Designing an Automated Machine to Sort Argan Nuts for Kibbutz Ketura and Understanding Decision Making Structures

An Interactive Qualifying Project submitted to the faculty of WORCESTER POLYTECHNIC INSTITUTE in partial fulfillment of the requirements for the degree of Bachelor of Science

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Abstract

A new solution for sorting Argan nuts is necessary to increase the output of Argan oil for Kibbutz Ketura's experimental Argan oil program. The continued support of Kibbutz Ketura's community is required for further production. We designed an automated machine to sort argan nuts by size and researched different organization structures to understand how decision-making influences the argan oil program. The design autonomously sorts argan nuts and can be scaled up and implemented into the existing pilot process.

Acknowledgments

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Introduction

Across Israel, homesteaders have established communal villages called *kibbutzim.* On a *kibbutz*, residents live and work together as a tight-knit community. The origins of kibbutzim have roots in Zionism, an ideology born in the late nineteenth century which advocated for the establishment of a permanent homeland for the Jewish diaspora (Tishby, 2021). Kibbutzim originated in the early twentieth century in the form of agricultural communes founded by young groups of socialist Zionists. Today, kibbutzim are similar to villages, where residents work in a wide variety of industries. Kibbutzim use complex internal structures of leadership, utilizing committees and boards to manage member's jobs, the resources they produce, and the salaries that they are paid (N. Solowey, Personal Communication, 2024). A member of the kibbutz is a person who has applied for and been accepted into the kibbutz's community. Simple residents, those on trial periods, and children being raised on the kibbutz are not considered members (Tishby, 2021).

Kibbutz Ketura is located near the city of Eilat in Southern Israel's Arava Valley. Ketura is predominantly agricultural, and their primary product is medjool dates. In 2018, kibbutz member Nadav Solowey started a pilot program on Ketura to introduce argan oil as a product manufactured by the kibbutz. The program is meant to provide Kibbutz Ketura with an additional agricultural output, diversifying their economy and providing them with an alternative revenue source if medjool dates fail to remain profitable. The work for this project began in 1992, when Solowey's mother, botanical scientist Dr. Elaine Solowey, domesticated the argan tree on Kibbutz Ketura. These trees were grown with seeds obtained from Morocco, where the native argan tree grows in large forests (N. Solowey, Personal Communication, 2023).

Kibbutz Ketura's argan oil production program, being an experimental project, relies on the continued support of the community for resources and growth. The goal of the argan program is for argan oil to become a primary product of Kibbutz Ketura. One of the aims of the program is to advance argan production to where it can be produced globally. The pilot process uses a low-budget setup to create and refine a process to make argan oil within Kibbutz Ketura. One step in this process involves sorting the argan nuts into groups of different sizes. This step in the process has been identified as the main problem with the current process, as it is entirely manual and not scalable. A new solution for sorting argan nuts is necessary to increase the output of argan oil.

The goal of this project is to design a machine that will automate the process of sorting argan nuts on Kibbutz Ketura. There exist specific requirements for this project, the most important of which is that the sorting process should be automated. A worker should not be occupied manually shaking the containers but can rather walk away and do other work. Additionally, the argan nuts should be sorted into at least five size groups, so that there is less variation in the sizes and thus less chance for error in the size-calibrated cracking machines. The successful completion of this project will provide a potential improvement to the argan oil production process on Kibbutz Ketura and a possible use of further investment from the community.

Kibbutzim and Organizational Management

The Israeli Kibbutz

A *kibbutz* is a type of communal village in Israel. *Kibbutzim* operate collectively, with members working and living together on the kibbutz, each receiving an identical share of the total production of goods and money. Kibbutzim began in 1910, with the founding of kibbutz Degania as part of a movement of young Zionist Jews from Europe who established communities in what is now Israel (Tishby, 2021). The founders of kibbutzim also subscribed to a number of growing socialist movements (Abramitzky, 2018). Due to a combination of socialist ideology and necessity for survival in the harsh climates in which they lived, *kibbutzniks* established systems of extreme collectivism. One of the driving ideas behind the structure of kibbutzim is that of mutual guarantee - summarized in the Marxist phrase: “From each according to his ability, to each according to his needs” (Tishby, 2021, p. 55-56).

Kibbutzim today are more similar to regular neighborhoods, with each kibbutz adopting various reforms unique to their economic and cultural evolution (Russell et al., 2011). For example, some kibbutzim still redistribute all collected income evenly, while others pay different salaries to employees based on their occupations (Shohet, 2023; Moskovich, 2020). About 80% of Israeli kibbutzim have undergone some form of privatization, meaning that their economies have become based on free-market competition as opposed to the need to provide for their members (Moskovich, 2020). Many kibbutzim, however, have maintained their original community-based structures while still seeing increased economic development.

One example of this kind of economic progression alongside the persistence of traditional kibbutz values can be found on Kibbutz Yotvata. Kibbutz Yotvata redistributes its income equally in accordance with the “old-fashioned” style of kibbutz living and prioritizes collective action for the good of the community as opposed to for economic growth (N. Segev, Y. Aloni, Personal Communication, 2024). At the same time, Kibbutz Yotvata’s dairy company, Yotvata Limited, has been economically successful. In a decision made by the community of Kibbutz Yotvata, Yotvata Dairy partnered with Strauss Group Ltd., an outside food and beverage company. Negotiations were made with Strauss Group such that the community of Yotvata would retain control over their company’s management structure (I. Garfunkel, Personal Communication, 2024).

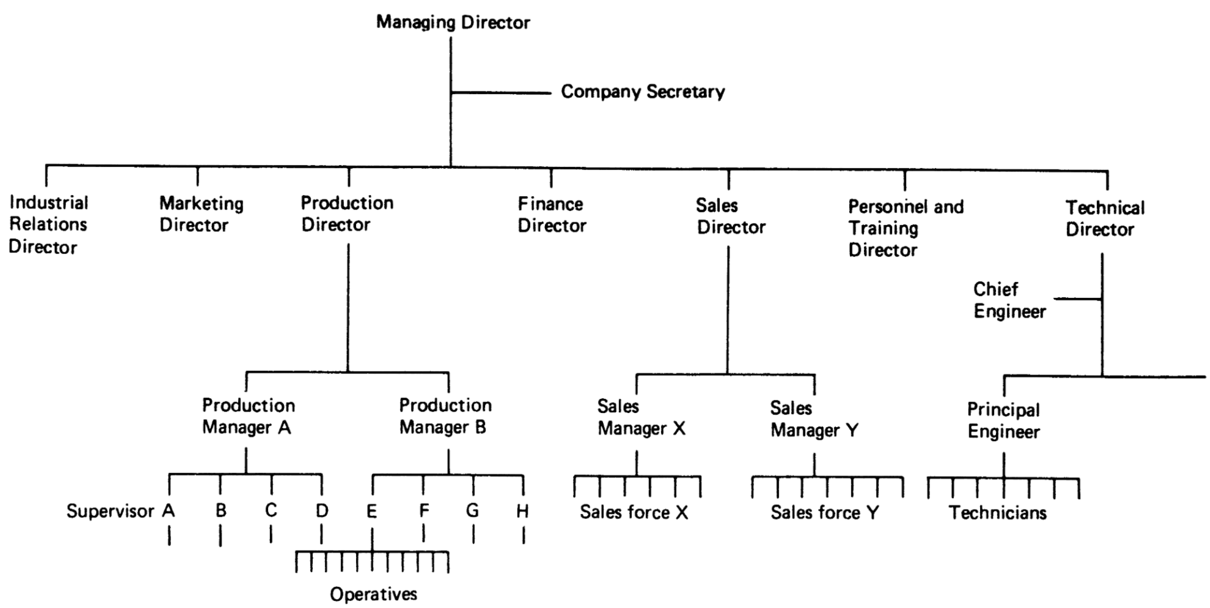
Decision-Making Structures

The way that any organization makes decisions is integral to its operation and trajectory. Organizations are “shaped by the activities of people whose behaviors are geared towards the achievement of a goal or goals” (Chell, 1987, p. 157). Organizations are a “theoretical abstraction,” meaning that how decisions are made is not straightforward (Chell, 1987, p. 157). Many tend to have a hierarchical structure, where there are levels of authority built within. Smaller organizations will have fewer levels, whereas “large, complex organization[s]…consist of several tiers between organization and work group” (Chell, 1987, p. 158).

Organizations can take many forms, such as companies, governments, communities, or school clubs. An example of a company structure is shown in Figure 1, which depicts a branch of an organizational chart. This specific type of organization is known as a top-down hierarchy. In a top-down hierarchy, an individual or group has a direct superior(s) from which they take orders. Additionally, responsibilities deemed outside of the scope of an individual are sent to their direct superior, who may choose either to act on it or delegate it to another individual, up to and including their superior. In a top-down hierarchy, there is typically a single person or a small group of people who have the highest degree of influence over the entire organization's decisions.

Figure 1

Schematic Diagram of a Partial Organization Chart



Note. Image from Chell, E. (1987). What are Organizations? In E. Chell (Ed.), *The Psychology of Behaviour in Organizations* (pp. 157–176) [Digital Art]. Palgrave Macmillan UK. https://doi.org/10.1007/978-1-349-18752-2_7

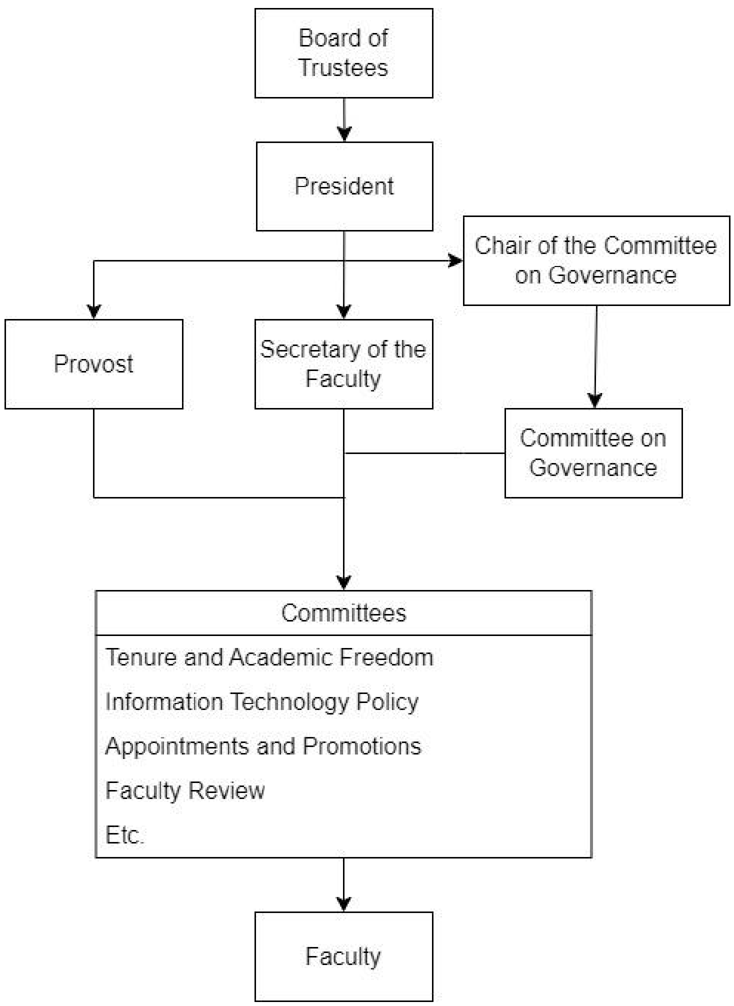
In top-down decision making structures, supervisors can act as decision-makers, decision-reviewers, or both. For example, the CEO of a corporation is actively involved in the decisions made by the company, while the Board of Trustees at a non-profit private university simply reviews and approves decisions made by the managers beneath them. In both cases, the ones making or approving the decisions have vested interests with the organization. CEOs want their company to succeed to improve their portfolio, increase the value of their shares, or for profit. The Board of Trustees at non-profit private universities are generally alumni and aim to maintain the status of their degrees by upholding the prestige of the universities. In this manner, the culture and priorities of an organization can influence internal decision-making.

Non-Profit Private Universities

A majority of non-profit private universities have an "assembly of representatives as the governance body with the highest authority" (Bradford et al., 2018, p. 911). This assembly, called the Board of Trustees, "approve corporate strategies and implementation plans, and review and approve relevant operating and financial decisions" (Bradford et al., 2018, p. 916). Unlike for-profit organizations, "donors rather than shareholders provide funds" in non-profit private universities (Bradford et al., 2018, p. 911). The governance structure of WPI, a private university, is shown in Figure 2. Each university has its own structure, but is generally organized in a similar manner.

Figure 2

Governance Structure of Worcester Polytechnic Institute



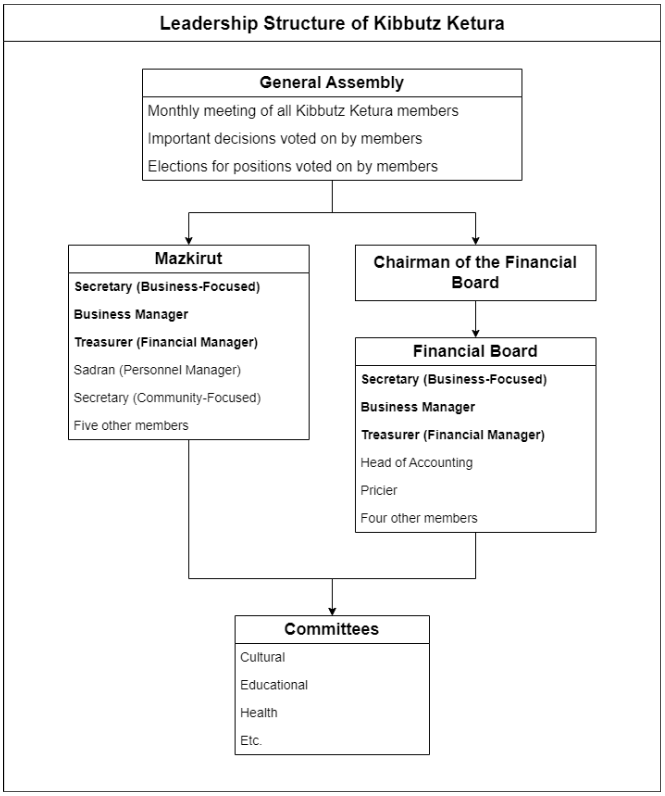
Note. Adapted from *Worcester Polytechnic Institute Faculty Handbook* by M. Richman, L. Albano, A. Danielski, T. Dominko, S. LePage, G. Heineman, A. Heinricher, W. Soboyejo, D. Strong, & K. Troy, 2023, Worcester Polytechnic Institute, (https://www.wpi.edu/sites/default/files/2023-09/Reorganized-Faculty-Handbook-CLEAN-DRAFT---May-9-2023.pdf).

Decision-Making on Kibbutz Ketura

A core value of kibbutzim is equality, which is practiced in the General Assembly meetings held at Kibbutz Ketura each month. During each meeting, members discuss and vote on important decisions and elections of members to leadership positions (N. Solowey, Personal Communication, 2024). On Kibbutz Ketura, General Assembly meetings have changed over time to prioritize discussion and inclusion of members, as opposed to meetings consisting of a “cold enumeration of votes” (Reisinger, 2019, p. 103). This is to promote consensus decisions, as votes can leave the losing minority uncomfortable. Thorough discussion develops a greater understanding of the problem, resulting in more compromises (Reisinger, 2019).

The decision structure in a kibbutz (Figure 3) consists of several boards and committees. The executive board, called the *Mazkirut,* is composed of a *Sadran*, whose job is to delegate tasks to other members of the kibbutz, a business manager, treasurer, and two secretaries called *Mazkirim*. Dividing the secretary responsibilities between two people is uncommon in kibbutz structure, but the members of Ketura believe it is effective (N. Solowey, Personal Communication, 2024). One *Mazkir* focuses on working with the community, while the other manages business. The executive board approves and manages operations for the whole kibbutz.

Figure 3
Leadership Structure of Kibbutz Ketura



Note. Flowchart of the leadership structure at Kibbutz Ketura (N. Solowey, Personal Communication, 2024)

For doing work that sustains the kibbutz, the Sadran assigns job rotations for every qualifying resident. For work done outside the kibbutz, salaries are reallocated and equally distributed to families by headcount. Forty-five percent of Kibbutz Ketura's workforce works outside of the kibbutz (N. Solowey, Personal Communication, 2024). Reallocating salaries are not mandated, but rather an ingrained agreement. Working assigned jobs and contributing salaries to support the entire community reflects on the socialist ideologies that kibbutzim were founded upon.

Committees on the kibbutz have up to ten participants in each. Examples include cultural, educational, and health. Each week, they meet and present proposals to the Mazkirut requesting approval and or funding. Committees have their own budget and can make internal decisions independently. Decisions that would affect the whole Kibbutz need to be presented to a General Assembly (Reisinger, 2019).

Discussion of Decision-Making Structures

The dependency the argan oil pilot program has on support from Kibbutz Ketura prompted our team to further understand decision making in kibbutzim and other entities. Through research and interviews, our team gained a deeper understanding of how an organization's culture, values, and stakeholders affect the decision-making process. We learned about the organizational structure of Kibbutz Ketura, Kibbutz Yotvata, private universities, and organizations in general. Despite kibbutzim and private universities having different goals, the decision-making structures are similar. Both forms of organizations have committees to manage different aspects of everyday life. A few examples of these committees include financial, educational, and cultural. Additionally, there is a position in both kibbutzim and private universities that oversees the organization's main aspect of life; Sadran for kibbutzim, and provost for private universities. The focus of kibbutzim is allocation of labor, so the Sadran is directly responsible for distributing labor. Private universities focus on education, and the provost is in charge of education faculty.

The different goals cause differences in decision making structures. For example, the highest level of power in a kibbutz, the General Assembly, allows all members of the kibbutz to vote. In a private university, the Board of Trustees has the highest level of power, but not every member has a say in the Board. Additionally, kibbutzim are not top-down decision-making structures, whereas private universities are. A possible reason for this is the size of the organizations. A private university has thousands of members, including faculty and students, whereas a kibbutz has far fewer members. Having too many members complicates the process, and the need to streamline important decisions made it necessary to have a few people in charge.

Argan Oil

Agriculture in the Arava Valley

The Arava Valley is a region of the Negev Desert, a subtropical desert in the south of Israel. Kibbutzim in the Arava Valley have practiced agriculture for decades, despite the suboptimal conditions. The region is hot, with average temperatures of 12 °C in the winter and 36 °C in the summer, with a highest annual temperature of 49.3 °C. The area is dry, receiving only about 25 mm of rainfall annually, most of which occurs during the winter (Bruins, 2012). The groundwater in the Arava Valley is also saline (Yechieli et al., 1992). These factors of the Negev render it a place that few plants can endure.

Despite the Arava Valley's difficult climate, kibbutzim in the area, such as Kibbutz Ketura, have been able to create thriving agricultural industries. Some members of Kibbutz Ketura work steady jobs in various aspects of agriculture. Temporary residents, including volunteers, university students, and immigrants, work on farms alongside Kibbutz Ketura's members (N. Solowey, Personal Communication, 2024). The majority of date palms grown in the Arava Valley are medjool dates. This cultivar, native to Morocco, is well-suited to the Arava's climate (Cohen et al., 2015).

Medjool date palms are grown as a monoculture on Kibbutz Ketura. Monocultures, where the majority of a crop consists only of one plant, are problematic in agriculture. First, the lack of diversity can leach the soil of the nutrients used by the plant, causing imbalances in the soil. Second, crops grown as a monoculture are susceptible to disease and parasites, as the area lacks other plant and animal species that may mitigate these threats (Ekroth et al., 2019). If an outbreak were to spread through Kibbutz Ketura, it would presumably wipe out significant portions of the date palms. This would decrease, if not remove Kibbutz Ketura's main agricultural product and the livelihoods of its residents. One crop being considered to diversify Kibbutz Ketura's agriculture is argan trees.

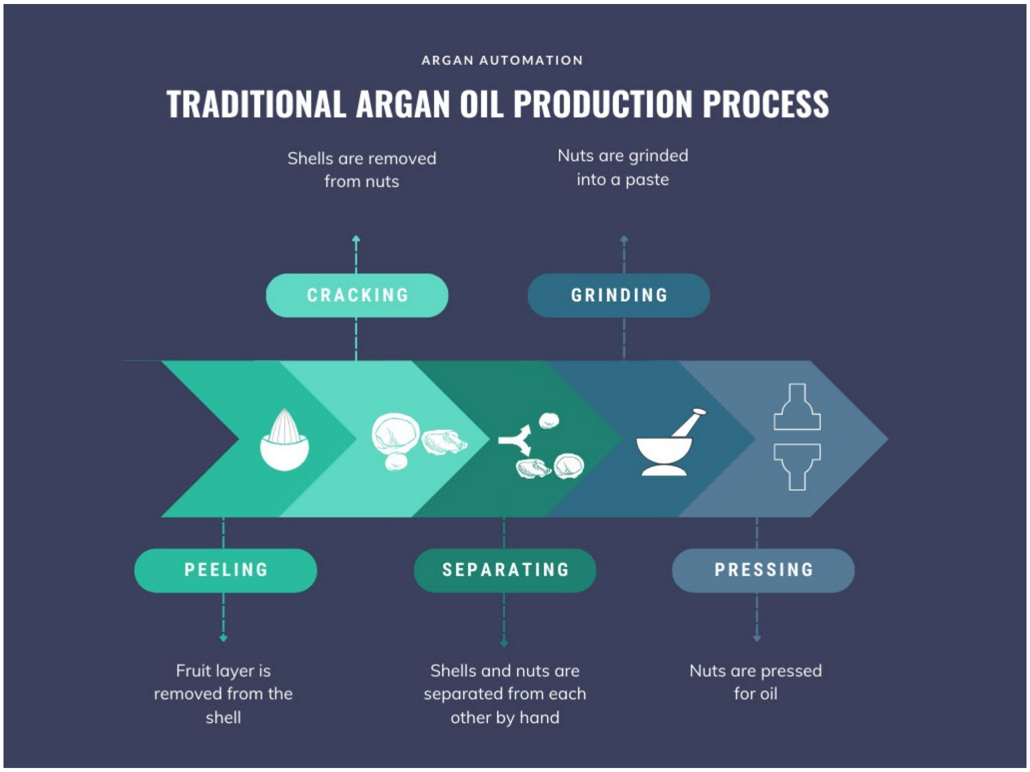
Origins of Argan Oil

Argan trees are native to Morocco, where the indigenous Amazigh people have extracted argan oil by hand for over nine hundred years (le Polain de Waroux & Lambin, 2013). Argan oil takes two to three days to extract, and the process involves "cracking the hard shell of argan nuts, roasting the kernels, grinding to produce a thick paste, and kneading this paste to extract oil" (le Polain de Waroux & Lambin, 2013, p. 590). Modern developments to this process include fruit peelers and extraction presses to reduce the labor intensity (Gharby & Charrouf, 2022).

The conventional production process (Figure 4) starts by removing the fruit layer of the argan nut, which is done by feeding goats and harvesting undigested nuts from goat manure (Lybbert et al., 2004). A fruit peeler is used nowadays to speed up the process and not rely on unsanitary practices. The shells are then removed by hand. If the oil is meant to be edible, the nuts will be roasted (Gharby & Charrouf, 2022). After, they grind the nuts into a paste with a grindstone, add water to solidify the paste, and finally press the paste for oil. In regions where water is scarce and the climate is poor, argan is a viable opportunity for agricultural expansion.

Figure 4

The Traditional Production Process of Argan Oil



Note. Image created using Canva (https://www.canva.com/)

Properties and Uses of Argan

The traditional argan industry in Morocco started a process of modernization, resulting in a dramatic expansion of marketing and processing of argan oil. This market surge is a pivotal phase for argan oil's overall sustainability and market viability. The oil has been able to sell for close to $300 per liter, which makes it the world's most expensive edible oil. The value of argan oil can be accredited to the various applications it can be used for ("Argan Oil can cost," 2020; Lybbert et al., 2004).

Argan oil has been beneficial in the cosmetic, culinary, and health industry. Traditionally, it was used as a therapeutic for dry skin, acne, joint pains, and skin inflammation. The oil is a fast-absorbing moisturizer. It can be used for many different foods. According to Guillaume and Charrouf, research has shown that consuming argan oil provides an increase in HDL cholesterol levels. The oil has also been linked to reducing the risk of certain forms of cancer cells. There is ample opportunity for additional research into this oil (Bennani et al., 2007; El Abbassi et al., 2014; Guillaume & Charrouf, 2011; Villareal et al., 2013).

Argan Trees in the Arava

Argan trees were introduced to Kibbutz Ketura by Dr. Elaine Solowey, as she recognized the market opportunity of argan oil. Solowey has spent her life challenging the capabilities of agriculture in the Arava Valley, experimenting with crops that could tolerate the harsh conditions and provide income for farmers. In 1992, she was able to grow argan trees. Out of 1000 trees, 8 were deemed suitable (Surkes, 2021). Clippings from the selected trees are now replanted, making the new trees genetic clones. Cloning the ideal trees has led to consistent yields of argan nuts, and Kibbutz Ketura now extracts argan oil for selling to tourists (N. Solowey, Personal Communication, 2023).

Argan trees tolerate the Arava's harsh climate and soil composition, and argan fruits possess excellent durability. The outer layer of the fruits protects the nuts inside from the elements, and therefore can lay in the groves for as long as necessary. Kibbutz Ketura extracted high-quality oil from argan nuts that had been left outside for over 6 years. The low-maintenance requirements of argan trees are significant for farmers, especially in climates where it is difficult to grow crops. Improving the efficiency of argan industry cultivation and oil extraction has the potential to benefit not only the agriculture of Kibbutz Ketura, but also of other communities.

Argan Oil Production in Kibbutz Ketura

The process that Kibbutz Ketura currently uses to make argan oil can be broken down into seven steps, shown in Figure 5: growing, harvesting, peeling, sorting, cracking, separating, and pressing. Speeding up one step boosts productivity, as each subsequent step depends on its predecessor to advance. However, the process is slow and tedious. Much of the process is manual. A person must spend over two hours shaking crates with slotted holes on the bottom to sort argan nuts by size. The process is as follows:

<u>Growing, Harvesting, & Peeling</u>

Argan trees take around eight years to mature before the fruit can be harvested. It takes two people four hours to harvest eight tons of fruit using a harvester. Without a harvester, it would take ten workers about a week to harvest eight tons of fruit. The harvested fruits are put into a modified potato peeler, which separates the outer shell of the nut from the fruit.

<u>Sorting</u>

The argan nuts are sorted into four size groups before being cracked to reduce the number of manual adjustments required for the cracking machine. The nuts are sorted by getting poured into two stacked crates at a time. If a nut is too large to fall through, it will stay on top. This separates the large nuts from the small ones. Because the nuts tend to stick together, argan dust is added to reduce clumping. The current sorting process takes about 2.5 hours per liter of oil, or 25 kilograms of nuts (N. Solowey, Personal Communication, 2023).

<u>Cracking</u>

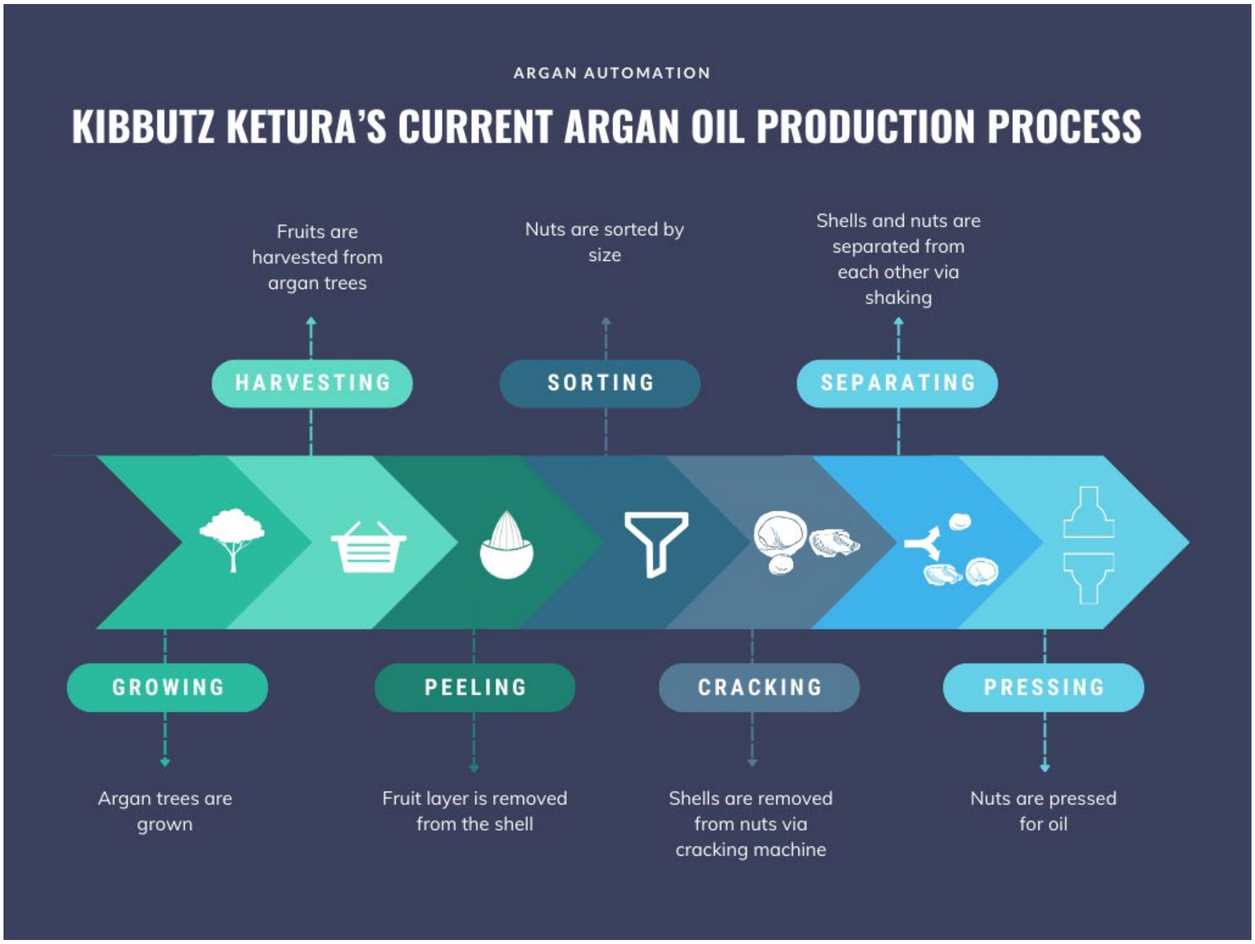
Kibbutz Ketura uses a cracking machine instead of the traditional way of cracking nuts by hand. The cracking machine contains two metal plates: one stationary, and one that rotates. A nut is placed in between the two plates, and the plates are closed to a distance in which the shell cracks. Then, the plates are readjusted for the next size of nuts. With the current design, nuts that are too large or small cannot be cracked effectively. Only about 20% of large nuts can be broken. Sorting the large nuts out beforehand will allow for less plate readjustment, making the process smoother.

Separating & Pressing

The shells and nuts are then separated from each other. Kibbutz Ketura currently uses crates to sift the shells out of the mixture, similar to how the nuts are sorted by size. The argan nuts are then put into a press and the oil is extracted. Overall, this process makes use of modern technology to increase the efficiency of argan oil production. This process still includes manual components, such as when sorting the nuts by size. The goal of this project is to automate this manual component of Kibbutz Ketura's argan oil production process.

Figure 5

Kibbutz Ketura's Current Argan Oil Production Process



Note. Image created using Canva (https://www.canva.com/)

Design of an Automated Argan Nut Sorting Machine

Selecting a Design

The comprehensive process for this project included brainstorming and a group discussion. Requirements were created to help determine the final design.

Design Requirements

The most imperative requirement to include was automating the design, controlled by an on/off function such as a button or dial. In addition to sorting the argan nuts, the shells and dust coating the nuts also had to be sorted. The requirements also called for five or more size groups for sorting the argan nuts, as opposed to the current four used at Kibbutz Ketura. Preventing all contents from spilling out was also prioritized.

Approximately 60 percent of argan nuts from Kibbutz Ketura are between 12.10mm and 15.10mm. These were the newly proposed size groups, including the current:

- Less than 12.10mm
- Between 12.10mm and 15.10mm
- New Size Group
- Between 15.10mm and 17.00mm
- Greater than 17.00mm

Brainstorming & Group Discussion

Individual designs were made by team members, which allowed for creative depictions of the prototype, and discussed amongst the team. A list of pros and cons were considered for each design. The different conceptual views of a sorting machine are highlighted in the figures below. A machine that relies on gravity alone is presented in Figure 6. Other designs that incorporate the automation requirement are shown in Figures 7, 8, and 9. These include the use of a DC motor, conveyor belts, and a vibration motor. The following sketches were considered, giving different views on the automated machine.

Figure 6
Slotted Ramp

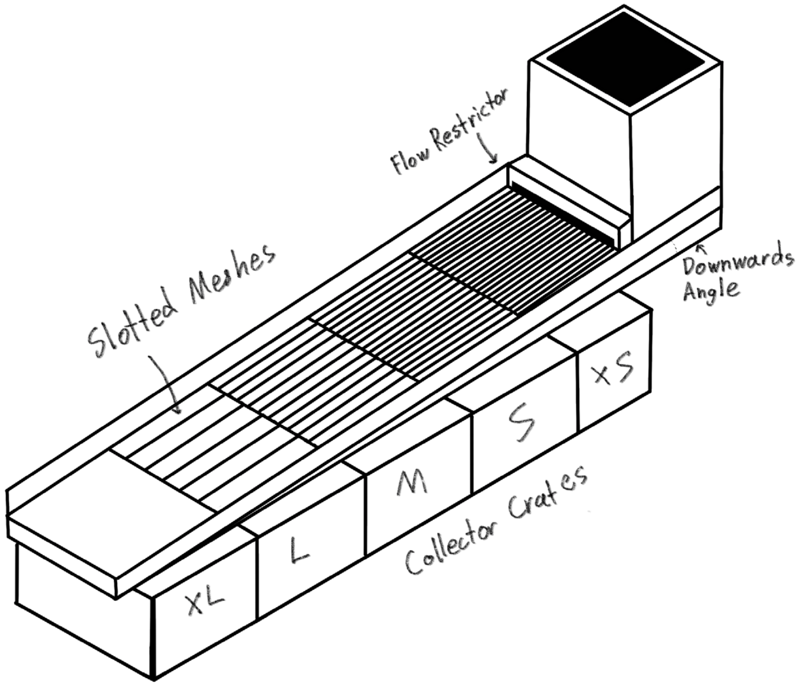


Figure 6 is a ramp concept that relies on gravity. The argan nuts are poured into the top of the container and roll down the ramp, falling into their respective size groups. As the ramp approaches the extra-large bin size, the distance between the rods increases. The use of the flow restrictor prevents the argan nuts from going down the slope at the same time. This design is similar to another project which utilized a ‘roller’ consisting of two downward sloped bars that were gradually spaced apart to sort argan nuts by size (Raymond et al., 2023). The design proposed by Raymond et al was not implemented as it did not deliver the desired results.

Figure 7
Rotating Disc

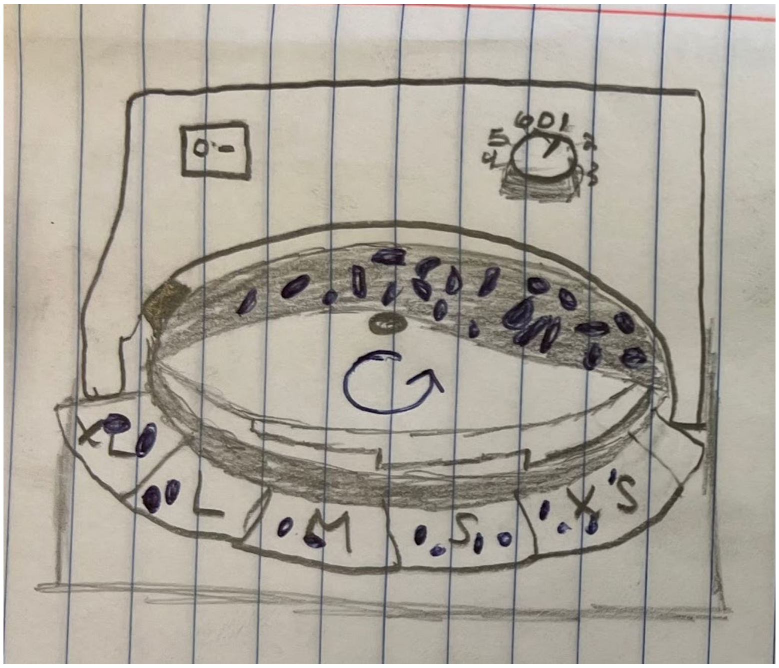


Figure 7 incorporates the use of a DC motor that revolves continuously, pushing the argan nuts into a roof of varying heights. The roof allows the smaller nuts to travel along its path until the height is low enough. There is a curved structure for the nuts to roll against, assisting them to get pushed into the correct size group container. There is a dial on the top right of the design which controls the speed of the DC motor and can be powered on by a push of a button.

Figure 8
Conveyor Belt

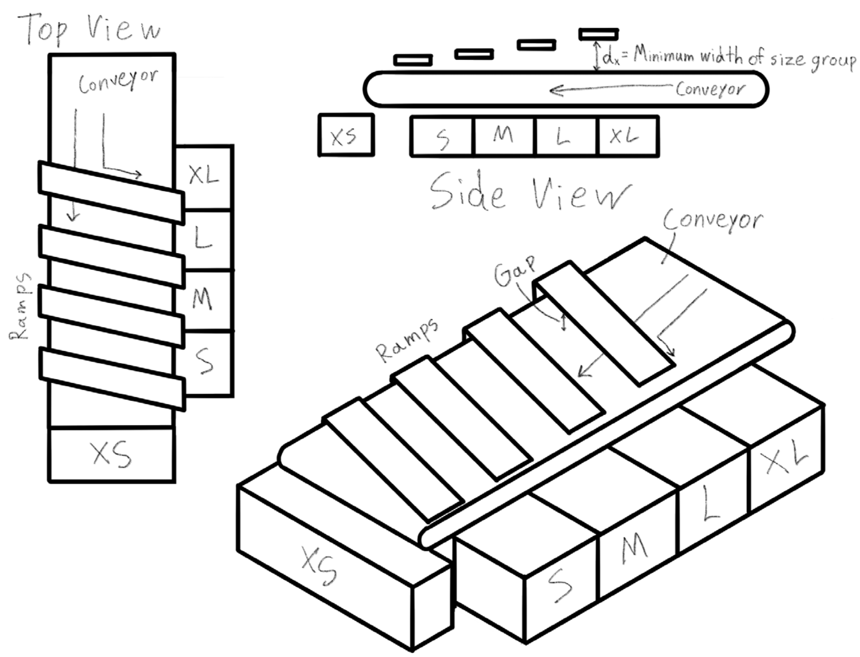


Figure 8 is a horizontal conveyor belt that promotes controlled input and output. The top view of the figure implies the direction for the argan nuts to travel. Similar to Figure 7, the smaller size groups slide under the higher height layers, falling into their determined size bins. The top right of the figure provides a side view of the differing gap heights, leaving the last bin to contain only extra small nuts.

Figure 9
Shaking Table

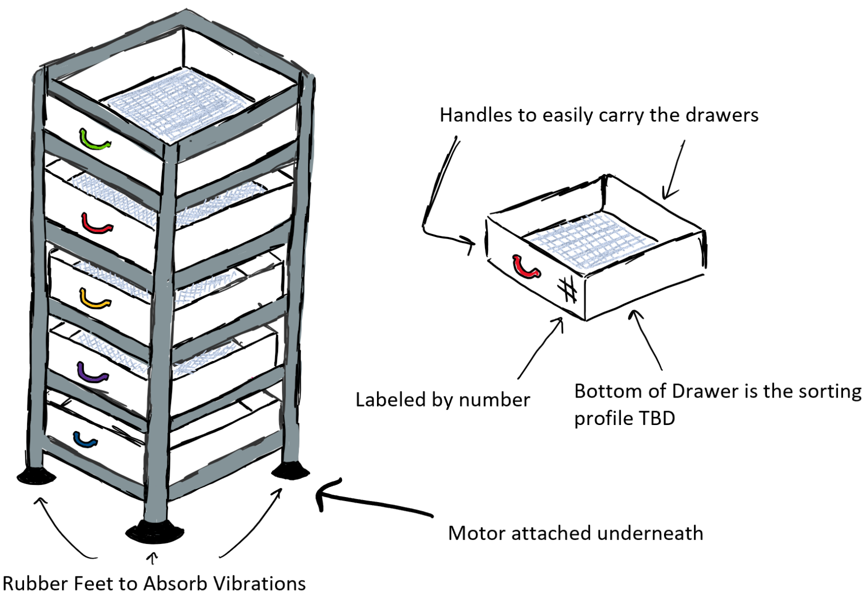


Figure 9 is a multi-layered sieve table, operated by a vibration motor. The motor location is at the bottom of the structure, moving the system as a whole. The layers are labeled drawers that have different mesh sizes. The top drawer is for the extra-large argan nuts, allowing the smaller nuts to pass down to the next layer. Each drawer has handles to grab and slide out of the system. At the base of the design, there are rubber feet that are meant to absorb the vibrations. For illustration purposes, the drawers are not stacked on top of one another, as they would be for the prototype.

Final Design

The design selected (Figure 10) iterates upon Figure 9 and is a multi-layered sieve with five main containers for sorting argan nuts, and one for collecting dust. Each has a custom mesh tailored for the target argan nut size group. The containers stack onto a platform supported by springs, and a vibration motor shakes the stack from underneath. Each container has corner holes for guiding poles to go through. The holes are oversized to allow for movement within the confines of the structure. The guiding poles are attached to a baseplate, which can be weighed down or mounted to secure the structure. Figure 11 is a SOLIDWORKS rendition of the design.

Figure 10

Revisited Drawing of Shaking Table

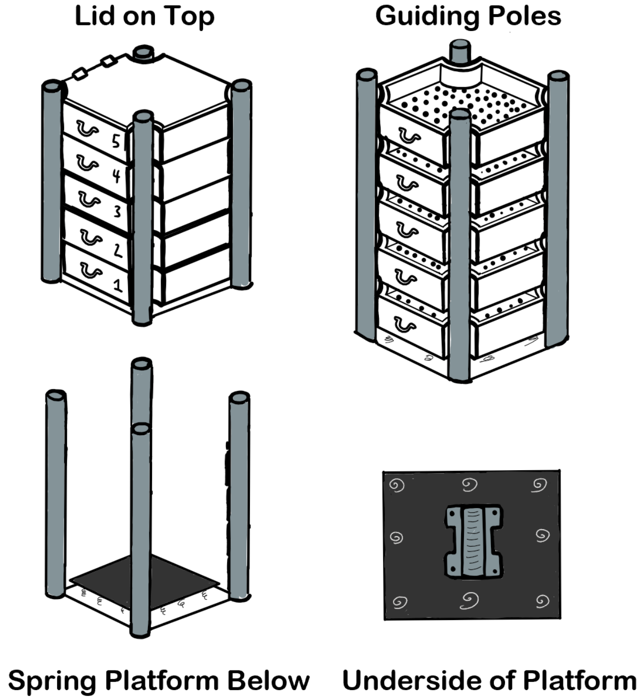
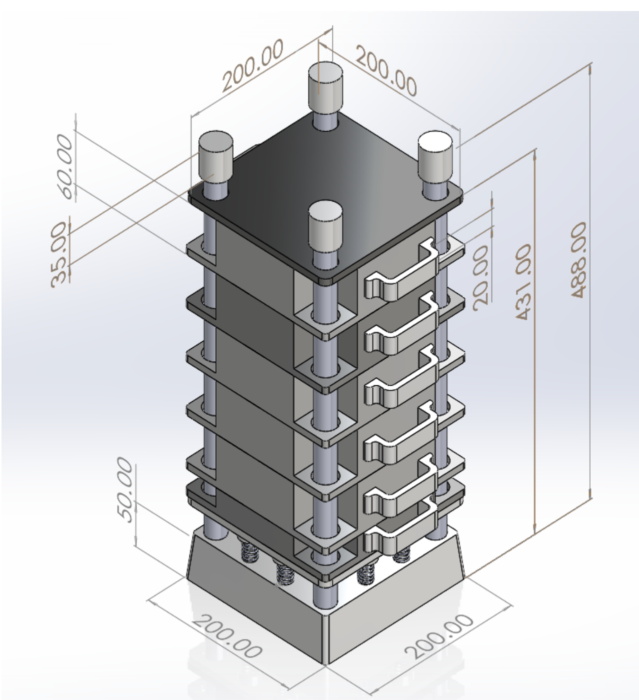


Figure 11

Final SOLIDWORKS Assembly



Note. Dimensions are in millimeters.

Prototype Development

Components

The prototype (Figure 12) is 200x200x488mm. The springs, fasteners, dowels, and vibration motor were purchased, and the remaining components 3D printed. The prototype is scaled down because the bed size of the 3D printer is 220x220x250mm.

Figure 12
Completed Prototype

Primary Containers

The five main containers all have a 200x200x8mm baseplate, 52 mm high walls, and 29mm diameter holes on each corner. The holes are toleranced for a loose running fit to shake freely within the guiding poles. Each has two 3D printed handles adhered with Loctite super-glue (Figure 13). A 3D printed lid with printed end caps that cover the top container prevents argan nuts from spilling (Figure 15). The dimensions of each mesh profile are as following starting with the top layer:

- 17.00mm
- 15.10mm
- 13.60mm
- 12.10mm
- 5.00mm

<u>Dust Container</u>

The 3D printed dust container (Figure 14) has a 200x200x8mm base plate with ⌀29mm guiding holes, and walls in a cross shape. The walls of this container stand at 22mm tall, and the underside does not have holes.

Figure 13
Container with Handles

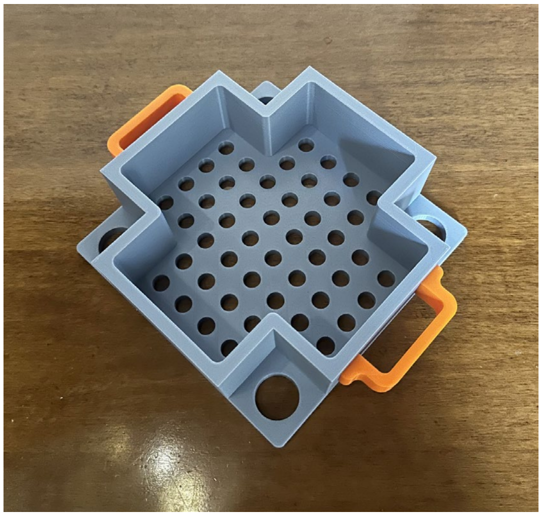


Figure 14
Dust Container

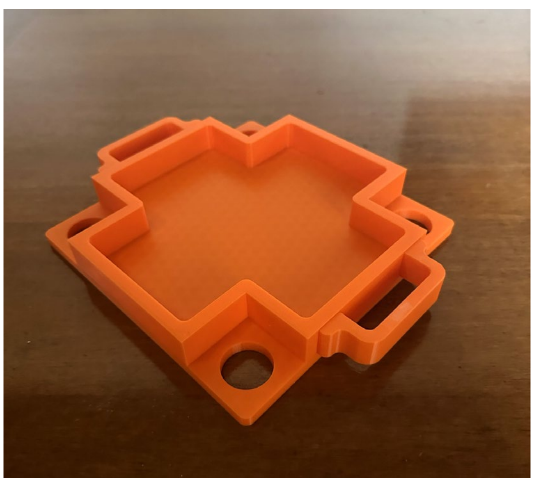
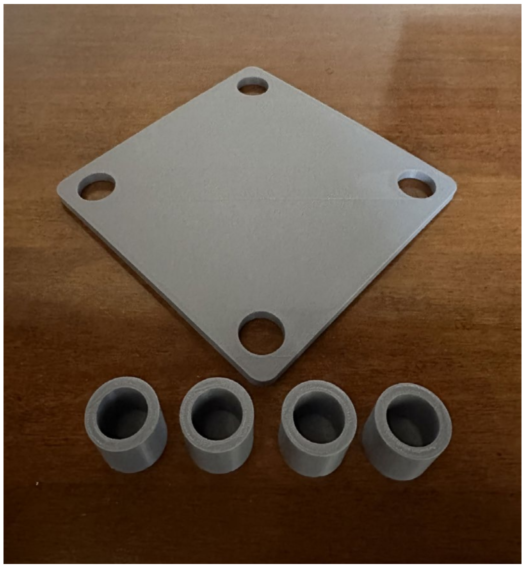


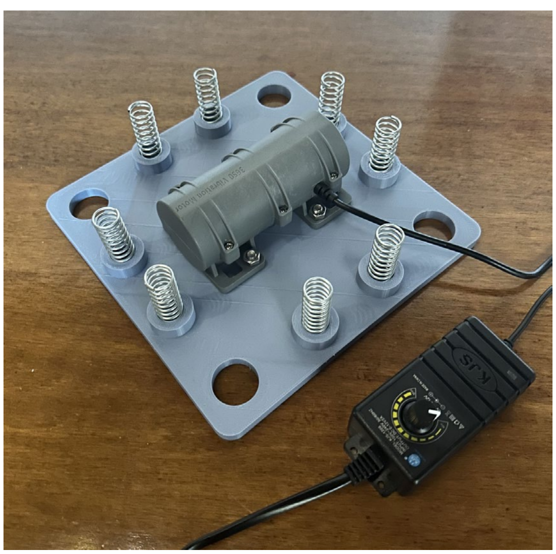
Figure 15
Lid and End Caps



<u>Motor Platform</u>

The motor platform (Figure 16) contains eight ⌀15mmx45mm coil springs to connect to the baseplate and hold the stack of containers. 10mm high collars protrude from the platform to further support the springs. The vibration motor is mounted to the underside by four M6x15mm bolts, with countersunk holes on the platform so the bolt heads do not protrude and allow the dust container to lay flat.

Figure 16
Motor Platform



Vibration Motor

The prototype uses a LeTkingok 3650 12V Vibration Motor (Figure 17). The motor is advertised for DIY projects of vibrating sieves and other vibrating machines. The dial allows for turning the motor on and off, as well as adjusting the frequency up to 3800 RPM. The motor also has a mounting plate with four holes for M6 fasteners (*Letkingok - Buying Guide | GistGear*, n.d.).

Figure 17
Vibration Motor

Supporting Structure

Four ⌀23.5x465mm wooden poles confine the stack of containers and motor platform. The baseplate has a raised platform with eight holes for the springs to be press fitted into, and a cutout in the middle for vibration motor clearance (Figure 18). Each pole is also press fitted into the corner holes of the baseplate (Figure 19).

Figure 18
Baseplate

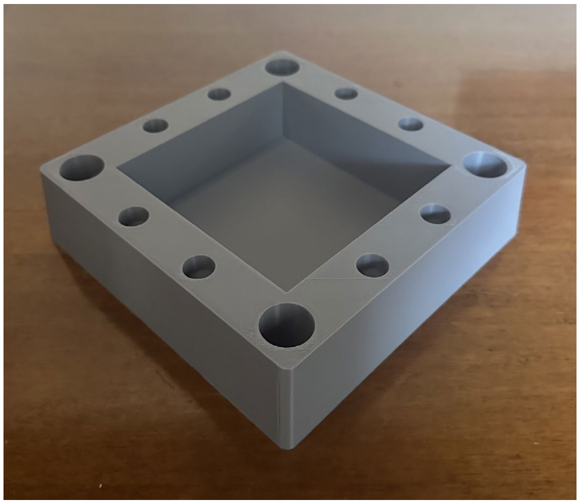


Figure 19
Baseplate and Dowel

Equipment & Materials

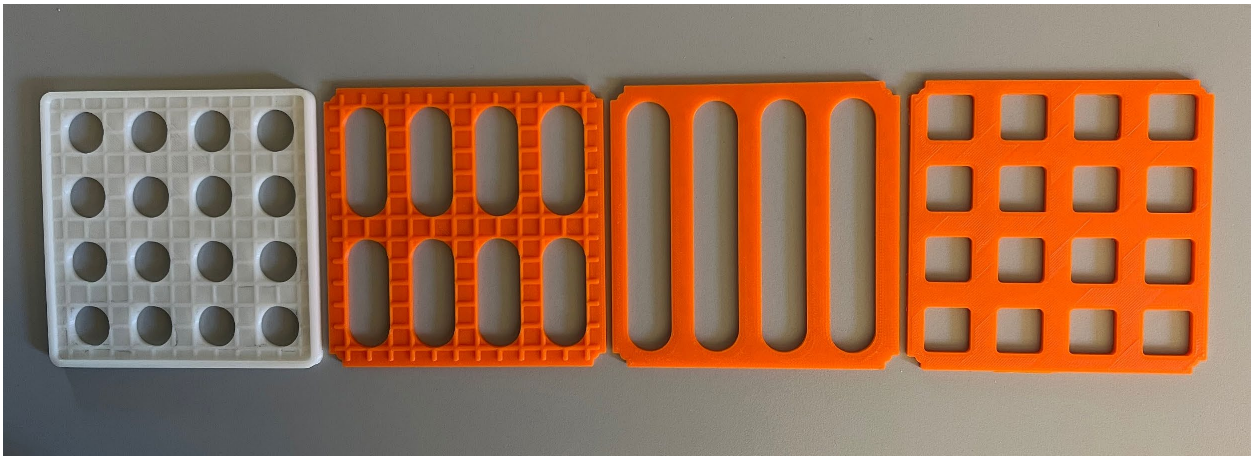
To develop the prototype, we used a Creality Ender V3 SE 3D Printer. SOLIDWORKS 2022, Student Edition, was used to model the assembly and format the parts for printing. UltiMaker Cura 5.6.0 was the software used to slice and prepare the prints. The settings in this software were adjusted for the filament that we used: PLA+. This filament recommends a heating temperature of 215 ℃ ± 15 ℃ for better print quality.

Tolerancing: 3D Printer

Several mesh geometries were considered for the drawers of the prototype. There are two characteristics that affect the size of the meshes: the shrinkage of the PLA+ filament after printing, and the oblong asymmetry of the argan nut cross section. Both were determined experimentally. A test experiment was conducted of a small mesh design of 16.95mm (first print shown in Figure 20) to assess the shrinkage. Ten measurements were taken around the holes using calipers with a tolerance of ±0.02mm to determine the average diameter. The calculations shown in Appendix A indicate that the filament shrank by ≈0.434mm, meaning any models made in SOLIDWORKS must be scaled that much larger for an accurate print.

As shown in Figure 20, four main geometries were considered. Starting from the left, there is a circle mesh design printed in white, followed by a small slot design. Both have a ribbed pattern on the surface, allowing for more movement of the argan nuts. The third print has larger slots in order to use less material and increase the amount of surface area the nuts can fall into. The last design with squares is similar to a large grid, testing if another shape was viable. The dimensions of these meshes are based on experiments and tolerancing.

Figure 20
Test Mesh Prints



Shape of the Argan Nut

The cross section of the nut is not circular, but rather elliptical. This means that the difference between the maximum and minimum diameter of the extra-large nuts (17.00mm) could be upwards of 2mm. An example of this is shown in Figure 21, where the largest diameter of the cross-section is 18.40mm and the smallest is 16.54mm. The sorting results for the two slot meshes in Figure 20 are less effective due to the non-uniform size. There is a different outcome for the circular holes, because the nuts can be reorientated to the smallest diameter to slide through the slots. Figure 22 is an accurate representation, as an argan nut with a diameter of 18.31mm passes through a 17.00mm mesh when rotated slightly from its largest dimension. This behavior allows for argan nuts to sort into different size groups. The square mesh design on the right of Figure 20, although similar, is less structurally sound as the circular pattern. This is due to poor stress analysis and cracking. It can be expected that the material, thickness, and circular design pattern exhibit better longevity and accuracy. Therefore, the continued design of a circular mesh without the ribbed surface area was selected.

Figure 21

Cross-Section of Extra Large Argan Nut

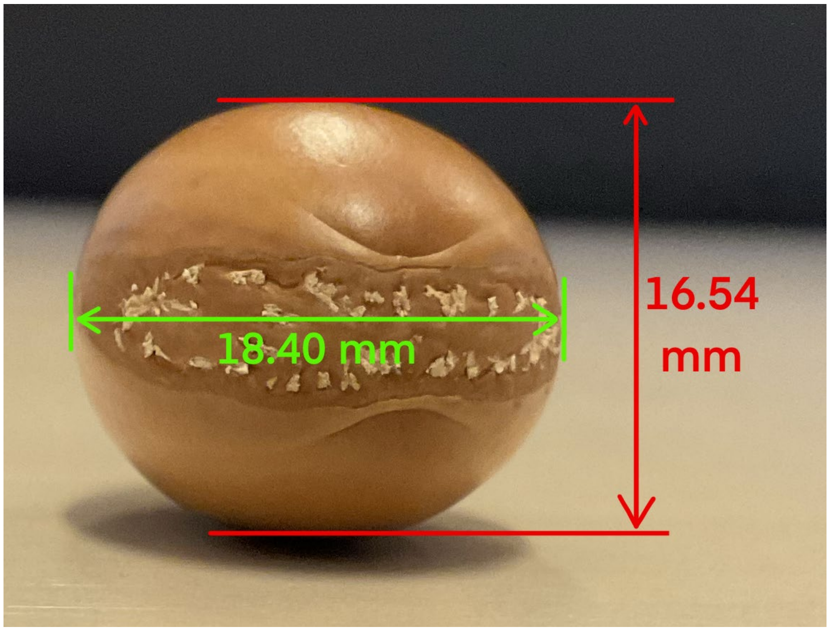
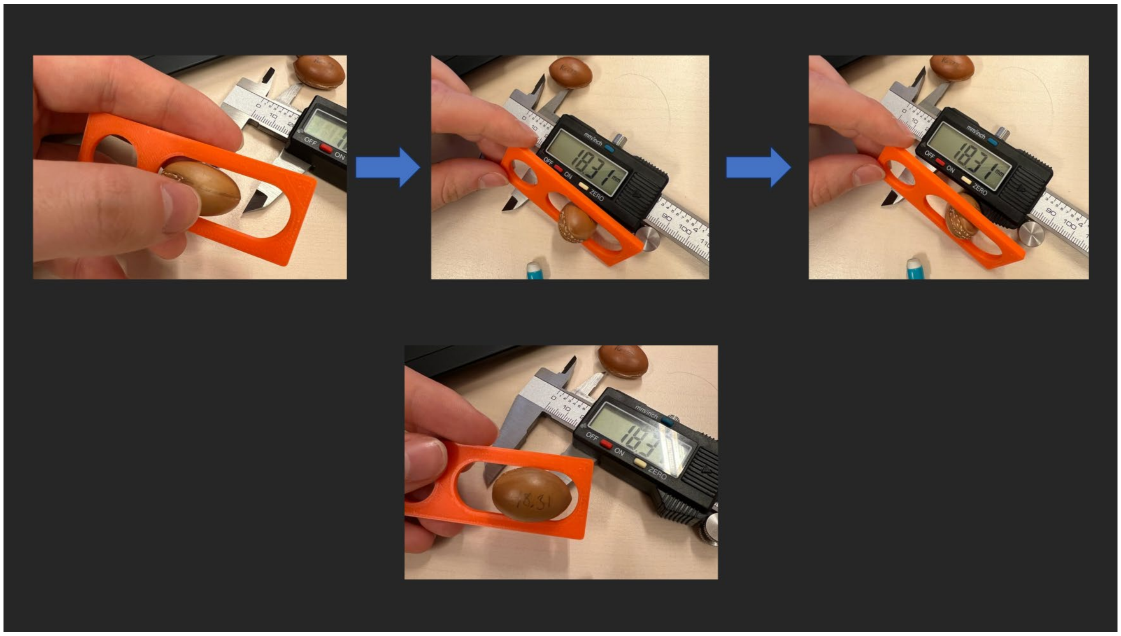


Figure 22

18.31mm Argan Nut Passing Through Slot Design



Mesh Development

Basic tolerance tests were performed for the additional test mesh prints of the other size distributions. The print in Figure 23 is a 1:1 size tolerance test of the large argan nuts (15.10mm - 16.90mm). This is to confirm that the larger scaled prints are accurate. The SOLIDWORKS file was dimensioned to 15.534mm, and the printed file was 15.10mm. Since this test was successful, the full test mesh for this layer was produced (see Figure 24). This 1:1 procedure was repeated for each group size to ensure consistency. The shrinkage of the PLA+, as determined earlier, remained unchanged.

Figure 23
Large Argan Nut Tolerance 1:1 Test

Figure 24
Large Argan Nut Test Mesh

Selecting a New Size Group

A midpoint value of 13.60mm was chosen to split the 60% size distribution for the medium-small argan nuts (12.10mm-15.10mm). A new mesh was printed using the same 1:1 process to test the split. The results in Figure 25 show the distribution of the argan nuts. The medium sized argan nuts (left) are now measured to be between 12.10mm and 13.60mm, and the small size group (right) between 13.60mm and 15.10mm.

Figure 25

Argan Nut Distribution for 13.60mm Test Mesh

Operating the Prototype

First, the argan nuts are poured into the top layer until full. Some nuts may initially fall through the layers. The lid and end caps are placed on top to fully enclose the system, preventing any argan nuts from falling out during the shaking process. Turning on the vibration motor shakes the stack until each nut is at a layer with holes that are too small for them to fall further. After the nuts are sorted, each container can be picked up using the handles on the sides and poured into their respective size bins. The containers are then stacked back on the platform beginning with the dust layer, followed by the mesh dimensions in ascending order.

Limitations

This project was originally supposed to take place on Kibbutz Ketura between January and March of 2024. However, our team was instead relocated to Venice, Italy. Although the time zone difference between us and Kibbutz Ketura was reduced, the project was conducted remotely. This limited our ability to test using the full argan nut production setup on Kibbutz Ketura. On Kibbutz Ketura there is a fabrication laboratory which is often used to build, repair, and maintain devices. Additionally, the 220x220x250 mm printer bed of the Creality Ender V3 SE 3D Printer restricted the size of prototypes we could make.

Recommendations

New materials should be considered for an upscaled design of this prototype. Our team recommends aluminum for a full-scale design, as aluminum alloys are strong and machinable. Computer Aided Manufacturing (CAM) machines use digitally guided instructions that could achieve the precision needed for fabricating the mesh layers (*What Is CAM (Computer Aided*

Manufacturing)?, 2018). Drilling the holes could be a cheaper alternative, but the precision may be less accurate than software-controlled methods.

A scaled-up design will likely need a motor stronger than the 3650 vibration motor used for the prototype. We recommend selecting a motor with a built-in mounting plate for design compatibility, and an adjustable dial to experiment with different frequencies for sorting.

Traditional hex nuts can loosen over time in vibrational applications, which is a possible safety hazard for an upscaled design. The nyloc nut is an alternative fastener designed for withstanding vibrations. We recommend mounting the vibration motor to the motor platform with nyloc nuts to ensure safety (*Unlocking the Benefits of Nyloc Nuts*, 2023).

A re-evaluation of the size groups could be helpful to incorporate the slot design structure for the containers. If a study is conducted to approximate the average difference in size between the largest and smallest diameter of the argan nuts, a more precise mesh design could be made. The slots would be based off the new smallest dimensions, and more research can be done for an efficient automation process. Factors such as the length of argan nuts and rolling should be taken into consideration for this iteration. General studies for the sorting of irregularly shaped 3-dimensional objects through 2-dimensional profiles would further support this.

To make the collection process easier for the workers, the front of the containers could automatically open. This means that the containers do not have to be lifted from the baseplate each time they are used. More ways could be researched about automatic containers, which can later become a system that dispenses the sorted argan nuts into their respective bins.

Sorting Rate of an Upscaled Design

The design can be scaled to accommodate the desired target volume of argan nuts processed. All dimensions can be modified before development to correspond with the containers planned to be used.

A vibration motor is automatic and can be adjusted to a constant RPM. Manual labor results in inconsistent shaking and taking breaks from fatigue, which can reduce the sorting rate.

The prototype utilizes more containers at once, leading to a larger volume once upscaled. The current process in Kibbutz Ketura involves shaking two containers at once, swapping out containers to filter through each layer. The new design stacks and sorts all six containers at once.

For a scaled-up design with equivalent container volumes used at Kibbutz Ketura, we can extrapolate that the argan nut sorting rate would match or exceed 60 kg/hr. We infer that the sorting rate would improve when using a vibration motor at an optimal frequency versus manually shaking.

Conclusion

This project was about creating a design to automate the sorting step in Kibbutz Ketura's experimental argan oil production program. Along the way, the team researched how decisions are made in Kibbutz Ketura, Kibbutz Yotvata, and private universities. We interviewed four members from Kibbutz Yotvata and gained insight about the differences in decision making in kibbutzim. The team printed a small-scale prototype of the proposed design using a 3D printer, wooden dowels, springs, super glue, and a vibration motor. A new size group was identified. Ultimately, the prototype worked, and the nuts were properly sorted. Implementation of the upscaled design would improve the sorting step efficiency of this argan oil program.

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Appendix

Appendix A: 3D Printer Tolerance Calculations

3D Printer Tolerancing test

SOLIDWORKS → 16.95mm
3D Print → 16.516mm

10 Trials using calipers at 16.95mm

Trial #	Diameter (mm)
1	16.48
2	16.55
3	16.47
4	16.53
5	16.60
6	16.45
7	16.50
8	16.49
9	16.51
10	16.58

Calculations:

Trials 1-10 = 165.16mm

$$\frac{165.16}{10} = 16.516\text{mm}$$

$$16.95\text{mm} - 16.516\text{mm} = 0.434\text{mm}$$

New SOLIDWORKS Test Print: $16.95\text{mm} + 0.434\text{mm} = 17.384\text{mm}$

Results: successful diameter of 17.00mm!

When printing, tolerance at 0.434mm larger than intended for an ideal print.