755	0,0435	43,5	
4	0,2185	0,043	43	
5	0,2625	0,044	44	
6	0,3055	0,043	43	
7	0,3455	0,04	40	
8	0,3845	0,039	39	
9	0,4275	0,043	43	
10	0,4705	0,043	43	
11	0,5125	0,042	42	
12	0,5545	0,042	42	
13	0,5985	0,044	44	
14	0,6375	0,039	39	
15	0,679	0,0415	41,5	
16	0,722	0,043	43	
17	0,764	0,042	42	
18	0,807	0,043	43	
19	0,846	0,039	39	photo
20	0,887	0,041	41	
21	0,93	0,043	43	
22	0,971	0,041	41	
23	1,012	0,041	41	
24	1,054	0,042	42	
25	1,096	0,042	42	
26	1,1365	0,0405	40,5	
27	1,178	0,0415	41,5	
28	1,2195	0,0415	41,5	
29	1,2575	0,038	38	
30	1,2985	0,041	41	
31	1,337	0,0385	38,5	
32	1,375	0,038	38	
33	1,4165	0,0415	41,5	
34	1,4585	0,042	42	
35	1,498	0,0395	39,5	
36	1,5395	0,0415	41,5	
37	1,578	0,0385	38,5	
38	1,6195	0,0415	41,5	
39	1,6625	0,043	43	
40	1,7025	0,04	40	photo
41	1,744	0,0415	41,5	
42	1,785	0,041	41	
43	1,828	0,043	43	lancer chaque nourrissage seule
				une erreure qui s'affiche pas: code dit qu'on est en train de nourrir,
44	1,8725	0,0445	44,5	mais le moteur tourne pas, piston pas bloque
45	1,913	0,0405	40,5	
46	1,9545	0,0415	41,5	

47	1,9955	0,041	41	
48	2,04	0,0445	44,5	
49	2,0815	0,0415	41,5	
50	2,1235	0,042	42	
51	2,1655	0,042	42	
52	2,205	0,0395	39,5	
53	2,248	0,043	43	
54	2,2905	0,0425	42,5	
55	2,335	0,0445	44,5	
56	2,3775	0,0425	42,5	
57	2,42	0,0425	42,5	
58	2,46	0,04	40	
59	2,5025	0,0425	42,5	photo
60	2,5415	0,039	39	change of code: on check valeur du ir du container à chaque tour
61	2,583	0,0415	41,5	
62	2,627	0,044	44	
63	2,671	0,044	44	
64	2,712	0,041	41	
65	2,757	0,045	45	
66	2,8	0,043	43	
67	2,843	0,043	43	
68	2,888	0,045	45	
69	2,9295	0,0415	41,5	
70	2,971	0,0415	41,5	
71	3,012	0,041	41	
72	3,053	0,041	41	
73	3,092	0,039	39	
74	3,1315	0,0395	39,5	
75	3,17	0,0385	38,5	
76	3,2095	0,0395	39,5	
77	3,246	0,0365	36,5	
78	3,288	0,042	42	
79	3,326	0,038	38	
80	3,368	0,042	42	photo
81	3,409	0,041	41	
82	3,448	0,039	39	
83	3,49	0,042	42	
84	3,532	0,042	42	
85	3,574	0,042	42	
86	3,6165	0,0425	42,5	
87	3,656	0,0395	39,5	
88	3,6945	0,0385	38,5	
89	3,734	0,0395	39,5	
90	3,772	0,038	38	
91	3,8125	0,0405	40,5	
92	3,8535	0,041	41	
93	3,8925	0,039	39	
94	3,9325	0,04	40	
95	3,973	0,0405	40,5	
96	4,0135	0,0405	40,5	
97	4,053	0,0395	39,5	

98	4,0935	0,0405	40,5	
99	4,132	0,0385	38,5	
100	4,1705	0,0385	38,5	
101	4,209	0,0385	38,5	photo
102	4,2515	0,0425	42,5	reload code
103	4,291	0,0395	39,5	
104	4,3305	0,0395	39,5	
105	4,372	0,0415	41,5	
106	4,4135	0,0415	41,5	
107	4,454	0,0405	40,5	
108	4,495	0,041	41	
109	4,5365	0,0415	41,5	
110	4,5785	0,042	42	
111	4,6205	0,042	42	
112	4,6605	0,04	40	
113	4,7015	0,041	41	
114	4,742	0,0405	40,5	
115	4,782	0,04	40	
116	4,8235	0,0415	41,5	
117	4,864	0,0405	40,5	
118	4,904	0,04	40	
119	4,946	0,042	42	
120	4,985	0,039	39	
121	5,0255	0,0405	40,5	photo
122	5,0675	0,042	42	
123	5,109	0,0415	41,5	
124	5,151	0,042	42	
125	5,1945	0,0435	43,5	
126	5,2365	0,042	42	
127	5,2755	0,039	39	
128	5,3165	0,041	41	
129	5,3565	0,04	40	
130	5,395	0,0385	38,5	
131	5,438	0,043	43	
132	5,479	0,041	41	
133	5,5215	0,0425	42,5	
134	5,5635	0,042	42	
135	5,6045	0,041	41	
136	5,645	0,0405	40,5	
137	5,687	0,042	42	
138	5,7285	0,0415	41,5	
139	5,7725	0,044	44	
140	5,8125	0,04	40	
141	5,8545	0,042	42	
142	5,896	0,0415	41,5	
143	5,936	0,04	40	photo
144	5,9755	0,0395	39,5	
145	6,017	0,0415	41,5	
146	6,0585	0,0415	41,5	
147	6,099	0,0405	40,5	
148	6,1405	0,0415	41,5	

149	6,1785	0,038	38	
150	6,2195	0,041	41	
151	6,2605	0,041	41	
152	6,3005	0,04	40	
153	6,342	0,0415	41,5	
154	6,3815	0,0395	39,5	
155	6,421	0,0395	39,5	
156	6,4625	0,0415	41,5	
157	6,5	0,0375	37,5	
158	6,539	0,039	39	
159	6,5815	0,0425	42,5	
160	6,6215	0,04	40	photo
161	6,6625	0,041	41	
162	6,701	0,0385	38,5	
163	6,74	0,039	39	
164	6,7795	0,0395	39,5	
165	6,817	0,0375	37,5	
166	6,8586	0,0416	41,6	
167	6,8975	0,0389	38,9	
168	6,941	0,0435	43,5	
169	6,981	0,04	40	
170	7,023	0,042	42	
171	7,0625	0,0395	39,5	
172	7,102	0,0395	39,5	
173	7,14	0,038	38	
174	7,1795	0,0395	39,5	
175	7,2195	0,04	40	
176	7,26	0,0405	40,5	
177	7,3	0,04	40	
178	7,3405	0,0405	40,5	
179	7,38	0,0395	39,5	
180	7,4235	0,0435	43,5	
181	7,462	0,0385	38,5	photo
182	7,501	0,039	39	
183	7,5435	0,0425	42,5	
184	7,584	0,0405	40,5	
185	7,625	0,041	41	
186	7,6665	0,0415	41,5	
187	7,7085	0,042	42	
188	7,749	0,0405	40,5	
189	7,7895	0,0405	40,5	
190	7,8295	0,04	40	
191	7,87	0,0405	40,5	
192	7,91	0,04	40	
193	7,95	0,04	40	
194	7,9925	0,0425	42,5	
195	8,0335	0,041	41	
196	8,076	0,0425	42,5	
197	8,118	0,042	42	
198	8,159	0,041	41	
199	8,2015	0,0425	42,5	

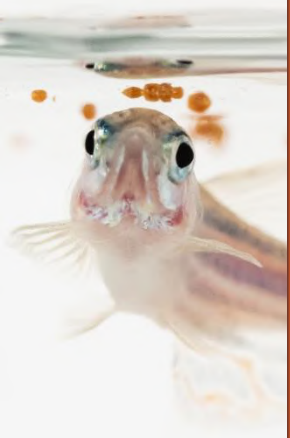
200	8,241	0,0395	39,5	photo
201	8,2805	0,0395	39,5	
202	8,325	0,0445	44,5	
203	8,367	0,042	42	green LED: refill container
204	8,4095	0,0425	42,5	
205	8,45	0,0405	40,5	
206	8,4915	0,0415	41,5	
207	8,5325	0,041	41	
208	8,5745	0,042	42	
209	8,615	0,0405	40,5	
210	8,661	0,046	46	
211	8,7025	0,0415	41,5	
212	8,744	0,0415	41,5	
213	8,788	0,044	44	
214	8,8285	0,0405	40,5	
215	8,869	0,0405	40,5	
216	8,905	0,036	36	
217	8,944	0,039	39	
218	8,983	0,039	39	
219	9,02	0,037	37	
220	9,0575	0,0375	37,5	
221	9,0955	0,038	38	photo
222	9,1365	0,041	41	
223	9,178	0,0415	41,5	
224	9,219	0,041	41	
225	9,2605	0,0415	41,5	
226	9,3045	0,044	44	
227	9,3475	0,043	43	
228	9,386	0,0385	38,5	
229	9,4265	0,0405	40,5	
230	9,469	0,0425	42,5	
231	9,512	0,043	43	
232	9,5525	0,0405	40,5	
233	9,595	0,0425	42,5	restart card
234	9,6345	0,0395	39,5	reload code
235	9,6755	0,041	41	
236	9,717	0,0415	41,5	
237	9,76	0,043	43	
238	9,8	0,04	40	
239	9,8425	0,0425	42,5	
240	9,882	0,0395	39,5	photo
241	9,921	0,039	39	
242	9,9605	0,0395	39,5	
243	10,0015	0,041	41	
244	10,0415	0,04	40	
245	10,0805	0,039	39	
246	10,121	0,0405	40,5	
247	10,1645	0,0435	43,5	
248	10,21	0,0455	45,5	
249	10,2505	0,0405	40,5	
250	10,292	0,0415	41,5	

251	10,3345	0,0425	42,5	
252	10,375	0,0405	40,5	
253	10,418	0,043	43	
254	10,4595	0,0415	41,5	
255	10,5025	0,043	43	
256	10,5435	0,041	41	
257	10,5845	0,041	41	
258	10,6245	0,04	40	
259	10,6615	0,037	37	begv
260	10,709	0,0475	47,5	photo
261	10,7515	0,0425	42,5	
262	10,7945	0,043	43	
263	10,8375	0,043	43	
264	10,8825	0,045	45	
265	10,926	0,0435	43,5	
266	10,97	0,044	44	
267	11,012	0,042	42	
268	11,0545	0,0425	42,5	
269	11,09	0,0355	35,5	problème
270	11,136	0,046	46	
271	11,179	0,043	43	
272	11,22	0,041	41	
273	11,26	0,04	40	
274	11,3005	0,0405	40,5	
275	11,3425	0,042	42	
276	11,3845	0,042	42	
277	11,424	0,0395	39,5	
278	11,4625	0,0385	38,5	
279	11,5005	0,038	38	
280	11,5345	0,034	34	photo
281	11,572	0,0375	37,5	
282	11,609	0,037	37	
283	11,645	0,036	36	
284	11,675	0,03	30	
285	11,708	0,033	33	
286	11,7385	0,0305	30,5	
287	11,768	0,0295	29,5	
288	11,795	0,027	27	
289	11,823	0,028	28	
290	11,851	0,028	28	red LED: groove empty
291	11,8735	0,0225	22,5	valeur de nourriture captée lors de l'erreur (n'a pas été dispence)

mean	40,66267123
std	2,826630306

7.6 Product Sheet of Zebrafeed

ZEBRAFEED by sparos



ZEBRAFEED

A standard diet for zebrafish

Product Features:
- Constant nutritional composition
- Balanced for the entire life-cycle of zebrafish (from larvae to breeders)
- Excellent breeding performance
- Low impact on water quality
- High welfare standard

Product description: a complete feed for zebrafish

Composition[1]: Fish meal, vital wheat gluten, fish protein hydrolysate, shrimp meal, pea protein, soy lecithin, fish oil, gelatine.

Analytical constituents (typical)[1]	ZEBRAFEED <100	ZEBRAFEED 100-200	ZEBRAFEED 200-400	ZEBRAFEED 400-600
Crude protein, %	62.0	62.0	62.0	62.0
Crude fat, %	13.0	13.0	13.0	13.0
Crude fiber, %	1.8	1.8	1.8	1.8
Crude ash, %	12.0	12.0	12.0	12.0

[1] The list of ingredients and analytical constituents are indicative. For exact information please refer to label. While every effort is made to ensure maximum constancy, the information provided in this sheet is only a guideline and SPAROS reserves the right to modify it without prior notice.

Pellet sizes: ZEBRAFEED <100 (<100 µm) / ZEBRAFEED 100-200 (100-200 µm) / ZEBRAFEED 200-400 (200-400 µm) / ZEBRAFEED 400-600 (400-600 µm).

Usage: ZEBRAFEED <100, 100-200 and 200-00 are to be fed *ad libitum* in three daily meals. ZEBRAFEED 400-600 should be fed 4-5% of the biomass, twice a day. The ZEBRAFEED range is compatible with automatic feeding devices.

Storage & Shelf life: store in a cool and dry place. Unopened, in a dark and cool place, the product can be kept for twenty four months after manufacture date. Once opened, the product should always be kept refrigerated and used within two months. For details on exact consumption date please refer to label.

Feed safety parameters	ZEBRAFEED
Escherichia coli, CFU/g	$< 1 \times 10^1$
Coagulase-positive Staphylococcus, CFU/g	$< 1 \times 10^1$
Enterobacteriaceae, CFU/g	$< 1 \times 10^1$
Molds, CFU/g	$< 1 \times 10^3$
Yeasts, CFU/g	$< 1 \times 10^3$
Salmonella (in 25 g)	Absent

Packaging	Type	ZEBRAFEED <100	ZEBRAFEED 100-200	ZEBRAFEED 200-400	ZEBRAFEED 400-600
ZEBRAFEED	Aluminum/PE bags	150 g	150 g	250 g	250 g
		1 kg	1 kg	1 kg	1 kg
		2.5 kg	2.5 kg	2.5 kg	2.5 kg

sparos I&D nutrition in aquaculture

Manufacturer: SPAROS LDA.
Área Empresarial de Marim, Lote C, 8700-221 Olhão, Portugal
Phone: +351 289435145 | Email: zebrafeed@sparos.pt
Establishment: aPT7AA11574

7.7 Test Setup

7.7.1 Torque test

In order to establish the force needed from a motor to action the rotation of the cylinder and the movement of the piston, a torque test was done. In the following pictures display the setup of such test.

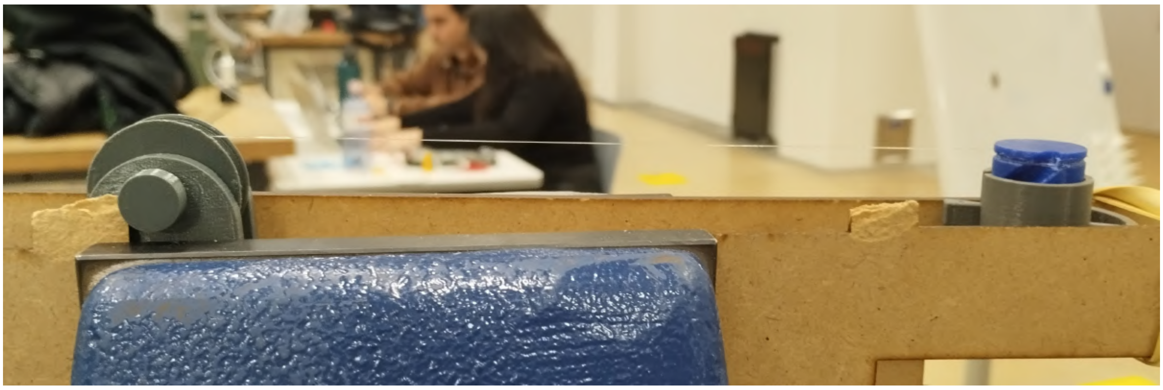


Figure 7.4: Connecting string between weight and cylinder

Figure 7.5: Measured weight

Figure 7.6: Entire pulley setup

We used a simple pulley system to measure the torque. Weight was added (in form of a small water filled bottle, see Fig. 7.5) to a string, attached to the cylinder. And the minimal weight needed, to start moving the piston gave us the static friction force of 47,3mN.

7.7.2 Humidity test

This test encompassed using a spray bottle to humidify different areas of the dispensing mechanism. Those included the bottom window of the outer cylinder, where the food falls out. We also sprayed on the top part of the cylinder to imitate water falling down from a tank above. Both tests led to humidity entering the system and the food granules sticking together, leading to blocking the motor and triggering the error "empty groove".

7.7.3 Measurement test

To explain how the measurements were conducted, one can consult the image of the setup below.

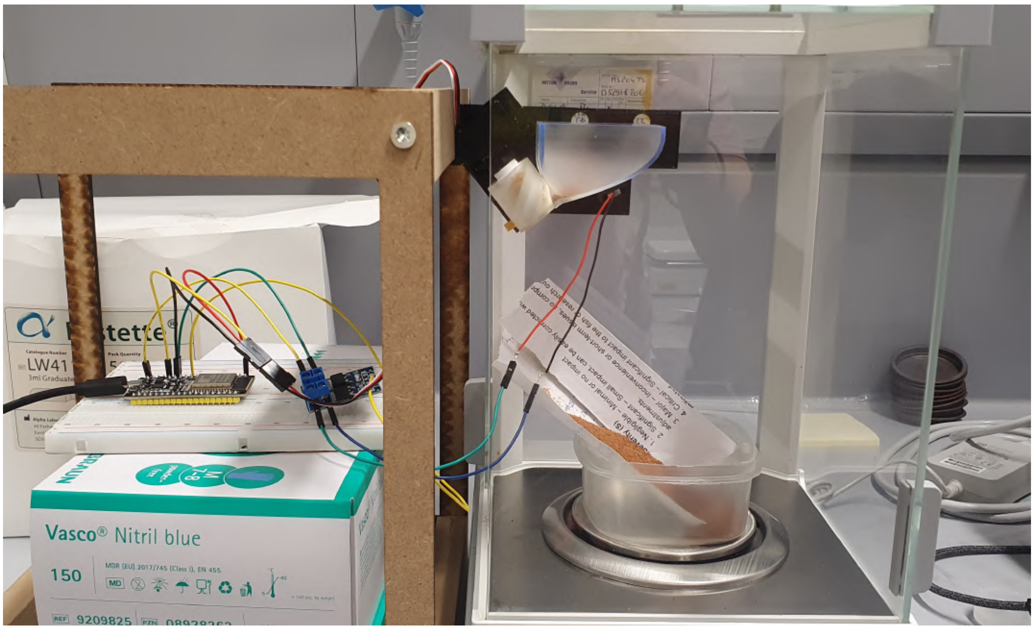


Figure 7.7: Measurements setup

The measurements were conducted with the prototype device attached to the rack model and using the Mettler Toledo micro scale model MS204TS.

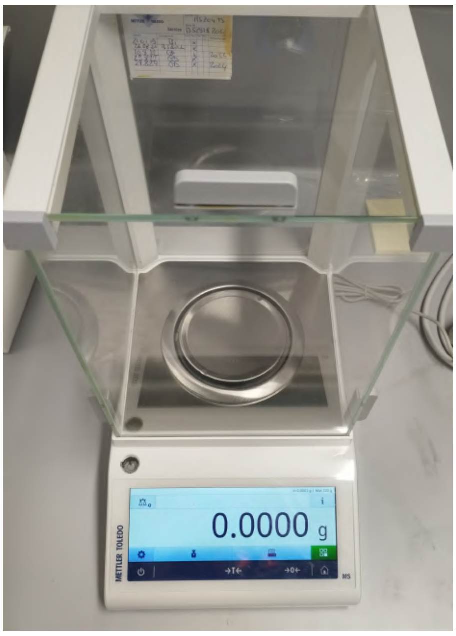


Figure 7.8: Top view of micro scale

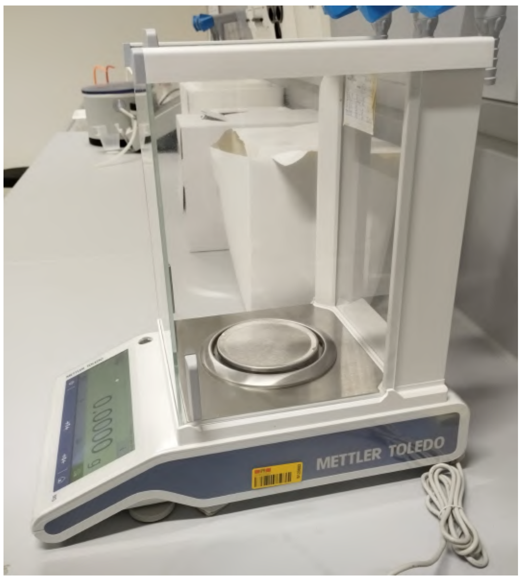


Figure 7.9: Sideview of micro scale

Bibliography

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[3] Giovanni B. Ramello. “What’s in a Sign ? Trademark Law and Economic Theory”. In: *Journal of Economic Surveys* 20.4 (2006). _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1467-6419.2006.00255.x, pp. 547–565. ISSN: 1467-6419.