An-Najah National University
Faculty of Engineering and Information Technology
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Graduation Project 2

Granomatic

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Abstract

This project aims to develop a fully automated production line for granola, addressing the increasing demand for healthy and convenient food options. As more consumers shift towards nutritious diets, granola has become a popular choice due to its versatility and health benefits. This system ensures efficient production of high-quality granola that can be consumed as a standalone snack or added to various meals. The production process is carefully designed to maintain consistency, taste, and quality at every stage:

1. Ingredient Selection: Customers can personalize their granola by selecting from a variety of ingredients, including grains, nuts, seeds, and natural sweeteners, allowing for tailored flavors and nutritional benefits.
2. Mixing and Roasting: The chosen ingredients are automatically transferred into a mixing chamber, where they are thoroughly blended and roasted at an optimal temperature to enhance texture, aroma, and flavor. The roasting process ensures a crunchy, golden-brown finish while preserving the natural goodness of the ingredients.
3. Packaging: Once the granola is roasted, it is packed into containers designed to maintain freshness and product quality. By fully automating the production process, this system guarantees efficiency, hygiene, and precision while catering to the growing consumer preference for healthy and on-the-go snack options.

Introduction

In today's fast-paced world, people are becoming increasingly health-conscious. Many individuals are shifting their eating habits toward healthier and more natural foods that are also quick and easy to consume. Granola has become a popular choice due to its versatility, nutritional value, and convenience. It can be eaten on its own as a snack, used as a topping for yogurt, or included in various meals. However, preparing granola manually takes time and may lead to inconsistencies in taste, texture, and hygiene. For this reason, our project focuses on designing and building a fully automated granola production system that allows users to customize their mix while maintaining consistency and quality throughout the process. This system combines the fields of food production, electronics, and automation.

1.1 Problem Statement

Traditional granola production methods often rely on manual labor, which results in several draw backs .These include inconsistent quality, increased human error, longer preparation time, and limited options for ingredient customization. Most granola available on the market comes in fixed combinations, offering little flexibility to consumers with dietary preferences or allergies. Additionally, manual handling of ingredients increases the risk of contamination. Therefore, there is a strong need for an automated system that produces granola efficiently, maintains hygiene, and allows customers to personalize their mix based on their own preferences.

1.2 Objectives

The primary objectives of this project are:

1.To design and implement a fully automated granola production system that reduces human intervention.

2.To allow users to select their desired ingredients, such as oats, nuts, seeds.

3.roast the ingredients automatically while maintaining proper temperature and timing to achieve consistent quality.

4.To ensure the entire process is clean, efficient, and repeatable.

1.3 Scope of Work

This project focuses on developing a functional prototype of an automated granola production system. The system includes a user input interface for selecting ingredients, an automated mixing and roasting system, and a microcontroller that manages the entire process. It is designed for small-scale production and is intended to serve startup businesses, cafes, or even home use.

1.4 Significance:

This project addresses the growing demand for nutritious, customizable food solutions in an increasingly health-aware society. By automating granola production, the system offers convenience to consumers and reduces effort for producers. It ensures a cleaner, safer production environment and helps prevent cross-contamination or human-related errors. Technologically, it encourages students to apply knowledge from various fields—such as electronics, embedded systems, and control engineering—to solve real-life problems. Moreover, the ability to personalize granola recipes makes the system more appealing to niche markets and individuals with specific dietary needs.

1.5 Organization of the report :

The report starts with the introduction, included the problem statement, the objectives of the project, the scope of work, significance.
The second chapter takes the limitations and constraints the forces us during work on the project, also the standards we use and the programs we used in coding and application, finally the earlier coursework.
The next chapter takes the literature review, In that chapter, relevant work and results are included.
Then, the chapter of methodology, which goes deeply on the project, its structure, components used to build it, the electronic hardware components, and talking specifically with details about how the system works.
The fifth chapter includes the results and analysis, then the conclusion and discussion chapter, which give the summary of the project, and the future work that can be done to the project.

Constraints and Earlier Coursework

2.1 Constraints and Limitations

1.The main problem was finding the appropriate structure for each stage to complete its work perfectly.
2.The nature of the ingredients used to make granola, such as the moist cocoa, made it difficult to handle.
3.The process required additional time for roasting the ingredients.

2.2 Standards / Codes

• For the development of the code, we used the Arduino IDE environment, which allowed us to directly control the hardware using the functionalities provided in the Arduino platform.
• The web page was created to allow users to control the system remotely.

2.3 Earlier Coursework

• The Critical Thinking course taught us how to research effectively, which helped a lot with documenting our work and writing reports.
• The Microprocessor and Microcontroller and their labs gave us hands-on experience with controlling the hardware components in our project and knowing how to deal with the components' datasheets.
• The Wireless and Networks courses played a key role in helping us understand how to connect different devices, which we applied by linking the system to the web page.
• The Electronics and Digital Circuits courses provided a strong foundation in electronic systems, which was vital for our project. Along the way, we also relied on self-learning through YouTube Arduino tutorials and independent research to deepen our understanding.

Literature Review

Granola has become one of the most popular healthy snacks due to its nutritional benefits and versatility. It is a commonly consumed breakfast or snack item made from a mixture of oats, nuts, seeds, dried fruits, and sweeteners like honey or sugar. The growth in demand for granola has led to an interest in streamlining its production while maintaining its nutritional and cultural value.

Oats, the primary ingredient in granola, are considered a rich source of soluble fiber, particularly beta-glucan, which helps lower cholesterol levels and supports heart health. Studies have shown that consuming oats can reduce harmful cholesterol levels and improve blood sugar regulation, making it an ideal ingredient for a healthy snack (Slavin, 2013). Oats also provide sustained energy, which is beneficial for athletes and individuals with high physical activity levels (Rogers et al., 2018).

Nuts like walnuts, almonds, and cashews are excellent sources of proteins and unsaturated fats, which help promote heart health and strengthen the immune system. Nuts also contain essential minerals such as magnesium and phosphorus, which support bone and muscle health. Research suggests that nut consumption can improve cholesterol levels and reduce inflammation, thereby enhancing overall health (Berryman et al., 2018). Nuts are also known for their antioxidant properties, which help reduce oxidative stress in the body (Ros et al., 2010).

Cocoa, despite being known for its flavor, is also rich in antioxidants, such as flavonoids, which help improve circulation and cardiovascular health. Studies have indicated that cocoa consumption can lower blood pressure and enhance vascular function, thus benefiting heart health (Mursu et al., 2011). Additionally, cocoa has been shown to have cognitive benefits, improving brain function and memory (Desideri et al., 2012).

Sunflower oil is considered a healthy source of unsaturated fats, helping improve cholesterol levels and reduce the risk of heart disease. It is also rich in vitamin E, a key antioxidant that promotes skin health and strengthens the immune system. Research has shown that sunflower oil can help reduce inflammation and improve heart health (López-García et al., 2004). Furthermore, sunflower oil is often used in cooking due to its mild flavor and high smoke point, making it an ideal option for granola preparation (Yuan et al., 2019).

The demand for healthy food products like granola is continuously increasing, and the integration of technology into its production process has become crucial. In industries like olive oil production, technology has significantly sped up production while maintaining product quality (Foxhall, 2008). Similarly, for small-scale producers of granola, employing technology can meet rising demand without compromising the traditional values of the product.

The development of scalable machines for granola production can provide prosperity to local communities by increasing efficiency while preserving the cultural value of the product. Food technology research demonstrates that such innovations can benefit both small farms and larger operations (Hameed et al., 2018). The introduction of technology in granola production could help small-scale producers maintain quality while increasing output to meet the demands of global markets.

Using modern technology does not only help in increasing production speed but also in ensuring that ingredients like nuts and oats are evenly distributed, improving the overall quality of the final product. This efficiency and consistency in production are vital for the long-term success of granola as a healthy food choice in the marketplace.

Methodology

4.1 System Structure

4.1.1 Project body

The structure of the granola-making prototype was built using wood. It consists of a long, rectangular box, open from the front to showcase the main components of the system, such as the ingredient containers and roasting mechanism. The back part of the structure is a closed cabinet that houses the hidden components such as motors, electrical wiring, and control elements. The total length of the structure is approximately 170 cm, while the width is estimated to be around 60 cm.`

Figure 1 Project body

4.1.2 Ingredient Storage

To ensure organized and efficient ingredient handling, several plastic containers were integrated into the front section of the system. These containers are designed to store both dry and liquid materials essential for the granola-making process.
Some of the containers include internal vertical rods connected to motors, which rotate to stir dry ingredients. For other solid ingredients, servo motors are used in specific containers to control their release when needed . As for the liquid containers, a dedicated pump is utilized to accurately and hygienically transfer fluids during the preparation process.

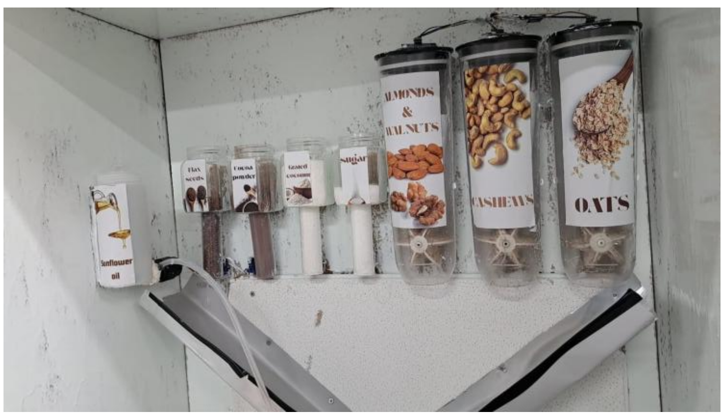

Figure 2 Ingredient Storage

4.1.3 Ingredient Release

Beneath the ingredient containers, thin iron sheets were installed to serve as inclined platforms for releasing materials. When ingredients are dispensed from the containers, they fall onto these sloped metal sheets, which guide and roll the materials smoothly into the designated mixing and roasting area.

Figure 3 Ingredient Release

4.1.4 Mixing and Heating Unit

At the core of the preparation process is a stainless steel bowl that functions as the main unit for both mixing and heating the ingredients. A DC motor is mounted on top of the bowl to rotate an internal stirring mechanism . Beneath the bowl, a heating element powered by 220V is installed to roast the granola mixture to the desired level. Additionally, the bowl is supported from the back by a stepper motor, which provides controlled rotation as needed.

Figure 4 Mixing and Heating Unit

Figure 5 Heating

4.1.5 Ingredient Guiding Funnel

To ensure that the mixed and roasted ingredients are directed accurately into the final container, a metal funnel-shaped piece was installed at the bottom of the mixing unit. This iron component serves as a guide, collecting the materials and channeling them smoothly into the designated section of the final packaging container.

Figure 6 Ingredient Guiding Funnel

4.2 Hardware components

4.2.1 Arduino MEGA

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTS (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller. We used it for the large number of inputs/outputs it has that we needed to get this project done. We basically connected most of the components on it like ESP8266 (NodeMCU), all the sensors, the DC motor. This will also include another stepper motor,water valves and a water pump.

Figure 7 Arduino MEGA

4.2.2 ESP32-S Module

The ESP32-S is a powerful and compact development board designed for IoT and embedded applications. It is based on the ESP32 microcontroller, which integrates both Wi-Fi and Bluetooth connectivity, making it ideal for wireless communication tasks. The module supports the 802.11 b/g/n Wi-Fi standard at 2.4 GHz and includes an integrated TCP/IP stack, allowing reliable data exchange over networks.

The ESP32-S also features a built-in PCB antenna, micro USB connector, and essential components such as a reset button and voltage regulator. It is programmable via the Arduino IDE and other platforms, offering compatibility with various programming languages and libraries. The board supports multiple GPIOs, PWM, ADCs, DACs, and communication protocols like UART, SPI, and I2C, enabling flexible interfacing with sensors, actuators, and other peripherals.

In our project, the ESP32-S was used to wirelessly transmit sensor data and control signals between different modules. It played a key role in managing the communication logic and integrating the system components efficiently.

Figure 8 ESP32-S Module

4.2.3 Computer Power Supply

ISO-450 ATX Computer Power Supply 350W, 5V 32A, 12V 16A. Also we needed to yse an external power supply 24-volt for water valves which will explain later.

Figure 9 Power Supply

4.2.4 Water Pump

We used a high-pressure 12V 3.7A DC pump to transfer oil from the container to the mixing bowl. It ensured a strong and continuous flow, allowing the liquid to move efficiently during the preparation process.

Figure 10 Water Pump

4.2.5 Water Valve

GEMS SENSORS and CONTROLS P/N- A2017-S174 / 24VDC / 7.4W. Valves are used to control oil flow in pipes. They can allow oil to flow in one direction only (check valves), control the flow rate (control valves), or completely stop oil flow (shut-off valves).Three valves are used for one for filling and two for control the direction of oil.

Figure 11 Water Valve

4.2.6 DS18B20 Temperature Sensor

Waterproof DS18B20-Compatible Temperature Sensor is a digital thermo probe or sensor that employs DALLAS DS18B20 used to measure temperature inside the mixing bowl.

Figure 12 DS18B20 Temperature Sensor

4.2.7 Ultrasonic sensor

An ultrasonic sensor was used to measure the quantity of materials inside the containers by detecting the distance from the sensor to the surface of the contents. This allowed the system to monitor ingredient levels accurately. three sensors were used in the project for this purpose.

Figure 13 Ultrasonic sensor

4.2.8 NEMA 17 Stepper Motor

The NEMA 17 stepper motor is widely used due to its compact size and high torque output. It requires 200 steps to complete one full revolution, with an accurate step angle of 1.8 degrees. Each coil can handle up to 3.5 A of current, and the motor operates within a voltage range of 3 to 12 volts. In this project, the NEMA 17 stepper motor was used to control the release of solid ingredients from the storage containers. By rotating the motor, it moves a connected mechanism that opens the container outlet, allowing materials to drop into the mixing area. Reversing the motor's direction resets the mechanism for the next cycle.

Figure 14 NEMA 17 Stepper Motor

4.2.9 NEMA 32 Stepper Motor

The NEMA 23 stepper motor is known for its larger size and higher torque compared to smaller stepper motors like the NEMA 17, making it suitable for applications that require more mechanical force. It typically requires 200 steps for a full revolution, with a step angle of 1.8 degrees per step. The motor can operate within a voltage range of 3 to 12 volts and supports higher current ratings. In this project, the NEMA 23 stepper motor was used in tasks that required greater mechanical strength, such as rotating or moving heavier parts of the system.

Figure 15 NEMA 32 Stepper Motor

4.2.10 SG37BL-A DC Brushless Gear Motor

A 12 volt DC Motor is used when both a high starting torque and good speed regulation is needed. In this project we used two DC motors to move the nut to release HCl and chlorine from the syringe during the disinfection process.

Figure 16 DC Brushless Gear Motor

4.2.11 Relays

Relay is a device which is electrically controlled to initiate and end electrical connections, or activate and deactivate operation of other appliances within the same or different electrical network. We used active low relays to turn on/off the heater, water pumps, valves , and dc motor.

Figure 17 Relays

4.2.12 Power adapter from 220v to 12v & 9v

It was used to supply electricity to the solenoid valve, and the DC motor.

Figure 18 Power adapter

4.2.13 Servo Motors

Servo motors were used to control the release of dry ingredients from specific containers. By rotating a small internal arm connected to an outlet mechanism, the servo motor allowed precise opening and closing of the container exit. This enabled accurate dispensing of the required quantity of materials into the mixing area.

Figure 19 Servo Motors

4.2.14 Arduino Wires

To be able to connect the components to the Arduino.

Figure 20 Arduino Wires

4.2.15 Intercom Wires

We used them for wiring and connecting different components together.

Figure 21 Intercom Wires

4.2.16 Microstep Driver

A microstep driver was used to control the stepper motor with high precision. It receives pulse and direction signals from the microcontroller and regulates the current delivered to the motor coils. The driver supports a wide input voltage range (9V–42V DC) and allows adjustment of both current and microstepping resolution using built-in DIP switches. This ensured smooth and accurate rotation of the stepper motor according to system requirements.

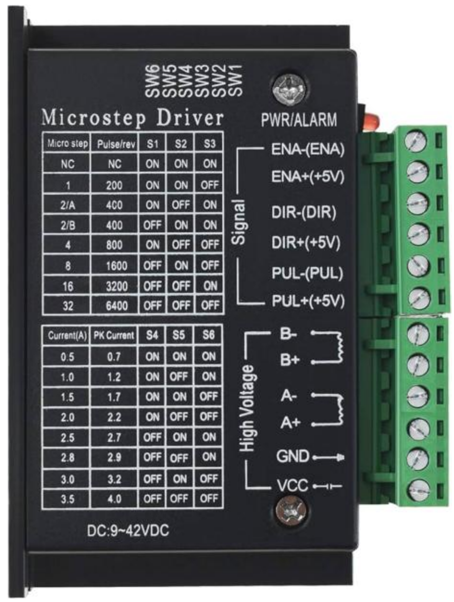

Figure 22 Microstep Driver

4.2.17 4.7K ohm resistor

It is connected to the 1DS18B20 Temperature Sensor.

Figure 23 4.7K ohm resistor

4.3 Mobile Application

The system is connected to a web application that enables remote control and monitoring. It includes five interfaces: four for users to select granola ingredients and track the manufacturing process in real time, and one for the owner to monitor key operational data like heating temperature and ingredient levels. The app ensures effective interaction between users and the machine, improving system management.

4.3.1 Start page

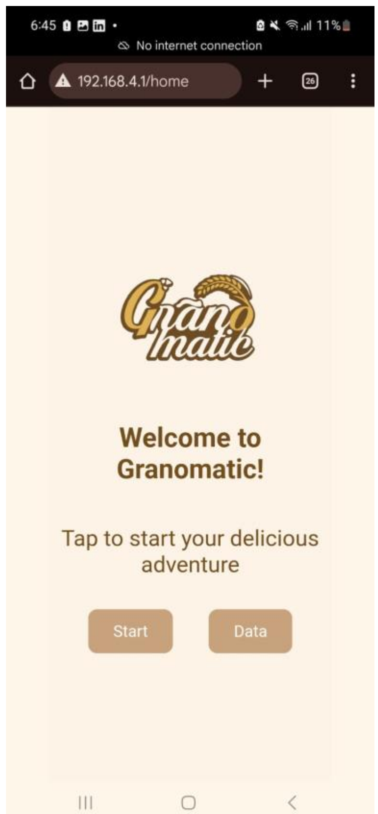

Figure 24 Start page

The page includes 2 buttons implies to other pages.

4.3.2 Ingredients Selection Page:

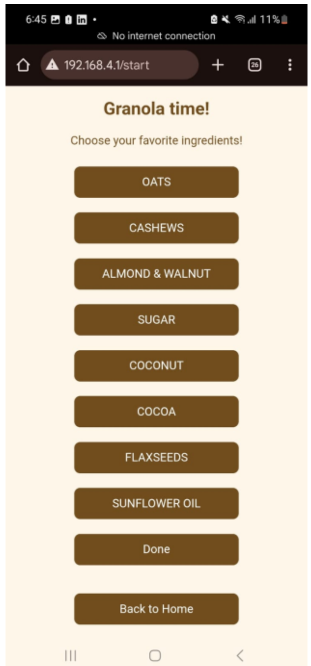

Figure 25 Ingredients Selection Page

This page allows users to choose the specific ingredients they want to include in their granola mix. Users can also specify the quantity of each ingredient, customizing their order before starting the production process.

4.3.3 Roasting Process Page:

Figure 26 Roasting Process Page

On this page, users can monitor the real-time progress of the roasting phase.

4.3.4 Granola Ready Page:

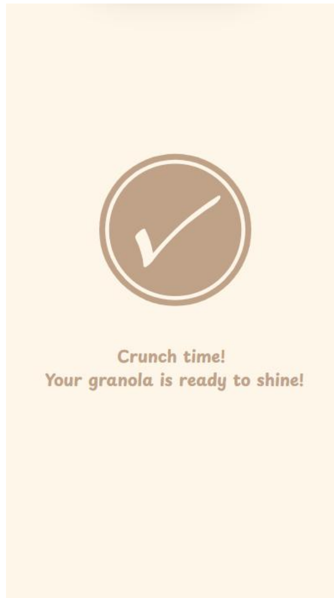

Figure 27 Granola Ready Page

Once the roasting and mixing are complete, this page notifies users that their granola is ready.

4.3.5 System Readings Page:

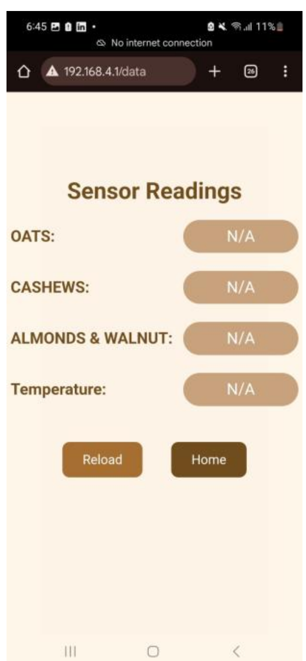

Figure 28 System Readings Page

Designed mainly for the machine owner or operator, this page shows critical operational data including the current temperature of the heating unit and the remaining quantities of each ingredient in the storage containers. This helps in maintaining optimal performance and timely refilling.

4.4 How the system works?

Since the Arduino mega and esp8266 connected to the power, and the application-tion is now opened and the WIFI network is the one for the Esp, the system starts, and all components are stopped, waiting for the user to choose what process he needs, the processes are as follow:

The process begins when the user presses the "Start" button in the application. At this point, the system automatically dispenses oats and oil to start the base mixture.
Next, the user selects additional ingredients according to their preference. These can include walnuts, almonds, cashews, sugar, cocoa, chia seeds, and coconut. If the user wants to add a larger amount of any ingredient, they can simply double-tap the button to increase the quantity.
Once the ingredients are selected, the user confirms their choice by pressing the "Done" button. This triggers the roasting and mixing phase of the production.
During the roasting and mixing phase, a cycle is repeated 22 times. Each cycle consists of mixing the ingredients for 3 seconds, heating them for 40 seconds, and then mixing again for 3 seconds. While heating, the system continuously monitors the temperature. If the temperature rises above 150°C, heating stops temporarily, and only mixing continues until the temperature drops below 150°C, after which heating resumes as normal.
After completing all 22 cycles of roasting and mixing, the granola undergoes the stirring phase for packaging preparation. Then, the system automatically transitions to the "Granola is ready" screen, indicating that the product is finished and ready.

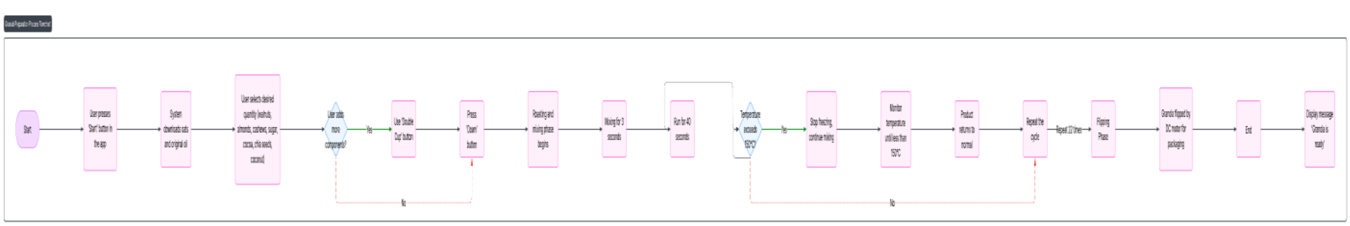

Figure 29 How the system works

4.5 Hardware connections

4.5.1 Filling part

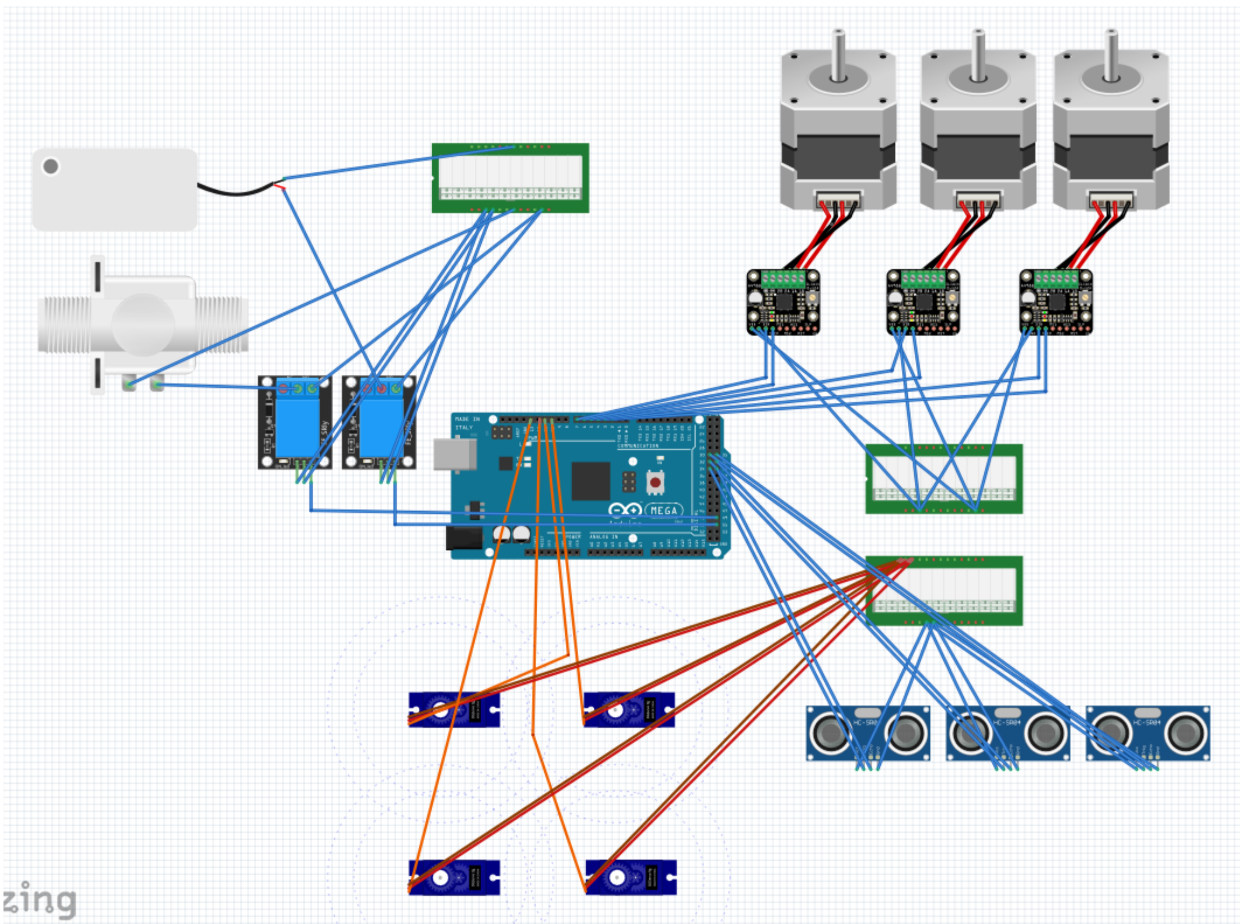

Figure 30 Filling part

4.5.1 Roasting, stirring and flipping part :

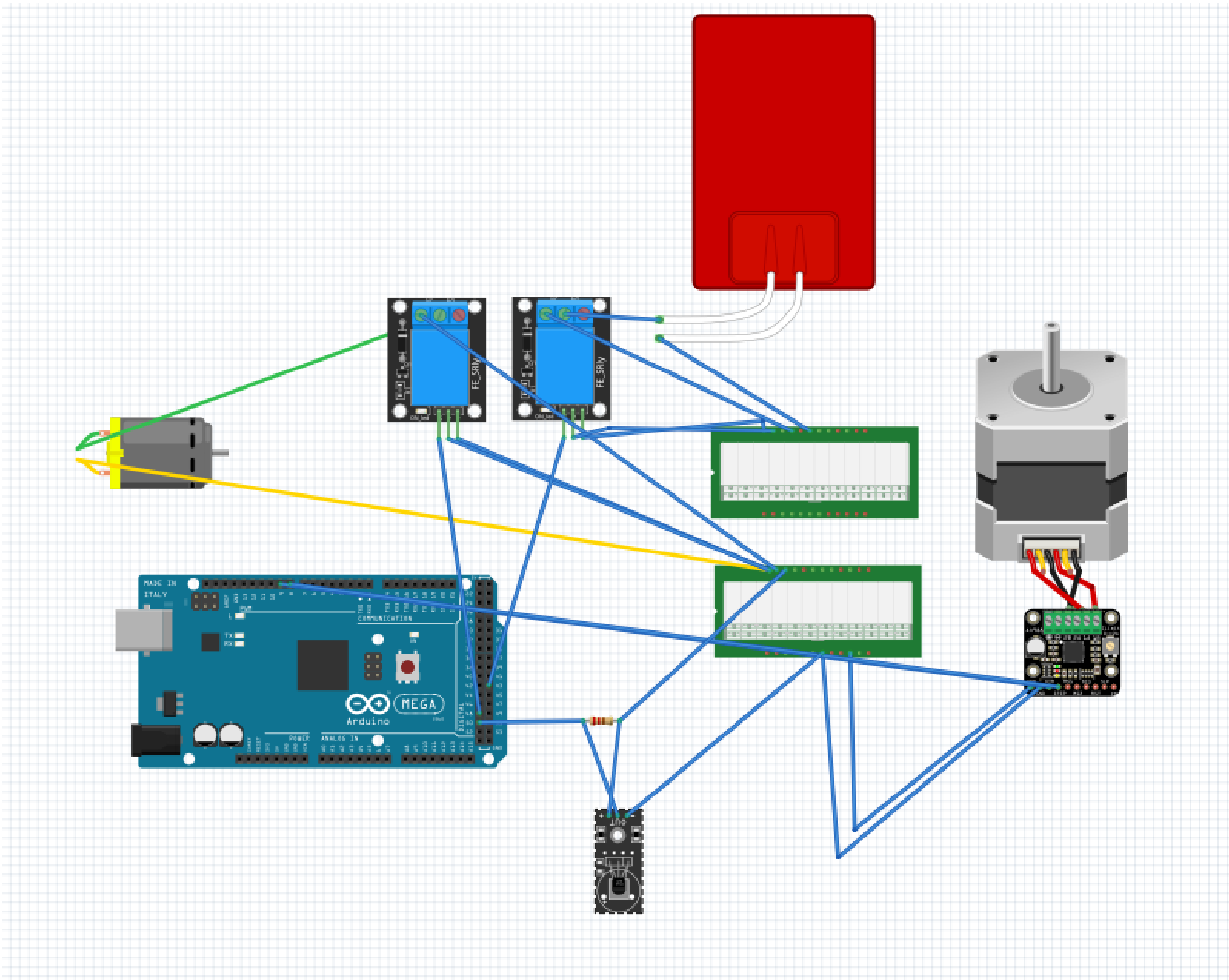

Figure 31 Roasting, stirring and flipping part

Results and Discussion

We successfully transformed raw oats and nuts into granola, and we are pleased with the outcome. We also added sweeteners like sugar, coconut, cocoa, and other ingredients.
However, we encountered some challenges during the process:

1.Oil Control: One of the difficulties was controlling the amount of oil that needed to be pumped. We had to find a mechanism to regulate the oil flow accurately.

2.Slipping Problem: Some materials had a different consistency, making it difficult for them to slide across the surface. Specifically, some ingredients were sticking. To solve this, we chose a specific type of metal that allowed the materials to slide smoothly into the pot without sticking.

3.Uneven Cooking Speed: We faced a challenge where some ingredients cooked faster than others, leading to burning before the granola was fully ready. The solution was to adjust the distance between the heat source and the pot to ensure more even heat distribution.

4.Nut Size: The large nuts were causing uneven roasting, so we decided to break them into smaller pieces for more uniform roasting.

Conclusion and Future Work

Conclusion

The granola model based on Arduino and various motors demonstrates how a single machine can automate every aspect of granola production. It efficiently dispenses nuts, flavors, oil, mixes them, and roasts, saving time and effort. The system also provides enhanced convenience, safety, and efficiency. This system serves as an example of automation in a context where more machines are likely to be used in kitchens due to the benefits offered by digital technology in daily tasks, opening the door for further innovations in granola production.

Future Work

• Implement autofill mechanisms for ingredients such as oats, nuts, and flavors.

• Enable the option to scale production size and select the desired weight for the final product.

• Use weight sensors to handle ingredient measurements more accurately, replacing timing-based methods.

• Develop a wrapping system to improve the efficiency of production.