Waste Not, Want Not: An Investigation of Repurposing Argan Fruit Waste in the Development of Commercial Products in Kibbutz Ketura

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Submitted to:
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Abstract

Argan oil is a major agricultural product with several cosmetic and medicinal applications. The process of extracting oil from the fruit produces waste, such as the shells, that have the potential to produce additional streams of revenue for the industry. Our project focused on identifying and exploring creative ways to repurpose argan fruit waste into commercial products to eventually be sold by a local community in Ketura, Israel that is just beginning to develop this resource. We designed and conducted exploratory experiments with different agricultural waste products from the argan oil pressing process. The outcomes of our preliminary experimentation indicate that pellets made from the shells for fuel, pet bedding, and cosmetic exfoliants warrant further research and development.

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1.0 Introduction

Argan oil, also known as Moroccan oil, can be found in a multitude of health and beauty products sold in almost any drug store or supermarket. While this oil is of great value, the process of producing it generates a significant amount of waste that has untapped potential given its unique material properties.

Kibbutz Ketura is located in the Arava region, 31 miles north of Eilat, Israel. The Arava region has a history of being a mostly barren land with high salt concentration, little annual rainfall (.91 inches per year), and temperature extremes given its desert climate (“Eilat, Israel - Detailed Climate Information and Monthly Weather Forecast”, n.d.). The region is covered in sand dunes and the water has a high mineral content which makes for a hostile agricultural environment and results in harmful deposits surrounding plant roots (Solowey, E.M, 1980). These conditions make it difficult for agriculture to be successful and profitable. To remedy this, there have been several land reclamation projects in Arava since 1974 with the aim of desalinating the soil to a reasonable pH level with large-scale sprinkler systems and tractor machinery (Solowey, E.M., 1980). These operations were meant to manage the sand dunes and level the terrain in preparation for agriculture. After several cultivation trials in the 70’s, the local community determined that the date palm was the most resilient in the harsh climate conditions of the Arava and doesn’t require as much high-maintenance protection from the elements (Solowey, E.M, 1980). As a result, Ketura’s main agricultural product is dates, which unfortunately, require massive amounts of water (Coren, O., n.d.).

According to the Agricultural Marketing Resource Center, dates thrive in environments that can provide their roots with continual groundwater and may require a minimum of up to 83 inches or 60,000 gallons of water a year (Dates, n.d.)(“How are dates grown?”, n.d.). Argan trees, on the other hand, consume less water (only ~80 liters of water a day) and are able to survive on water and soil with higher saline levels than most trees (Kechebar, M. S. A. et al., 2017) (Solowey, 2021). Because of this, Kibbutz Ketura has been testing its prospects as an additional, lower maintenance cash crop. Native to Morocco, argan trees produce a fruit that contains a nut kernel from which argan oil is extracted. The oil can be cosmetic or edible grade, and is very valuable.

Argan oil only accounts for about 3% of the fruit's mass, with the rest currently being considered waste. At the moment, Morocco is responsible for 99.9% of the world’s argan oil, producing close to 4,500 tons of oil each year and generating about 92,000 tons of waste with it (Rosengren, 2020). Kibbutz Ketura and the surrounding region are currently generating about 1 ton of nut waste per year. Provided 12 acres of trees are planted within the next year, Ketura will be generating close to 70 tons of waste per year in 5 years and 100 tons of waste per year in 10 years (Solowey, 2022).

Currently, there are not many commercial uses for the waste and the nut shell in particular. In Morocco, the fruit is fed to goats and the shell is discarded or burned, however, the shell and other argan nut waste byproducts may also be just as valuable as the oil itself (Lybbert et al., 2002)(Ruas et al., 2016). Previously, the Kibbutz has used some of the shells as mulch and has stored the rest, but neither of these options are feasible for the large-scale production of argan oil that is planned. In Morocco, oil production has been limited by the time intensive, manual extraction process, leaving no clear model for managing the waste. As such, research is required to determine viable and scalable methods of reuse for the resulting nut waste.

Following Ketura's push for sustainability, it is important that the Kibbutz considers all aspects of a localized argan oil production operation. The goal of this project is to identify and evaluate methods of repurposing argan fruit waste in order to develop commercial products for the next 10+ years as Kibbutz Ketura scales the argan tree domestication process and therefore, how much waste they produce annually. To fulfill this goal, we have appointed the following objectives:

1. Evaluate the potential of immediate waste solutions to address current argan waste build up within Kibbutz Ketura
2. Investigate the production feasibility of mid to long term waste solutions to facilitate scaling of the argan operation in Ketura
3. Explore expansion opportunities with current business partners of the Kibbutz for public distribution of commercial cosmetic nut waste products

2.0 Literature review

This chapter presents an overview of our research on the reuse and disposal of argan nut waste. After providing the cultural and geographical context surrounding the growing argan nut industry in Israel, we identify the most prevalent current methods for processing the nut waste. Finally, we evaluate past IQP's that have focused their research within similar areas.

2.1 Contextualization of argan nut waste in Israel

2.1.1 Kibbutz Ketura emphasis on sustainability

Kibbutz Ketura is under a unique set of pressures with regards to geological and environmental factors. Since Israel is significantly affected by climate change, local communities such as Kibbutz Ketura must carefully consider optimizing natural resources with sustainable technologies (Price, C., 2020). One manifestation of this sustainability-centered culture is Ketura's water recycling system, in which treated bathing and sewage water is used for agricultural irrigation (Cohen, R.M., 2022). The treatment of this water, also called gray water, requires less energy input than is typical of drinking water purification systems. The kibbutz is exploring the argan tree as a potential supplemental cash crop, as it requires significantly less water than the date palm (Solowey, N., 2021). This endeavor has been the impetus behind finding novel ways to reuse argan nut byproducts.

2.1.2 General background on argan oil and nut waste

Argan nuts are a valuable agricultural commodity most widely grown in Morocco, a semi-desert, Mediterranean climate (Lybbert et al., 2002)(Guillaume, D. et al., 2019). The tree's deep roots and smaller leaves contribute to its unique ability to thrive in arid climates without much water ("Argan oil us-en"., n.d.)(Guillaume, D. et al., 2019)(Solowey, N., 2021). Additionally, argan trees can tolerate a high level of soil and water salinity (Solowey, N., 2021). Argan oil is one of the most unique cosmetic and edible products within the agricultural industry ("Argan oil us-en"., n.d.)(Lybbert et al., 2002). Argan oil is commonly used in hair and skincare products, marketed particularly to those with curly hair and dry skin. It is also used for its anti-inflammatory properties, general wound healing, treatment of chronic metabolic illnesses, and various other health benefits (Bellahcen, S. et al., 2012)(Hill, A., 2018). Finding ways to capitalize on the favorable characteristics of argan byproducts will ease the dependency of the argan industry on the oil itself in the case of a market failure due to unscalable endemic argan trees (Guillaume, D. et al., 2019).

2.1.3 Nadav Solowey's exploration and implementation of argan nut commercialization

Nadav Solowey, a leader and agricultural expert within Kibbutz Ketura and the son of Elaine Solowey, has been continuing his mother's work with argan trees through his efforts to domesticate and commercialize the plant within the Kibbutz and in the surrounding region (Solowey, N., 2021).

Currently, Solowey is using specialized machines to separate and harvest oil from argan nuts, which produces about 1 or 2 tons of nut waste every year (Solowey, N., 2022). At the scale that he wants to automate and expand the harvesting industry, it is projected that the Kibbutz will produce close to 100 tons of nut shell waste annually in 10 years (Solowey, N., 2022).

After investigating how Morocco handles the large amounts of waste, Solowey decided not to follow their precedent of feeding parts of the fruit to livestock (Charrouf, Z., Guillaume, D., 1999). Instead, he has been disposing of the argan nut shells by using them as mulch and fertilizer. One issue the kibbutz has been having with using the shells as mulch is that they are too jagged and harsh for people to walk on. Additionally, the arid climate slows decomposition, making the nutrients inaccessible to decomposing organisms (Solowey, N., 2021).

2.1.4 Important considerations for a successful waste recycling operation

When requesting approval for a business venture in a community where all members are direct stakeholders, such as a Kibbutz, it is crucial to acknowledge community values such as profitable sustainability and ethical business practices (Solowey, N., 2021). Given the projected waste metrics, the main considerations for this pilot project were: (1) the complexity of the process, (2) the amount of input resources required for the solution to be marketable and profitable, and (3) the anticipated impact it will have on the environment (Solowey, N., 2021). By assessing each potential waste solution through the lens of these three categories, we can evaluate the feasibility of each waste solution specifically with regards to the scope of our project and the nature of clean-technology systems that Kibbutz Ketura will require.

2.2 Potential argan nut waste solutions

This section presents a discussion of each potential argan nut waste solution using different components of the fruit, namely the nut shells (after they have been cracked to get to the kernel), the kernel after its been pressed for its oil and dried out, and the extrusion paste that comes out of the machine when the kernels are being pressed for their oil. Each waste solution capitalizes on a specific material property of argan byproducts for applications in a commercial product to be sold by the Kibbutz.

2.2.1 Repurposing the Argan Nut Shell in commercial products

Argan nut shells (ANS) make up 46% of the argan fruit's weight. Because of this, and their ability to be stored without decay for long periods of time, the shells are the most important part of the fruit to find a use for (see Figure 2.2). The following ways to use the shell tend to capitalize on the shells' similarities to wood and the potential to replace wood in commercial products with ANS.

ANS-based Burnable campfire pellets

Camping is a popular activity in Israel, and there has been research suggesting that nut waste can be consolidated into burnable pellets for people to use as portable campfire fuel (Shtotland, I., 2020). The burning temperature of argan nut shells is comparable to wood pellet fuel (Rahib, Y., 2021). With the argan nut shell making up almost half of the entire fruit by weight, it has potential to serve as a readily available fuel source, both in the Arava region, where there is a prevalent outdoor activity industry, and Morocco, where it is already traditionally burned. Hydrocarbons comprise a large part of the argan nut shells structure in the form of 25% cellulose, 34.3% hemicelluloses and 34.5% lignin (Tatane M., 2018). This composition makes the plant an ideal source of energy dense fuel for fires. Generally, the plant material is desiccated by the arid environment it is typically grown in, making it easier to ignite (see Figure 2.1).

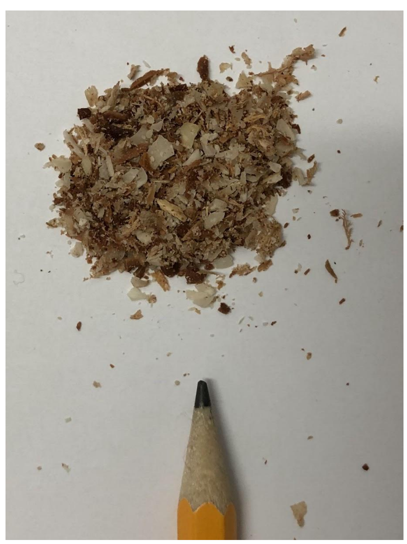


Figure 2.1. Fine crumbs from the nut cracking machine that are used to make the burnable campfire pellets

ANS Pet bedding/cat litter

Walnut shells are a common analog for wood in pet bedding materials due to their high absorbency capabilities. Argan nut shells, however, are more absorbent than walnut shells with a water absorbency rate of 26% compared to walnut shell powder's 10% (Jannat, N., et al., 2021). To make an ANS pet bedding material the shells would ideally be processed to reduce their jagged, brittle edges or shredded into soft shavings such that animals could walk on them safely (Angulo, F. J. et al., 2006). An adjacent use that requires the same high absorbency is to use ANS pebbles/shavings in cat litter. Similar products exist that contain wood or walnut shell shavings, meaning it is likely argan nut shells would be a comparable analog.

Figure 2.2. Argan nut shells

Activated charcoal

Hydrothermal Carbonization (HTC) is a chemical process that utilizes the high carbon content in argan shells to produce a biomass material, activated charcoal, that acts as an adsorbent to remove harmful pesticides and general contaminants from water (Zbair, M. 2020). At its most basic level, HTC involves feeding the nut shells through a pressurized vessel at elevated temperatures. The shells are dried, cooled, and stripped of volatile ingredients, resulting in a simplified, structured carbon filtration substance (Zbair, M. 2020). This method of processing requires specialized equipment, however, it yields a 92-95% efficacy rate in removing harmful contaminants such as BPA and Diuron from water (Zbair, M. 2020). Figure 1 below visually depicts the HTC process in its simplest form. Although this process is easier with a specialized pressure cooking vessel, ANS can be transformed into activated charcoal on a smaller scale with a simple hot plate, sealed pot, distilled water, and an activator like lemon juice or calcium chloride ("How to Make Activated Charcoal (with pictures)", 2018).

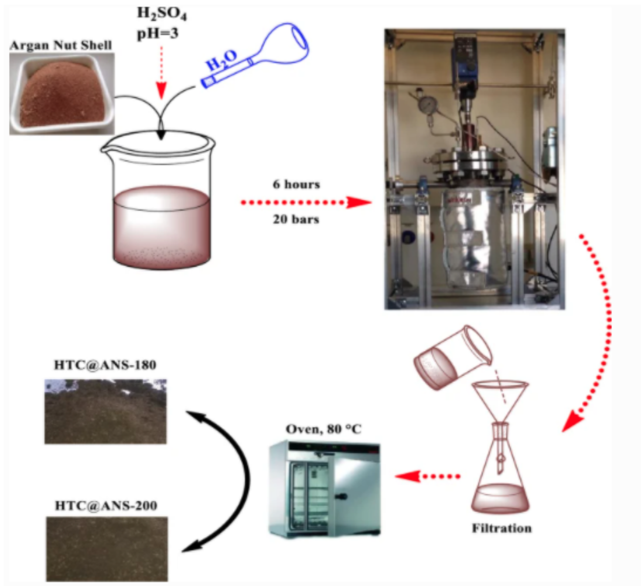


Figure 2.3. The hydrothermal carbonization (HTC) process performed at 180 degrees Fahrenheit and 200 degrees Fahrenheit (Zbair, M., 2020)

2.2.2 Commercial products using multiple argan waste materials

Cosmetic exfoliant

An argan waste cosmetic exfoliant is unique among other proposed commercial waste products because it may utilize multiple different kinds of argan byproducts such as the nut shell, the extrusion paste, and the dried kernel flakes. While the oil of the argan nut is commonly used in cosmetics and hair care, the powdered nut shells have a gentle abrasiveness that can be used as an exfoliating skin cleanser (Charme D'Orient, n.d.)(Guillame, D. et al., 2019). Upon further inspection, the crushed dried kernel flakes may also be used as an abrasive component in a body scrub for those with more resilient skin (See Figure 2.4). The extrusion paste already takes on many qualities of a scrub and has a high oil content, giving it merit as a foundational ingredient for an argan waste-based cosmetic physical exfoliant (see Figure 2.5).

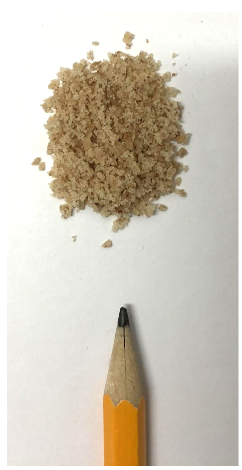


Figure 2.4. Ground up dried argan kernel flakes (Left) output from the extraction machine

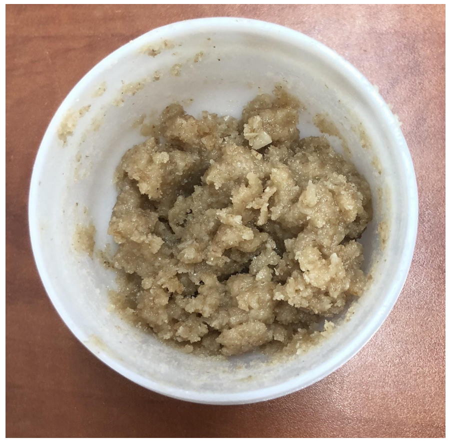


Figure 2.5. The paste output from the extraction machine

Cellulose extraction

Cellulose is a highly coveted preservative substance within the culinary and pharmaceutical industries (Hu, Y., 2017)(Wang, X., et al., 2011). Typically, cellulose may be extracted from argan press cake (APC) (also referred to as extrusion paste above), which is the mashed inner kernel residue of the argan seed after it has been pressed for oil (Hu, Y., 2017). To accomplish this, the APC is cooked in a pressurized vessel and recovered as a bleached, purified substance. (Beluns, S., et al., 2021). Then, structural polymers, also called lignins, are dissolved with an ionic chemical and decanted to isolate and extract pure cellulose (Industrial Adhesive, 2020). This is a relatively low-cost and efficient method for producing cellulose, making it favorable over other extraction methods (Hu, Y., 2017)(Wang, X., et al., 2011). Cellulose may theoretically also be extracted from ANS as they contain 25% cellulose, which is a lot larger than the cellulose content in the APC/kernel (Tatane M., 2018) . Although there is no precedent for extracting cellulose from the argan nut shells in particular, it may be a more efficient source of it (Hu, Y., 2007).

2.3 Past IQP

2.3.1 Theoretical research on repurposing argan nut waste in Israel

In a previous IQP, team members started the process of discovering and evaluating opportunities to valorize the argan nut waste. Focusing primarily on the Argan Nut Shell (ANS), they categorized these opportunities into three main groups: “Easy to Implement”, “Requires Further Research to Implement”, and “Unmarketable”. The team placed creating kindling blocks, through the compression of powdered ANS (with or without a binder), into the “Easy to Implement” category, (Evans, D., et al., 2021). The “Requires Further Research to Implement” group contains activated charcoal (which is the adsorbent filtration product of HTC mentioned earlier), biocomposites and plastics, and active packaging (Evans, D., et al., 2021). Activated charcoal is used for air and water purification, biocomposites and plastics use

ANS as a biofiller, and active packaging provides thermal or chemical protection for its contents. Liquid biofuels and large scale water treatment were deemed “Unmarketable” because they were unprofitable.

Further, the team determined that the most important factors when selecting an argan nut waste use were the equipment required, recurrent materials necessary, environmental impact, marketability, and further research required (Evans, D., et al., 2021). After rating the six identified uses for argan nut waste in each of these categories, kindling blocks had the highest feasibility score with activated charcoal and then active packaging behind it (Evans, D., et al., 2021). Although the previous team was able to categorize a few ways of repurposing the nut shells, we investigated a wider variety of options for reuse and conducted more detailed research into the materials properties of the nut shells. Specifically, the flammability, absorbency, and abrasiveness. Based on this research, we hope to capitalize on these properties in the development of commercial ANS products and create a structured business plan to be implemented in Kibbutz Ketura.

2.4 Summary

As Kibbutz Ketura continues to investigate and evaluate the potential of argan oil as a business venture, the large proportional amount of waste produced needs to be addressed. To this end, we plan to evaluate waste product solutions to utilize the potential influx of waste while still providing monetary return.

3.0 Methodology

The goal of this project was to identify and evaluate methods of repurposing argan fruit waste in order to develop commercial products for the next 5+ years as Kibbutz Ketura scales the argan tree domestication process and therefore, how much waste they produce annually. To meet this goal, we:

1. Evaluated the potential of immediate waste solutions to address current argan waste build up within Kibbutz Ketura
2. Investigated the production feasibility of mid to long term waste solutions to facilitate scaling of the argan operation in Ketura
3. Explored expansion opportunities with current business partners of the Kibbutz for public distribution of commercial cosmetic nut waste products

By evaluating each proposed waste solution and cultivating business relationships, we hope to develop an avenue through which Kibbutz Ketura may domesticate the argan tree and generate profit in a sustainable manner.

In order to further contextualize our initial background research on each waste solution discussed in the previous chapter, we ranked each according to multiple criteria and ultimately classified them as immediate, midterm, or long term waste solutions. Each criterion was determined based on which information would be most relevant for our sponsor to be aware of when implementing each of the proposed waste solutions on a 10 year timeline. Immediate waste solutions (IWS) were defined as those that would be implemented by the Kibbutz right away, or within the next 1-3 years. Mid-term Waste Solutions (MWS) were defined as those which would be ideal for implementation within the next 5+ years, assuming the Kibbutz continues to produce the amount of nut waste projected in the previous chapter. Finally, Long term Waste Solutions (LWS) are methods of reuse that would operate at a scale best for implementation in the next 10+ years, provided the Kibbutz is producing close to 100 tons of waste annually.

After classifying each method as an IWS, MWS, or LWS, we constructed a comprehensive classification matrix to visualize how each waste solution scored in comparison to the others (see Appendix A). It was from this matrix that we determined ANS-based pet bedding and burnable campfire pellets to be IWS, argan-based activated charcoal and cosmetic exfoliants to be MWS, and cellulose extraction to be a LWS. To reference the classification matrix or how each waste solution was classified, refer to Appendix A.

3.1 Objective 1: Evaluating the potential of immediate waste solutions

We conducted a number of controlled experiments for each of our methods of repurposing argan waste materials to gain a hands-on understanding of the material characteristics involved in each method. These experiments were exploratory in nature, such that we could gain some preliminary information on working with argan waste materials in general and establish some foundational procedures for future research to build on. All weight related data for these experiments was measured in grams using an SX-7002D Electronic Food Scale with a resolution of ± 0.5 g or a Hyundai HASC-4350 battery powered scale with a resolution of ± 0.5 g.

3.1.1 Evaluating ANS in burnable campfire pellets

We performed combustion tests to evaluate the efficacy of ANS as a material used for burnable campfire pellets (see Appendix B). We constructed two different types of pellets: one using 100% fine ANS crumbs and one using 75% fine ANS crumbs and 25% small ANS chips. We compressed the compound material mixtures into pellets roughly 6 mm in diameter using the argan oil extrusion machine on an extraction speed of 2.5 out of 10 (see Figure 3.1)(Yazdanpanah, F., 2009).

Figure 3.1. Argan burnable pellets made from post-cracking crumbs fed and extruded through the oil extrusion machine

We ignited a 31.0 g pile of ANS pellets, redistributing and relighting the pile until it was completely reduced to ash. We then compared the weight of the residual ash to the original 31.0 g of the pellets before combustion to determine the rough amount of emissions produced. We initiated the ANS pellet fire igniting the surface of the pile with a propane blowtorch (see Figure 3.2). We conducted a controlled, comparative test with pinewood shavings, a common material in commercial fuel pellets. Because of the size of the pinewood shavings, we used a standard lighter to avoid blowing away the shavings (Rahib, Y., et al., 2021)(Brunner, P., 2014)(Martyr, A., et al., 2012). The percent reduction by weight of the burnt pine wood and ANS pellets was calculated using Equation 1 below.

$$\text{Equation 1: } \frac{[Initial\ weight\ (g) - Final\ weight\ (g)]}{Initial\ weight\ (g)}\ x\ 100$$

The percent weight reduction of pine wood and ANS pellets were then compared to determine the viability of repurposing ANS as commercial burnable pellets.

Figure 3.2. ANS burnable pellets being ignited by the propane blowtorch

3.1.2 Evaluating ANS as a pet bedding or cat litter analog

We performed preliminary absorbency tests to determine the efficacy of ANS pebbles as pet bedding to provide general comfort and absorb animal excretions. The goal of these tests was to determine if crushed ground ANS are a comparable analog for wood or walnut shell shavings in a commercial pet bedding/litter material given their high absorbency (Jannat, N., et al., 2021). We first made ANS pebbles from the shells themselves by using a manual grinder on a particle size setting of 4 out of 6 (see Figure 3.3 and 3.4).

Figure 3.3. ANS pebbles made from ANS chips

Figure 3.4. Manual grinding machine used to make the ANS pebbles and ANS powder

We performed two different types of absorbency trials: pouring trials and soaking trials. For the pouring trials, we poured 75 mL of water slowly and evenly over a 75 g sample of ANS pebbles in a strainer (see Appendix C). The pebbles were left to drip into a container as shown in Figure 3.5 below and the amount of water in the container was recorded at intervals of 30 seconds, 3 minutes, 10 minutes, 20 minutes, and 45 minutes. For the soaking trials, we soaked 10 g of contained ANS pebbles in 550 g of water and recorded the amount of water that was absorbed by the pebbles at 30 minutes, 45 minutes, and 60 minutes (see Appendix C). For both sets of trials, we calculated the amount of liquid in grams that had been retained by the sample and calculated the absorbency of the nut shells at each recording interval as shown in Equation 2 below.

Equation 2: $$\frac{[Initial\ water\ (g) - Final\ water\ (g)]}{Initial\ water\ (g)}\ x\ 100 = \frac{[75\ g - Final\ water\ (g)]}{75\ g}\ x\ 100$$

For the pouring trials, we compared the absorbance values to those of a sample of commercially available silica gel cat litter material (Fan Q., 2008). For the soaking trials, we conducted two comparative control trials: one with pinewood shavings and one with silica gel cat litter. Pinewood shavings were included as a control group for the soaking trials to mimic a commercially available pet bedding ingredient and include another natural, unprocessed material for comparison. All results were averaged and transferred to a bar graph to quantitatively compare the absorbency between the three pet bedding/litter materials.

Figure 3.5. Testing setup for the silica gel cat litter absorbency pouring trials

3.1.3 Evaluating argan waste products as cosmetic abrasives

To test the potential of using argan nut waste products as a cosmetic exfoliant, we made samples of argan waste scrubs and observed how they interacted with the surface of a clementine, as fruit skin (mostly citrus) is typically used to demonstrate the effect of cosmetics on human skin. Additionally, clementine skin is more similar to that of humans than orange skin (see Appendix D) (Roberts, A., 2018). We made three different types of scrubs to select the argan material best suited to act as an abrasive in a cosmetic physical exfoliant. All three scrubs contained the extrusion paste from oil production as a base ingredient, with either ANS powder, argan flake powder, or sugar as an abrasive. Sugar was used as a control because it is a very common abrasive ingredient in commercial scrubs (Yamaguchi, M., et al., 2019). Sample scrub recipes ranged from 1 part paste:4 parts abrasive to 4 parts paste:1 part abrasive. For the specific recipes of the sample scrubs made, refer to Appendix D. Two-fingers full of each scrub were applied to the clementine peel for 15 seconds.

After gently rubbing the sample scrubs against the fruit skin, we visually inspected the scrub and fruit to evaluate the effectiveness of the ANS powder scrub and argan flake powder scrub compared to the sugar control scrub with regards to their consistency, abrasiveness, oil content, and moisturizing ability. Then, scrubs were sorted into categories of the type of skin they would most likely be best suited for on a range of dry to oily skin as well as sensitive to more resilient skin. Sample scrubs that were more visually abrasive in nature were classified as being suitable for more resilient skin. Sample scrubs that were less visually abrasive in nature were classified as being suitable for those with dry skin. Sample scrubs that had a lower oil content and deposited smaller streaks of oil on fruit skin were classified as being suitable for those with oily skin. Sample scrubs that had a higher oil content and deposited larger streaks of oil on fruit skin were classified as being suitable for those with dry skin.

3.2 Objective 2: Identifying feasible mid to long term waste solutions

3.2.1 Evaluating the effectiveness of ANS activated charcoal

We made one batch of activated charcoal from argan nut shells (See Appendix E). To prepare the batch, we burned 1500 g of shells at low levels of oxygen for 7 hours using a lidded pot and electric stovetop (see Figure 3.6). After that, we ground the charcoal to powder with a mortar and pestle. In a larger scale operation, the process of hydrothermal carbonization and the associated equipment outlined in the background section, would be used. We used a simpler, manual process to transform the ANS and wood into activated charcoal. The process of burning the biomass at low levels of oxygen is an established way to create charcoal, however there is some flexibility in the activator. In order to prepare for future absorbency tests where the identification of different shades of colors would be important, we developed a program in Java that determines the color of a specified water sample.

Figure 3.6. ANS shells after being cooked in a lidded pot for 7 hours to make charcoal

3.2.2 Investigating cellulose extraction from ANS

We performed a standard cellulose extraction procedure on ANS to explore the possibilities and obstacles of sourcing cellulose from argan waste (see Appendix F)(Industrial Adhesive, 2020). To break down the lignins that bind together the cellulose, we cooked our source material with an electric hot plate on a heat setting of 2 out of 4 for 30 minutes in 425 mL of water and 5 grams of sodium hydroxide (NaOH) (see Figure 3.7). We then decanted this solution through a strainer. We conducted a qualitative analysis of the viscosity, texture, color, and amount (in grams) of cellulose produced. For a controlled, comparative analysis, cellulose extraction was also conducted on samples of pinewood shavings.

Figure 3.7. Crushed ANS being boiled in sodium hydroxide solution in an attempt to extract cellulose fibers

3.3 Objective 3: Exploring expansion opportunities with current business partners of the kibbutz

We conducted informal interviews with local business owners pertaining to our immediate and midterm waste solutions. Specifically, we met with a Kibbutz Ketura spa employee and a local all-natural cosmetic vendor who already works with Solowey to package and distribute argan and algae-based cosmetic products to the local Kibbutz gift shop. We met with them to discuss the feasibility and next steps for selling a physical exfoliant made from repurposed argan waste products. We have outlined the topics and specific questions that were discussed with each interviewee in Appendix G.

The objective of these conversations was to gain insight about the market potential of each nut waste product as an ingredient in cosmetic exfoliants and the next steps that we would need to take to make them marketable and/or ready for distribution. While the points of discussion listed in Appendix G are what we used to guide our interactions with each contact, it should be noted that these conversations were informal and the interviewee was free to redirect the conversation whenever and wherever they felt it was necessary.

By conversing with local community members, we were able to gain a better understanding of the peripheral factors of initiating a new agricultural project on the Kibbutz and how it may impact the community's joint functionality.

4.0 Results and discussion

This chapter presents the results that we have obtained from the exploratory controlled and experimental testing discussed in the previous chapter. Specifically, we cover the experimental % weight reduction of the ANS burnable pellets, absorption rate of ANS pebbles, and abrasiveness of ANS powder and dried kernel flakes. We also discuss the results of our attempts at extracting cellulose from ANS and generating ANS charcoal. Finally, we discuss our casual conversations with local business owners. Further information with regards to procedures, peripheral background information and assumptions, and minor observations can be found in the appendices chapter.

4.1 Burnable campfire pellets

The results of our controlled and experimental burning trials for ANS-based burnable campfire pellets are summarized below in Tables 4.1 and 4.2 respectively.

Table 4.1: Control trials - Burnable pellets - Weight of pinewood samples before and after burning

Trial Number	Initial Weight (g)	Final Weight (g)	Burn Duration (min)
1	31.0	2.0	42
2	31.0	2.0	25
3	31.0	2.0	26

Table 4.2: Experimental trials - Burnable pellets - Weight of ANS pellet samples before and after burning

Trial Number	Initial Weight (g)	Final Weight (g)	Burn Duration (min)
1	31.0	2.0	33
2	31.0	3.0	38
3	31.0	3.0	35

The pine shaving control group had a 94% weight reduction after burning and the ANS pellets had about a 90% weight reduction after burning. For the most part, the weight after combustion was fairly comparable between the control sawdust and experimental pellets, with the latter weighing slightly more.

4.1.1 Discussion

Pinewood is a relatively soft wood and usually contains a significant amount of sap. It is considered to have a lower burning efficiency than other woods, especially hardwood. The fine ANS crumble pellets are also very soft and contain a small amount of residual argan oil. In each case, if a fire reaches a certain point, it will evaporate and ignite the oil and sap within the fuel.

During the experimental ANS trials, the last two sets of pellets were made only hours before the burning trials, as opposed to the first set, which had two days to “dry” and lose the residual oil in the material. This might explain the slightly increased final weights of the last two sets of burnable pellets. These results might also imply that, on average, less of the ANS pellet fuel will convert to emissions.

During the control trials with pinewood sawdust, there were fairly high winds (5 mph to 15 mph) that seemed to extinguish flames when a fire was starting or ending. They did, however, also cause the flames to grow rapidly when they had ignited a large area of the wood. These high winds may have caused a decrease in burn time considering they accelerated ignition at the fire's peak. Conversely, the wind could have increased burn time considering it was occasionally difficult to sustain a flame, and the pile frequently required attention and relighting. When reflecting on the experimental trials, the same could be true to a minor degree, but the pellets could only be effectively lit with a blowtorch, and there was rarely any wind at all (less than 5 mph).

Using a blowtorch significantly decreased the amount of time required to burn an entire pile of fuel. It was extremely troublesome to ignite the pellets with standard lighters, and the blowtorch would have blown the sawdust away if we had used it, just as it blew away some of the pellet ash. Because we used a different method of ignition, it would be dubious to compare the burn durations of the experimental and control trials with each other, and to some lesser degree, the same could be said about the weight reduction.

The smoke from the pellets smelled strongly of wood smoke, similar to hickory. When standing in the pellet smoke, it didn't sting our throat and eyes as much as is typical of other wod smoke. These properties could make ANS pellets an ideal campfire and barbequing fuel.

Scaling Estimates

Despite our experiments using the fine crumbs from nut cracking as the input material for making burnable campfire pellets, the intended plan is to find a way to use the whole nut shell to make the pellets. This would enable the product to be produced at a profitable scale, as the nut shell is available in larger quantities. Given the assumption that the pellets are made from the full shell, the Kibbutz can expect to produce 70 tons of burnable campfire pellets in 5 years, and 100 tons of pellets in 10 years.

4.2 Pet bedding/cat litter

Figure 4.1 and 4.2 below depict the average absorbency of ANS pebbles compared with commercially available materials over the course of 45 minutes and 60 minutes respectively. More specifically, Figure 4.1 below displays the water absorption of silica gel cat litter and argan nut shell pebbles during pouring trials. Figure 4.2 below summarizes the absorption rates of ANS pebbles compared with silica gel cat litter and pinewood pet bedding shavings during soaking trials. Based on our pouring trials, the 75 g of silica gel crystals absorbed on average 63.7 g of water, while the ANS pebbles absorbed an average of 22.0 g of water.

During soaking trials, the wood shavings absorbed 67 g of water after 60 minutes, which is 670% of their mass. Comparatively, the silica gel cat litter absorbed 16 g of water (160% of its mass) in 60 minutes, and the ANS pebbles absorbed 11 g of water (110% of its mass) in that time.

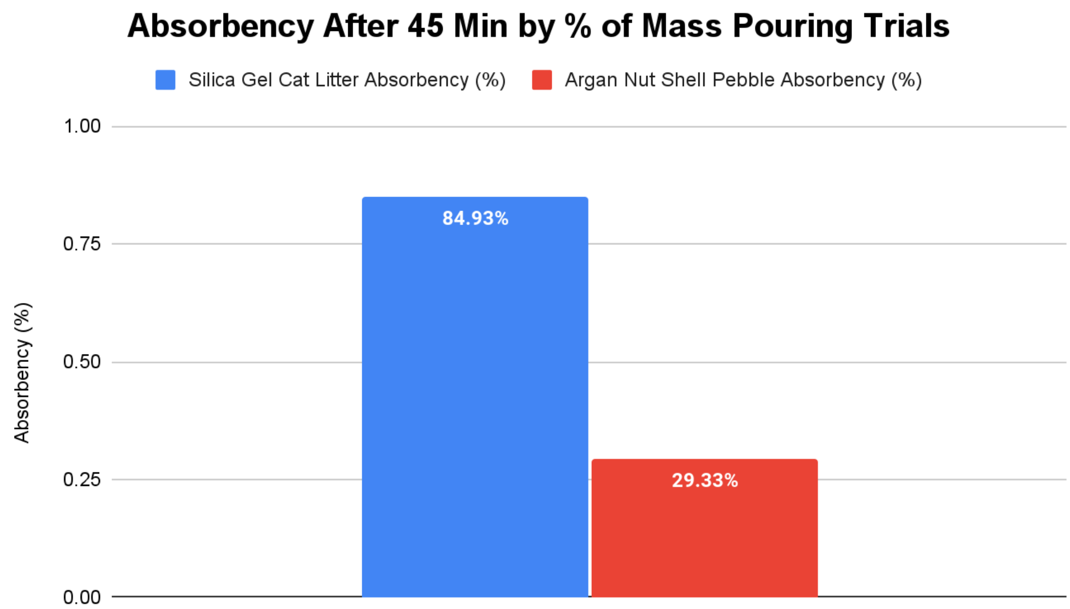


Figure 4.1. Bar graph comparison of silica cat litter and ANS pebble water absorbency rates (%) during pouring trials

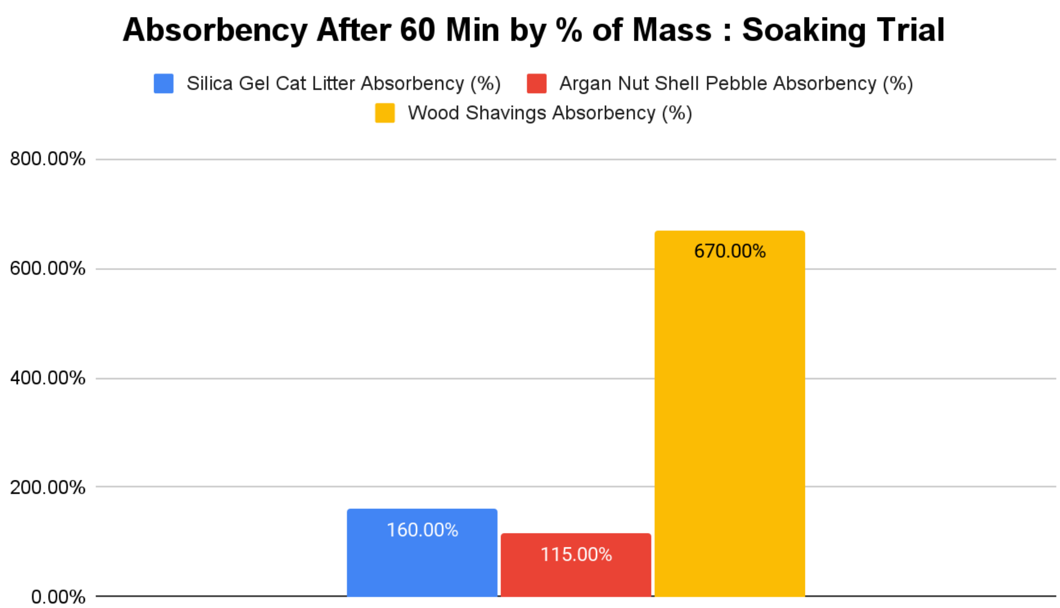


Figure 4.2. Bar graph comparison of pinewood shavings, silica cat litter, and ANS pebble water absorbency rates (%) during soaking trials

Scaling Estimates

When making the pebbles with the hand cranked grinding machine, about 10% of the ANS was turned into powder, while 90% became the ANS pebbles we used for our experiments. Based on these numbers and the estimates for growth the Kibbutz could expect to produce about 45 tons of ANS pebbles in 5 years and 90 tons of ANS pebbles in 10 years. The resulting powder could also be used for the cosmetic exfoliant as described in later sections.

4.2.1 Discussion

The commercial silica gel cat litter more closely resembled the ANS pebbles in how it appeared after being soaked (like wet pebbles) as well as the amount of water it absorbed. The silica gel cat litter is almost 3 times more absorbent than the ANS pebbles and has a higher absorption speed overall. It is for this reason that ANS pebbles are likely not a superior replacement for commercially available cat litter. However, ANS pebbles may have potential applications in an ANS-wood composite pet bedding material for smaller animals. Despite the large amount of water they absorb, wood shavings alone are not ideal for pet bedding. At the end of the trial the shavings were mushy and sopping wet, which would likely be unpleasant for an animal to walk on and require more maintenance on the part of a pet owner. The pebbles resembled wet mulch at the conclusion of these trials which is likely more pleasant for animals to walk on (Angulo, F. J. et al., 2006). Therefore, it may be useful for further research into a composite pet bedding material of wood shavings and ANS pebbles. This would theoretically provide maximum absorption over longer periods of time, while still providing a comfortable bedding material for smaller animals.

Evaluating the approach to testing absorbency

The difference in absorbance between the ANS pebbles and the silica gel cat litter was much more pronounced in the pouring trials. Any water that was not immediately absorbed fell into the lower catching container leaving no possibility for later absorption. As such, our pouring trials demonstrated the considerable difference in absorption speed between the silica gel cat litter and ANS pebbles, while our soaking trials displayed a closer similarity between materials in total absorption over time.

The literature gives the absorption of argan nut shells as 26% and walnut shells as 10% (Jannat, N., et al., 2021). Our experiments show that the absorption rate, overall, of ANS is 120%. The difference between these two absorbency rates could be explained by the difference in particle size. The literature references tests done with ANS powder, while we were testing small pebbles.

Possible sources of error

In the third trial of commercial silica cat litter, there was some variance in how the water was poured over the litter. It was slower and more evenly spread out over the litter which may account for the sudden increase in absorbance compared to the other two control group pouring trials. This change in absorbency was also visible, since the silica crystals in the litter become transparent after absorbing water. In the third trial, a larger area of the silica gel crystals were transparent, especially on the top layer.

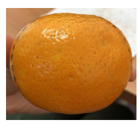
Controls

When conducting experiments over longer periods of time with water in an open container, there is some concern over consistency when it comes to temperature and humidity. In order to cut down on the possibility of having confounding variables like temperature and humidity, the experiments were conducted in the same room.

4.3 Cosmetic exfoliant

Table 4.3 below displays the fruit skin after each sample scrub was applied on to the surface for 15 seconds each and lightly rinsed with water. The parts paste is denoted by a “P” and the parts abrasive is denoted by “A” (ex. 1P:4A = 1 parts paste to 4 parts abrasive). For a similar table depicting the fruit skin with sample scrubs still on the surface, refer to Appendix D.

Table 4.3: Cleaned/Washed Fruit Testing Strips with Argan Paste Cosmetic Test Scrubs

Washed	1P:4A	2P:3A	3P:2A	4P:1A
Sugar				
Flakes				
Powder				

Generally, scrubs with more of the abrasive than paste had a greater tendency to fall off of the fruit during application as they were dry and had a less cohesive consistency. Therefore, it was more difficult to get an even and equal application over the area of the fruit skin compared to other scrub samples. The ANS powder-based scrubs stuck on the fruit skin for a longer period of time after application, but still washed off the skin fairly easily. As the amount of paste in each scrub increased, so did the oil-content due to the paste still containing residual oil.

After testing each scrub on fruit skin, we determined the following qualitative information about which scrubs are most ideal for dry, oily, sensitive, and/or resilient skin based on their consistency, abrasiveness, oil-content, and moisturizing ability (see Table 4.4). For detailed notes and experimental observations on how each scrub affected fruit skin, refer to Appendix D.

Table 4.4: Classification of argan-based cosmetic exfoliants

	Dry	Oily
Sensitive	Flakes - 3P:4A	Powder - 3P:2A Powder - 4P:1A
Resilient	Flakes - 4P:1A Flakes - 2P:3A	Powder - 2P:3A

Both the powder and flake scrubs with an ingredient ratio of 1 part paste: 4 parts abrasive were not as generally effective as body scrubs compared to the other samples tested. These scrubs were too dry and hard to apply evenly over the fruit skin.

Scaling Estimates

The Kibbutz generates about 170 g of extrusion paste every 2 weeks on average (Solowey, 2022). This means that based on current waste production rates, Kibbutz Ketura can export about 1 commercial scrub via the local factory every 14 days. While this is not a significant output at the moment, this product can be used within the Kibbutz regularly without a high production cost. Further, based on our conversations with local business owners, it has a high profit potential for the next 5 years, when the Kibbutz is generating close to 12,000 g of extrusion paste and therefore, about 20,000 g of cosmetic exfoliant every 2 weeks on average.

In terms of the ANS powder, the shells could either be completely ground up into powder or they could be taken from other production processes that create powder as a byproduct. If the full shell was turned into powder, the Kibbutz could expect to produce about 70 tons of ANS powder in 5 years and 100 tons in 10 years. However, if the kibbutz decides to take the powder from the pebble making process as described in earlier sections, they could expect to produce about 7 tons of ANS in 5 years and 10 tons of ANS powder in 10 years. Either option would produce ample powder to be mixed with the argan paste.

4.3.1 Discussion

Scratches, bruises, or other blemishes were noted on each fruit skin test strip before application trials were run in order to obtain less biased data on how effective each scrub was at cleaning the fruit skin while still moisturizing it properly. However, we acknowledge that there are still major limitations to testing a cosmetic product on fruit skin as opposed to human skin. Although each of the scrub samples provided some minor benefit to the fruit skin, those with paste to abrasive ratios of 2:3 or 3:2 were more applicable to a wide variety of skin types than those with compositions of 1:4 or 4:1. Before moving to human testing, more prolonged testing should be done with the powder and flake scrubs of a 2:3 and 3:2

composition to confirm the integrity and effectiveness of each scrub over time rather than a one time test treatment.

4.4 Activated charcoal

After cooking the ANS in the lidded pot, the shells appeared mostly black with some appearing slightly silvery and others retaining some of their original woody brown color. In general, the lower in the pot the shell was, the more likely the ANS was to be completely black or silvery. Higher up in the pot, the ANS maintained some spots of brown, especially on the inner surface of the shell. There was a weight reduction from 1500 g of ANS to 886.5 g of cooked ANS.

Grinding the cooked ANS with the mortar and pestle revealed that the silvery shells were the driest and broken up the most easily. The slightly brown shells seemed to retain some moisture and were less brittle, proving more difficult to grind up. The result of this grinding was a fine black powder, charcoal.

4.4.1 Discussion

We have determined that it is possible to make basic charcoal out of ANS by cooking the nut shells at a high temperature with low oxygen levels. However, the ANS needs to be cooked for longer than the time used in the exploratory experiment. Based on the horizontal layers of color and "doneness", the proximity of a nut to the heat source directly influenced how quickly the ANS was cooked. Therefore, the ANS might have cooked all the way through if there were fewer nuts in the pot. Another factor that may impact cook time is the temperature of the heat source. A stronger heat source would mimic the ANS being closer to the heat and speed along the cooking process.

Scaling Estimates

Based on the weight reduction after the cooking process, we then calculated that 591 g of charcoal can be produced per kilo of shells. With the expected growth of oil production, this means that the Kibbutz would be able to produce about 41.7 tons of charcoal in 5 years and g in 59.1 tons 10 years. We recognize that any future cooking process will potentially be more effective and remove even more mass so the previous estimates will likely be over the true yield of charcoal made from ANS.

4.5 Cellulose extraction

Table 4.5 below indicates the initial and final weight in grams of wood and ANS samples before and after we attempted cellulose extraction on each material. In both the control and experimental extraction trials, the water became a dark shade of brown. The experimental ANS trial produces a darker shade of brown than the control.

Table 4.5: Weight of samples before and 5 days after cellulose extraction

Sample Material	Initial weight (g)	Final weight (g)	Cellulose extraction duration (min)
Pine Sawdust	16	16	30
ANS Chips	16	16	30

After 5 days of evaporation, both sawdust and ANS samples appeared and weighed exactly as they did before cellulose extraction was attempted. There is no definitive indication that cellulose was successfully extracted from the pinewood shavings or the ANS.

4.5.1 Discussion

Based on the lack of observable differences present in the sawdust and ANS chips before and after cellulose extraction attempts as well as their unchanged weight, we can not conclude that the the sodium hydroxide solution was potent enough to properly dissolve the lignins of the pine sawdust, let alone the ANS chips. Ideally, we would observe a reduction in weight after the lignins dissolve in the sodium hydroxide solution and pass through the strainer, leaving only the cellulose fibers. If we were to repeat this process, it would be with a sodium hydroxide solution that is more concentrated than what we had found recommended online (See Appendix F) or another ionic liquid and extend the time beyond 30 minutes.

4.6 Conversations with local business owners and community members: Argan waste cosmetics

While talking to the local cosmetic business owner, we clarified the process of developing a new product and having it made and exported. Ingredients need to be licensed by the government in order for them to be incorporated into commercial products. In addition to this, the factory of this business requires time and samples of the material to develop a recipe specific to the new ingredient. Once the license has been obtained and the recipe finalized, the production of a new product can begin. With regard to argan materials in particular, the business owner seemed to be open to the idea of using the different waste products, specifically mentioning the ANS powder as a possibility for a face peel or in soap.

We consulted another person in the field of cosmetics: the Kibbutz's massage and spa employee. The employee reiterated what the local business owner had stated about obtaining a license for the ingredients, and then proceeded to detail how each part could be used and how it would be a beneficial treatment. The paste could be used as is for a scrub or face mask and the ANS powder could be used in a face peel or body scrub for sensitive skin when mixed with a carrier oil. All of these uses would take advantage of either the moisturizing capability of the residual oil content in the material, the natural abrasive properties, or both.

4.7 Next steps and recommendations for future research endeavors

Burnable campfire pellets

Various parts of the argan fruit are flammable, some more than others. Based on the results of our experiment, we recommend that future efforts to create ANS burnable pellets center around exploring methods of constructing pellets using a binder, such as wax to increase flammability and keep the pellets together for a longer period of time, especially in the context of larger-scale distribution.

Depending on the structure of the fuel, one can employ various ignition methods. Normal lighters will only be able to effectively ignite small pieces of argan without the help of a more volatile fuel such as paraffin wax, butane lighter fluid and other types of plant/wood tinder. Argan nut shells and kernels will smolder and form coals at lower temperatures which may be sufficient for certain heating applications where flames are unnecessary.

Pet bedding

The pet bedding made of ANS pebbles was not as absorbent as the sawdust. One possible explanation for this is the difference in shape. In order to determine this is the case, trials should be run comparing the absorbency of saw dust, wooden pebbles and the ANS

Cosmetic exfoliant

Given the added complexity of this product being intended for human skin, the next step for this potential method or repurposing the argan waste will likely be conducting research of the requirements for an ingredient to be licensed by the government. After the license has been obtained, then it would be prudent to provide the waste materials and sample scrubs to the local cosmetic business owner we spoke with to develop an official, standardized recipe for a commercial exfoliant to be sold by the Kibbutz. Once the recipe is solidified, the next step would be to do clinical trials under the Israel Ministry of Health to test the effects of the product on potential consumers and obtain their feedback as well.

Activated charcoal

Activated charcoal requires a lot more research before it could be implemented as a waste solution. Firstly, the process of making charcoal from ANS needs to be modified for efficiency and thoroughness. Experiments should be run to measure the effect of temperature, amount of ANS being cooked, as well as the amount of time the ANS is left to cook impact the success of the charcoal making process.

After an efficient charcoal making process has been identified, the next step will be evaluating the capability of different compounds as activators. Absorption trials of lemon juice, calcium chloride, zinc chloride, and sodium chloride should be attempted and compared against a trial of regular charcoal to gauge the activator's true impact on the charcoal's absorption rate. See Appendix E for a detailed procedure to follow as well as code to analyze the results.

Cellulose extraction

To further the exploration of this waste solution, trials should be attempted with various ionic liquids at different concentrations. A method for determining the success of the cellulose extraction without expensive ingredients and/or equipment should also be developed.

5.0 Conclusion

We determined that ANS pellets had a significant weight reduction after burning, and burned continuously once ignited. We recommend future tests to further investigate burning duration and thermal output of the pellets in different environments. We determined that ANS pebbles had a comparable total absorbency to silica gel cat litter. Due to the slower absorbecy speed of the ANS pebbles, it was concluded that ANS pebbles are not a worthy analog for silica gel in commercially available cat litter. However, we recommend that there be further research into composite ANS-wood pet bedding materials for smaller animals in order to maximize absorbance over time while providing a comfortable material for prolonged contact with small animals. We determined that ANS powder and dried kernel flakes are both viable as abrasive components in a body exfoliant. After conversations with local cosmetic business owners and performing our own exploratory trials, we concluded that the ANS powder scrubs are more ideal for those with oily skin and the dried kernel flake scrubs are more suitable for those with dry skin. Further, we recommend that more in-depth testing be done with the scrubs containing 2 parts paste to 3 parts abrasive and 3 parts paste to 2 parts abrasive. This is because they were the most applicable to a wide variety of fruit skin types.

There was no change in weight of physical difference in ANS samples before or after cellulose extraction attempts. Therefore, there is no definitive confirmation that cellulose was successfully extracted and we recommend that future attempts are made with higher concentrations of sodium hydroxide and/or other ionic liquids. We successfully generated charcoal from ANS, however, we recommend further experimentation with the temperature, duration, and batch size of cooking to develop a consistent procedure for making ANS charcoal. Beyond this, we recommend experiments to determine which activator (lemon juice, calcium chloride, zinc chloride, sodium chloride) works best at boosting charcoal absorbency.

Capitalizing on the favorable material properties of argan nut waste products is not only an avenue for creating additional revenue streams in local communities, it is imperative for easing the dependency of the argan market solely on argan oil. From these preliminary findings, Kibbutz Ketura can continue to explore the argan industry while maintaining their values of sustainability and their goal of achieving a circular economy.

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7.0 Appendices

Appendix A: Waste Solution Classification

This appendix goes into further detail regarding how our team ranked and classified each waste solution as a method of repurposing argan waste that would be ideal for implementation within the next 1-2 years, the next 5 years, or the next 10+ years. These rankings did not directly impact our experimentation or results, however, they played an important role in our project, facilitated enlightening discussions with our sponsor, and contextualized the initial theoretical research that we had conducted on each waste solution in consideration.

In order to evaluate the feasibility and usefulness of each of the proposed waste solutions and classify them based on an implementation timeline, our team identified the following criteria:

1. The amount/part of the argan fruit that is used
2. The complexity of the equipment or input materials required
3. The physical or chemical byproducts produced during processing
4. The profit potential
5. The scale/amount of waste input necessary to reach feasible marketability
6. The level of skill required to safely operate
7. The amount of physical and/or automated labor required
8. The duration of processing the nut waste into its new form
9. The projected impact on the environment

Each potential waste solution was ranked with respect to each of these criteria, usually on a high-medium-low basis. Once each waste solution was ranked high, medium, or low in each area, the team constructed a comprehensive classification matrix to visualize how each waste solution scored in comparison to the others (see Figure A.1.).

After each waste solution was ranked according to these criteria, they were classified as an immediate (green), mid-term (yellow), or long term waste solution (red) using a flowchart (see Figure A.2.). It should be noted that the criteria not explicitly included in the flowchart do not directly impact where each waste solution fits on the implementation timeline, but are still important for providing a holistic evaluation of each method.

Immediate Waste Solutions (IWS) are those that would be implemented by the Kibbutz right away, or within the next 1-3 years. Mid-term Waste Solutions (MWS) are defined as those which would be ideal for implementation within the next 5+ years, assuming the Kibbutz continues to produce the amount of nut waste projected in the previous chapter. Long term Waste Solutions (LWS) are methods of reuse that would operate at a scale best for implementation in the next 10+ years, provided the Kibbutz is producing close to 100 tons of waste annually.

	Amount of fruit used	Equipment needed (incl. inputs)	Byproducts produced	Profit potential	Scale Needed	Labor Required (Skill)	Labor Required (Amount)	Processing Time	Environmental Impact
Burnable Campfire Pellets/Rocks	Shell	Low	Smoke, ash	Medium	Low-Medium	Low	Medium	Low	High
Pet Bedding/Cat Litter	Shell	Low	None	Medium-High	Low-Medium	Low	Low	Low	Low
Hydrothermal Carbonization (Activated charcoal)	Shell	Medium-high	Smoke	Medium-High	High	Medium	Medium	Medium	High
Cosmetic - exfoliant	APC, shell, kernel	Medium	None	High	Medium	Low	Low-medium	Medium	Low
Cellulose Extraction	APC, shell	High	Lignin, lipids	High	High	High	High	Medium	Medium

Figure A.1. Waste Solution Decision Matrix for classification of Immediate, Mid-term, and Long term argan nut shell waste solutions

Repurposing ANS into burnable campfire pellets was classified as an immediate waste solution (IWS), because it doesn't require a large amount of nut waste input, skilled labor, processing time, or high-maintenance equipment. Additionally, manufacturing argan-based campfire pellets would use about 50% of the argan fruit post-pressing and has a high profit potential given the outdoor activity market in Israel.

Using ANS shavings as a sustainable pet bedding or cat litter material was also classified as an IWS due to the fact that it requires little to no high-tech equipment or skilled labor, doesn't require a large amount of waste input, and has a low processing time. Similar to argan-based campfire pellets, there is also a large local market for pet bedding/litter in Israel and therefore, a high profit potential. It should also be noted that this sustainable product could be recycled back into the soil as a fertilizer after it has been used.

Chemically processing the argan fruit into an adsorbent, water filtration material (Hydrothermal Carbonization), was classified as a MWS because although it has the potential to reuse close to 100% of the argan fruit, it requires a high amount of waste input as well as a fair amount of skilled labor to operate machinery.

Using powdered ANS as an abrasive component in a cosmetic exfoliant was classified as a MWS because of the estimated high amount of waste input needed as well as the considerable amount of labor required. It should be noted that this waste solution is particularly well-suited to the Kibbutz because of the several parties they already work with to manufacture and distribute argan oil based cosmetic products locally.

Finally, extracting cellulose from the argan fruit was classified as a long term waste solution (LWS). This is because of the high scale (waste input) needed, the significant amount of skilled labor required, and complexity of necessary materials and equipment. This waste solution is most suited for implementation in about 10 years, when the Kibbutz is closer to producing 100 tons of waste annually.

It should be noted that argan-based biofuels (as mentioned in the previous chapter) were also ranked in accordance with these criteria. However, it was determined that this waste solution could not be classified as an IWS, MWS, or LWS because of the extremely high waste and energy input required

paired with a low product yield. Therefore, biofuels are not a feasible waste solution for Kibbutz Ketura given the scope of the current and future argan tree planting operation.

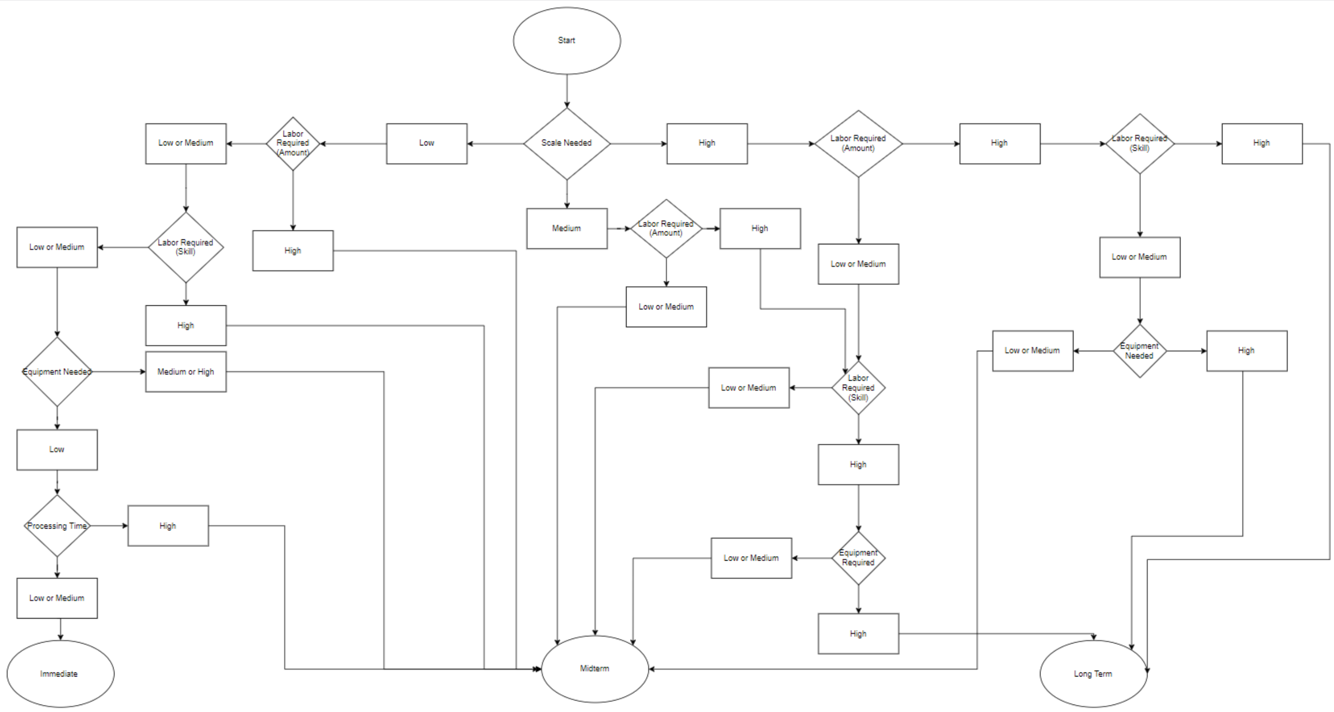

Figure A.2. Flowchart to determine whether a waste method of reuse is immediate, mid-term, or long term.

Appendix B: Burnable Campfire Pellets Experimental Protocol

This appendix contains details of our combustion experiments in exploring possibilities for ANS burnable fuel pellets. Here, we discuss any relevant background information regarding pellets as a commercial product, our initial assumptions and external considerations pertaining to our experimental set up, an annotated materials list and procedure, and any remaining observations, results, or discussion not covered explicitly in the previous chapters.

Preliminary assumptions, external factors, and important considerations

While pieces of ANS are a viable fuel material, there are a number of reasons we focused our efforts on the investigation of burnable campfire pellets:

- Compressed pellets have the advantage of having a greater physical, and therefore caloric, density.
  - Additionally, the shape of pellets can provide the benefit of creating airways through a pile of fuel that would be obstructed by smaller pieces of ANS. While this may also be true for ANS that are split only once to remove the kernel, these shells lack the surface area of a compressed pellet composed of small ANS pieces.
- Apart from their technical advantages, fuel pellets have a degree of commercial recognition that ANS lacks, as many people desire an established style of fuel for their cooking, camping, and heating endeavors.
- Pieces of ANS have been the subject of extensive burning experimentation and use in Morocco and during last year's argan waste IQP project, but we recommend that future projects continue investigation into its use alongside other forms of fuel.
- The goal of the test is to get a qualitative and quantitative analysis as to how similar the combustive properties of argan nut shell chips/pellets are to those of wood (pine) in commercial burnable pellets.
- We will use chips that are about half a centimeter in diameter, but we will use whatever we can access. We have some chips that fell through the sifter, and we are planning on using the nutcracker on its lowest setting as well as grinders from the machine shop.
- We imagine that the smaller the chips are, the more flammable they will be, but we think that we will meet a point of diminishing returns where the pellet/log either lose structure or lack airflow.
- We want to light one fairly large area and sustain the fire with an air pump in a way that is strong enough to spread the flames, yet weak enough to keep ash settled so that it will have a detectable weight compared to the tin trays. (expand to camping accurate fire)(find concrete research to back up decisions)(why the shape size particle chips. Look for things about surface area ratio etc.)
- Any difference in manufacturing or ingredients will cause a difference in things like temperature, flame size and duration, but not in ash amounts

- We will be delicate with moving and placing the fuel in a pile, but the structural strength of the pellets has been a concern for us. We have considered using a flammable binder such as wax, or a string of jute or candlewick, which Nadav has offered for us to use. This being said, our primary intention is to use mechanical force/pressure and the resultant heat to melt the lignin of the nut shell chips. one question that we've been considering is if we will extrude a pellet or pellets through a hole of reduced size, or if it will be better to compress the pellet within a completely constrained space.
- Our discussion of size has been informed by many of the same concerns about the method of manufacturing, as well as about airflow and consistency with what is on the market. Like Seth said, there may be an ideal size that has been determined by the industry standards. It would be ideal to make the controlled tests as similar as possible, but even a differently sized log can be analyzed comparatively, at least in terms of proportion of weight burned away during combustion.

Materials

- Argan post-cracking crumbs[1]
- Oil extrusion machine
- Fire source
    - Long Fresco lighter
    - Small Clipper lighter
    - Propane Blowtorch
- Aluminum-tin tray for ash
- Steel tray for ash
- Scale
    - Hyundai, 2018, HASC-4350 (silver, battery powered)

Procedure

1. Grind argan nut shells into chips
2. Use oil extrusion machine to press 31.0 g of fine post-cracking crumbs into pellets
3. Place pellet pile on ash tray
4. Record initial weight of pellets
5. Use a blowtorch/lighter to ignite four square inches of the pile: around 0.5 kg or 1.1 lbs. (measure and record temperature periodically if necessary)
6. After 10 minutes, or after fire dies, weigh the ashtray again
7. Calculate the difference in weight before and after ignition

[1] Nadav already has fine crumbs/dust made from the nut-cracking machine that contain shells and very fine kernel particles that were ready for us to use/extrude to make the pellets for testing

Pellet Formation Testing with Nadav on Green oil extraction machine

Just using fine nut cracking dust/crumbs

- Speed 2.5 (out of 10 on the speed scale)
- Produced ~100 mL of pellets
  - Pellets look good and are staying together
  - Very oily

25% of small ANS chips (fr. hand crank grinder) and75% of fine nut cracking dust/crumbs

- 20 g of small ANS chips
- 60 g of fine nut cracking dust/crumbs
- Produced less than 100 mL of pellets (12 g by weight incl. storage bag)
  - Pellets were good, but shorter that the pure nut cracking dust pellets
  - A couple of shades darker than the pure nut cracking dust pellets
  - Still fairly soft, if not taking less force to displace and deform, but felt more grainy and came apart less consistently
  - Slightly less oily than the pure nut cracking dust pellets (might be pertinent to remove the pellets from the bag to "dry" them out before the burning test)

Jammed "plug" of 25% of small ANS chips (fr. hand crank grinder) and 75% of fine nut cracking dust/crumbs

- The plug was fairly hard, brittle, and glossy. It was hard to break off and scratch with my fingernail, but it was doable. The plug was progressively softer further down the screw threading

Combustion Testing - Control Trials

- Control pine sawdust - Trial 1: 02/17/2022 @ 5pm IST
  - Burned a pile starting at 31.0 g down to 2/0 g
  - Burnt for about 42 minutes
  - Winds were about 8 km/h (~ 5 mph)
  - Used lower quality lighter (orange) because we did not have butane gas to screw into the blow torch - used all of the fuel from the lighter
  - Spread out the sawdust and lit as much as we could until we found a solid coal. Centralized sawdust around that coal.
- Control pine sawdust - Trial 2: 02/18/2022 @ 9:40am IST
  - Burned a pile of sawdust starting at 31.0 g to 2.0 g
  - Burnt for about 25 minutes
  - Winds were about 13 mph
  - Different burning strategy - lit a couple deep holes within a centralized mound at the same time and upturned unburnt sawdust from the least lit areas onto stronger flames and coals, probably why it took less time to burn
  - Used about half the fuel from the long lighter and some of the clipper lighter
- Control pine sawdust - Trial 3: 02/18/2022 @ 10:36am IST
  - Burned a pile of sawdust starting at 31.0 g to 2.0 g
  - Burnt for about 26 minutes
  - Winds were about 15 mph
  - Mostly used clipper lighter, but drained the long lighter to slightly under half its fuel.
  - Same strategy as trial 2, was able to sustain flames better than last time because of practice.

Combustion testing - Experimental Trials

- Experimental trial fine shell and kernel flakes - Trial 1: 02/20/2022 @ 8:41 am
  - Successful trial with blowtorch
  - Went from 31g to 2g
  - Used pellets made with the fine argan shell and kernel flakes that are a byproduct of the nut cracking process
  - They were made in the green machine on February 16
  - Therefore, they had 4 days to “dry” and lose oil
  - Burned 33 minutes
- Experimental trial fine shell and kernel flakes - Trial 2: 02/20/2022 @ 9:22 am
  - Successful trial with blowtorch
  - Went from 31g to 3g
  - Used pellets made with the fine argan shell and kernel flakes that are a byproduct of the nut cracking process
  - They were made in the green machine on February 20 at 8:20
  - Therefore, they had about 1 hour to “dry” and lose oil
  - Burned 38 minutes
  - Maybe the decreased drying time caused there to be more oil remaining in she ash, causing the slight increase in final weight
- Experimental trial fine shell and kernel flakes - Trial 3: 02/20/2022 @ 10:07 am
  - Successful trial with blowtorch
  - Went from 31g to 3g
  - Used pellets made with the fine argan shell and kernel flakes that are a byproduct of the nut cracking process
  - They were made in the green machine on February 20 at 8:20
  - Therefore, they had about 2 hour to “dry” and lose oil
  - Burned 35 minutes
  - Again, maybe the decreased drying time caused there to be more oil remaining in the ash, causing the slight increase in final weight

Observations and additional results

Calculations - Control Trials - wood shaving % reductions by weight

- [Initial weight (g) - Final Weight (g)] / Initial weight (g)
- Trial 1: [31.0 g - 2.0 g] / 31.0 g = 0.9355 = ~ **94% weight reduction**
- Trial 2: [31.0 g - 2.0 g] / 31.0 g = 0.9355 = ~ **94% weight reduction**
- Trial 3: [31.0 g - 2.0 g] / 31.0 g = 0.9355 = ~ **94% weight reduction**

Calculations - Experimental Trials - ANS pellet % reductions by weight

- Trial 1: [31.0 g - 2.0 g] / 31.0 g = 0.9355 = ~ **94% weight reduction**
- Trial 2: [31.0 g - 3.0 g] / 31.0 g = 0.9032 = ~ **90% weight reduction**
- Trial 3: [31.0 g - 3.0 g] / 31.0 g = 0.9032 = ~ **90% weight reduction**

Additional Notes

- Much of the ash from all six trials was blown away, by the wind during the control trials and by the propane blowtorch during the experimental trials.
- During the experimental burning trials, there was a large amount of oil residue around the burning area.
- On the second experimental test, we measured a residual ash weight above 2 grams, which was an outlier from all three control tests and the first experimental test. Because of this, we tried especially hard to completely incinerate all that we could during the third experimental trial. Even after our efforts, the result of the third experimental test was the same as the last (3 grams). As mentioned in the results and discussion section, we believe that this is because of the oil content within the pellets that were created the same day as the test.
- While moving the unburnt fuel in both the experimental and control trials, the structure of some ash, black and white, seemed to be crushed and caused to drop down to the base of the tray. It is uncertain exactly how this impacted the test.
- As mentioned in previous sections, we used a propane blowtorch during the experimental trials and a lighter during the control trials. This blowtorch deformed and split the aluminum-tin alloy tray, forcing us to use a steel tray of different dimensions.

Appendix C: Pet Bedding/Cat Litter Experimental Protocol

This appendix contains details of our absorbency experiments in exploring possibilities for commercial ANS pet bedding and/or cat litter materials. Here, we discuss any relevant background information regarding bedding and/or litter as a commercial product, our initial assumptions and external considerations pertaining to our experimental set up, an annotated materials list and procedure, and any remaining observations, results, or discussion not covered explicitly in the previous chapters.

Preliminary assumptions, external factors, and important considerations

What is the goal of these tests?

The goal of these tests are to determine if ANS shavings are a comparable or better analog for wood/walnut shell shavings in commercial pet bedding and/or cat litter

Is there a question related to the size or shape of the shells?

Maybe - we do have different types of shells available to us, so we may be able to control the size of the shavings we get from the nut shells, but we think that the shape is something that we will have to get a feel for once we actually start testing

Are there other considerations?

We have to consider the amount of urine that an average pet/cat expels per day (see calculation below) and the corresponding amount of material that would be needed and how that translates to the quantity of nut shells necessary to arrive at a certain amount of shavings. We think we will get a better idea of how many nut shells will translate into a certain amount of shavings once we actually start making the shavings and testing. For the purposes of our testing, we will be using a near-identical amount of shavings as liquid because we are testing with water, however, we need to consider that urine and other animal waste contents may require a different amount of bedding/litter material per amount of animal waste. Other considerations include but are not limited to:

- Remaining oils on the nut shells that could potentially (although unlikely) cause irritation to animals - this would involve us washing the nut shells before shaving them down
- Different shapes and textures for different animals
- It may be absorbent but that doesn't necessarily mean it will be as efficient in odor-reduction as it is absorbance
- Do the nut shells need to undergo any additional treatment (ex. Heat drying) before shaven down to make them more absorbent/effective?
- There are many different types of pet bedding: wood, hemp, corncob, paper, straw, hay, wood chips, saw dust, sand, and waterbed, but it is important to note that we are using wood as our control/standard bedding because it is the most effective in both categories of absorbency AND

odor-control and wood shavings seem to be the easiest material to get our hands on other than current on-the-market pet bedding

Does cat litter typically have additives?

Sometimes

If so, what are they?

In cat litter, there may be additional additives such as clay, which is popular here in Israel, but for the purposes of our initial testing we think we may start by testing the shavings as a pet bedding exclusively.

Materials

- Wood shavings (control group)
- 3.6 L bag of *Leader Choice* Silica Gel Cat Litter (control group)
- Argan Nut Shells - Pebbles (experimental group)
- Manual grinder[2]
- Catching container for dripping liquid/general set up
- Strainer
- Water/liquid

Procedure

(1) Grind shells down into minute shavings using manual grinder to obtain ANS powder/pebbles[3]

(2) Sift through the mixture to separate the powder and the pebbles

For pouring:

(3) Measure out 75 g of ANS pebbles and 75 g of water

(4) Place catching container on scale and tare(zero) the scale

(5) Place strainer with the ANS pebbles on the catching container on the scale

(6) Pour water over the pebbles and begin a timer, let pebbles drip into catching container

(7) As shavings dry, measure amount of water in catching container @ 30 seconds, 3 minutes, 10 minutes, 20 minutes, 45 minutes

(8) Repeat steps 3-7 with silica gel control group

For soaking:

(9) Repeat step 3 and fill catching container with 550 mL of water

(10) Immerse bedding material (wood/litter/ANS pebbles) in a water bath (75 mL) [4]

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[2] This was mentioned above and can be found in a workspace right next to the Arava Institute - when grinding the shells into pebbles, first mash them, put them through the machine on a setting of 6 out of 6, and then run them through again on a setting of 4 out of 6 (so the machine doesn't get damages due to the brittleness of ANS)

[3] We initially used 75 g of nut shell shavings in accordance with the 75 mL of water being poured over them (density of water is 1 g/mL and the average absorption for similar wood is about 120%)

[4] We will be performing a set of tests (3 tests) where the water is poured on to the shavings over the duration of 15 seconds and another 3 tests where it is poured over the shavings for the duration of 1 minute. Also, the amount of

(11) Let bedding material (wood/litter/ANS pebbles) sit remain in water bath - lift strainer and record the amount of water absorbed by the bedding material at 30 minutes, 45 minutes, and 60 minutes

Analysis

(1) Calculate amount of water retained by shavings or absorbed by bedding material to original amount of water poured over bedding/amount of water in the water bath

Observations and additional results

Table C.1.: Control Trials - Pouring - Amount of water to pass through silica litter in grams

	30 sec	**3 min**	**10 min**	**20 min**	**45 min**
Trial 1	12.5 g	13.0 g	14.0 g	14.0 g	14.0 g
Trial 2	12.0 g	12.0 g	13.0 g	13.5 g	13.5 g
Trial 3	5.5 g	5.5 g	6.0 g	6.0 g	6.5 g
Average	10.0 g	10.2 g	11.0 g	11.2 g	11.3 g
SD	3.9 g	4.1 g	4.4 g	4.5 g	4.2 g

Calculations - Control Trials - Pouring - Silica gel absorbance values

- % water retention @ 30 seconds (g/g ~ %):
  - [75 g - Final Water (g)] / 75 g
  - [75 g - 10 g] / 75 g = 65 g / 75 g
    = **0.8667 g/g ~ 87% water retention/absorbency**
- % water retention @ 3 minutes
  - [75 g - 10.2 g] / 75 g
    = **0.8640 g/g ~ 86% water retention/absorbency**
- % water retention @ 10 minutes
  - [75 g - 11.0 g] / 75 g
    = **0.8533 g/g ~ 85% water retention/absorbency**
- % water retention @ 20 minutes
  - [75 g - 11.2 g] / 75 g
    = **0.8507 ~ 85% water retention/absorbency**
- % water retention @ 45 minutes
  - [75 g - Final Water (g)]/ 75 g

---

water being poured over the shavings is representative of the estimated amount of urine that a cat expels per litter box visit (see calculation below)

- [75 g - 11.3 g] / 75 g = 63.7 g / 75 g
  = **0.8493 g/g ~ 85% water retention/absorbency**

Table C.2: Control Trials - Soaking - Wood Shavings - Amount of water absorbed in grams

	30 min	**45 min**	**60 min**
Trial 1	64.0 g - 640%	59.5 g - 595%	56.0 g - 560%
Trial 2	80.0 g - 800%	77.5 g - 775%	72.0 g - 720%
Trial 3	74.5 g - 745%	73.5 g - 735%	72.0 g - 720%
Avg	72.8 g - 728%	70.17 g - 701.7%	66.67 g - 666.7%
SD	8.1 g	9.5 g	9.2 g

Table C.3: Control Trials - Soaking - Silica gel litter - Amount of water absorbed in grams

	30 min	**45 min**	**60 min**
Trial 1	14.5 g - 145%	15.0 g - 150%	14.5 g - 145%
Trial 2	15.5 g - 155%	16.0 g - 160%	16.5 g - 165%
Trial 3	17.0 g - 170%	17.5 g - 175%	17.0 g - 170%
Avg	15.7 g - 157%	16.2 g - 162%	16.0 g - 160%
SD	1.3 g	1.3 g	1.3 g

Table C.4: Experimental Trials - Soaking - ANS Pebbles - Amount of water absorbed in grams

	30 min	**45 min**	**60 min**
Trial 1	11.5 g - 115%	11.0 g - 110%	11.0 g - 110%
Trial 2	11.0 g - 110%	11.0 g - 110%	12.0 g - 120%
Trial 3	11.25 g - 112.5%	11.0 g - 110%	11.5 g - 115%
Avg	11.3 g	11.0 g	11.5 g
SD	0.3 g	0	0.5 g

Calculation - Estimate of liquid expelled per urination per average cat in mL

- Cat urinates 2-4 times a day (The Ultimate Guide to Your Cat's Pee - Nekoya Cat Daycare & Boarding Hotel Singapore)
- Cats urinate <50mL/kg/day (Increased drinking and urination in cats — Elwood vet)
- Ideal weight of cats is 10 lbs (Ideal Cat Weight | How Heavy Should My Cat Be? - My Family Vets)
- Therefore
    - <50mL/kg/day * (10lbs / 2.205lbs/kg) / 3 times a day
    - **< ~75.586 mL per urination**
- Additional resources
    - Kains, Frank; Lovell, Barbara; Payne, Mike; Tremblay, Rob (1997). "Livestock Bedding Alternatives".

Appendix D: Cosmetic Exfoliant Experimental Protocol

This appendix contains details of our experimentation with powdered ANS and dried argan kernel flakes in exploring possibilities for argan waste cosmetic exfoliants. Here, we discuss any relevant background information regarding cosmetic physical exfoliants as a commercial product, our initial assumptions and external considerations pertaining to our experimental set up, an annotated materials list and procedure, and any remaining observations, results, or discussion not covered explicitly in the previous chapters

Preliminary assumptions, external factors, and important considerations

What is the goal of these experiments?

The goal of this experiment is to see if powdered argan nut shells are a worthy analog for sugar and other standard abrasives in body scrubs

What are we varying?

For this experiment, we are not varying only one thing, as this is more informal in terms of being a controlled experiment. We are trying to see if we can make a scrub from various argan waste materials that Nadav has (i.e. powdered argan nut shells as an abrasive mixed with oily base-paste that is a byproduct of the oil-pressing process that is already VERY similar in texture and ingredients to a normal body scrub). Here we are just looking to confirm that this will work - as it will use many different types of nut waste, it's marketable/useful, and it's simple to produce

Why sugar as a control?

Sugar is readily-available and is one of the most common types of body scrubs currently on the market - we also know that sugar scrubs, although popular, can be a bit too abrasive at times, and if we can compare sugar with ANS powder and prove that ANS powder is less abrasive, than this scrub would be better for the skin, and more importantly, it would be more suitable for dryer local environments (like southern Israel) when people shouldn't be too abrasive on their skin which would dry it out/compromise their skin barrier

What are the variables and ranges that we will investigate?

Variables are amount of abrasive in each respective scrub recipe, and the range will be 0-100% abrasive in each scrub

How clean does this all have to be?

Since we are working with all natural ingredients, both scrub recipes will already be inherently "clean" and as far as keeping things anti-bacterial/anti–contamination "clean", the following safety precautions will be exercised: gloves would be worn at all times, hair will be tied back while handling nuts that will be used in the scrub, all nut shells will be washed carefully before being powdered, and all scrub materials will be made in a clean, safe space (i.e. NOT in testing warehouse or outside)

Did we expect advantages from this solution? What kinds?

Yes, we expect this scrub to be slightly less abrasive than standard sugar scrubs (for those with sensitive skin or live in a dry environment) while still properly exfoliating the skin

Could there be disadvantages?

Yes, this could be potentially inaccessible to those with nut allergies, there would be an obvious but not detrimental disadvantage if the ANS powder was more harsh than sugar as an abrasive - as the point of this is to find a use for the waste and not necessarily find the most optimal ingredients for a body scrub

Materials

- Argan nut shells (experimental)
- Dried kernel flakes (experimental)
- Sugar (control)
- Manual grinder/pulverizer
- Mortar and pestle
- 4 clementines
- Spoon
- 12 sample glass vials
- Scale
- Permanent marker
- 3 mixing cups

Procedure

We selected four clementines to test the four different proportions of abrasive to paste. Since there are three different abrasives we are testing, we selected the four best looking clementines and using a permanent marker, divided them into three roughly equal sections. We used clementines because the skins are smoother and are a closer companion to human skin, also we had more of them available in test worthy condition. By testing the same proportional scrubs using different abrasives we will obtain a closer comparison as there are less differences between sections of the same clementine's skin as between different clementine's skin.

1. Mix the powdered argan nut shell (and flakes of dried material left from pressing the argan kernel) with the paste byproduct (that still contains small amounts of oil) according to the recipes below
2. Gently rub the 15 mL (about 1 Tbsp - 2 fingers full) of scrub into the fruit skin as you would into human skin for the duration of 15 seconds
3. Inspect the changes to the fruit skin
4. Compare the differences in scrub abrasiveness
5. Repeat with a different team member to account for individual styles of exfoliation

Scrub Recipes

Argan Nut Flakes Recipes

1. 1 part paste to 4 parts abrasive - upper limit

2. 2 parts paste to 3 parts abrasive
3. 3 parts paste to 2 parts abrasive
4. 4 parts paste to 1 parts abrasive - lower limit

Argan Nut Shell Powder Recipes

5. 1 part paste to 4 parts abrasive - upper limit
6. 2 parts paste to 3 parts abrasive
7. 3 parts paste to 2 parts abrasive
8. 4 parts paste to 1 parts abrasive - lower limit

Sugar (Control Group) Recipes

1. 1 part paste to 4 parts abrasive - upper limit
2. 2 parts paste to 3 parts abrasive
3. 3 parts paste to 2 parts abrasive
4. 4 parts paste to 1 parts abrasive - lower limit

Mixing the scrubs

1. Putting the paste in first to make measuring easier - mixing paste first
2. Starting with the 1 part paste 4 parts abrasive
    a. 2.5 g of paste
    b. 10 g of abrasive
3. Then the 2 part paste 3 parts abrasive
    a. 5 g of paste
    b. 7.5 g of abrasive
4. Then the 3 part paste 2 parts abrasive
    a. 7.5 g of paste
    b. 5 g of abrasive
5. Then the 4 part paste 1 parts abrasive
    a. 10 g of paste
    b. 2.5 g of abrasive

Observations and additional results

Table D.1: Fruit Testing Strips with Argan Paste Cosmetic Test Scrubs

Scrub	1P:4A	2P:3A	3P:2A	4P:1A
Sugar				
Flakes				
Powder				

- 1P:4A (S)
    - Difficult to keep together - close to the consistency of straight sugar
    - Deposited a bunch of oil on to the surface of the fruit
    - Sugar would crumble instead of actually exfoliating
    - More oil on the clementine even after being rinsed with water - more shiny
- 1P:4A (F)
    - Difficult to keep together - close to the consistency of straight flake powder but more integrated than the sugar scrub of equal proportions
    - Deposited a fair amount of oil into the surface of fruit - little bit less than the sugar
    - Shiny but not as shiny as the sugar (could be because it was wiped dry not patted dry)
    - Still smoother and more “moisturized” than before
- 1P:4A (P)
    - Easier to get all of this scrub out, seems to be more cohesive as opposed adhesive
    - Very dry scrub, powder seems to have absorbed the paste
    - Crumbles very easily
    - Easiest to rinse off - less time
    - Same amount of shininess as the flakes, sugar was the shiniest
    - Skin was still “moisturized” but not as much as the others
- 2P:3A (S)
    - Little bit of an oil deposit
    - Little bit more shiny than how it started
    - A little difficult to keep together (not as much as the 1:4)- little clumpy
    - A little bit moisturized - barely noticeable from before scrub

    - Nicer texture than previous sugar scrub
- 2P:3A (F)
    - More oily than before scrub - little bit
    - More shiny - little bit, texture pretty much the same
    - Groups together in small chunks
    - Damp clumps
    - Quite moisturized
- 2P:3A (P)
    - Slightly damp dirt - holds together when compressed - can be packed in very easily
    - More cohesion with base paste
    - Darker in color
    - Can see the particles of the paste in this because the powder particles are so small
    - Moisturized and shiny, but less than the sugar
- 3P:2A (S) *this was successfully tested on the fruit, however, the sample broke right after, so what was still in the bowl was recovered and placed into a new container, the following observations are from the original test/original sample*
    - Consistency of clumped spirulina cake - larger damp clumps
    - Skin is very oily
    - Very shiny
    - Very moisturized
    - Lightly removed some of the marker markings
- 3P:2A (F)
    - Did not want to come out of bottle
    - Clementine has a small bruise on this section of the fruit
    - Very clumpy - forms larger clumps - Very soft
    - Forms larger balls when shaken in the jar
    - Removed a good amount of the marker
    - Left visible and distinct streaks of oil
    - In a scratch groove - looks a lot cleaner
    - Flakes is shinier than the sugar
    - Streaks of moisture and oil, but not consistent
    - Consistency of cookie dough before the flour is added
- 3P:2A (P)
    - Consistency of used coffee grounds - Finer quinoa
    - Adheres to the skin of the fruit for a lot longer than the flakes and sugar
    - Smaller streaks of oil than the flakes
    - A lot clumpier than the other powder scrubs
    - Darker hue than other powder scrubs
    - Fairly shiny, but not as shiny as the flakes and sugar in this proportional group
    - Very moisturized
- 4P:1A (S)
    - A lot darker than other sugar scrubs
    - Extremely mushy - no loose abrasive

- Very dense - a lot like the paste
- Sticks to the skin a lot
- A lot less falls off on initial application
- Medium streaks of oil
- Large variety of particle sizes in clumps
- Easy to use and coat evenly
- Water when rinsing doesn't run clear immediately - almost milky
- Skin is a lot smoother
- Pretty oily
- Very moisturized
- Removed a little bit of the marker

- 4P:1A (F)
  - Layer of oil that has separated at the top
  - Very cohesive - a lot more body and fluffier
  - Larger streaks of oil
  - Very gentle on both the persons and the fruits skin
  - Easy to get an even application
  - When it fell off it fell in larger clumps
  - Feels slightly oily
  - Moisturized
  - Same amount of shine as sugar of same proportion
  - Forms large balls when shaken in container
- 4P:1A (P)
  - Very cohesive
  - A little more coarse than the flake of the same proportion
  - Smaller particles stick to the skin
  - Larger streaks of oil
  - Very easy to apply - if it falls it falls in larger clumps
  - Very oily
  - Consistent application
  - Pretty shiny
  - Washed off easily
  - Very moisturizing
- In general/conclusion:
  - 3p:2a - flakes = best for dry, sensitive skin on the body - oil collecting, etc.
  - 4p:1a - flakes = best for sensitive, body
  - 3p:2a/4p:1a - powder = best for oily, sensitive skin (face or body) b/c shells are more absorbent compared to flakes/sugar and smaller particle size
  - 1p:4a - powder = not as effective in general as a scrub - too dry with smaller particle size
  - 2p:3a - powder = oily skin, for more resilient skin (maybe a foot scrub)
  - 2p:3a - flakes = dryer scrubs, for those with more resilient skin
  - 1p:4a - flakes = not as effective in general as a scrub

Appendix E: Activated charcoal Experimental Protocol

This appendix contains details of our attempt at making ANS-derived charcoal in exploring possibilities for ANS activated charcoal adsorbents. Here, we discuss any relevant background information regarding activated charcoal as a commercial product, our initial assumptions and external considerations pertaining to our experimental set up, an annotated materials list and procedure, recommendations for future testing, and any remaining observations, results, or discussion not covered explicitly in the previous chapters.

Preliminary assumptions, external factors, and important considerations

What is the goal of this exercise?

The goal is to identify the most effective and sustainable way to create activated charcoal using the resources available, mainly by identifying the best activating chemical that produces the most absorbent activated charcoal and whether the slurry of charcoal and activator needs to be boiled.

Why did we pick this process to make activated charcoal?

The process of burning the shells is an established process to make charcoal. The activating chemicals are being modified in order to identify which is the most effective activator and at what concentration levels.The boiling part of the process has been mentioned in some of the existing processes to make activated charcoal.

Is it important how clean the activated charcoal is in the end?

Yes, it needs to be washed with distilled water after being activated because

How would this process be scalable?

Larger batches could be made as well as utilizing machinery that automates the burning process as a\well as the activating process

Materials

- Argan nut shells - Fill pot up
- Wood - fill pot up
- Big pot with loose lid
- Stove/grill/campfire
- Mortar and pestle (Something to grind up the charcoal)
- Lemon juice/CaCl/ZnCl - 2 cups?
- Distilled water - 2 gallons?
- Flat pan to dry in
- Activated charcoal (argan nut shell and wood) - ¼ cup per test
- Dye/colorant (red, green, and blue) - 1 little bottle of each
- Strainer - 1

- Coffee filters - 1 per test
- Clear containers - 3?
- White paper - a couple sheets

Procedure (Ideal procedure/Not what we did)

1. Gather dried argan nut shell
2. Place in a large pot with a lid
3. Place pot on a stove/grill with hot flames
4. Wait until shells are turned into charcoal (do not let shells burn with flames)
5. Wash charcoal to remove ash
6. Grind up charcoal[5]
7. Add lemon juice/CaCl/ZnCl/NaCl until it's a slurry (add water to the powders to the proper dilutions)
8. Wait 24 hours
9. Wash charcoal with distilled water and air dry (or bake)
10. (Repeat with regular wood to compare)
11. Add X drops of blue dye or colorant to water
12. Take a strainer and place a coffee filter on it
13. Place X grams activated charcoal into the coffee filter
14. Pour the colored water through the charcoal and coffee filter into a clear container
15. Take a picture of the container against a white piece of paper with a fixed lighting setup
16. Repeat steps 1-5 without the charcoal in the coffee filter
17. Digitally analyze the images by
    a. Convert the image to the 2D array of pixels level and rgb values
    b. Average the rgb values over a set area
18. Compare the rgb values and calculate % difference in the blue value (as well as r and g values to a lesser degree)
19. Repeat steps 11-18 for red and green dyes

Observations and additional results

We would have liked to thoroughly test the various methods of making activated charcoal, however due to time constraints we were only able to make one batch of regular charcoal from the ANS. While the ANS was cooking for 7 hours, there was a continuous emission of strongly smelling smoke. The smell is not unpleasant, however it is prudent to do this step outdoors or in a well ventilated room.

[5] We completed the procedure up to the point of grinding up the charcoal into powder. We cooked 1500 g of ANS and ground up 5 g into powder. We were not able to activate the charcoal or test the absorbency due to time constraints.

At the end of the 7 hours, we removed the cooked shells from the pot. The majority of the shells were black at this point, though some had a silvery sheen, and some retained small patches of brown. The silvery shells were mostly located at the bottom of the pot, and the brown spots were at the top. When grinding up the cooked shells, the silvery ones were easier to break up while the ones with brown spots were more difficult to work with.

Additional Notes

We would like to have tested three different activators (lemon juice, Calcium Chloride, and Sodium Chloride) to assess which was the best option (Cobb et al., 2012). We would evaluate the activated charcoal made from the ANS to assess if it absorbs the same amount of a solute as the charcoal made from the regular wood (See Appendix E). To do so, we would test the charcoal's ability to remove food coloring from water by measuring the change in color in a solution of water and food coloring after activated charcoal had been soaked in the solution (Cobb, A., et al., 2012). Pictures would be taken of the water before the food coloring was added, after the food coloring had been added, and after the activated charcoal had been soaked in the mixture. These pictures' RGB values would be analyzed to determine the difference in color before and after the activated charcoal has been soaked in the mixture with pure water being used as a baseline. We would then use a Java program we wrote to analyze the colors in the aforementioned photos to compare the RGB values of the water solutions and therefore how absorbant the charcoal in question is. If the efficacy of the argan nut shell activated charcoal was similar to that of the regular wood, it would be possible to market the activated charcoal as a viable option for using the nut waste.

We were unable to fully complete the experiment outlined above, so we recommend future experiments going through the full procedure and evaluating the absorbency of the charcoal made with different materials and activators. These experiments would help determine the potential of ANS as an activated charcoal.

Appendix F: Cellulose Extraction Experimental Protocol

This appendix contains details of our attempt at extracting cellulose from ANS in exploring possibilities for larger cellulose distribution from the Kibbutz in the next 10+ years. Here, we discuss any relevant background information regarding activated charcoal as a commercial product, our initial assumptions and external considerations pertaining to our experimental set up, an annotated materials list and procedure, recommendations for future testing, and any remaining observations, results, or discussion not covered explicitly in the previous chapters.

Preliminary assumptions, external factors, and important considerations

Materials

- Grinding mill
- Hot plate
- Thermometer
- Glass beaker
- Glass stirring stick
- Steel Strainer for cellulose fibers that can withstand sodium hydroxide

Specialty Items:

- Sodium hydroxide (NaOH)

Procedure

1. Shred plant material
2. Place the beaker 1 on hot plate
3. Add 16 g of plant material to beaker 1
4. Place 5 grams of NaOH in a second beaker (beaker 2)
5. Dilute 5 grams of NaOH with 425 ml of water in beaker 2 and stir solution for 10 seconds
6. Add diluted NaOH plant material in beaker 1
7. Cook mixture in beaker 1 on heat setting 2 of 4 for 30 minutes
8. Pour mixture through a strainer and collect water, lignin and sodium hydroxide solution in bowl underneath strainer
9. Squeeze the sample to release excess liquid through strainer
10. Allow the sample to dry for 2 days, and then again at 5 days
11. Weigh the sample and compare with original weight
12. Qualitative analysis, rubbery, is lignin separated, is it bleached

This procedure and dilution ratio is based on an online source (Industrial Adhesives, 2020).

Observations and additional results

One day after the extraction, the sawdust looked slightly translucent, which could suggest that lignin had been removed. However, this could have merely been a result of dampness. Two days after the extraction, the samples have not dried out enough and both currently weighed more than what they originally had. The sawdust and ANS no longer do not look or feel any differently from their original counterparts. The increased weight after two days of drying could be a consequence of the process of boiling the samples in sodium hydroxide to boil the lignin and not because of insufficient drying time, however we do not see this as likely. After five days of drying, all changes to weight had reversed, leaving both samples as what they had originally weighed. Because of this, we concluded that cellulose extraction was unsuccessful and we recommend using higher concentrations of sodium hydroxide than were used in the source (Industrial Adhesives, 2020).

Appendix G: Points of Discussion - Informal Interviews

This appendix contains details on the casual, semi-structured conversations we had with a local cosmetic business owner who works with our sponsor to distribute argan oil products and a local Kibbutz spa employee regarding the potential for argan waste products as key ingredients in cosmetic exfoliants. Here, we provide the points of discussion we used as general guidelines for directing conversations, pertinent notes from the interviews, and any remaining observations, results, or discussion not covered explicitly in the previous chapters.

General points of discussion

For both factory/business owner and spa employee:

- How they would feel about argan nut shells as ingredients in an exfoliant - present them with French company who has already done this as well as the garnier fructis one
- Given that we will be testing on fruit skin, would there need to be any additional testing that is done…if so, what?
- How large of a part does the factory play in the development of these products?
- Are there other local cosmetic stores in Israel that would be willing to sell these products? (beyond Kibbutz gift shop or spa or other contact who makes all natural cosmetics?)
- How many items do you sell in a year? Is there currently room/a plan for growth?

For spa employee:

- How are the other argan products used for massage and spa treatments? Would a scrub be useful for any of the treatments or could you add a treatment that would need one?

Notes from conversation with local cosmetic factory/business owner

- Didn't deal with argan until more recently
    - Used different types of oil like vegetable oils
- Argan oil only for special projects
    - When you use the pulp of the argan oil, it's good for commercial purposes
- Usually makes exfoliants - in order to do this, you need some sort of standard sized particle-size
    - But there will always be residue, so exfoliator, especially with oil is good for moisturizing in addition to exfoliating
    - Also has exfoliants in masks
    - Can also use in a soap/bar form
        - If its bigger its a stronger exfoliant
- Small factory between 10-50 employees, have a shop within the factory, do export, do private labor (similar to what he already does for the Kibbutz), have about 40% exported internationally
    - Factory has existed since 1999, started by mistake
    - Coconut oil and olive oil washing soap
    - Produce more than 200 different types of products

        - 60 lines of products and in “every line we have the main winners”
        - 20/80 - 20% of the customers make 80% of the income
- Kibbutz would have to decide what kind of product (3 possibilities - 1 is to make a soap, 1 is to make a body scrub, 1 is to make face mask/exfoliating mask)
    - If the kibbutz decides to do a body scrub - needs the ingredients, needs samples to play around with, and see what the kibbutz would want them to make
    - The kibbutz would need to get the ingredients approved before sending it to the factory to be further analyzed and he would play around with it for the best recipe
- In Israel, there is a very big Moroccan community, so they appreciate argan/moroccan oil in products and that’s why it became very marketable in Israel - its a good oil he says with many benefits, but other dozens of other oils with also good benefits, “so when you’re talking about sales or marketing the main idea is the story behind it and argan oil has a very good story” [referring to the goats in Morocco]

Notes from conversation with Kibbutz spa employee

- Said she could definitely use all of the scrubs and scrub components that we presented her with for different services and people with different types of skin (sentisitive, oily, dry, etc.)
- Could use plain powder in combination with other oils (not argan) to adjust price range of products and/or services
- Doesn’t think there would be much difficulty getting it approved for use within the kibbutz - said something about insurance/liability for people with allergies? But still unsure about what it would take to get permission to use within the kibbutz to use on regular customers/tourists/etc… (ask Nadav)
- Could use powder in peeling masks
- Could use powder in exfoliating soap as well for the face
- Was aware of what nadav was doing with the argan