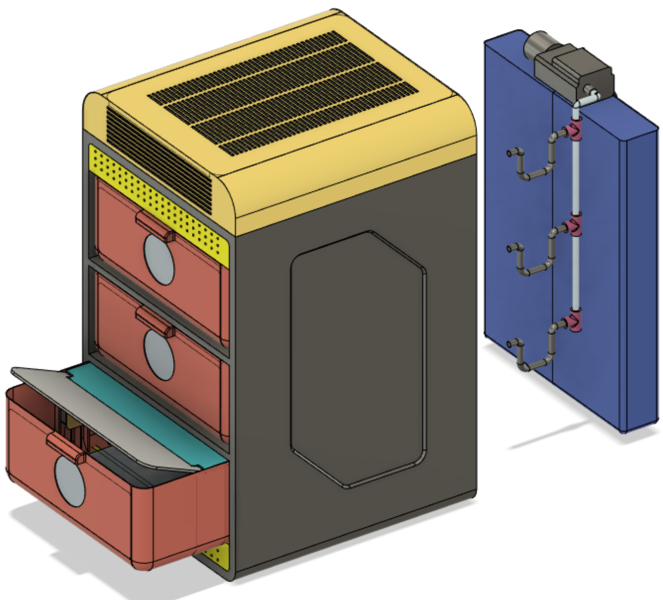

A Rearing Unit For Mass Production of Crickets For Insect Farms

BREE 495: Design project 3

Prof: Dr. Chandra Madramootoo

Mentor and Client: Dr. Mark Lefsrud

Department of Bioresource Engineering

McGill University

Bowen Fu

Zheming Shan

April 14th, 2021

Abstract

The world's population is projected to reach 11 billion by the end of the century. Feeding that many people will be a challenge and it is further complicated by the impact of climate change on agriculture. That is why some people advocate an unusual way to boost the food supply and feed people sustainably: by eating less meat and more insects.

This paper introduces a breeding unit that can be put into massive production of crickets to the market. The design involves a multi-layer tray system for the rearing and harvest of the cricket (Gryllus assimilis). Crickets are nutritious, fast growing and accepted in many cultures and continents. The unit is a controlled environment that has sensors to control temperature, humidity, and air ventilation. It is user friendly and requires minimum labor that can maximize yield and profit.

Table of contents

1 Introduction

1.1 Background

The world's population had doubled in just four decades. In the next 30 years, the world's population is projected to reach 9 billion people. But the world's population is growing at a much faster pace than the world's food supply. The increasing scarcity of resources like land and water will make it far more difficult to answer how exactly we will feed 9 billion mouths. More importantly, how can we grow nutritious and sustainable food that supports healthy and productive lives with far fewer resources available.

Insects are among the most abundant and nutritious animals on the planet. Grown at a large scale, insects like grasshoppers, crickets, mealworms, and even cockroaches might be the answer to feeding 9 billion people. Insects offer us protein for the future, one that is sustainable, nutritious, and above all, tastes delicious. Insects are sustainable because they are so efficient, and they are efficient because they are exothermic. This means that they don't undertake the complex and energy-intensive physiological processes that other animals like cows or humans do to regulate their body temperature. This allows them to convert whatever they eat onto mass on their bodies much more efficiently. In livestock rearing, this is referred to as feed efficiency. Feed efficiency is the ratio of how much food an animal needs to consume to put on one pound of weight. Cows are among the most inefficient of the proteins, requiring 25 pounds of feed to produce 1 pound of beef. On the other hand, crickets only require 2 pounds of feed to produce 1 pound of cricket protein powder. Cows also require an astonishing 2000 gallons of water to produce 1 pound of beef. Crickets require only one gallon. It takes 200 square meters of land to grow 1 pound of beef; it only takes 15 square meters to grow 1 pound of crickets. Furthermore, by 2025 it is expected that 1.8 billion people will live in areas with little to no freshwater. And yet, 70 percent of our freshwater sources are used in agriculture alone. Crickets and insects are also a remarkable source of nutrition. Crickets have more protein than beef jerky, chicken, salmon, and eggs. They have more iron than spinach and more calcium than milk. Mealworms are another popular type of edible insect. They have more protein than lean beef and more Omega threes than salmon.

Insects also offer us these benefits while emitting far fewer greenhouse gas emissions than other animals. Industrial meat production currently accounts for 37 percent of the methane in our atmosphere. Methane is a huge contributor to climate change and rising global temperatures. Cows are the biggest culprit of methane production: emitting 2 billion tons of methane into our atmosphere. Insect production releases less than 1 percent of the methane emissions of cattle production. Yet another compelling fact to support eating insects is that they require very little physical space. You can't stack cows on top of each other, but you can grow insects and enclosed spaces like a warehouse or a barn. Right now, forests are being cut down at an alarming rate. They're being converted into pastures for grazing cattle, or we are planting them with monoculture crops to grow grain to feed animals. 30 percent of the world's land is devoted to raising animals for meat. So, growing insects in an enclosed vertical space can alleviate pressure on land resources that we currently devote to meat production.

Insects can also be grown in places that livestock cannot. Many US-based edible insect farms are in dense urban areas like Detroit or Los Angeles, or San Francisco. As more and more humans move to cities, the need for accessible and nutritious food grown on non-arable land will become increasingly important. Incorporated into a backyard farm or perhaps grown in an old abandoned warehouse, insects will change growing food in urban spaces. This is even more exciting, considering many insects are detritivores, which means that they consume dead plant matter or waste. For this reason, they can be reared on agricultural waste products or garden scraps. Insects can make closed-loop systems a reality where we incorporate food waste into insect farming to create low-cost alternative protein sources.

There still wouldn't be a compelling case to be made for insects if they didn't also taste good. Eskimo, a type of ant egg considered a delicacy in Mexico, tastes like a bacon-flavored mushroom. Mealworms have a nutty, crunchy consistency that reminds people of eating corn nuts. Crickets remind people of eating dark toast. Some ants are sweeter than honey; others are tarter than lemons. Around the world, 2 billion people consume insects as part of their traditional diets precisely because they offer this delicious array of flavors.

It's only really in the West that the cultural perceptions of deliciousness and disgust dismiss insects as a viable food. But the western world is beginning to see the potential, both gastronomic and economic, of eating insects. Five years ago, there were only a handful of companies that were making insect-based products. Today there are over 150 and counting. Early adopters of this movement see the writing on the wall that as a species, we cannot continue consuming meat in the quantities or at the pace that we do, or we will rapidly deplete our world's limited resources. We need an alternative. We in the industry recognize the enormous potential of insects to revolutionize our food systems completely. But we're playing the long game.

Right now, insects are a premium luxury product. At 40 dollars a pound, cricket protein powder is used to make high-end products like chips, bars, and brownies. But at 40 dollars a pound, it's a difficult and expensive product to access. But insect protein powder has the potential to have a huge impact beyond the high-end power bar if we're able to make it price competitive with low-cost protein powders like whey, soy, and fish meal. At that price and at that scale, insects can be incorporated into every industry that relies on low-cost protein. It can be used to make animal feed to reduce our dependence on the negative impacts of land and fertilizer runoff from corn and soy production. It can be used as a fish meal replacement, which will decrease the pressure on fish stocks, which are rapidly declining as we exploit the ocean floor to get fish to make the fish meal, so then feed to salmon and chicken. Insects can make sustainable meat a reality. As a complete and shelf-stable source of nutrition, insects can also make hunger relief bars for areas suffering from drought and famine. As we decrease the price and the stigma around insects, as consumers, we might also consider replacing our weekly stay with the cricket burger instead, but this vision is light-years away.

1.2 Vision statement

Our project aims to provide affordable, sustainable protein in the form of insects at low cost to contribute to feeding a growing population and sustaining our environment.

2 Literature review

2.1 Literature review of Jamaican field crickets

Gryllus assimilis, also called Jamaican field cricket that is native in southern Asia and Southern American, is becoming widely used as the standard feeder insect for pets and the research industry. It's cold resistance and immune to cricket paralysis virus, a disease that commonly found in the rearing cricket industry that is extremely lethal for cricket, makes it the last standard species for cricket farming. (Parker, 2012) It has three stages in their life cycle from egg to nymph to adult. The average life cycle of Jamaican field cricket is between two months to three months. The egg will incubate for 10 to 14 days to develop nymph. It will break the egg capsule and dig out the substrate. Nymphs look like a small version of adult cricket but without wings and females do not have ovipositors. Usually a nymph has a lighter exoskeleton than an adult and it molts for 8 to 10 times to become an adult. It usually takes about a month to be developed as a fully adult, but this process can be accelerated under high humidity and optimum temperature (29.5℃-32℃) and nutrients. (Dossey, 2016)

The nymph can be harvested after molting for about 8 times and right before it turns into a fully grown adult. After bringing the temperature below -6 ℃, the cricket will turn into a hibernation and never wake up. Oviposition takes place about 48-72 hours after the copulation. A moist and soft oviposition substrate would be necessary to accelerate the process of oviposition. (Dossey, 2016) A female Jamaican cricket can deposit about 400 eggs and it hatches within about eleven days (Huber,1989)

3. Design approach

3.1 Design criteria:

In our design, the following criteria must be met in order to have the design suitable for mass production purpose. Achieving the following criteria is quite a big challenge for our design due to the design being durable, user friendly, and food safe within limited cost.

Maintenance

Having a design that requires a low level of maintenance is the most important aspect to consider when designing cricket farms for food production. The unit should deliver food and water for crickets automatically and the temperature and relative humidity of the unit should be kept at their best ambient condition. Allowing the design to have low labour requirements makes it easier for the owner to keep the cost down and easy to use. The low labour requirement is also the main advantage that makes our design outstanding from others.

Food Safety and Hygiene

One large concern for many people is the cleanliness of insects. Culturally, in western societies, insects have been labelled as "unclean" animals causing consumers to be skeptical of them being edible. Ensuring that there is as little chance as possible of food contamination is incredibly important. This can be ensured by having an enclosed environment to reduce the risk of contamination. Also, hygiene and food safety would be considered during the construction material selection, cricket feed, and environment control system.

Productivity

The design should be space efficient and allow a higher density of cricket population to save space for the owner and be more cost effective. The feed and environment should be designed that is optimized for cricket growth to reduce time of their life cycle and production.

Durability

Both structure and material should be cheap and durable to be cost effective for farm owners.

Flexibility

The cricket breeding can be suitable for all kinds of cricket during its life cycle. Humidity, temperature, and food delivery system is adjustable. The product structure needed to be flexible for both massive production and family production.

Cost

A low cost can help farm owners to start up the farm more easily. Based on existing designs on the market, we considered $300 - $400 to be the upper limit for how much our product would retail for.

Aesthetic

The design of the appearance should be aesthetically pleasant within the limited cost range. Better looking appearance would attract the customer and increase the acceptance of edible cricket for individual owners.

3.2 Design Parameter:

Climate Control:

The temperature inside the cricket farm should be controlled between 29.5-32℃. Humidity varies depending on stage of life cycle. For eggs, the humidity should be around 100%, for nymph humidity should be around 55% (increase time of food rotting and accelerate life cycle). For oviposition, the humidity should be around 70-80%. The substrate should be soft and wet. (coconut fiber, peat moss, vermiculite, sand, cotton, or tuff)

Reliability:

The design should be reliable for operation and production. The material selection during the construction must be durable. The structural design should be durable under individual and massive production. The electric hardware and software program should be operated constantly without any malfunction and faults.

Easy to Operate:

The design should be as simple as possible to make it easier for maintenance and operation. The user menu will be developed for the customer to operate the device properly. The software should be as much automated as possible that the farm should have a climate control system and feed system all automated.

Waste and Environment Protection:

The waste of the cricket, which is a good source of fertilizer and compost, should be able to be collected. Ventilation system should contain an odor control filter. Escaping of the cricket should also be avoided which may cause damage to the crops.

3.3 Benchmark

There are three different kinds of design of cricket farming that exist in the market and each of them have advantages and disadvantages. The most advanced and automated system comes from a company named Aspire Food Group which is founded by McGill alumni. This design is well protected by three different patents which involve water & food delivery robots, insect breeding units, and cricket collecting devices that can separate waste and crickets. This designed system makes massive production practical with less human resource input. The less advanced design for massive production of crickets is invented by Ahmed Hamdaoui which is widely used by the cricket farming industry. This design requires a lot of human resource input to take care of the environment, food supply, and harvesting. However, the cost of each unit is relatively low. The price range is between 45$ to 60$ per meter square. Finally, there are many kinds of DIY small scale units that are being spread on the media and internet. Most of them involve no electricity and must harvest cricket manually. The price range for DIY cricket farming units is between 50$ to 200$ depending on different design and size. For the design from Aspire Food Group, the cost of each unit is hard to be determined due to the different system they use.

Feature	Aspire Food Group	Ahmed Hamdaoui	DIY
Cost	N/A; high	45-60/m^2	Under 200$
Cricket per harvest	900g – 1100g/unit	1250g-1550g/m^2	350g – 500g
Labor/maintenance	Moderate	high	high
Flexibility	moderate	low	high

Durability	high	low	Moderate
Food Safety and Hygiene	high	moderate	N/A
Size	100cm*160cm*55cm(w*l*h)	N/A, farm size	53L container
Aesthetic	high	low	moderate

Table1: Benchmarking of Current design

3.4 Applicable Patent:

Our final design and automatic food delivery system is inspired by Aspire Food Group cricket farming patents. Their advanced massive cricket farming system requires little human operation with high productivity. The idea of using liquid cricket feed and using robots for feed delivery and harvesting inspire us to make an automatic cricket farming device. There are other parents about ventilation systems, air conditioning, tray design listed below that inspire us in our design.

3.4.1Aspire Food Group:
US20180007874A1: Precision water delivery system for insects
US20170360014A1: Autonomous feed delivery platform for insects
These two patents were invented by Aspire Food Group. They created the automatic feeding system based on these two patents. Figure 1 in Appendix A shows their design of the feed delivery robot where the feed is stored in the storage tank and transferred through a pipe with a spiral carrier to deliver the feed from bottom to up and send to each tray. Figure 2 in Appendix A is the flow diagram showing their humidity control system and water delivery where they combine them together. After the moisture sensor detects the humidity is below a certain level and there is no cricket in the water tray, the water will be delivered to the water tray.

3.4.2 Method and facility for breeding insects (WO2016153339A1):

This patent is also owned by Aspire Food Group for the method of breeding insects. The method described in this patent is for mealworm massive production. However, the ventilation filter, feed ingredients, and tray design can also be used in our design. Figure 3 in Appendix A shows the air inlet filter location and figure 4 illustrates the tray design and feeding pad design.

3.4.3 Combined ventilation and air conditioning system (CN1265143C)

The patent is invented by Yuanxi Li. The patent is originally designed for small devices that require ventilation and temperature adjustment. In our design, the ventilation and temperature control process is highly based on the diagram shown in Figure 5 in Appendix A that the inlet air flow would have heat transfer with outlet flow through the X shape conduit to decrease energy lost. Also, a separated control system for air conditioner and ventilation would reduce energy lost when only ventilation is needed.

3.4.4 Ventilation for livestock production building (US9179640B2)

Invented by Michael E. Lemmon, the patent is focused on ventilation for massive production of livestock. The air distributor design and odor control design give us inspiration that by placing an air distributor, air in each tray will be exchanged during the process. The odor filter ingredient is highly based on their design. Figure 6 in Appendix A is the air distributor and Figure 7 is the odor control and filter for outlet air flow.

3.4.5 Warming blanket and method of fabricating the same (US20190110615A1)

This patent is invented by Joseph Blase Vergona and Mark Kyler. By using a parallel connection of various heater strips and heat wire and carbon fiber based web, the thermal blanket can achieve maximum efficiency of energy and increase the efficiency of heating substrate of growing plants. By sealing the warming blanket with polyurethane cover, it can be made water proof that is more suitable for wet conditions. We are going to use this technique in our heating system.

4. Design constraints

4.1 Cultural and social acceptance

Insect-eating, known as entomophagy, has a long history throughout the history of humanity. Insects are among the many food sources that humans have relied upon in our journey toward developing our unique technological capability and complex social systems. People have been eating bugs centuries ago, everything from locusts to caterpillars, beetles, termites, grasshoppers, and dragonflies. Early humans presumably learned from animals that searched for protein-rich insects and followed suit. Insects played a role of staple food and delicacy as we evolved and became part of our dietary tradition. We reject insects as food due to historical reasons. The story probably begins around 10,000 BC in the fertile crescent, a place in the middle east that was the origin of agriculture. At that time, our once-nomadic ancestors began to settle in the crescent. Furthermore, as they learned to farm crops and domesticate animals, attitudes changed, rippling outwards towards Europe and the rest of the Western world. As farming took off, people might have spurred bugs as mere pests that destroy their crops. The population grew, and the west became urbanized, weakening our connection with our foraging past. People forgot their big-rich history. Although entomophagy is not generally accepted in a conventional Western diet, it remains popular today globally. About 2 billion people worldwide already eat insects, Mexicans enjoy chili-toasted locust, Thais enjoy cricket stir-fries, and Ghanaians eat termites as snacks. Insects are slowly creeping onto western menus as novelty items, especially in North America and Northern Europe.

4.2. Food safety

There are three aspects of food safety issues regarding entomophagy. The first is microbiological contamination. Complex microbial communities such as bacteria, viruses, fungi, protozoa, and archaea include a symbiotic spectrum of mutualistic and pathogenic contaminants in insects and other living organisms. The second is toxicological hazards. Existing compounds in insect feed such as fruits and vegetables that are synthesized by insects can be harmful to humans. The third is allergenicity. Crabs and lobsters are relatives of insects, so it is logical to be concerned if shellfish allergies or other allergies are related to insects.

Very few studies have been conducted to investigate the microbiological safety and quality of insects produced for human consumption. A preliminary study conducted in Germany between 2014 and 2015 did not find the presence of Salmonella, or generic E. coli (>100 CFU/g) in 38 retail samples of edible insects. The German study did, however, identify the presence of Bacillus cereus and Pseudomonas spp. in dried and powdered processed insect products, which are bacterial pathogens capable of causing infections in immunocompromised patients. Another study conducted in the Netherlands between 2015 and 2016 did not detect any genetic material of Salmonella spp., but did detect the presence of genetic material of Listeria spp. and Staphylococcus spp. in processed edible insects purchased from one local company. Some studies reported that the total bacterial load (aerobic bacterial counts) of raw insects was higher than in raw ground meat, and therefore an effective heat treatment (sterilization) is required to reduce the total microflora load, including gut flora and spore-forming bacteria. The scientific committee of the Federal Agency for the Safety of the Food Chain of Belgium has recommended a heat inactivation step (sterilization) as being essential to control microbial hazards in the final edible insect products.

4.3. Standards

For our electric system design, "IEEE 1801-2015 - IEEE Standard for Design and Verification of Low-Power, Energy-Aware Electronic Systems" should be used for verification of the structure and behavior of the design under given power management architecture. "2700-2017 - IEEE Standard for Sensor Performance Parameter Definitions" will be used to specify the humidity and temperature sensor that we are going to use in our electric system. It helped us to specify the parameter of the sensor.

In Canada and the United States, federal regulation of insects for human consumption has largely been characterized by regulatory inaction. Edible insects fall within the oversight of the U.S. Food and Drug Administration (FDA). Most of FDA's attention, however, has not been focused on regulating insects as human food, but rather on regulating insects as "filth". The agency has traditionally prohibited insect parts in food, treating them as adulterants under the Federal Food, Drug, and Cosmetic Act (FDCA). In fact, a recent review of available, relevant, and official FDA documents found that the term “insect” had only been used in relation to adulteration with defects.

The European Union on the other hand, is taking the lead at pushing edible insects to the market. The European Food and Safety Authority (EFSA) published a scientific opinion concluding that dried yellow mealworm is safe for human consumption in January 2021. If the Commission ends up granting the green light to yellow mealworm, European consumers will soon be able to find the insects as part of the ingredient in food such as snacks, biscuits, protein components etc.

As the edible insect industry in the United States has grown in recent years, many people have discussed how FDA could regulate insects as human food or food ingredients within the agency’s existing framework. Under the regulatory framework, insect food products and insect-based food products would be subject to all relevant sections of the FDCA and must be processed using current good manufacturing practices. Insect-specific processing standards are particularly important to ensure edible insects’ safety, as one recent study reported that the biological and chemical hazards of using farmed insects for human consumption depend on how the insects are reared and processed.

5.Design selection

Based on the existing design and applicable patents, we came up with three forms of design. The first one being the sketch 1 in figure 1 . This design is close to the result. The second idea being the sketch two in figure 1. It is cheap, straightforward, but requires a lot more labor and maintenance. It also takes a lot of space which results in reducing the yield. The third idea being the sketch three in figure 1. It involves a right and left displacement of trays which can maximize space utilization, but it makes it difficult for maintenance and harvest. We made a Pugh chart to evaluate all the ideas to help us make the right decision.

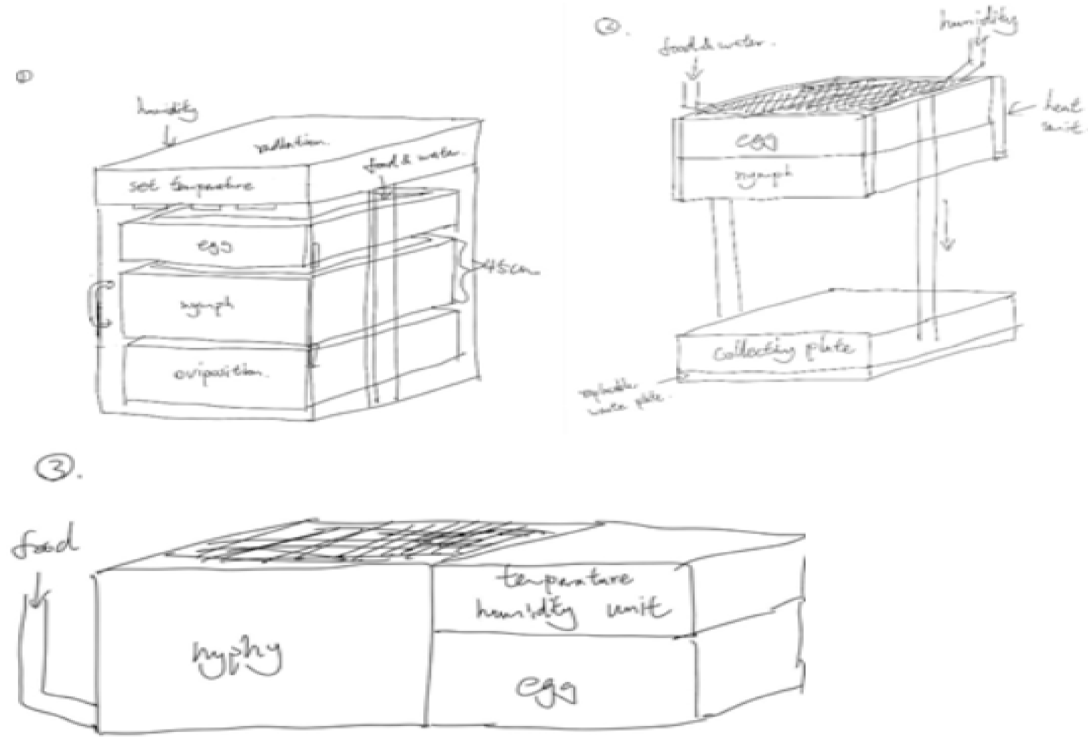

Figure 1: sketches of design ideas

	weight	idea 1	idea 2	idea 3
cost	5	-1	1	-1
health and safety	5	0	0	1
durability	3	1	-1	0
ease of maintenance	3	1	-1	-1
convenience	2	1	1	-1
total		3	1	-5

Table 2: Pugh chart of original ideas

6. Design implementation

6.1. Operational Flow

Our design can be categorized as two units: the rearing unit and reproducing unit. The farm is organized as follows:

- The rearing unit is the major part of our projection, its main purpose is to provide a suitable environment for the crickets that they can quickly grow from larvae to adult crickets ready to be harvested.
- The reproducing unit only provides larvae to the rearing unit and does not yield any crickets.
- The specific scale of our design is shown as an orthograph in Appendix C with a unit of mm.

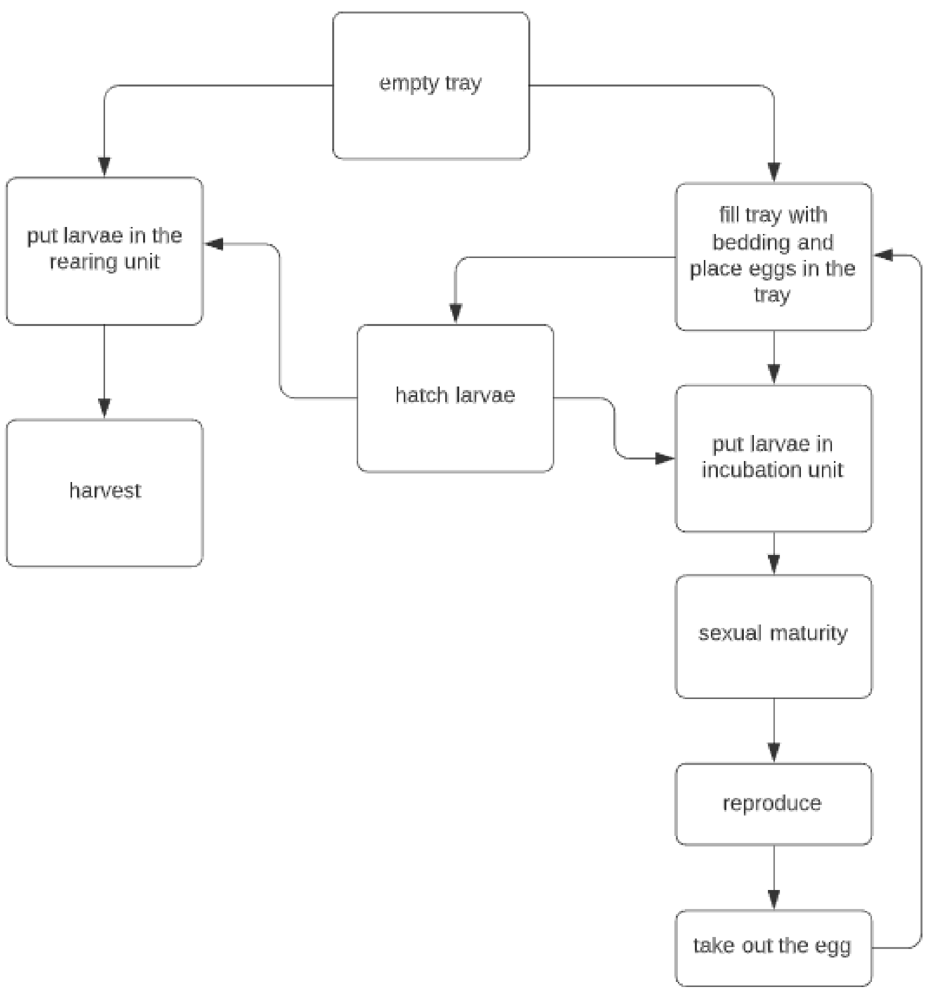

Figure 2: flow chart of the operational flow

6.2. Ventilation System

The ventilation system we designed in cricket farming device is based on patent US9179640B2 but on a small scale. The ventilation would deliver 4 air exchanges in each tray every hour to keep the sanitary and limit the growth of bacteria inside the device based on the health care facility ventilation standards 2020 (Kelechava, 2020). The fan we choose is an ultra silent ventilation fan from Aigo which satisfies the need for air exchange based on calculation 1 in appendix B. After the air inlet from the top vessel, the fan will drive the air to the HEPA filter on the top of the fan which would remove all particles and bacteria with more than 0.3 micrometer as shown in Figure 1 in Appendix C. Then, the air will go through the vent pipe and delivered to each tray through the entrance at the back of each tray shown in Figure 2 in appendix C. The air flow will exit through the bottom of each tray and outlet at the bottom of the structure. A filter with a combination of cellulose fiber and charcoal installed at the bottom of the structure will remove the odor. (Insect Mass Production Technologies, 2012)

6.2.1 Odor filter and HEPA filter

HEPA filter is a very common filter used in hospitals to remove dust particles and bacteria. [1] It can be easily found online for about 30CAD per pack. The odor filter design is based on patent US9179640B2 which contains cellulose and charcoal to remove odor for livestock production. Both cellulose and charcoal are good at odor absorption and easy access materials.

6.3. Temperature Control System

The temperature control system is designed to be operated by 2 parts. The first part is the heat system that the heat pad will be installed on the bottom of each tray to ensure the temperature inside. The second part is operated through the ventilation system. Both will be connected to the Arduino chip to control the on and off. From the literature review, we determined that the temperature inside each tray should be maintained between 29C-32C. When the DHT11 sensor detects the temperature inside each tray reaching below 29C, the heat pad will start working and stop at 31C. When the sensor detects the temperature inside the tray reaches above 32C, the ventilation fan will start working to bring down the temperature to 31C. The energy consumption will be calculated in Calculation 4 in Appendix B. The heat transfer coefficient will be used to run the simulation of the heating pad. Figure 3 in Appendix C shows the location of the heat pad installed. The operational flow diagram as shown in Figure 2 Appendix D.

6.3.1 Heating Pad

The heating pad we used is the same as the heating pad for plants which is mentioned above in the patent review. (Parrish, 2020) The initial design is built for plants that can keep the substrate temperature between 25-30C. However, according to their patent, with some adjustment for the input voltage and current, we can make the heat pad to keep temperature for our requirement. The heating pad will be installed at the bottom of the tray and a dust and waterproof layer should be added on the top of the heating pad in order to decrease the hardware failure as shown in Figure 3 in Appendix C. The heat strips should be designed as shown in Figure 4. Appendix C. where the rectangle blocks are located according to the patent US20190110615A1. By locating the heat strip in this way, the energy waste can be minimized and distribute the heat source uniformly through the bottom of the tray to heat the substrate gently without overheating at certain spots.

6.4. Humidity Control System

The humidity control system in our design is controlled by an Arduino chip. The water will be vaporized by the humidifier installed at the water container located at the back of each tray. The water will be delivered through the pump when the water level sensor detects the water level of the water container is low. When the DHT11 sensor in the incubate tray detects the humidity below 80%, the humidifier would start work and the water vapor would be generated. When the sensor detects the humidity below 40%, the switch will open and turn on the humidifier installed in the tray. The specific operational flow diagram for the program is listed below.

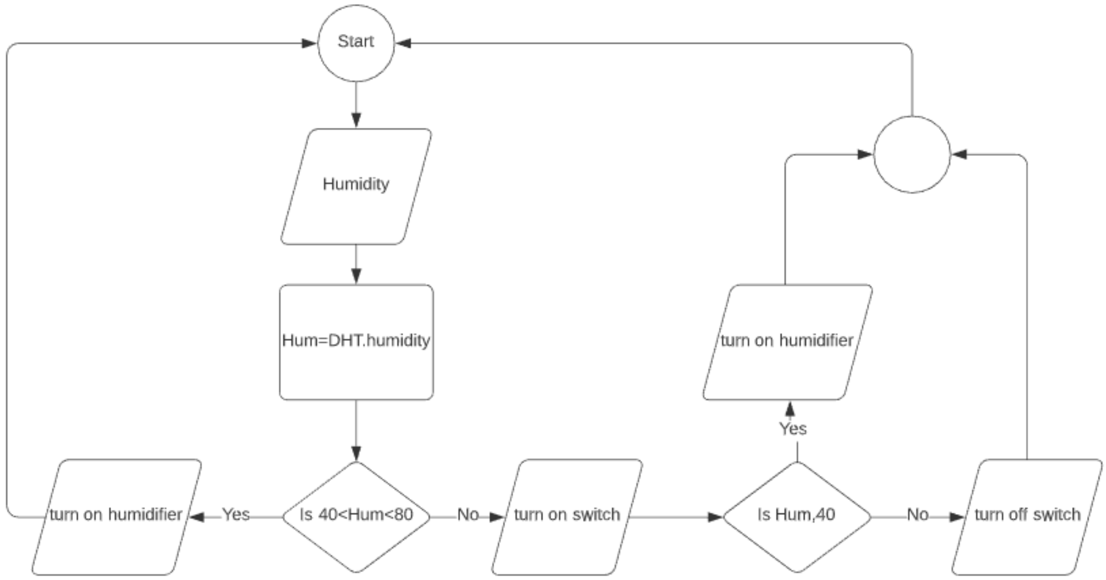

Figure 3: flow chart of how the humidifier works

6.4.1 Humidifier

The humidifier we chose is a DC 12V super ultrasonic humidifier. The humidifier will automatically turn on when the relative humidity in the unit is below the limit and turn off when the relative humidity reaches the upper limit. The maximum noise is 35dB so it will not disturb the crickets.

6.5 Feeding system

For the feeding system, we decide to use liquid feed that is much easier for automatic delivery. The feed design is based on patent CN107494912A with consideration of the ideal diet. The ideal diet ingredient for crickets is 20 to 30% protein, 32–47% carbohydrate, and from 3.2 to 5.2% lipid. (Insect Mass Production Technologies, 2012) We choose the ingredient of the feed with the most similar nutrient content from the patent which contains 40% soybean meal, 20% corn starch, 5% attractant peptide, 30% carrot, 5% vitamins. The dry feed should be mixed with 3 times the volume of water and be stored at the left side of the storage tank as indicated in Figure 5. Appendix C. The feed will be pumped from the storage tank to the feed plate as shown in the figure for every 8 hours. Based on calculation 3 in Appendix B, the pump will operate for 20.62s after starting to deliver enough feed.

Instead of a common suction pump, we decided to use a peristaltic pump for food delivery in our feeding system.The reason behind that is after doing the calculation, it seems we need a giant pump that can deliver the liquid with that viscosity. However, a peristaltic pump works very good with liquid that has a high viscosity or suspended solid in it. A peristaltic pump, also commonly known as a roller pump, has a roller to compress the tube as they rotate, creating a vacuum which draws fluid through the tube. The complete closure of the tube when it is occluded between the roller and the track, gives the pump its positive displacement action. The pump is connected to a relay module that turns on every eight hours to feed the crickets. This is realized using a relay module. Relay module is used to isolate components and create a sub-circuit in the circuit. We use the replay module to control our feeding system, which is set to turn on for a certain amount of time every eight hours.

6.6. Electronic

In our design, three Arduino chips will be used to achieve the automatic control since we have three layers of tray and the Arduino Uno microcontroller is only capable of controlling one tray. Three Arduino chips will be responsible for three different layers and each chip will control all the systems: humidity control, temperature control, ventilation and feeding system. These three systems will operate as previously described. Figure 1 in Appendix D illustrates example components of a control system associated with humidity control, temperature control, and feed system according to some implementations. The program of Arduino has been made based on the operational flow diagram of temperature control system shown in Figure 2 Appendix D and humidity operational flow diagram. The switch for feed system is controlled by Arduino Chip with a timer program. The ventilation system is also controlled by an Arduino chip with a timer program. The program of the microcontroller can be modified to meet different needs.

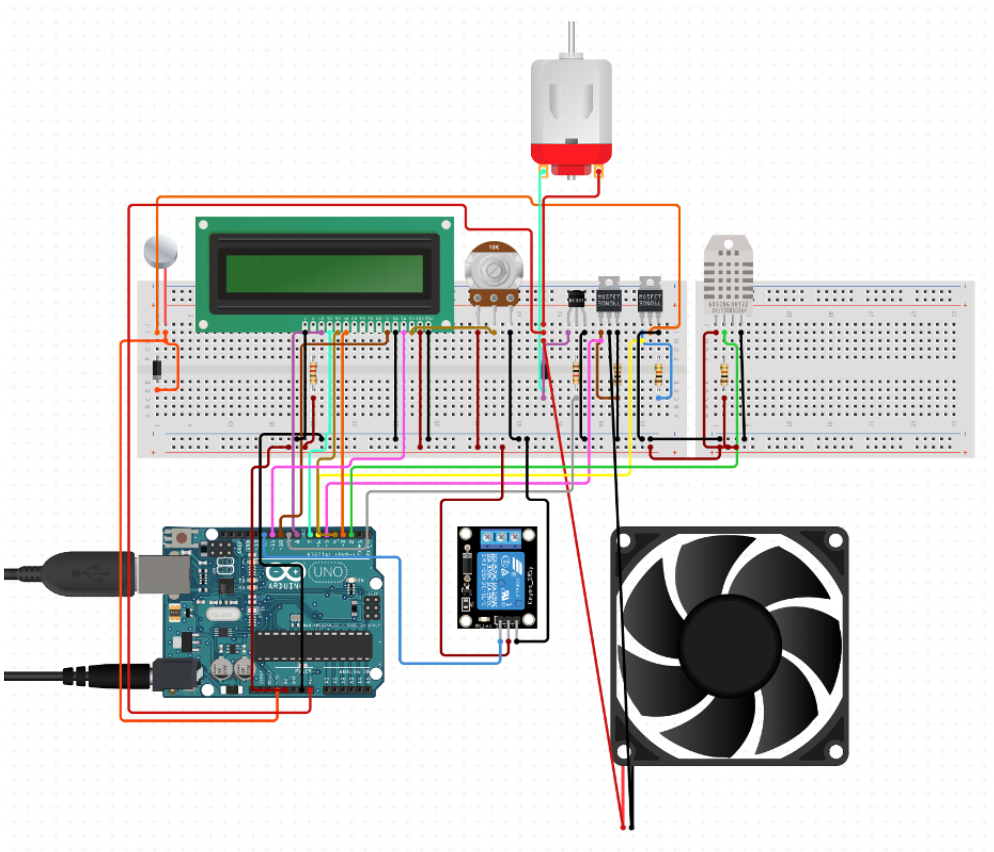

Figure 4: Schematic diagram for the control system

6.6.1 Control system using Arduino

To deliver a fully automated control system, we chose to use Arduino Uno and Arduino software. Arduino Uno is a microcontroller board that can run small simple software, so it is capable of controlling our automated system. We chose to use Arduino because it is relatively cheap, easy to use, and requires very little power to maintain operation. In this section, details of how our control system works will be elaborated. Major parts of the control system will be introduced and some accessories to make the whole system work.

Arduino Uno board is the most common board to get started with electronics and coding. It is a microcontroller board based on the ATmega328P datasheet. It has fourteen digital input/output pins, 6 analog inputs, a 16Mhz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. The fourteen digital input/output pins are used to connect to LCD display, temperature and humidity sensor, humidifier, fan, and feeding system. The USB connection can connect to the laptop to change settings for all the systems and see the real time humidity and temperature from the sensor. The reset button is for resetting the system in case of an unfortunate event. The light on the board is an indication of if the system is working properly.

6.6.2 DHT 11 sensor

DHT 11 has a capacitive humidity sensor and a thermistor. There is also a very basic chip inside that does some analog to digital conversion and spits out a digital signal with the temperature and humidity. It is Good for 20-80% humidity readings with 5% accuracy and for 0-50°C temperature readings ±2°C accuracy. It has a sampling rate up to 1 Hz. It is located in the center of the unit and connected to the Arduino board through a long jumper wire.

6.7. Tray design

The tray we designed is constructed by antibacterial polymer using PVC unplasticized to prevent bacterial growth and keep sanitized inside the tray. The hole at the back side of the tray and front side of the tray is covered with HEPA filters for ventilation purposes and prevents escaping of the crickets. The feed plate is designed for 5cm deep with many meshed projections to make sure the liquid feed can be evenly distributed after delivered from the feed pipe. The feed plate is at 30cm high above the bottom to make sure the feed is far away from the cricket manure to prevent mold and make space for substrate. The electric unit can be installed at the PVC box on the side of the tray. With the screen design at the bottom of the electronic unit box, the electric component can be able to measure the humidity and temperature inside the tray without contact with dirt. The tray is sealed on the top to make sure the ventilation efficiency. The only inlet and outlet of the air flow is through the ventilation system described previously. The whole design at the bottom of the tray is used for heat dissipation for the heat pad in case of overheating. The specific design is shown in the orthographic views in Figure 6 in the Appendices C. The specific dimension of each component installed in the tray can be found in Figure 1. Appendix E.

6.8 Manufacture and Assembly

The components of our device can be manufactured through many ways such as 3d printing or rotational molding through a factory for massive production. The specific dimension of manufacturing each component can be found in Appendix E Figure 1 to 3. The dimension of manufacturing doesn't include electronic components due to each electronic component in our design can be easily purchased online and have their specific dimension. For the electric circuit design, we only developed preliminary design which can be later developed and printed into chips that increase the lifespan and decrease the requirement of maintenance even further. The final assembly schematic diagram is shown in Figure 4. Appendix E.

6.8.1. Material and Cost

Our aim is to provide affordable, sustainable protein in the form of insects at low cost to contribute to feeding a growing population and sustaining our environment, so it is important to choose durable material while keeping the cost down. The total cost of one unit is around 250 canadian dollars(the detailed data is in Appendices . This may seem a lot at first, but with the current high price of cricket powder and other processed food, the payback period is around 3 months.

6.9. Maintenance

Since all our systems can operate automatically, our design requires minimum maintenance. According to the Calculation 2&3 in Appendix B, the water tank and food tank can store enough water and food for at least 14 days which is about the growing stage of crickets from larva to adult. The refill of water and food can be done while harvesting the adult crickets. All parameters of the environment can be changed to adapt different growing stages of crickets. The temperature and relative humidity can be set higher as crickets need a warmer and moisture environment as they grow from egg to larva.

7.0 Test Results and Model

In the model device built for the experiment and testing, there is no cricket used. There is no company in Canada that sells live jamaican crickets in larva stage and adult stage. Most cricket farms sell eggs which are in dormant state and require at least 1 month for incubating and another month to grow into larva stage which would take too much time. Furthermore, it is impossible for our team to have live cricket for testing under COVID-19 situation. The method to test and validate the automated system is through building a simplified model. The model built for the experiment contains a 12V 1.1W computer cooling fan instead of ultra silent ventilation fan as designed due to limitation of fundings. However, it can produce enough suction force for the air to pass through the HEPA filter and odor filter and provide more than 4 times air exchange per hour inside the box as shown in design.

By collecting the data output through a DHT 11 sensor which was installed at the middle of rearing box with 43.2cm*36.5cm*26cm dimension to make sure the accuracy of the data. The graph of changes of humidity and temperature can be made for testing the stability and maintenance of the environmental conditions as shown in Figure 1 and 2 in Appendix F. The data is measured every half minute and continuous for 2.5 hours and extracted directly through Arduino. The unit for temperature is Celsius and for humidity is the percentage of water in the atmosphere. Figure 5 in Appendix F shows the actual construction of the electric circuit we build in our model. Figure 6 in Appendix F shows the location of the sensor.

For the humidity as shown in figure 1., the humidity inside the unit is maintained steady at 65% to 80% in comparison to humidity in Montreal which is around 25%. The general shape of the graph proved the functionality of our system where the humidity starts to drop after reaching 80% and starts to increase after reaching 65%. The outlier of the data may be due to ventilation. By comparing the graph of humidity with temperature, when the ventilation starts working, the fan sucks the dry air from outside and needs some time to mix with the moisture inside. In figure 1., the humidity is relatively low at the beginning may due to the moisture created by humidifiers having higher density than dry air originally inside the tray and needs air flow to mix with dry air floating at the upper level.

For the temperature, there are more significant changes during the 2.5 hrs period as shown in figure 2. As shown, the temperature increases slowly at first 75 minutes as we expected since we want the heating process to be gentle in order to keep the safety of the cricket. However, after the first 75 minutes, the graph of the temperature starts to shift between 28C to 32C. After analysing our designed system, the vibration of the graph may be also due to the ventilation. In our automatic system design, the ventilation should start to work after the temperature reaches 32C. In our testing model, the environmental control system worked and caused a huge drop of temperature at 75 minutes since the fan brought cold air flow into the tray. The same reason causes another huge drop at 130 minutes. Another reason the temperature shifts after 75 minutes is the humidifier. By comparing the data with the graph of humidity, the graph of temperature vibrates every time when humidifiers start to work. The humidifier atomized the cold water into a gas state and mixed with warm air and brought down the temperature. Due to the sensitivity of the sensor and nonuniformly mixture of cold wet air and warm air, the temperature shifted.

7.1 Improvements

According to the results of our test model and simulation, we determined some misconsideration in our automation system that may cause significant extra energy. For the temperature control system, the ventilation should not start to work immediately after the heat pad stops working where the temperature is 32C. In our final design, the heat pad will stop when the temperature reaches 31C and the ventilation will start to work when the temperature reaches 32C and stops when the temperature reaches 31C.

From the test results, we find the automatic control system of the entire system still needs more development in the future due to the system interface. Furthermore, more data should be tested with cricket present in the tray to adjust the control system. We made the humidity and temperature adjustable in our model and left gaps in our program to make the modification of our designed automated system easier. However, with the time limit and shortage of data volume, we could not finish this part in the end.

8. Design considerations

8.1 risk factors matrix

With so many components in the device, we must take risk factors into considerations. Here is the risk factor matrix with risk rank, possible causes, and mitigation.

risk factor	risk rank	causes	mitigation
heat pad malfunction	3	Electronic component failure	choosing reliable product
humidifier malfunction	3	Electronic component failure	choosing reliable product
sensor malfunction	3	Electronic component failure	choosing reliable product
software malfunction	2	poor coding	tests and simulations

water run out	1	tank leakage	regular inspection
food run out	1	tank leakage	regular inspection
cricket cannibalism	1	over crowded	transfer two other unit

Table 3: risk factors matrix

8.2. Environmental impact

It's estimated that even if our population only increases by one-third, we will need to increase our agricultural output by 70% to make up for the increasing appetites of developing nations. This, of course, has a tremendous negative impact on the natural world, causing the degradation of what remains of our natural resources. There is a limit to how much food we can produce. Even if we cut down all the rainforests, fished the entire ocean, and ate every morsel of food produced, we still might not be able to accommodate the incoming populations. 18% of all greenhouse gas emissions produced globally comes from livestock, which heavily contributes to climate change; also massive amounts of crop production about 36% of US corn harvests and 75% of global soybean production goes to feeding livestock. In fact, a third of all arable land is used to grow crops that only feed livestock. Insects, on the other hand, produce negligible amounts of greenhouse gases. All cows and other animals produce methane and ammonia for cellular respiration. Besides termites, no farm insect is known to release either methane or ammonia. Replacing livestock with insects could have removed 18% of our greenhouse gas emissions and would be a great step towards ending climate change. Next and perhaps most importantly, , insects are incredibly efficient. With just 10 kilograms of feed, a Locust population can produce 9 kilograms of edible food, whereas a cow can only produce one measly kilogram, while pigs can only produce three and chickens five. A big reason for this increased efficiency in insects is that while all current livestock are warm-blooded animals meaning energy is needed to generate heat for their bodies, insects are ectothermic, meaning they receive their heat from the environment. Because of this, they only need food to grow and move, not to stay warm.

8.3. Social impact

Insects do not transmit diseases because humans are so similar to animals like pigs and cows, diseases have a relatively easy time crossing between species.Animal products can transmit diseases like H1N1 or salmonella, and as a result, more resources must be spent to ensure the quality and safety of the meat we eat. However, insects are so radically different from us that virtually no insect disease can be transferred to humans, making them far safer to eat. Insects can also offer us food security that we cannot find anywhere else today. 75% of our food is produced by just 12 plants like plantains, yams, sorghum, sweet potatoes, soybeans, cassavas, potatoes, rice, wheat, corn; and five animals: pigs, sheep, cows, and chickens. With something as vital as food, it is dangerous to rely on underlining a handful of species as we do now. Just one of these staple crops encountered a blank or other disease, global food production would take a hit, and food shortages would be experienced everywhere.

Moreover, many people worry about the conditions our livestock are subjected to being kept in small cages their entire lives only to die once they reach a certain age. insect agriculture, on the other hand, has proven to be a far more Humane process as many insects naturally tend to live in high numbers in small spaces anyway.

8.4. Economic impact

Insects not only provide a sustainable protein source, but also helps address the challenges of organic waste disposal. Insect farming contributes to the circular economy by converting food waste into protein source for animal feed and fertilizer for the crops. Look at the production of the consumer supply chain, the farm crops and animals are our main source of food today. After processing purchase and consumption. There is a missive 1.3 billion tons of organic waste. Most of this provides no further value and is lost. However, the waste can provide value as feed to insects. With the proper dosing, it provides the perfect feed to support the insect growth. The reared larvae can be processed to valuable proteins and lipids. And these are fed back to the farmed animals that we consume. The residue of the insect rearing can be utilized for thr farm crops that we consume. Above all, insects, if managing correctly, provide a sustainable source to both our farm crops and animals.

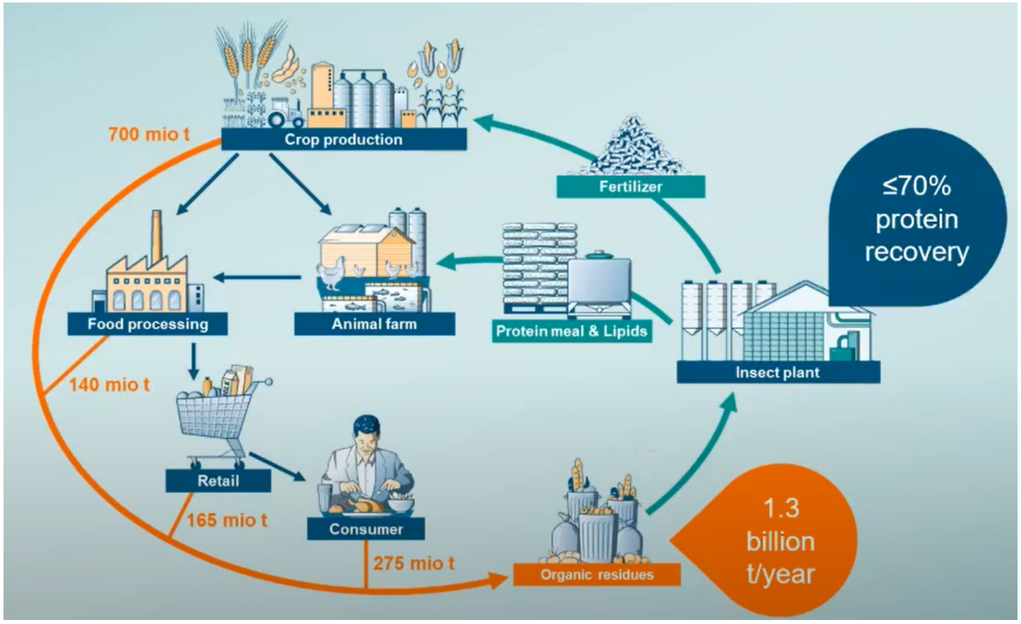

Figure 5: circular economy of insect farming

8.5. Future opportunities

The industry remains in its infancy. There's a great need for innovation, research, and development. Food scientists, farmers, and engineers are needed to take on this edible insect cause with more investment and human capital. We will begin to see developments that will make insect farming at a large scale a reality. If we can achieve cost-effective large-scale insect farming, insects will have their desired outcome: to create low-cost, delicious, and nutritious food that can meet the demands of a growing global population while alleviating pressure on our planet's limited and natural resources.

9. Conclusion

In short, this is a historic and exciting time for agriculture and the food industry. As the population grows, we face many challenges: climate change and environmental destruction. These also provide opportunities to explore new solutions to make the world a better place. I firmly believe that insects play an important role in this journey in many ways. With the latest development of the insect-based food industry, especially in developed countries, it is an exciting time for the transformation of resources from agriculture and other industries to become part of the revolution. The culture of eating insects on a regular basis is considered beneficial and is regarded as a nutritional, medicinal, environmental, sustainable and safe food. Once insects are widely accepted as respected food in developed countries, their meaning will have a positive and profound impact on enterprises, industries, governments and research. Replacing traditional livestock food and products with insect-derived food will also greatly improve the natural environment of the earth. Currently, insects are still not widely available in Western societies and industrialized countries, and are expensive compared to other animal-based food ingredients. However, as the production of insects as human food and animal feed increases worldwide, especially in North America, many aspects related to the practicality of insect-based food, such as cost, safety, availability, and large-scale production effectiveness. This has led to increased demand and will drive insects to the status of standard mainstream food ingredients rather than high-end products. In order to obtain the huge potential benefits of human consumption of insects on a global scale, it is necessary to establish closer links with different disciplines. Engineers are required to develop suitable feeding systems for various environments and insects. Food scientists are required to study the nature of insect food and the nutritional content, function and characteristics of insect-based ingredients in various foods, the basic principles of insect food processing and the improvement of insect-based foods. Nutritionists need to advise consumers on insect food and its nutritional impact on human health. Marketing, promotion and advertising experts are needed to promote the numerous benefits of insect-based foods and ingredients.

10. Reference

1.AGCanada. (2019, January 15). Farming insects may solve one problem, create others. Retrieved December 01, 2020, from https://www.agcanada.com/daily/farming-insects-may-solve-one-problem-create-others

2.Big Facts on Climate Change, Agriculture and Food Security. (n.d.). Retrieved December 01, 2020, from https://ccafs.cgiar.org/bigfacts/

3.Bryce, E. (n.d.). Transcript of "Should we eat bugs?" Retrieved December 01, 2020, from https://www.ted.com/talks/emma_bryce_should_we_eat_bugs/transcript?language=en

Cricket Farming: The Basics. (2019, July 16). Retrieved December 01, 2020, from https://bigcricketsolutions.com/knowledge-base/knowledge-base-article/

4.Dossey, Aaron T., et al. Insects as Sustainable Food Ingredients: Production, Processing and Food Applications. 2016.

5. Efficiency of the HEPA air filter: HEPA filter quality and bypassing. (n.d.). Retrieved December 01, 2020, from http://www.air-purifier-power.com/hepa-air-filter.html

6.Falke, "Use the Air Changes Calculation to Determine Room CFM," Contracting Business, 14-Apr-2017. [Online]. Available: https://www.contractingbusiness.com/service/use-air-changes-calculation-determine-room-cfm. [Accessed: 10-Apr-2019].

7.Foundation, T. (n.d.). Cars or livestock: Which contribute more to climate change? Retrieved December 01, 2020, from https://news.trust.org/item/20180918083629-d2wf0

8.Government of Canada, C. (2018, October 03). Government of Canada. Retrieved December 01, 2020, from https://www.inspection.gc.ca/food-safety-for-industry/food-chemistry-and-microbiology/food-safety-testing-bulletin-and-reports/bacterial-pathogens-in-edible-insects/eng/1536600379922/1536600380203

9.Hasell, J. (n.d.). Does population growth lead to hunger and famine? Retrieved December 01, 2020, from https://ourworldindata.org/population-growth-and-famines

10.Improved Mass Production of Beneficial Insects. (n.d.). Retrieved December 01, 2020, from https://www.sbir.gov/node/1254441

11.Insect Farming. (n.d.). Retrieved November 26, 2020, from https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/insect-farming

12. Kelechava, B. (2020, May 04). ANSI/ASHRAE/ASHE Standard 170-2017: Ventilation of Health Care Facilities - ANSI Blog. Retrieved December 01, 2020, from https://blog.ansi.org/2020/04/ansi-ashrae-170-2017-health-care-ventilation/
Parrish, R. (2020, September 21). Heating Pads for Plants. Retrieved December 01, 2020, from https://homeguides.sfgate.com/heating-pads-plants-22723.html

13. Rosemary Parker |. "Following Cricket Paralysis Virus Catastrophe, Top Hat Cricket Farm in Portage Rebuilds It Business." Mlive, 19 Jan. 2012, www.mlive.com/news/kalamazoo/2012/01/top_hat_cricket_farm_in_portag.html.

14. The Regulatory Review. (2020, June 22). Calls for Regulatory Approval of Edible Insects. Retrieved December 01, 2020, from https://www.theregreview.org/2020/05/06/gaulkin-calls-regulatory-approval-edible-insects/

15. Urbański, J. (2013). The effect of density on the breeding optimization of the tropical house cricket Gryllodes sigillatus. Retrieved December 01, 2020, from

https://www.researchgate.net/publication/320035054_The_effect_of_density_on_the_breeding_optimization_of_the_tropical_house_cricket_Gryllodes_sigillatus_Walker_Orthoptera_Gryllidae

16. Pitchers, C. (2021, February 11). Edible insects likely to HIT supermarkets within months. Retrieved April 14, 2021, from https://www.euronews.com/2021/02/10/edible-insects-likely-to-hit-supermarkets-within-months-after-eu-agency-s-green-light

17.The Regulatory Review. (2020, June 22). Calls for regulatory approval of edible insects. Retrieved April 14, 2021, from https://www.theregreview.org/2020/05/06/gaulkin-calls-regulatory-approval-edible-insects/

Appendix

Appendix A: Exist Design and Patent Available

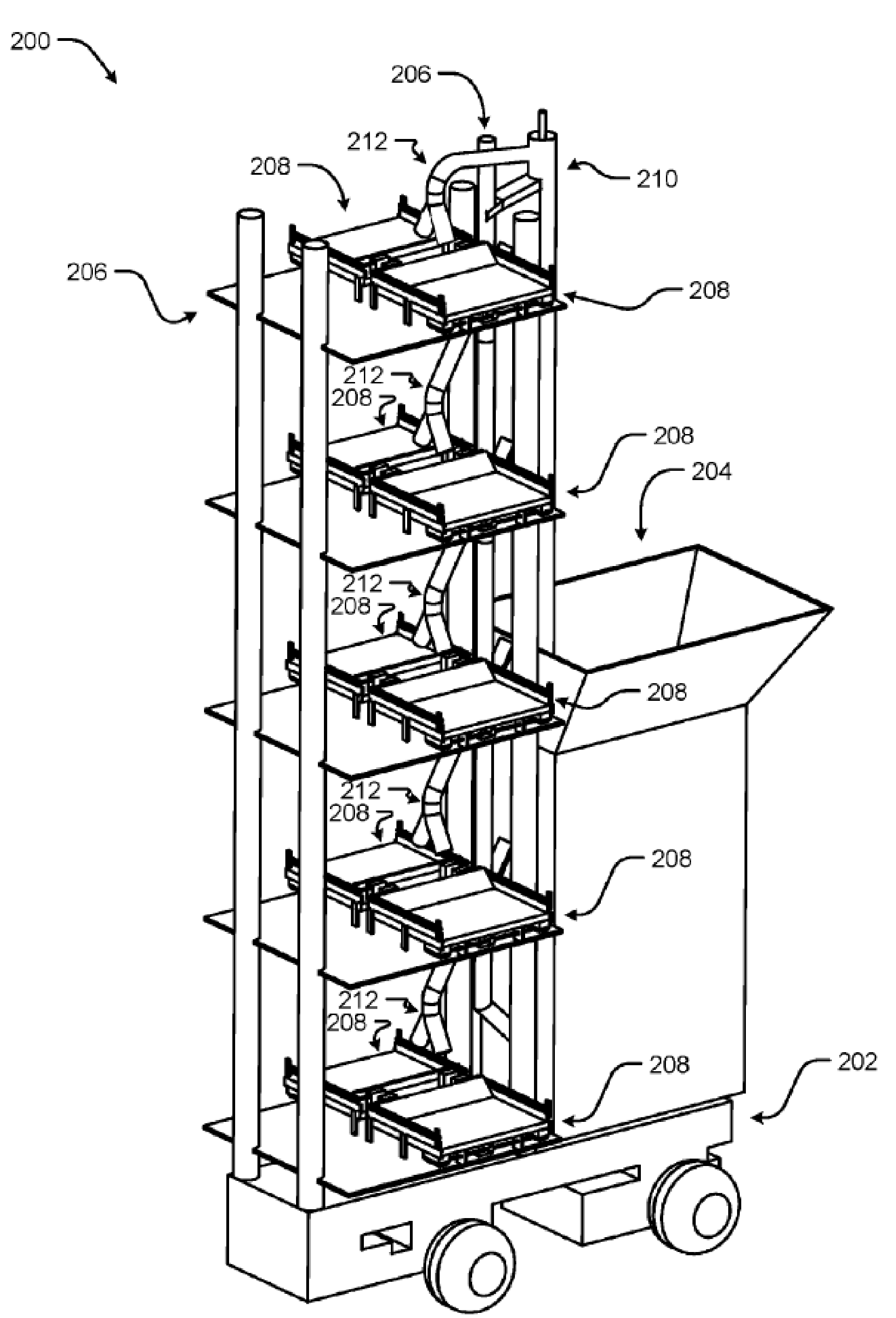

Figure 1

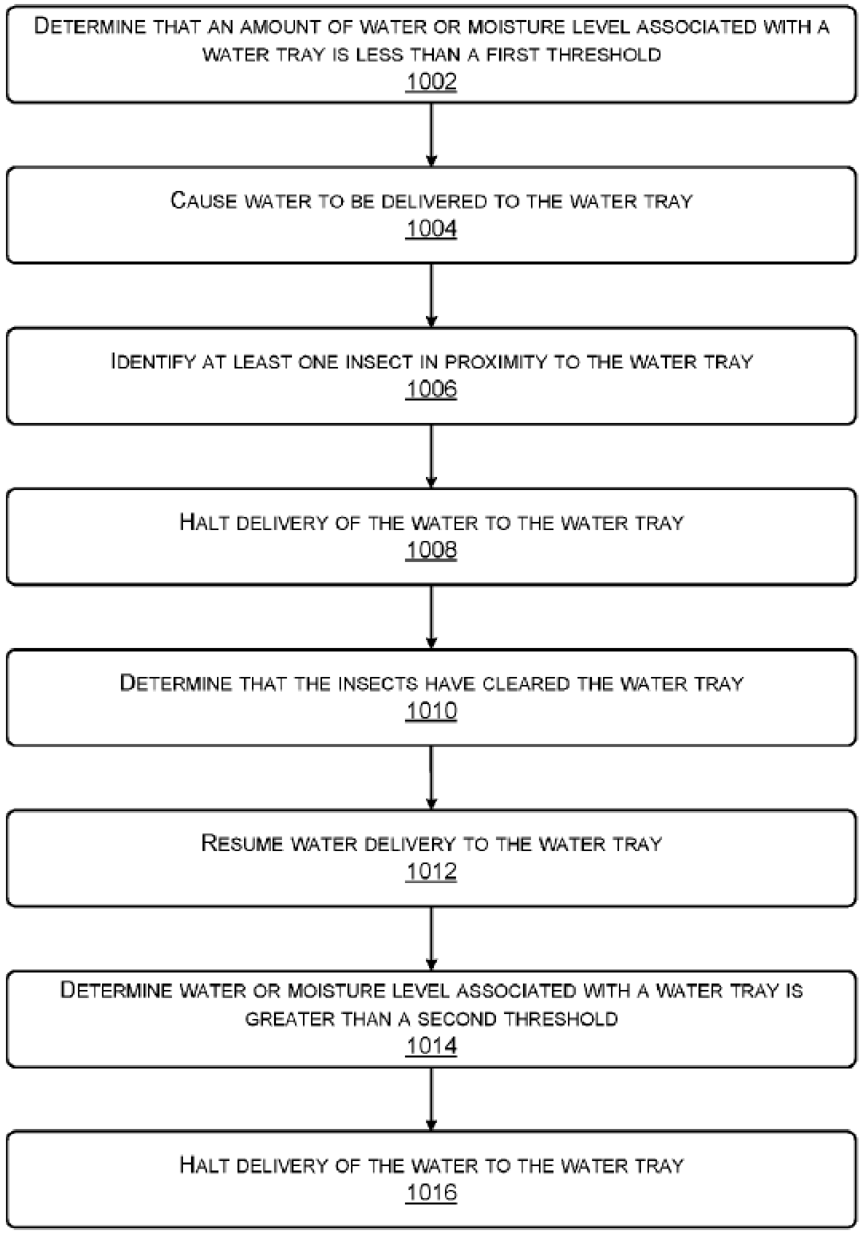
DETERMINE THAT AN AMOUNT OF WATER OR MOISTURE LEVEL ASSOCIATED WITH A WATER TRAY IS LESS THAN A FIRST THRESHOLD
1002
CAUSE WATER TO BE DELIVERED TO THE WATER TRAY
1004
IDENTIFY AT LEAST ONE INSECT IN PROXIMITY TO THE WATER TRAY
1006
HALT DELIVERY OF THE WATER TO THE WATER TRAY
1008
DETERMINE THAT THE INSECTS HAVE CLEARED THE WATER TRAY
1010
RESUME WATER DELIVERY TO THE WATER TRAY
1012
DETERMINE WATER OR MOISTURE LEVEL ASSOCIATED WITH A WATER TRAY IS GREATER THAN A SECOND THRESHOLD
1014
HALT DELIVERY OF THE WATER TO THE WATER TRAY
1016

Figure 2

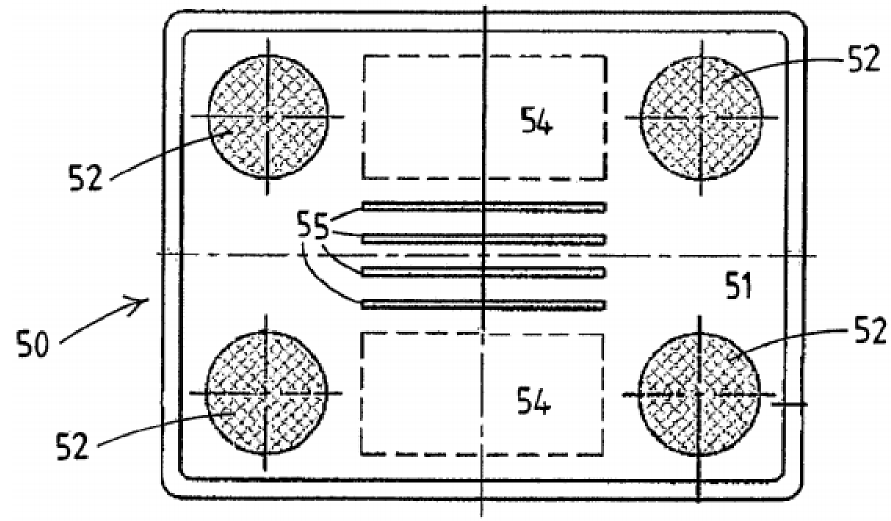

Figure 3

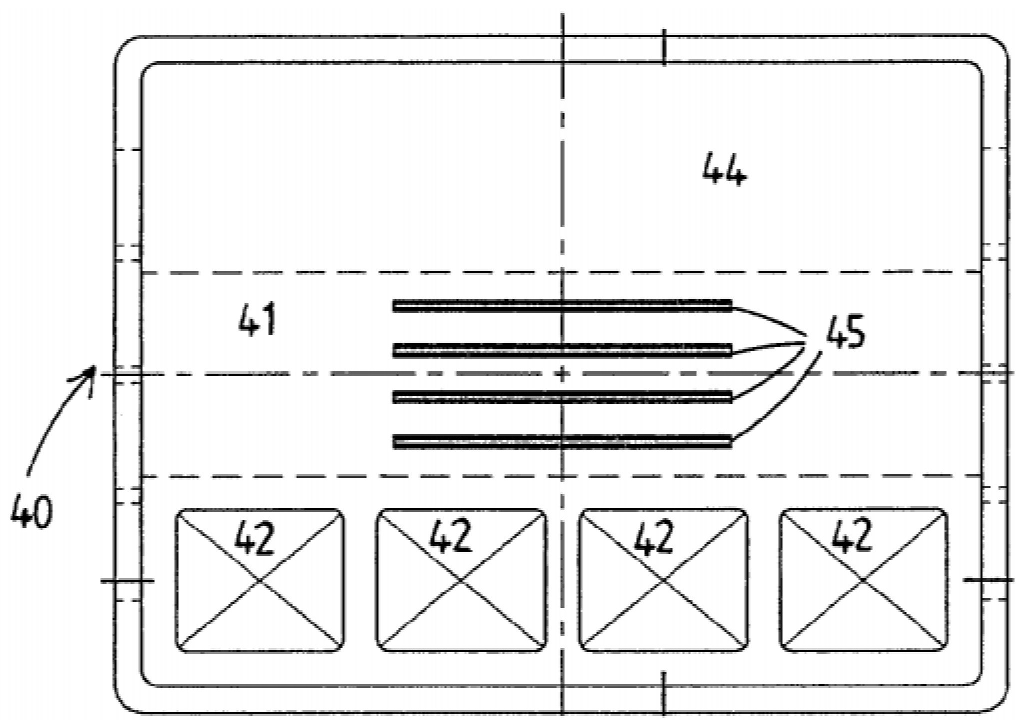

Figure 4

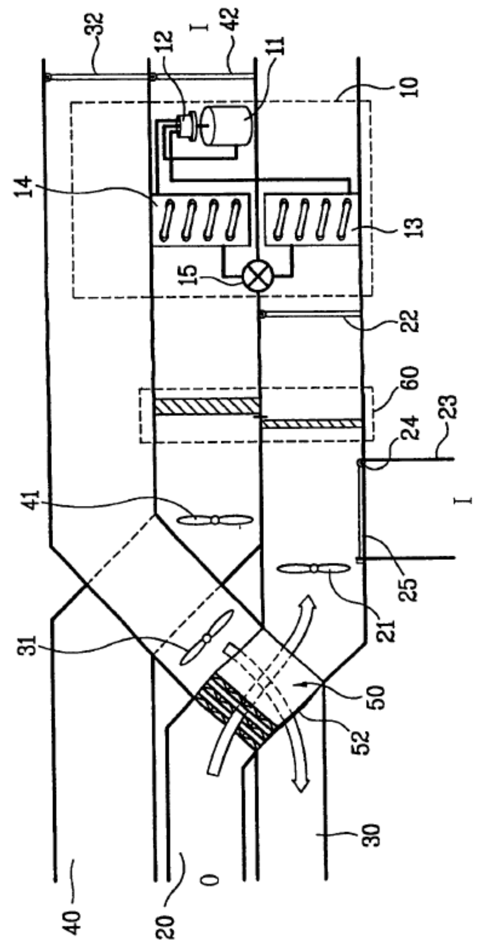

Figure 5

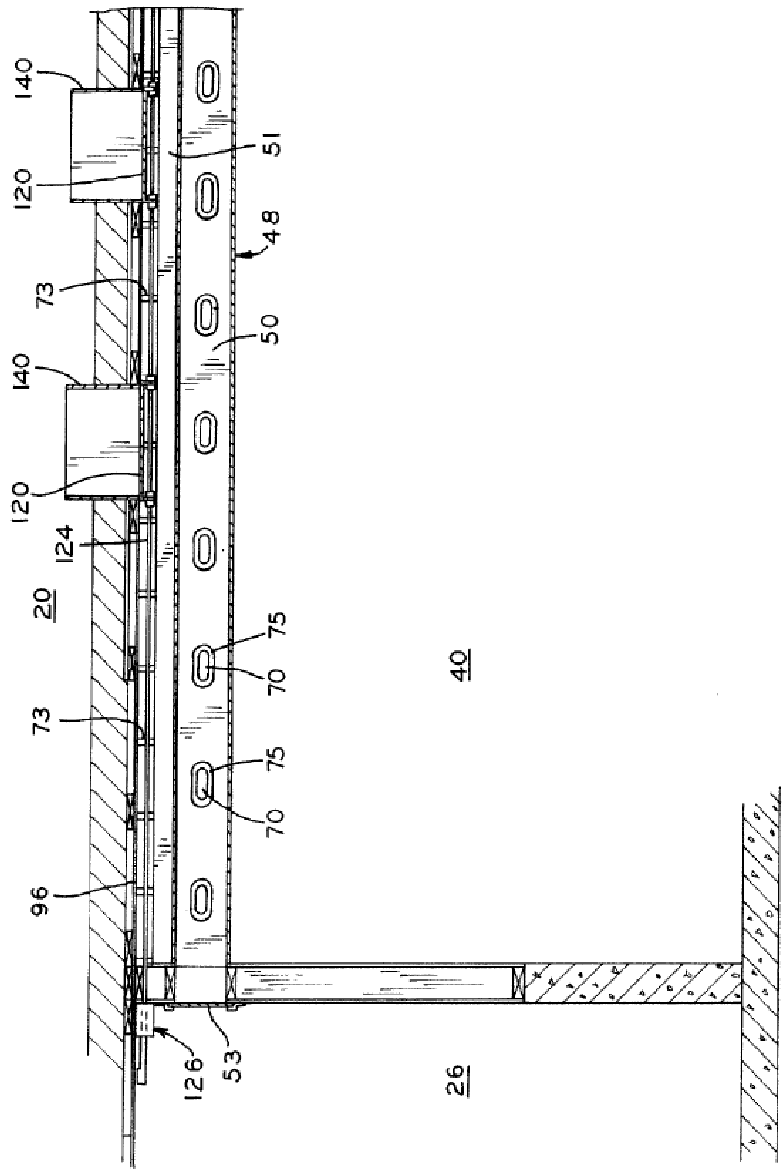

Figure 6

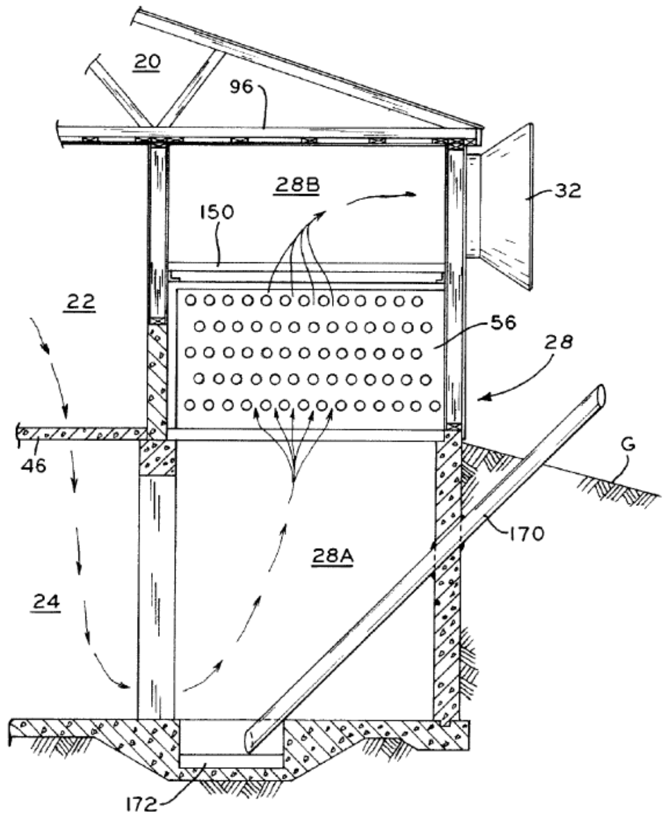

Figure 7

Appendix B: Calculation

Calculation 1: Ventilation

Assuming fan turn on for 1 min every 1 hr

ACPH $= 60 * Q/Vol$ (Falk)

ACPH = Air changes per hour

Q = Air exchange rate in cm3/min

Vol = Volume of air inside structure in cm3

The Volume we used is 100cm*100cm*144cm = 1440000cm^3

Q = 4*1440000cm^3/60= 96000cm^3/s = 0.096m^3/s

Calculation 2: Water Requirements

Assuming the outside temperature is 22C and humidity is 25% while the inside temperature is 30C and humidity is 70%.

Assuming the air density at 22C with 25% relative humidity is 1.193kg/m^3

Mass of air flow= 0.096m^3/s * 1.193kg/m^3 = 0.1145 kg/s

Mass moisture inside at 30C = 70% RH = 18.69gH2O/kg Dry Air

Mass moisture outside at 22C = 25% RH = 4.12gH2O/ kg Dry Air

Moisture to be added through the air flow = 0.1145kg/s * (18.69 - 4.12)gH2O/kg Dry Air

= 1.668 gH2O/s

Total Moisture added per day = 1.668gH2O/s * 60s/min *24 = 2402.9gH2O/day

Calculation 3: Operation Time for Pump

Each cricket occupies 4 centimeter squared of space, with our tray design 100cm*100 cm, each tray can contain about 2500 crickets. Each cricket weighs about 0.8 gram and with their energy efficiency, there will be a total of about 3000 grams of food for each tray for one harvest period.

$mass\ per\ feed\ =\ 3000g\ *\ 8hr\ /\ 14days\ /\ 24hr\ =\ 71.42g$

We assume the density of liquid feed is the same as dough as 1.11g/cm^3 since the water content and carbohydrate content is very similar. The diameter of the feeding pipe is 1.5cm.

V = mass /density = 64.34cm^3

The discharge rate is determined form the pum we choose which is 3.12cm^3/s

The time required for the pump to complete feed is 20.62 s

Calculation 4: Energy used in one cycle of production

Assume the ambiance temperature at 25 degrees Celsius and relative humidity is 25% which is the ambiance temperature and relative humidity for the test of our prototype.

Based on the data we collected from our prototype, the heating pad is working about half the time of the process. The heating pad is 18W and a full cycle of production is 14 days.

For our design, energy used by heating pad is

= 18W x 1/3 x 14 days x 24 hours/day x 3 layers per unit = 18.144 kWh

For the fan we used is 800 mW and total working time is about three minutes during our test of our prototype.

The energy used for the fan

= 0.0008kW x 0.05/2.5hours x 24 hours/day x 3 layers per unit=0.0001152 kWh

The total energy consumed by one unit during one cycle of production is about 18.5 kWh

The energy consumption of the Arduino microcontroller and peristaltic pump is negligible.

Appendix C: Scheme Diagram of Model

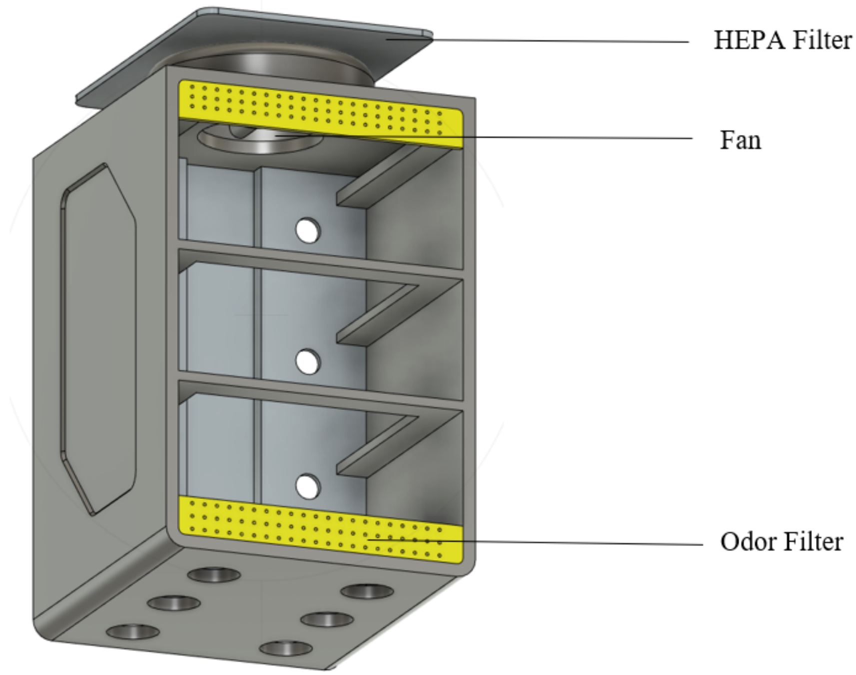

Figure 1: Ventilation System (1)

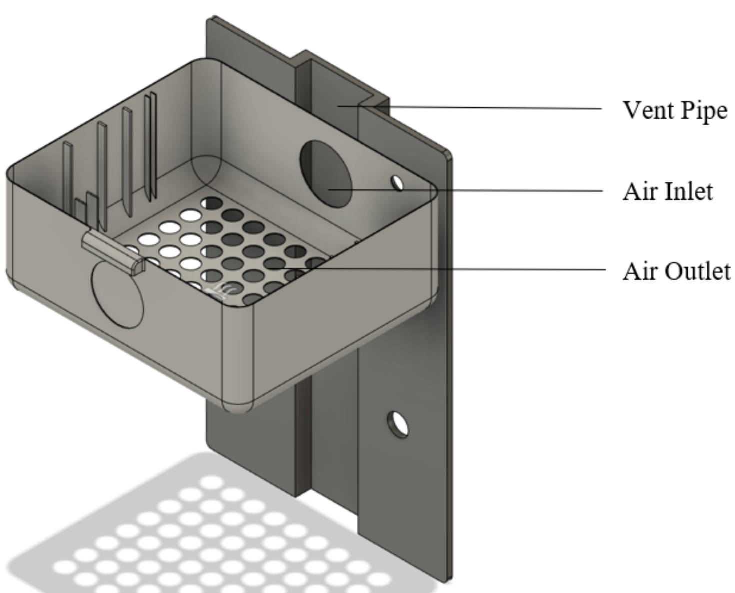

Figure 2: Ventilation System (2)

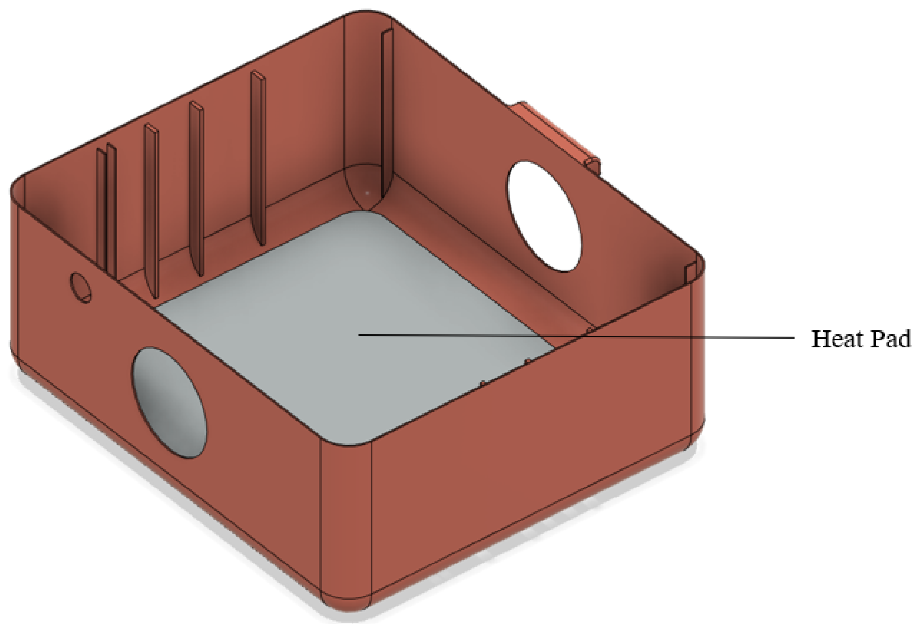

Figure 3: Heat Pad

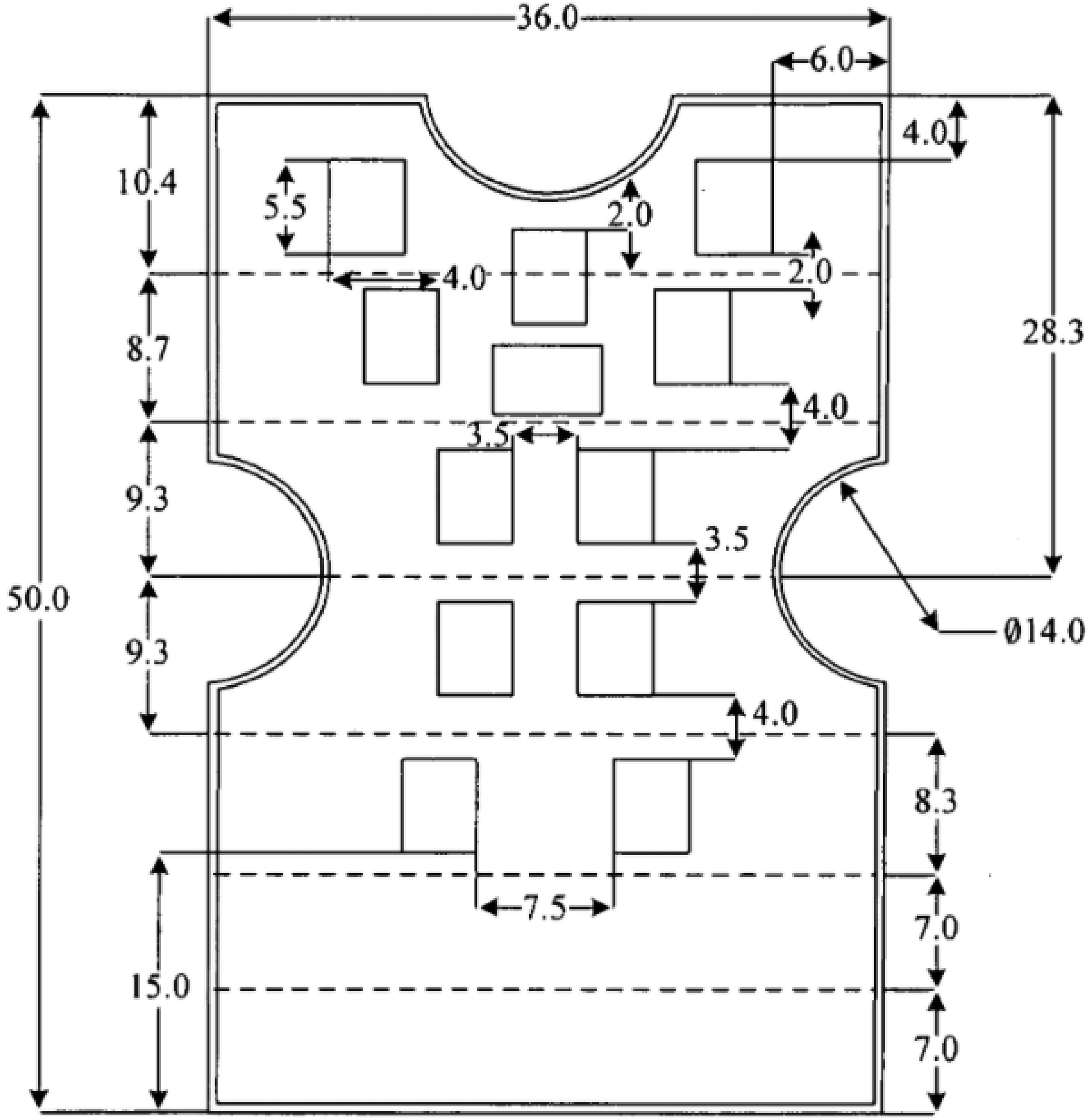

Figure 4: Heat Pad Design

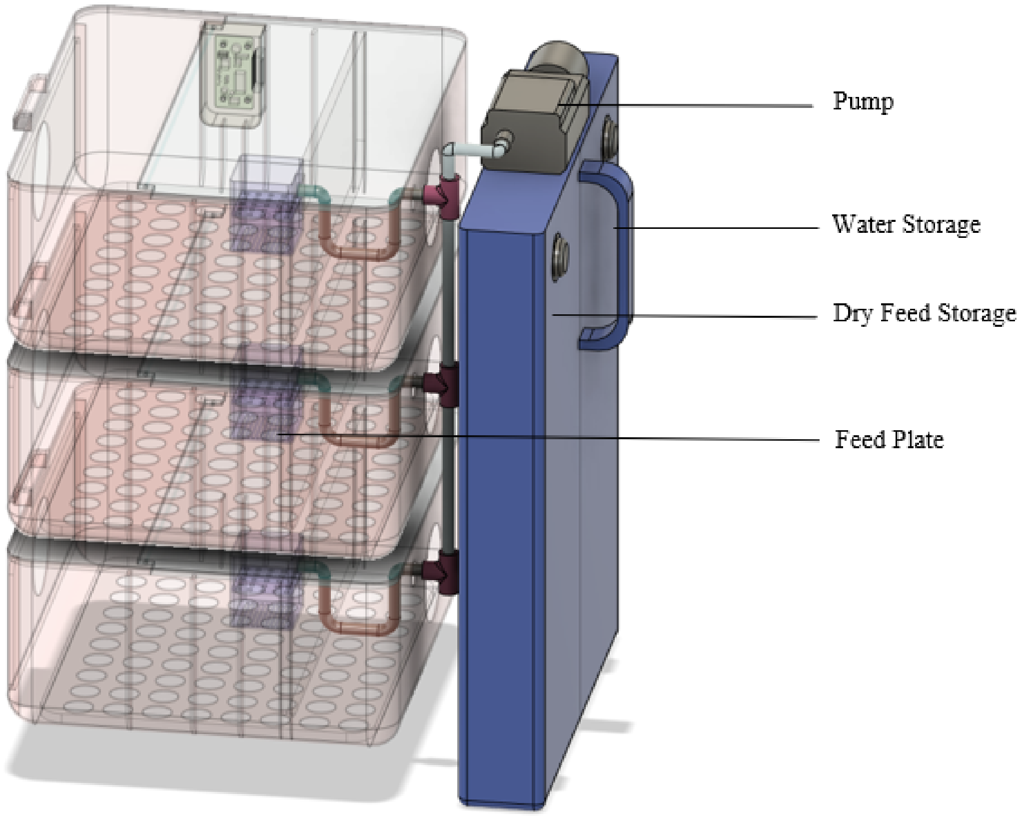

Figure 5: Feeding System

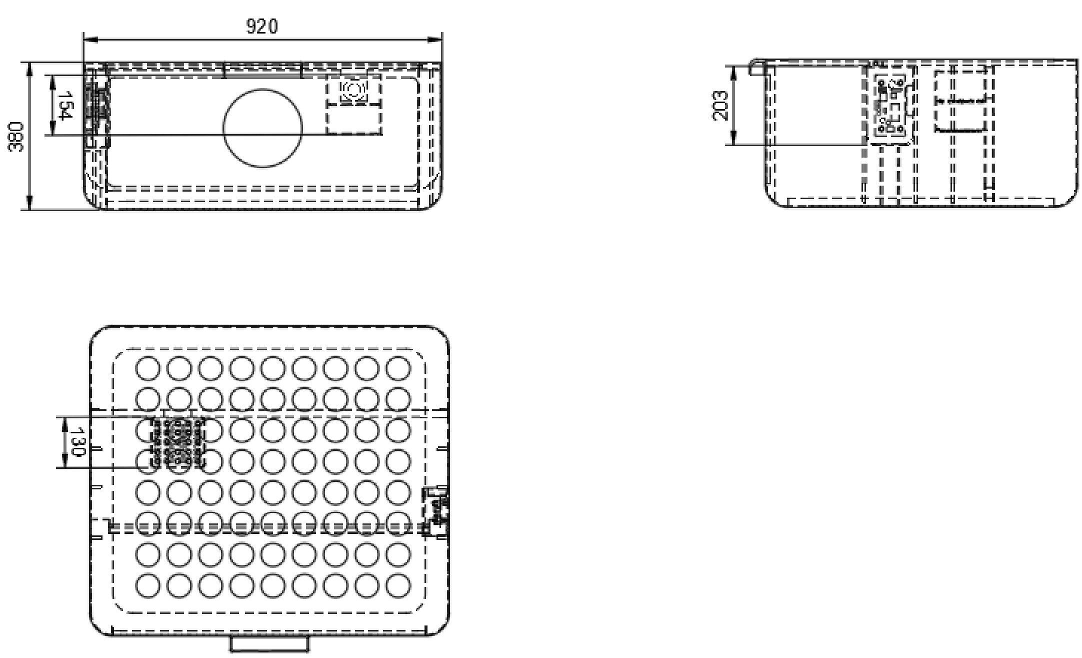

Figure 6: Orthographic View of Tray Design (mm)

Appendix D Operational Diagram and Flow Diagram of The System

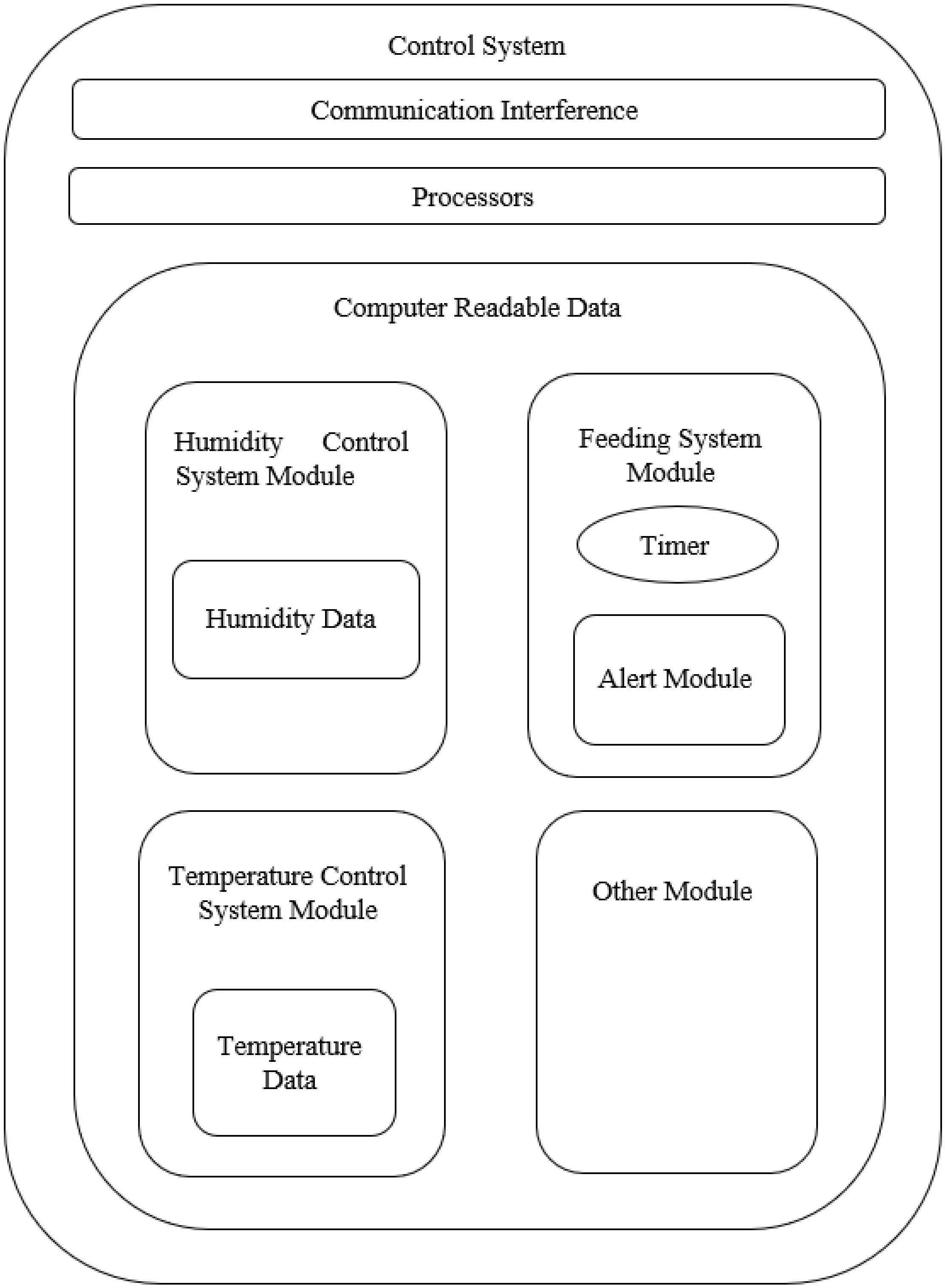

Figure 1: Control System Operational Diagram

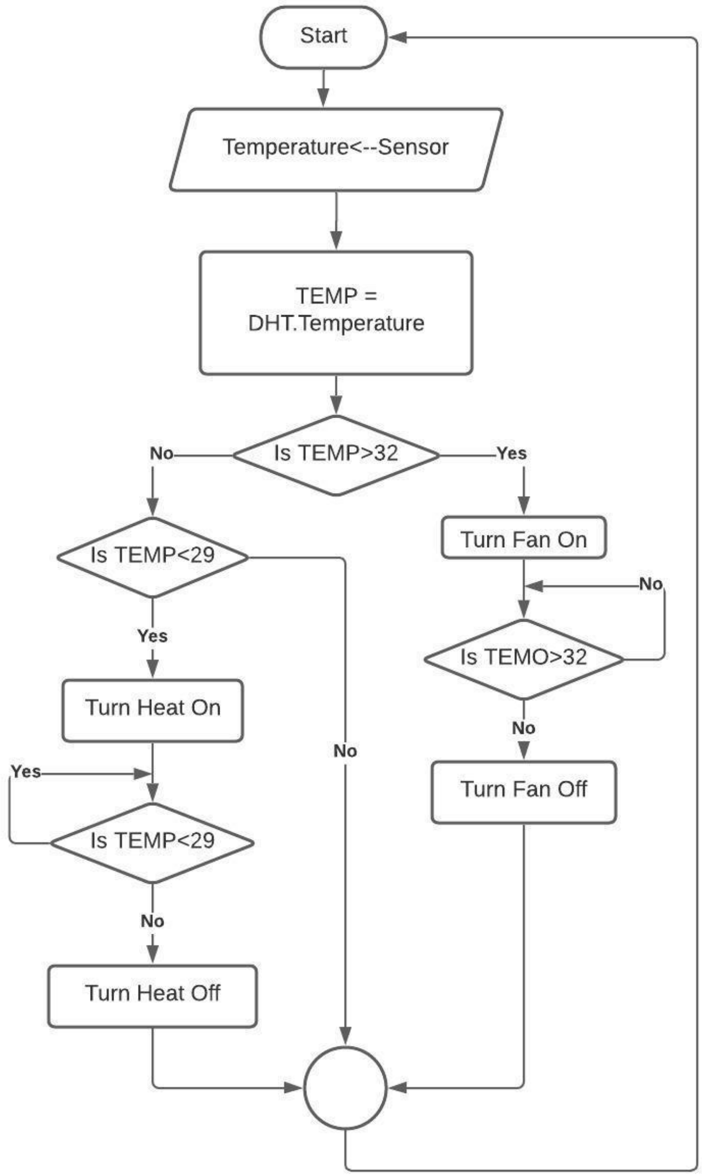

Figure 2: Temperature Control Flow Diagram

Appendix E. Manufacture and Assembly

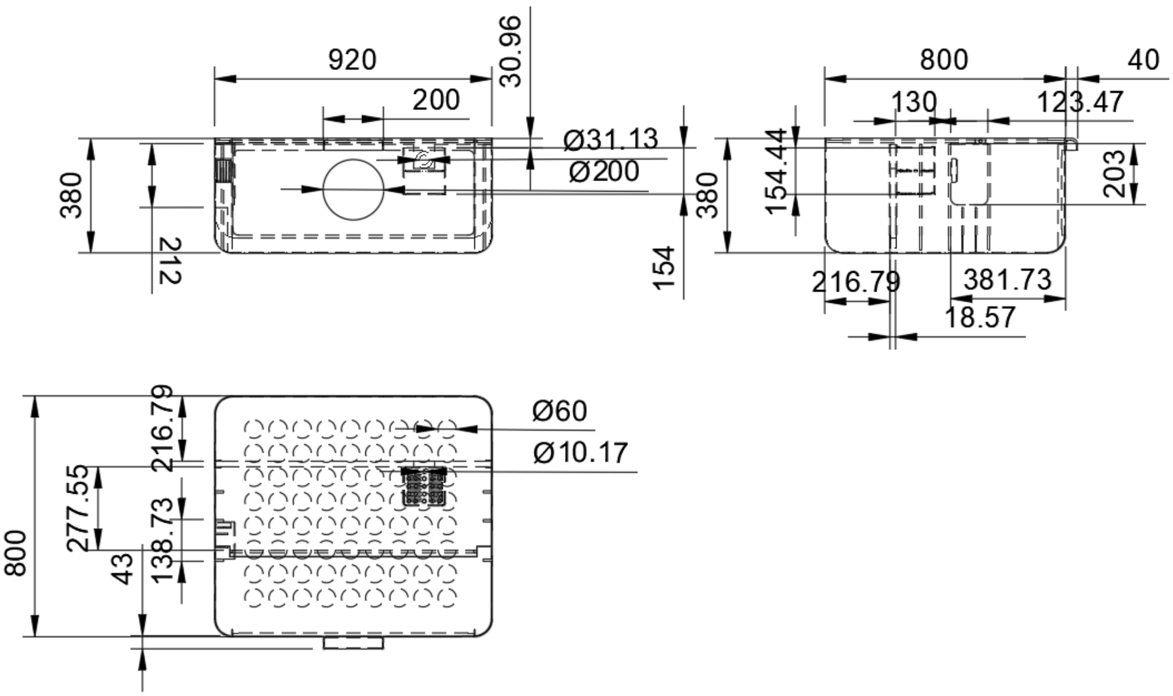

Figure 1. Dimension of Tray Design (mm)

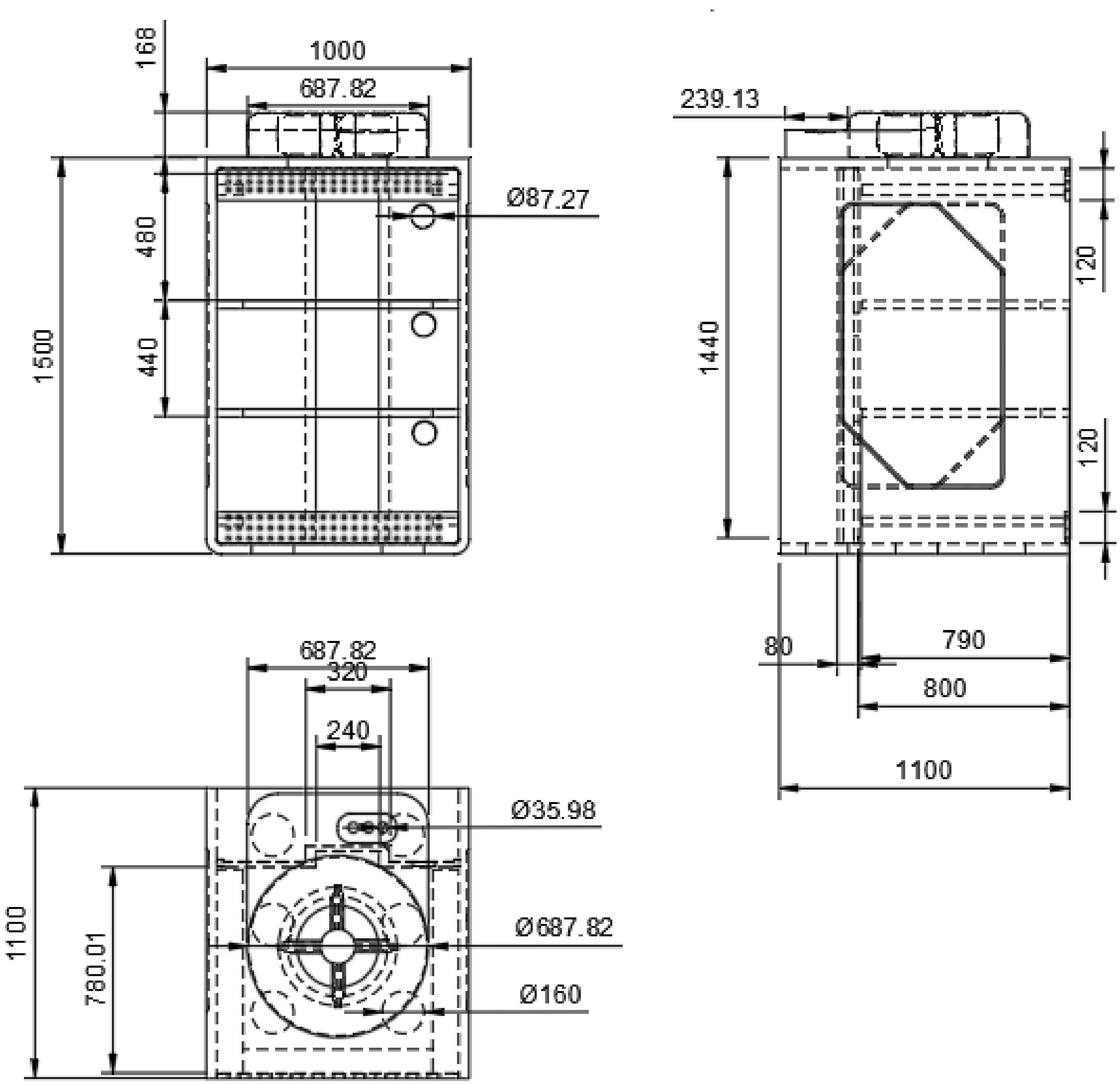

Figure 2. Dimension of Ventilation system

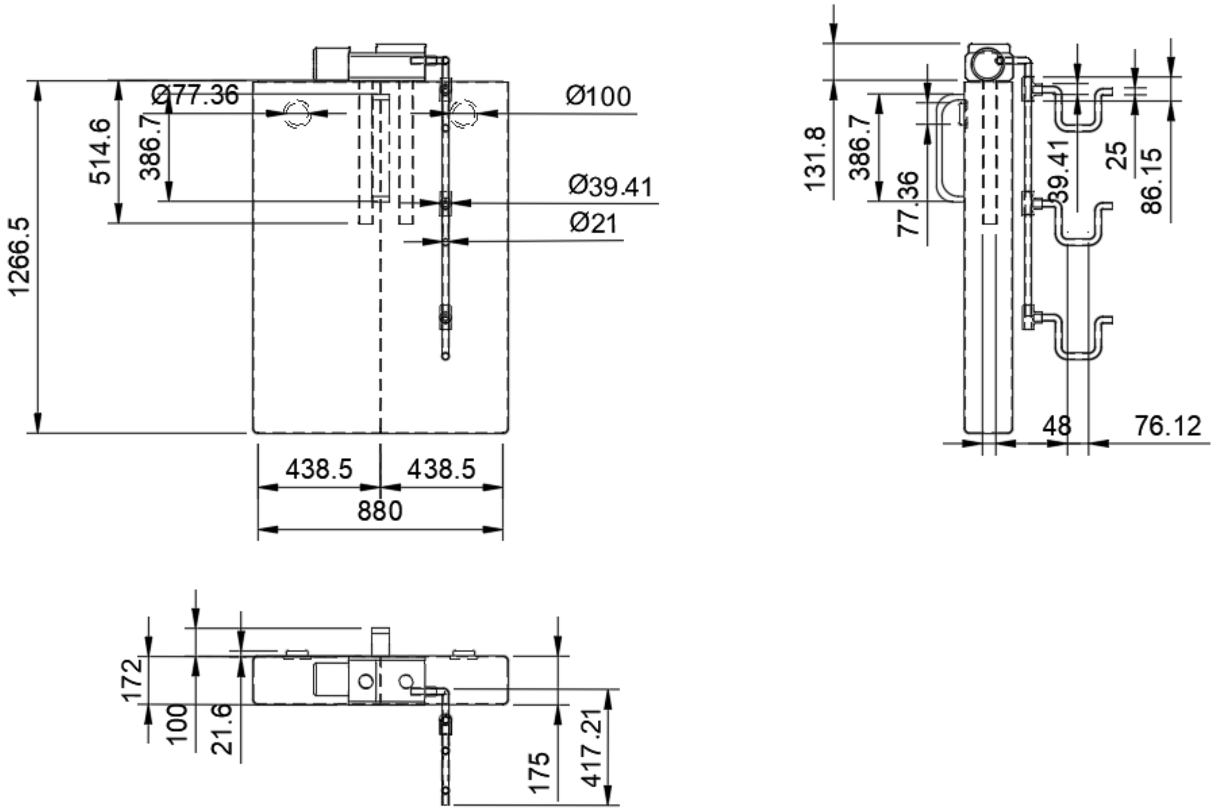

Figure 3. Dimension of Storage Tank

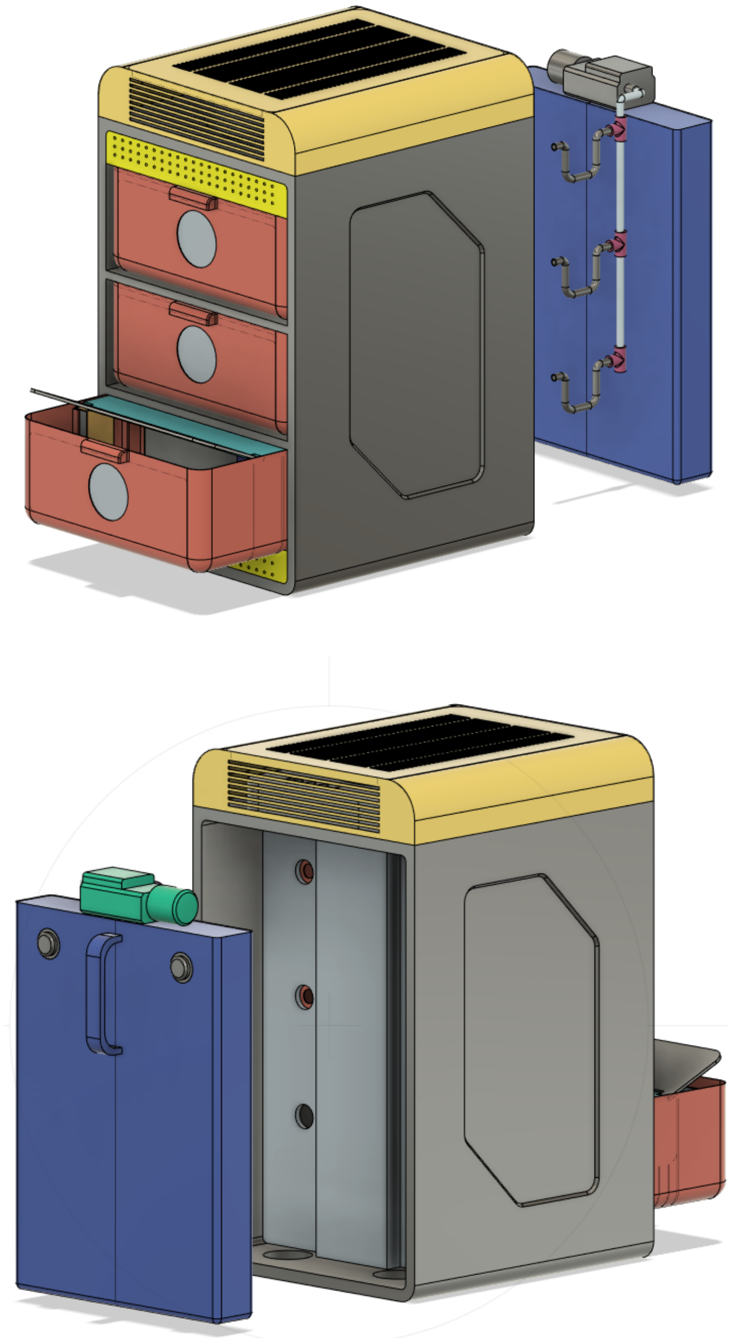

Figure 4. Assembly Schematic Diagram

Appendix F: Test Results

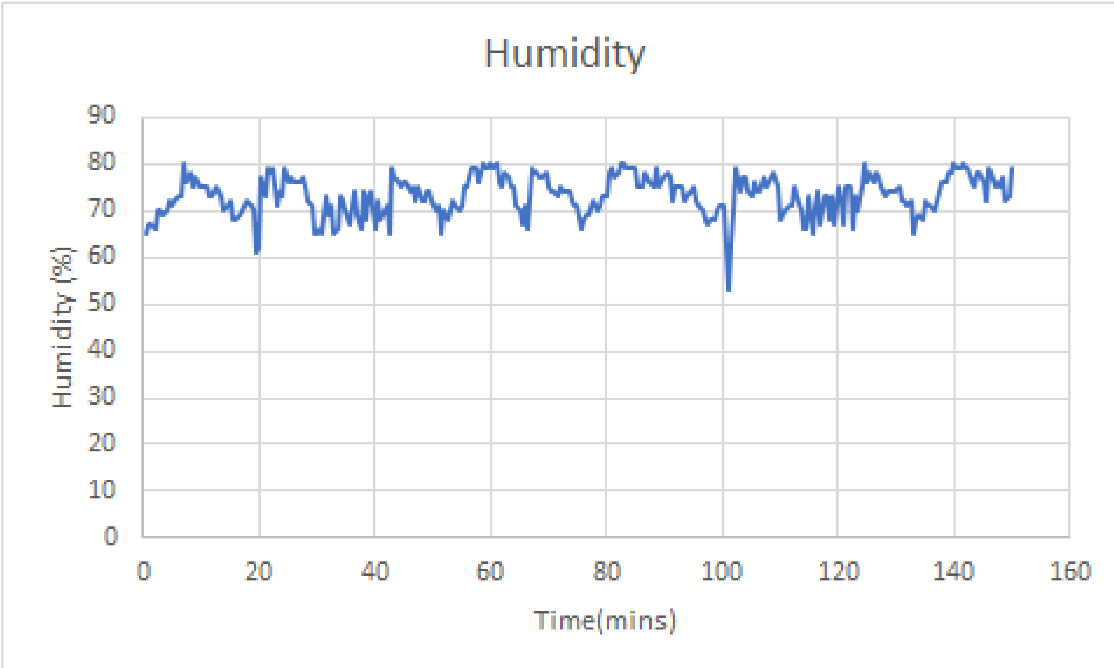

Figure 1. Humidity Test Results

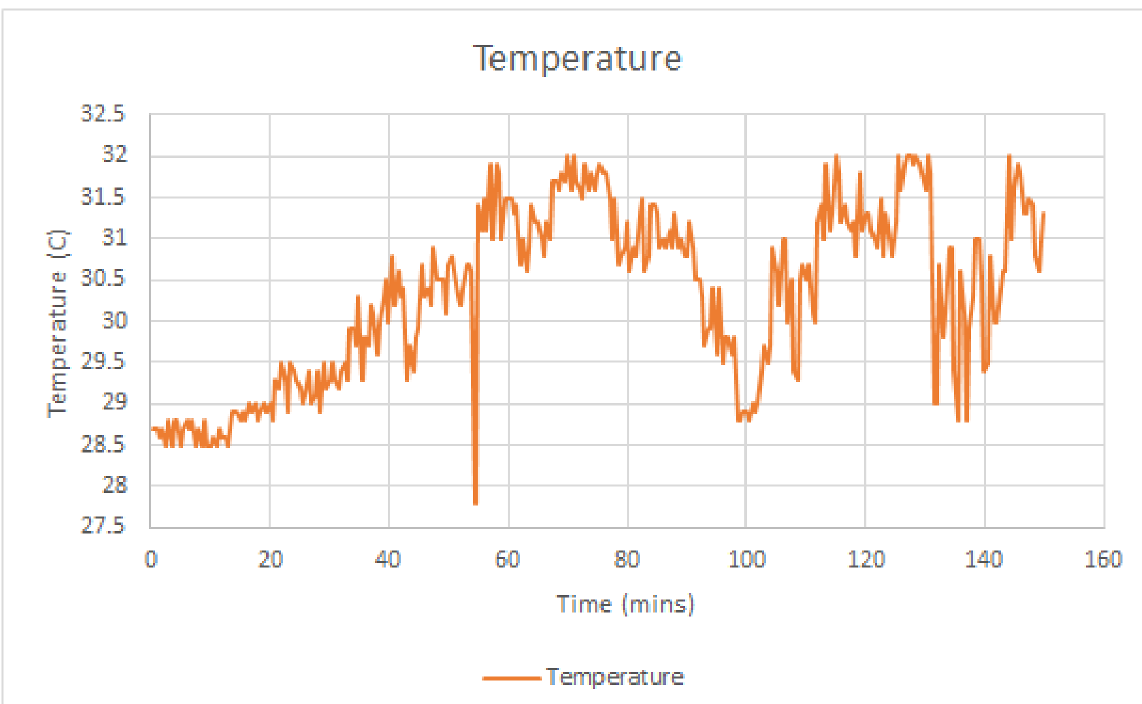

Figure 2. Temperature Test Results

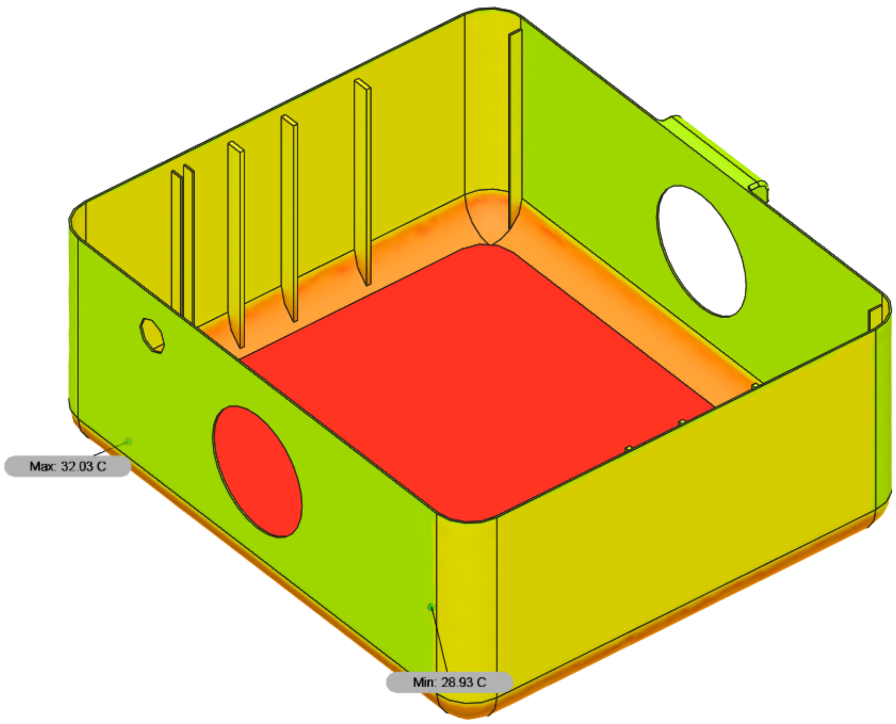

Figure 3. Simulation Result After 30mins

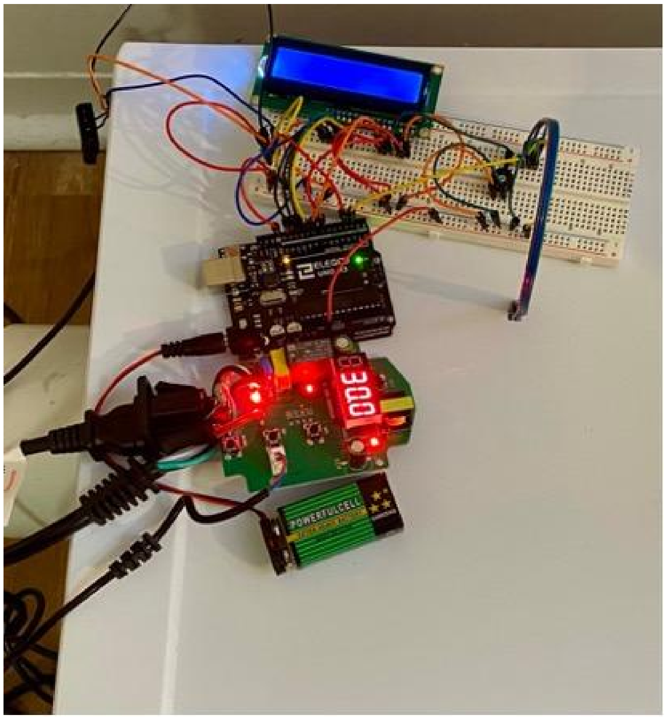

Figure 4: Control system and independent heating system of prototype

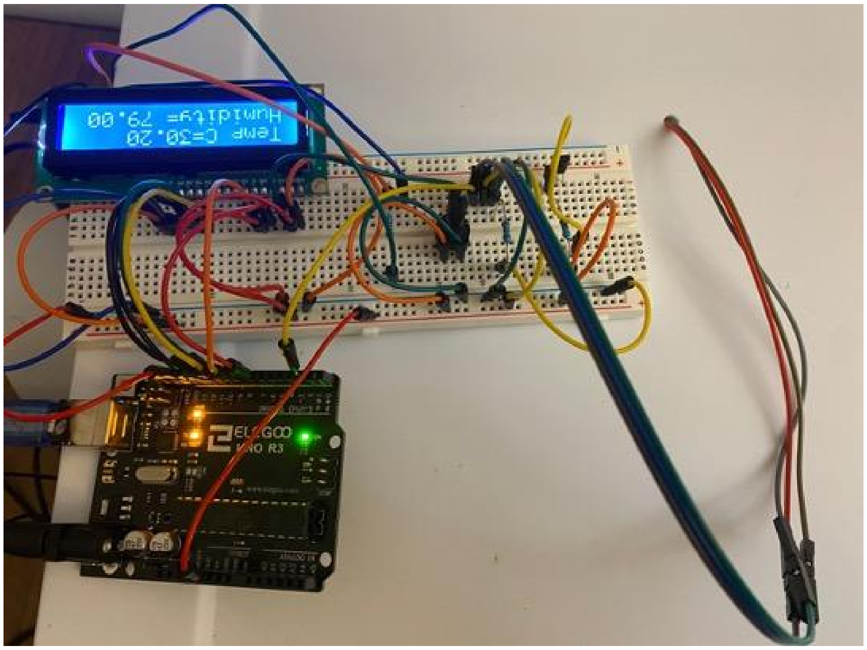

Figure 5: control system of protopype

Figure 6: sensor, humidifier and fan of prototype

Appendix G: Detailed Cost and Material

Component	Material	Cost (CAD)	Reference
Air Inlet Chamber	PVC, Unplasticized	13.56	
Vent pipe	Steel, High Strength Structure	14.50	
Outer structure	PVC, Unplasticized	43.56	
Structural Support	Aluminum	45.00	
Tray	PVC, Unplasticized	11.34	
DHT22 sensor	N/A	3.06	http://ali.pub/1z65wk
Ultrasonic Humidifier	N/A	10.72	http://ali.pub/1z657h
Computer Fan	N/A	3.01	http://ali.pub/1z65yp
Arduino Nano Chip x 3	N/A	49.68	https://store.arduino.cc/usa/arduino-nano
Adaptor 24V AC/DC	N/A	3.02	http://ali.pub/1z65k4
Resistor	N/A	0.67	http://ali.pub/1z66eu
MOSFET Module	N/A	0.40	http://ali.pub/1z65so

XM1587 DC/DC step down	N/A	1.22	http://ali.pub/1z663d
Odor Filter	N/A	0.67	https://www.aliexpress.com/item/4000463994112
HEPA Filter	N/A	29.99	https://www.aliexpress.com/item/1005001718819568
Pump	N/A	26.55	https://www.walmart.ca/en/ip/Domqga-12V-10W-DC-Brushless-Solar-High-Temperature-Water-Pump-for-Circulation-Pumping-Water-Pump-Solar-Water-Pump/PRD2RUEHPM3QFUP
	Total	246.95	