Greens for good

Nurtured within Sensorica

Decanter Centrifuge

Report on testing of the **second** prototype

by Anthony, Tibi

NOTE: Not working, see third prototype proposition. This second version was built on a first prototype designed and tested

Open main doc for this component

Part of Decanter Centrifuge venture

Deliverables work package

Files associated with this development are found here

This is a co-creation document, make sure you respect the Content rules

This document reports the testing results of the second Decanter Centrifuge prototype, a component of the Greens for Good plant protein extractor. To navigate the larger environment of

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this particular venture, visit the venture page (link provided above). To edit this document you need to Join the venture (from the venture page).

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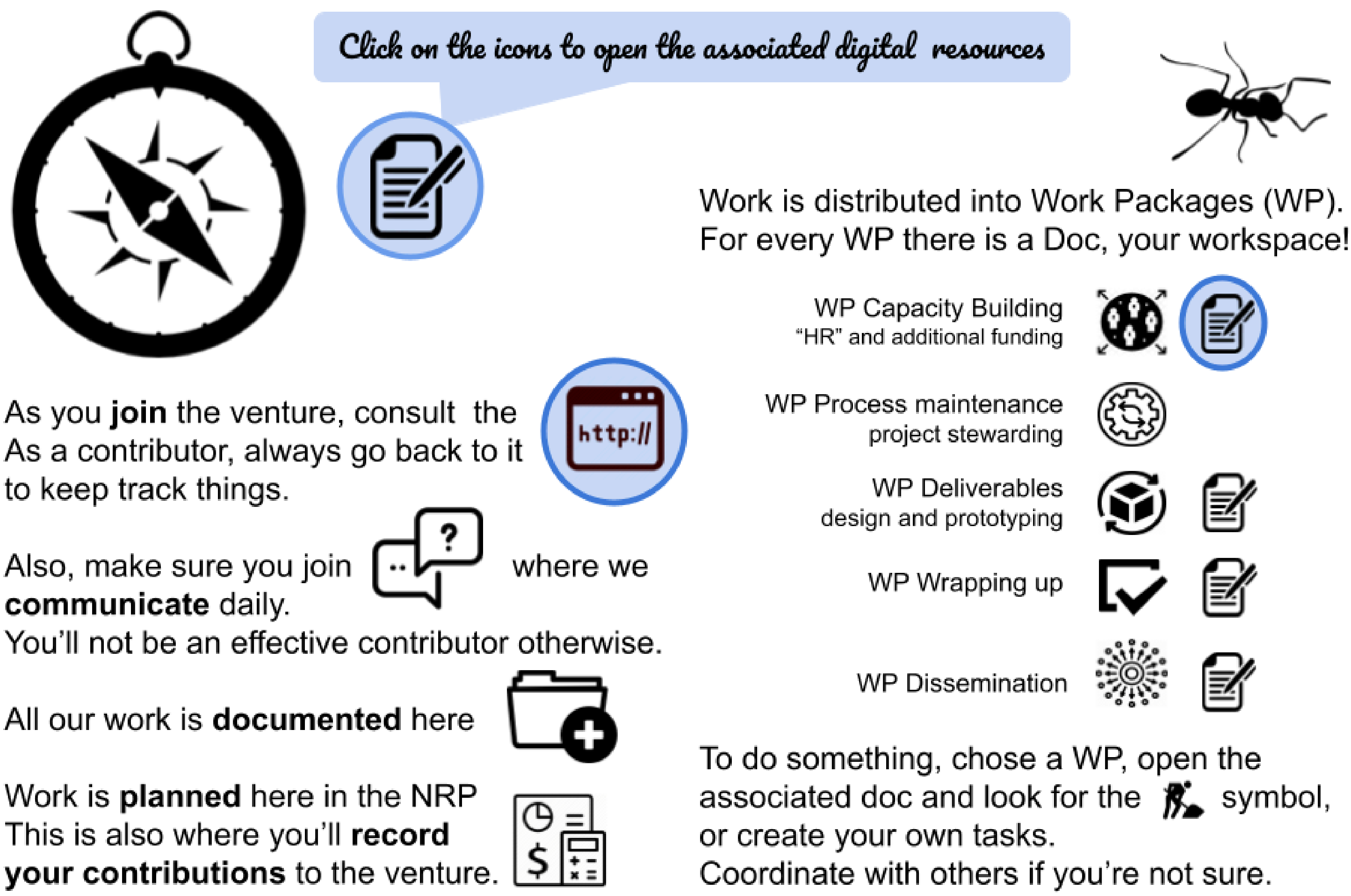
Orientation

This testing report is part of the Open Source Decanter Centrifuge device, which is a module part of the Greens for *God food processing device*, described in the Deliverables doc.



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How to read this document

This doc is a digital environment where participants engage in experimenting with the Decanter Centrifuge prototype. Consider it as your virtual R&D / Experimentation lab. Why a Google doc and not a wiki or Gitlab? Because a Google doc is easy to use, and that constitutes a low barrier to participation. All ventures within the Sensorica OVN are open (quasi permissionless access to processes); anyone should be able to contribute to this activity. Anyone can comment.

This document has a structure, as you can see in the table of contents. This structure reflects a methodology for reporting on open and collaborative experimental work. The method deployed here is part of a wider hardware development method used in the Greens for Good Deliverables document. The Greens for Good venture has been seed-funded by a Sponsor. **In order to be rewarded financially for their work done, contributors are required to follow the entire methodology**, which is the best guarantee that we are going to fulfill our commitments towards the Sponsor. That means working according to the constantly emerging planning. Participants are free to fork this planning and the aim of the venture, which should not be taken badly, but in doing so they may lose the privilege of having their work being financially rewarded.

If you are new to this, read the Greens for Good Deliverables and the Open Source Decanter Centrifuge documents first, make sure that you read the Design Considerations and that you've absorbed the Shared Understanding. Within Sensorica, we leverage social intelligence, we need to coordinate our cognitive processes!

Work within the Sensorica OVN is highly stigmergic. **Always announce what you're going to do, document what you do and indicate to others what they can do next**. Follow the icons on the left of the document. To know their significance go to the Signalization section. Use these signals (copy/paste one of these boxes of signalization and fill it with content) everywhere you see fit. Contribute to other people's signals. Delete these signals if you think their role has been fulfilled.

For discussions about this venture use the proper Communications channels.

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Abstract

In times of crisis, when industrial food supplies break down we can avoid famine by processing indigenous plants, which we see as a latent nutrient capacity. Most of these food sources are growing wild or are discarded as agricultural waste, they are not considered in normal times.
This venture's main motivation derives from Greens for Good, which is to provide a method to extract proteins from leafy biomass to bridge current protein demand deficits or during catastrophes.

Our overarching goal is to create a family of easily scalable food processing devices. The scale of these devices is between DIY home and industrial, village scale. Our design will be easily replicable, using stock components and make minimal use of custom parts (unless they can be digitally fabricated with a RepRap class 3-D printer or CNC mill –e.g. limit to what is found in most fab labs and avoid high energy processes and a skilled machinist). It minimizes cost and complexity while keeping throughput high (continuous if possible).

In this document we report on testing the first prototype of a 3D printable, table top Worm Screw Decanter Centrifuge (see testing of the first prototype here), following design considerations from the Greens for Good extruder, which separates protein from leaf juice. The fabrication, assembly and testing results are presented. Next iterations of the Decanter Centrifuge design and prototype are proposed. The hardware development roadmap is readjusted.

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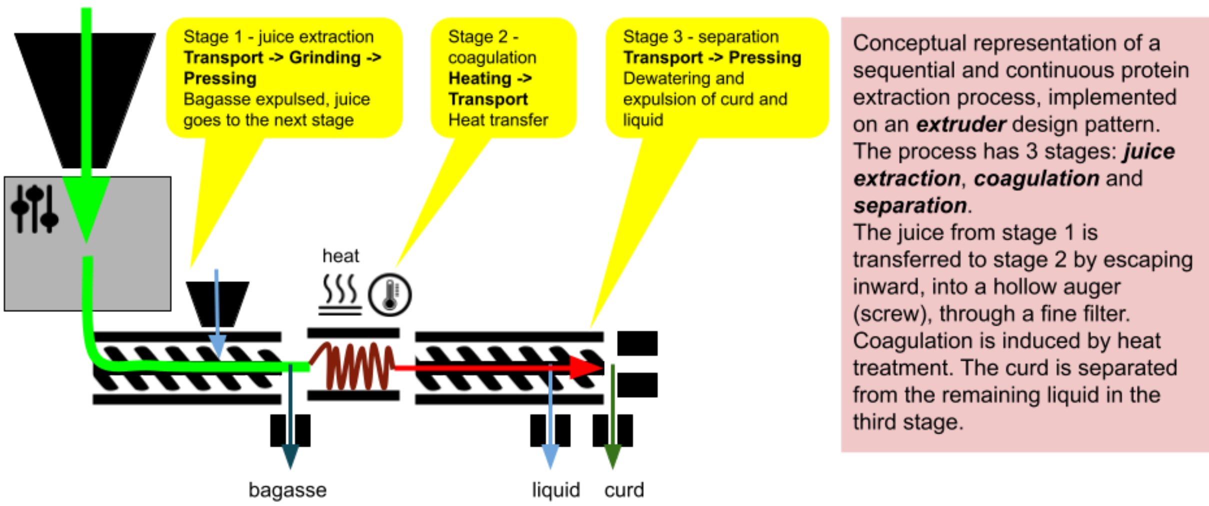
Introduction

The Greens for Good food processor is a multifunctional and modular device used to extract proteins from leafy biomass, among other functions. When used for protein extraction, the device is conceptually composed of 3 main sections: the Juicer, the Coagulator and the Separator. The Decanter Centrifuge that was tested and described in this report is the last module, i.e. the part that separates proteins that have been coagulated from the leaf juice, from the remaining fluid.

Schematic representation of the Greens for Good food processor and plant protein extractor.



NOTES:

- Internal pressure balance to avoid backflow. Need pressure control (adjustable expulsion die). Possible solution: variable gap using thread (barrel + ring).
- Curd separation filter. Possible solution a decanter centrifuge.
- Coagulation is temperature dependent, time is controlled with length of traver, coil. Temperature control can be achieved with the use of hot steam.

The process of extracting proteins from leafy biomass is composed of three mains stages that map onto the architecture of the Greens for Good device. First, green leaves need to be pressed to extract the *leaf juice*. This is achieved within the Juicer, which is essentially a single screw extruder designed to transport, compress, grind and press the fresh leaves, to separate their juice from the solid part, mainly fier. This juice contains soluble proteins, among other components. The second stage is to heat the leaf juice up to 70 °C to coagulate the solvated proteins. The coagulation is essentially thermal denaturing of the solvated proteins and their aggregation into larger particles, which is called coagulum. At last, the solid state coagulum, also called curd, which is rich in protein, must be separated from the remaining fluid.

Traditionally, the final stage of separation of the curd from the remaining fluid, which is essentially a dewatering process, has been done through filtration, a batch process similar to cheese making. The coagulated juice is placed in a filter (can be a cheesecloth) and hung, the liquid drips under the effect of gravity until the curd in the filter reaches the desired consistency. A press can be used to accelerate the process. This age-old and low tech batch filtering process is very simple and effective, but it becomes a bottleneck as we scale a protein extraction process. At large scales it is labor intensive, time consuming and it exposes the extracted protein to contamination. Since the chosen juice extraction method is supported by an extruder, a continuous process, our desired dewatering process, the separation of the curd, was also a continuous process that could be implemented inline with the Juicer. The most viable solution that we could identify was the *decanter centrifuge*.

Conceptually, the decanter centrifuge is a decanting process accelerated by centrifugation. As the liquid-solid mix is spun at a high rotational speed, the heavier solid is physically separated from the lighter fluid. In the Worm Screw design, a screw is used to scrape the solid material that is deposited on the barrel the device, while letting the excess fluid escape from the other side. No filter is used. This is done in a continuous manner. For a better description of the process see the Wikipedia page.

The Worm Screw Decanter Centrifuge, let's call it the Separator in the contest of the Greens for Good extruder, is a continuous process driven by a central rotating shaft, which is mechanically compatible with a single screw extruder, the Juicer. These two modules, the Juicer and the Separator can, at least in theory, be mechanically coupled, perhaps intermediated by some type of speed variation module (gearbox, pulley and belts, etc.). The goal of this study is to identify the mechanical solution for the interface between the two processes, the juice extraction and the separation. This solution requires both modules, the Juicer and the Separator to be able to process the same quantity of material in a given lapse of time. This means that the Worm Screw Decanter Centrifuge prototype must be able to intake coagulated juice at a certain debit and produce the proper conditions for a good separation. These conditions are related to the diameter of the centrifuge, rotation speed, and solid material scooping rate. In order to better understand these conditions the team has decided to **produce a first table-top prototype made almost entirely from 3D printed parts. This easy to fabricate and assemble experimental device would also allow us to iterate the design rapidly, while learning how to master the physics of the separation process.**

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Methods

3D modeling

The design process of the Worm Screw Decanter Centrifuge V2 is documented in the Open Source Decanter Centrifuge document. The initial requirement was a device for a continuous separation process that can be mounted inline with the Juicer, as part of the Greens for Good device. A series of other general design considerations were identified and discussed for the final product, but not fully. We moved rapidly to the production of a proof-of-concept Worm Screw Decanter Centrifuge V1 as described here, to be used in preliminary experiments, which would provide some initial insights into the physics of the separation process. In doing so, we also hoped to gain experience with high RPM applications. V2 was designed and prototyped based on the learning with V1.

Preliminary experiments were already performed at the Sensorica lab to gain more insight into the rheological properties of the coagulated juice, a homogeneous mixture of sub-mm curd aggregates and fluid.

This proof-of-concept decanter centrifuge is designed as a stand-alone device, intended to process a batch of coagulated juice that was to be produced separately, following the same protocol described in the Preliminary experiments. All the design constraints related to the mechanical interface with the Greens for Good device were dropped. The physical dimensions were also greatly reduced.

The following steps were used:

1. Make a conceptual sketch of the device
2. Source key parts, such as bearings and electric motors
3. 3D modeling around the available key parts
4. Order parts that cannot be 3D printed
5. Generate STLs files for 3D printing

Like in V1, to power the device we decided to use two 400W, 12,000 RPM CNC/spindle brushless motors. One motor drives the barrel of the centrifuge and the other one drives the inner screw. This allows an independent rotational speed variation, which is desirable to optimize the separation process. The two motors can be controlled programmatically via an Arduino board, but we did not use it in this experiment. The transmission (motor to barrel and screw) was direct drive, eliminating the pollies and belts used in V1, to reduce mechanical vibration and wear.

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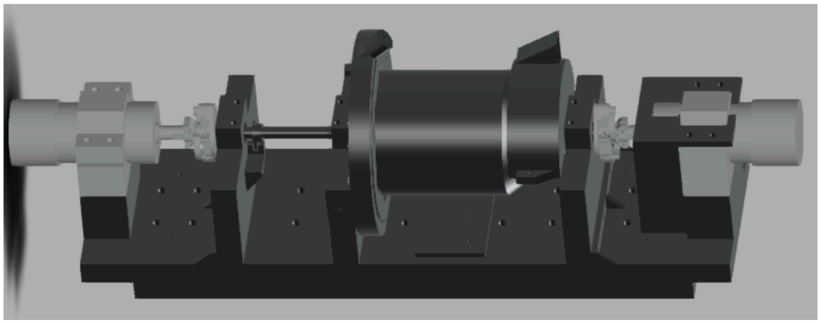

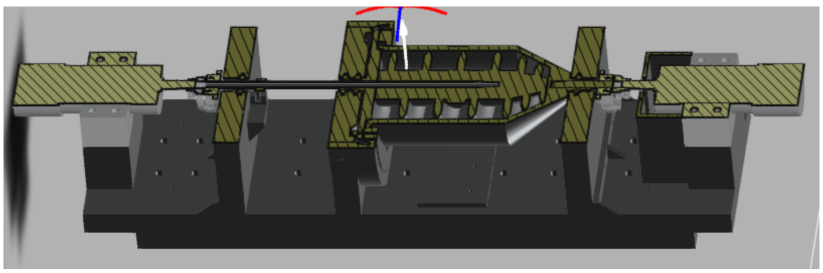

Open 3D model for visualization

For more information please consult the Open Source Decanter Centrifuge document.

Decanter centrifuge V…

Fabrication and assembly

Assembly of the device is detailed in the same doc as the Design, here.

Most of the device was 3D printed. The design of the barrel and the screw are similar to V2 and we used the same small bearings and the same driving motors.

Testing

The following protocol was used for this testing phase:

1. Assemble the device
2. Motion control and analysis
    a. Motion control testing: Dry (no fluids) testing of motors, motor control, RPM differential control (rotors relative rotation speed)
3. Structural analysis: Document signs of structural failure under increased RPM. Assess the necessity of design improvements.
    a. Go / No Go: Decide if it is safe to continue testing or reprint an improved version. Possibly build a wooden box around it.
4. Test with fluids
    a. Test water, observations
        i. Go / No Go: Decide if the system is able to handle fluids
    b. Test with coagulated leaf juice

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5. Push the limits - high RPM test, possibly destructive

All the steps above will be discussed in the sections below.

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Results and Discussion

Assembling the device

Post processing

Some 3D printed parts required sanding, standard printed post processing. The cap for the barrel had to be sanded with the Dremel a fair bit to get it all to fit well and turn, the stairsteps had to be removed from the threads.

We had to sand the diameter of the screw and inner diameter of the barrel to remove blobs so it rotates freely inside the barrel.

We had to sand the inside of the motor couplers to prevent binding as the layers of the coupler and shaft interlock. Ideally, the couplers should be printed with a smaller layer height.

Note that the shaft of the barrel and cap may rattle in the bearings if they are too loose. During the experiment, this caused a sound that was mistaken for parts hitting each other slightly. We solved it by putting some CA glue in between the shaft and inner bearing race. In the future, a compression spline could be used.

Assembly

It takes 30 minutes to fully assemble the device. Please watch the video *** for the step-by-step assembly of the video.

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Motion control and analysis

> *Motion control testing: Dry (no fluids) testing of motors, motor control, RPM differential control (rotors relative rotation speed).*

This section is about motion control, testing individual motors, as well as the entire assembly. The Worm Screw Decanter Centrifuge V2 uses the same two 400W CNC/spindle air cooled brushless motors, as in V1, that can go up to 12000 RPM. The motors came with their own drivers. The drivers have an integral PID controller that monitors RPM using back emf, and adjusts the throttle parameters to accelerate or decelerate the motor. They do include active braking functionality which regulates overspeed conditions.

Power is supplied by an adjustable power supply set to 48V DC, capable of 12.5A max.

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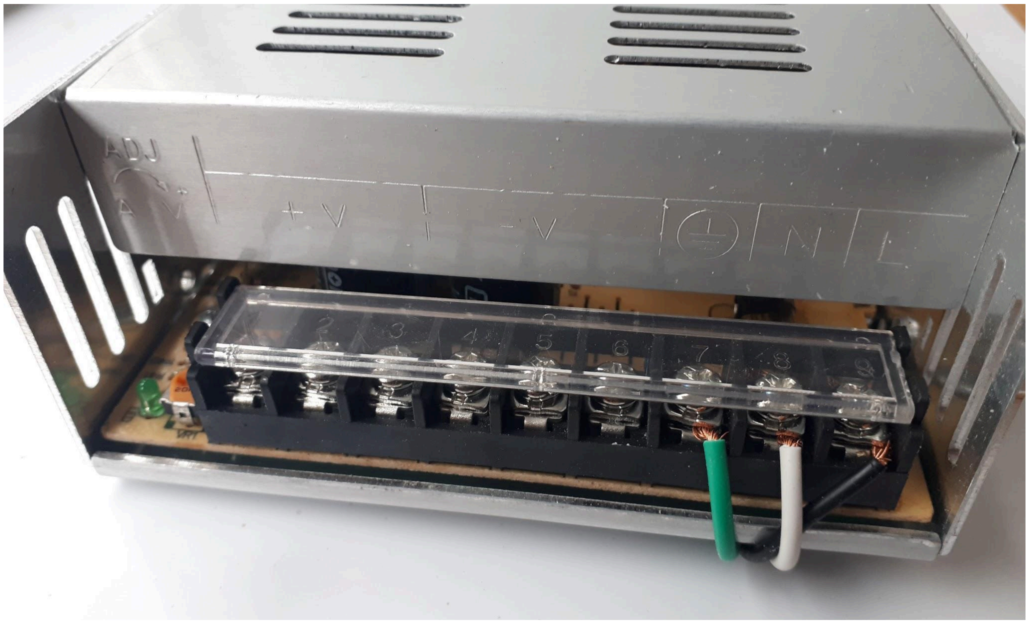
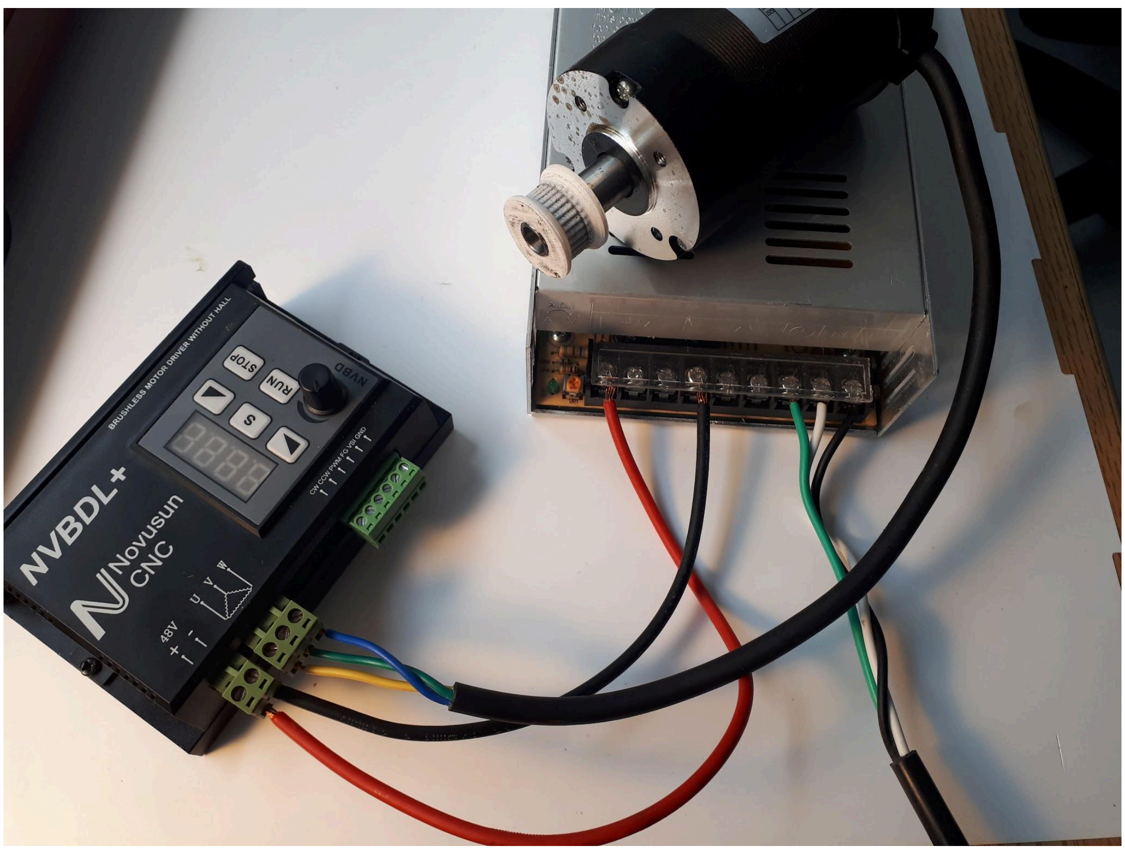


Wire connections are straight forward, as seen in the picture below.



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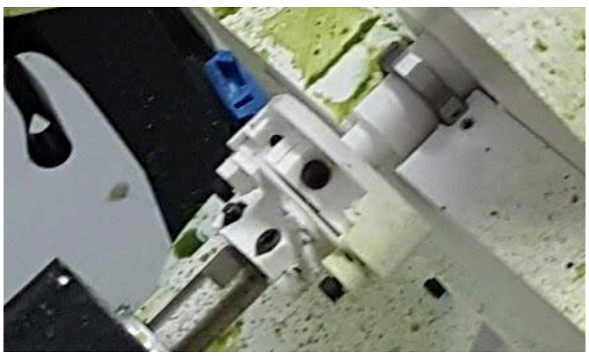
The drivers did not respond properly to parameter settings and inputs on the input pins, nor did the FG output pin work properly. The CW/CCW setting, for instance, was ignored. Motors were caused to rotate in the desired direction by changing the wiring to the screw terminals.

The power supply needs to be set to the proper grid voltage, 110V in our case. A voltage adjustment pot (light brown on the left side of the power supply's panel) must be adjusted to maximum voltage / power.

The motor controller has an LED display and manual controls. To start the motors you need to press RUN. We always make sure that the speed knob is turned to minimum when starting. Once the motor starts we manually increase the RPM from the speed knobs. The RPM is displayed on the screen. The actual setting is not actually displayed. Motors performed well when tested independently.



Next, we assembled the motors on the centrifuge. As seen in the picture, motors are coupled to the barrel and to the inner screw via flexible connections to allow for slight misalignments. These connections were carefully designed with one axis of symmetry in order to be properly balanced for high RPM.

Vibration tests

Testing the screw alone, click on the image below to open the video.

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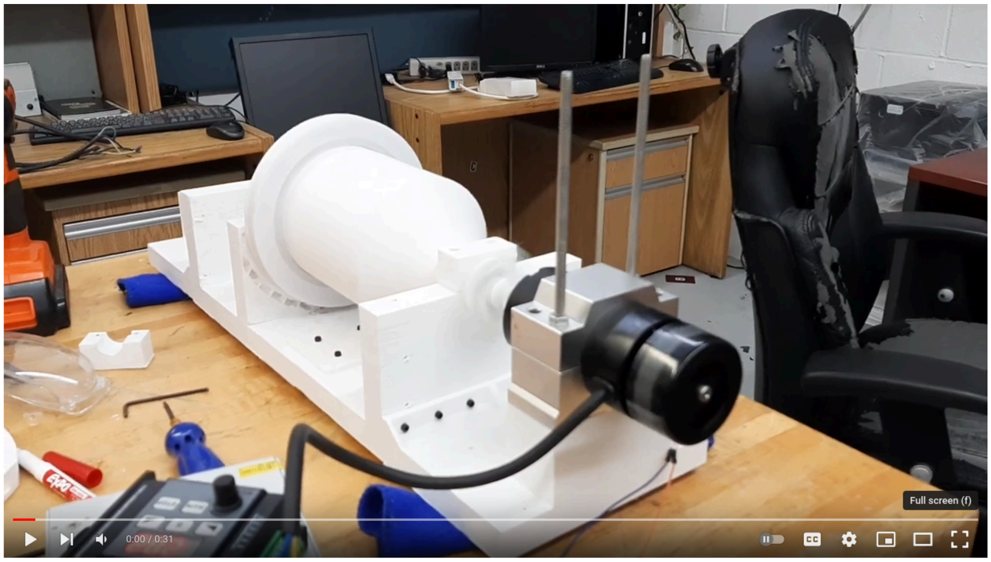
Testing the Barrel alone, click on the image below to open the video. The vibration was monitored using a speaker attached to the structure, connected to an oscilloscope. We could achieve 6000RPM, where vibration became more significant.



Important to note that the motor controllers can also be programmatically controlled from an Arduino or Raspberry Pi Pico board, which can contain and execute various speed profiles for both motors, tightly coordinated. Although we started looking into this control option when the first prototype was tested, we did not have time to fully implement it. Later investigation showed that the motor controllers do not respond precisely and reliably to external inputs, so we reverted to manual control.

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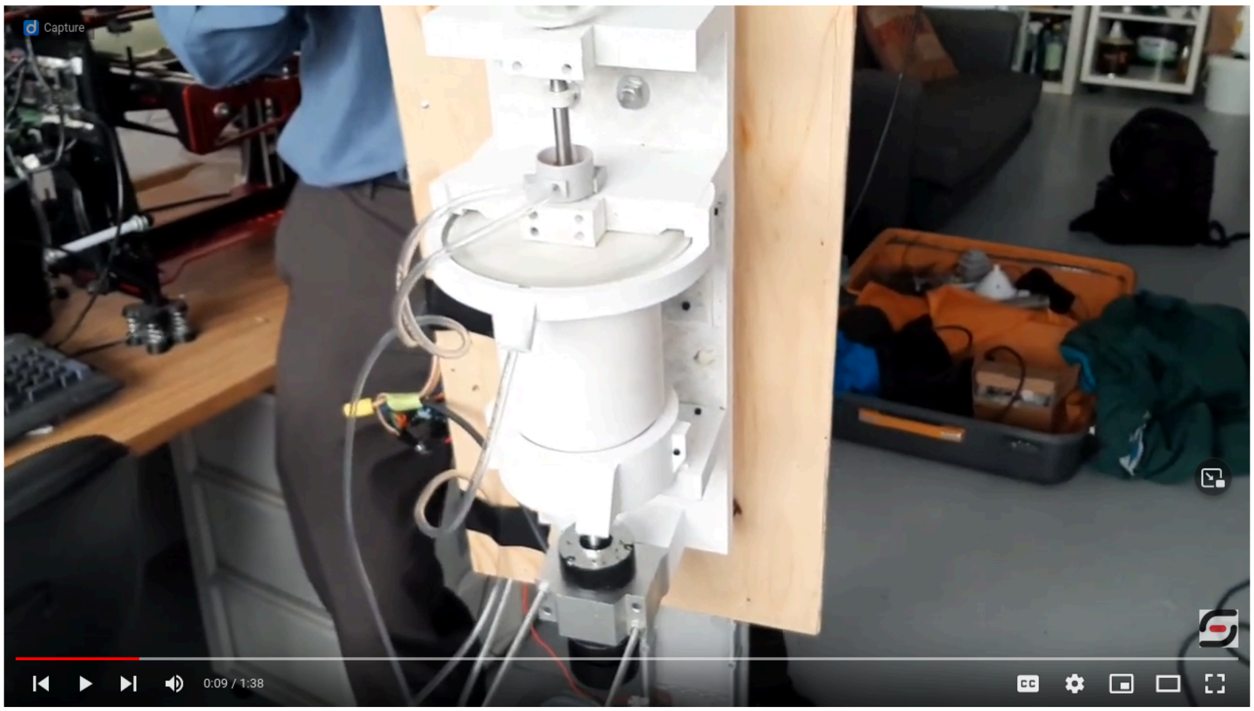
Structural analysis

> *Assess the necessity of design improvements. Go / No Go: Decide if it is safe to continue testing or reprint an improved version.*

After the assembly of the centrifuge we took it for a dry spin (no fluids) for testing of motors, motor control, RPM differential control (rotors relative rotation speed). We also looked for temperature increases, vibrations, and wear and tear. Everything was going well at this stage, click on the video below to see the video.



Wear and tear inspection

As opposed to testing the V1, no part overheated during the whole experiment.

Since V2 uses direct drive (motors are directly connected to the barrel and the screw via the flexible couplers), no wear was observed.

Vibration starts to be annoying between 4000 and 5000 RPM, during normal operations with fluids, with no real practical concerns. Between 7000 and 8000 RPM the flexible couplers broke.

Bearings get wet during normal operations with fluid, they require lubrication after use. **Improvement suggestion**: find better ways to install bearings to shield them from fluid leaks.

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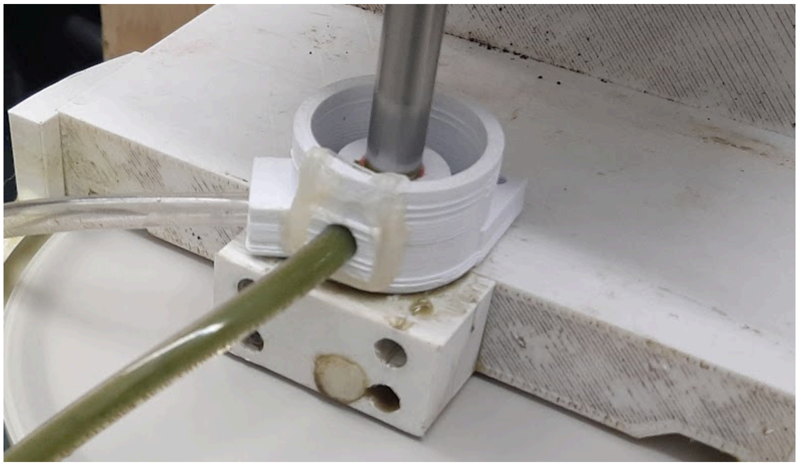
Other faults inspection



Intake leakage inspection: The first intake manifold was leaking, so we designed and 3D printed a second version with a collection ring, which worked pretty well. A tight fit also helped and we used some grease to reduce friction and keep the water from getting between the metal shaft and the intake manifold.

Error: The intake hole in the metal shaft was drilled in the opposite direction (assuming the rotation was in the other direction) - this was improved in subsequent trials and a second hole was made.

The robber oring between the cap and the barrel sealed fairly well with enough grease to help rotation of the cap for tightening, but did not seal properly without grease.

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Test with fluids

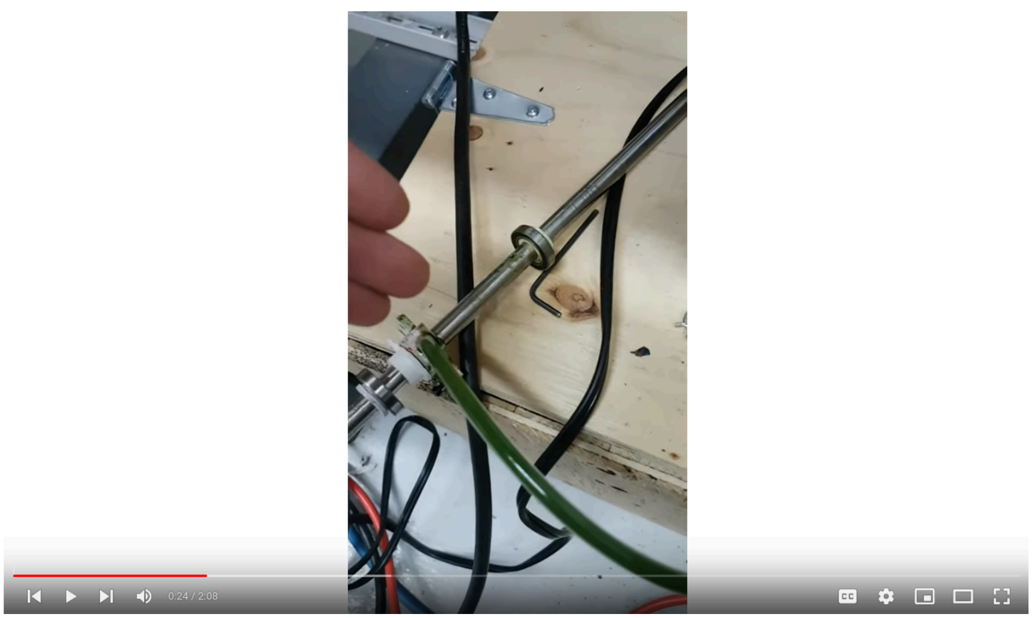
After a dry run we tested the centrifuge with water.

Our observation goals were:

- Examine the centrifuge for unusual leakage,
- Examine the performance of the fluid inlet,
- Get a feel of the differential speed control (between the barrel and the inner screw)
- Observe the overall behavior at around 1000 RPM.

After stabilizing the system at 2000 rpm for the barrel and 2010 for the screw, we switched over to the heat-treated kale juice substance as feedstock. The juice was prepared and coagulated as in this previous experiment.

We run the centrifuge for about 40 minutes most of the time at 2000 RPM. We also spun it for 10 min at 4270 RPM. Internal radius of the barrel is about 50mm. The relative centrifugal force can be calculated accordingly, and comes to about 1020 G. During the process, adjusting the pumping rate (around 40 ml per minute) and observing, we found that fluid was exiting from near the left motor, from the intake tube, on the side of the intake. When the centrifuge was dismantled we noticed that the intake metal tube was getting clogged with solid material. Click on the image below to open the video for more info. This problem was solved by redesigning the intake manifold, by enlarging the intake hole into the metal intake tube, by enlarging the two holes into the screw from where the fluid exits into the centrifuge, and by slightly increasing the fluid pumping rate.



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Upon halting the centrifuge, we found about 86 g of compacted sludge collected on the screw after dismantling. This meant that some fluid got into the barrel before the intake tube was clogged and solids were dewatered to a certain extent. We dried this to measure the water content, in a room at 22C and 22% humidity. Another 52 g of sludge was scraped off the barrel. This sample was frozen for future reference.

A subsequent experiment at 2000 RPM 40 ml/min pumping rate confirmed that higher RPM is needed to concentrate the solid material enough to have a chance to be pushed up the beach through the exit hole.

At some point the upper motor coupler broke due to a sudden torque overload of unknown origin. The couplers are deliberately made to be the weak point as they are small and cheap to replace. They are a sort of mechanical fuse. In this role it thus operated adequately.

We continued testing the machine to try to evaluate the promise of next steps. It appears that the intersection of the solidity of the solids fraction, the torque that can be transmitted to the

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screw while maintaining RPM within regulated, suitable limits, and the tendency for the solids material to climb the beach (the conical part of the barrel) and escape through the hole does not come to an adequate balance. The video below shows some on the spot reasoning based on immediate observations. This problem can theoretically be overcome by adjusting various parameters based on empirical observations and calculations, see more on heuristics of the worm screw decanter centrifuge.

Gears to couple rotation from the barrel to the screw could also be a viable approach, as the differential speed between the barrel and the screw can be fixed, high torque can be applied to overcome friction from the solid material.

Mechanical failure of the motor couplers was previously observed during operations when sudden braking occurs. We modified the design to make them stronger.

During subsequent trials we pushed the limits of the centrifuge at higher RPM. Based on the tensile strength of the plastic, volume of water in the chamber, diameter of the chamber etc., the 3D printed barrel with water in it should be able to withstand more than 20,000 RPM, however to approach that would infringe on the safety margin seriously. G-force is proportional to the square of the RPM, so 12,000 RPM allows a reasonable safety margin.

We did not have solid material exit the solid exit hole of the centrifuge, but we accumulated enough solid material within the barrel that the screw got stuck, due to increased friction. Evidently, the solid material could not be pushed up the beach (the conical part of the barrel) to the exit hole, either because the solid material accumulated too fast or because the solid material was not solid enough to sustain the centrifugal force pushing it sliding down the beach. This is discussed in the heuristics for the warm screw decanter centrifuge. When we stopped the experiment we collected a large amount of sludge. We weighed a portion of the sludge, dried at room temperature for a day and weighed it again. From memory we only achieved around 20% solid, which is not enough for the screw to push it up the beach, against the centrifugal forces. This is consistent with our findings using a lab centrifuge on similar samples.

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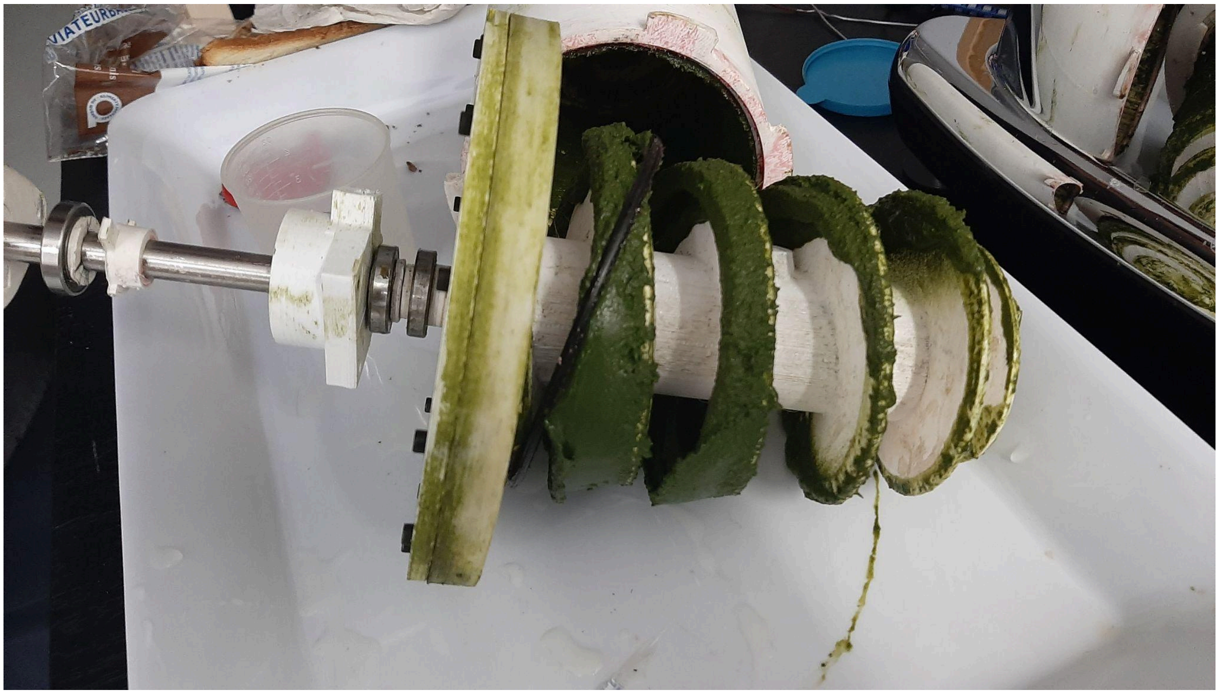

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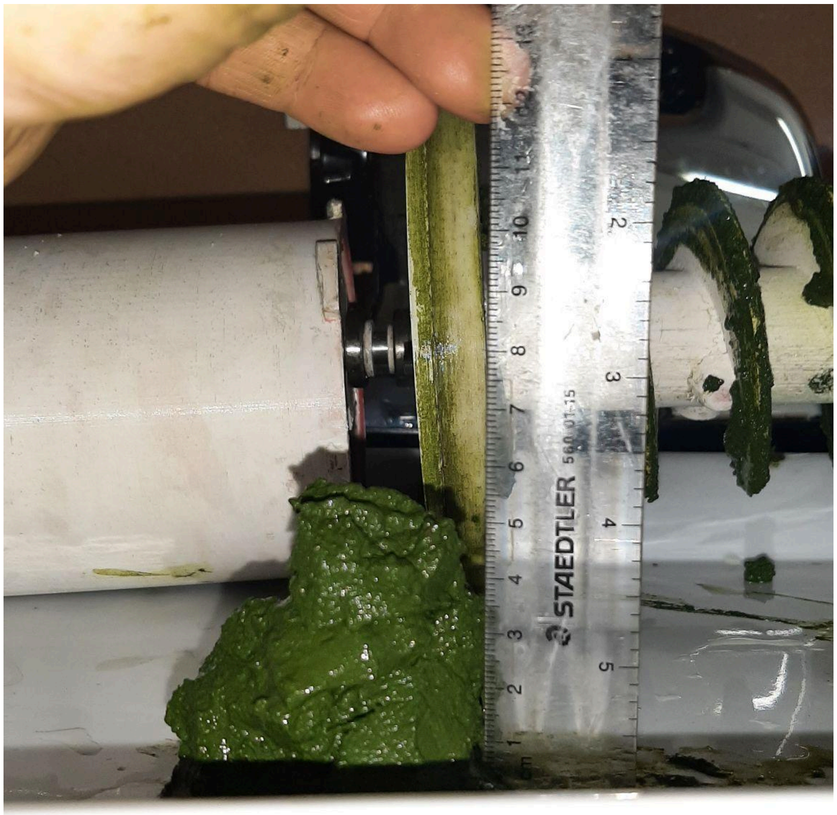

NOTE: There is an empirical theory used in the cement / construction industry that relates the height of a slurry to its capacity to be transported with a single screw. The measure in the last figure above and provide some interesting information.

Some new ideas

A different paradigm in several ways may be in order. The worm screw decanter centrifuge may not be the best design. We have discovered the possibility of eliminating the central screw entirely, and using a controlled outlet port on the periphery of the centrifuge chamber. This could simplify things considerably, and allow essentially the same performance for most food processing applications. For a large design, the additional complexity with the screw and control system for it may be acceptable, however for a small economical machine, simplification is important.

Another option is to continue with the central screw, but with a different method of rotating it relative to the barrel (the outer wall component). An actuator mounted on the barrel or cap (which connects to the barrel securely) that turns the screw directly at 3-20 RPM could be a more practical approach than the one we have thus far employed. Regulating the speed of the screw relative to the barrel in this situation has proven to be non-trivial, as expected. The relative RPM needs to be between approximately 3 and 30 RPM for adequate removal of solids material. At e.g. 5000 RPM, this implies regulating the speed to within a fraction of a percent. Although this is possible, it is not trivial. It cannot be done with a gear box, since there are no such devices with such a small ratio.

The most important issue we have encountered is clearly the strength and tolerances of the printed parts, as expected, however that we are able to get as far as we are is notable. The 3D printing layer lines are inconvenient as well, making parts prone to getting stuck, and cleaning difficult. The porosity of the walls of the centrifuge is also a problem. The fact that the screw and walls of the barrel are actually hollow is also detrimental, although we have successfully produced them with 100% infill, we have not yet employed those parts. The largest problem we had was the lack of straightness of the bearing block mounts, and strength of the shaft of the barrel. The entire structure was slightly curved, which required that the screw be sanded quite extensively to fit adequately. This was solved by using a backbone of extruded aluminum. Imprecision in the collars around the central tube, which adapted the 10 mm diameter tube to the 15 mm ID bearings, caused most of the wobble, combined with minor deficiency in the motor coupler design.

Printing has been shown to be a useful tool even in this context, however it does take some skill and time to effectively employ it. In one instance, the motor coupler broke due to sudden acceleration of the motor, but we were able to print a new one, modified to be stronger, in about 30 minutes of net labor and machine time. Secondly, in one case it was beneficial that the coupler broke instead of the shaft, which would have broken if the coupler were stronger. So the downsides are substantial, as are the advantages. This rapid iteration of design, rapid replacement of a broken part, as well as the production of a custom part which is made to break and thus spare downstream components, i.e. a custom “mechanical fuse”, would not have been viable with other manufacturing methods. Indeed, this project would not be at all economical with the use of machining, the next most viable method. Low cost FDM printing, despite its inadequacies, is thus a strong enabling factor in such research.

Sourcing parts is a serious problem, however we were able to do surprisingly well just sourcing bearings, screws, electronics, motors, etc. though rapid and economical consumer channels, with remarkable economy, as such undertakings normally go. The bearings should be stainless steel or ceramic for an eventual production machine, to avoid corrosion.

We believe that it is possible to employ 3D printing, combined with strategic metal inserts or even lost pla casting, or similar, to produce a viable production grade machine for effective, industrial use, although the per unit cost of production and quality would be lower than a machine produced through other means, the capital cost of achieving the production of such machines is far lower. The cost of printing low cost plastic parts with FDM is not a major factor.

We have more to learn from this particular prototype. We believe that by adjusting the angle of the beach (conical part of the barrel) and the location of the solids exit ports, we will be able to achieve efficient and rapid separation of protein coagulate from the liquid fraction. The time-centrifugal force product appears to be adequate for a processing rate of more than 1 liter

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per minute of juice, which translates to more than 2 tons of alfalfa per day, which is seriously viable economically. To achieve such a milestone in such an economical manner is unprecedented and notable.

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Discussion and conclusions

Things that went well and could easily have gone wrong

- The shaft of the barrel did not break, that would have shut everything down and been very hard or impossible to fix without reprinting the barre, which is not practical as the printer at the lab probably cannot deliver the required tolerances.
- The partial threads mechanism for the cap and barrel worked pretty well, it was a tight fit but worked, generally.

Fitting and vibrations

- The error stack up was worse than anticipated. It led to wobble due to the inaccuracies in the collars which adapted the tube to the bearings, in particular. The distortion from the ideal of the bearing mount structure required extensive sanding of the screw to compensate for. It would be advisable to mount the bearing blocks directly on an aluminum plate or extruded aluminum section, instead of bolting them to each other.
- The o'ring was slightly too small/didn't fit the barrel and cap as well as we hoped, but we were able to push the parts together ultimately. The fit did not appear to be a major source of vibration, which was good.
- There was contact between the collar of the cap and the metal tube, apparently. This was likely due to the distortions from the ideal form noted in the first bullet point.
- The sideways hole in the screw needed to be bigger, we were able to drill it out.
- The motor drivers were notably low quality. They did not process the PWM signal properly, and probably had a non linear response to pulse width. They also did not respond properly to the direction (CW/CCW) inputs. One of them stopped accepting PWM input at some point, it is unclear why, but prime suspects are a tiny amount of water intrusion or static electricity, however it should not be that susceptible to either. The arbitrary limitation on RPM as well as the erratic and unnecessarily unpredictable and non-smooth regulation of speed is also less than ideal. Their manual is poorly written and their current handling capacity is unclear. Most of the wasted time was due to the low quality of the motor drivers and their documentation, in retrospect.
- Adjustable flow is important for proper testing as we need to know the maximal processing rate in order to evaluate economic viability.
- The input manifold was redesigned with a collection channel and drainage.

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Changes in design

Screw
The transversal hole in the screw that lets the fluid from the metal shaft escape was enlarged manually with a drill.

Barrel
Very porous, water escapes through the walls, we had to coat the internal surface with Gloop to seal the pores.

Fluid intake
Input manifold was redesigned to collect the fluid that escapes the metal shaft and redirect it back to the juice tank.

Fluid collector
Redesigned to make a connection to a plastic hose, cleaner operation.

Solid collector
Was redesigned, made of 2 parts so that it can be easily assembled.

Motor couplers
Redesigned to reduce vibration, adding more springiness.

Overall architecture and user experience

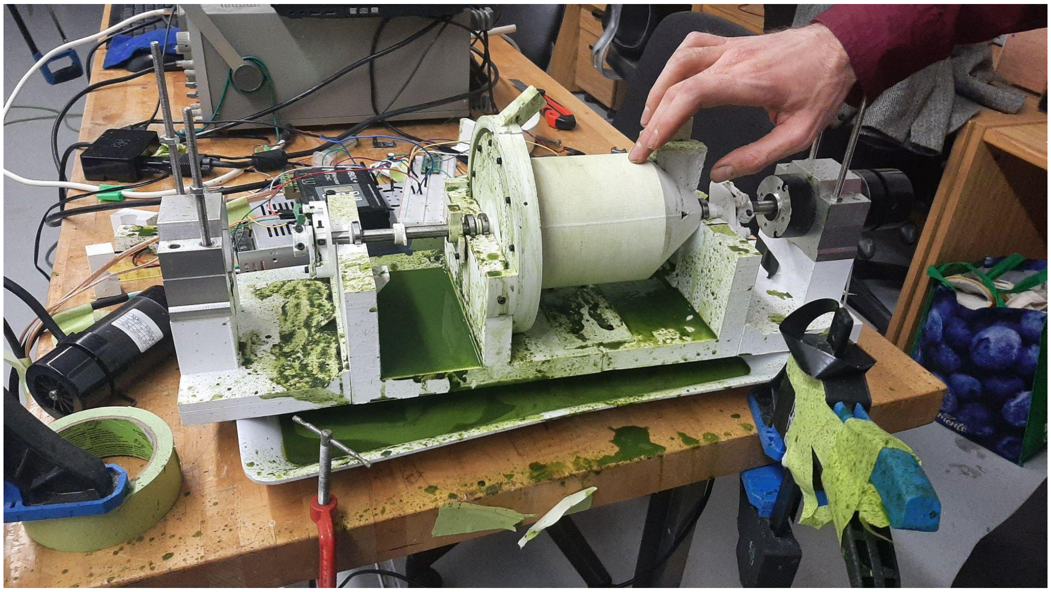
The assembly and disassembly of the device requires sequential steps and dealing with screws. It would be nice to replace screws with clamping mechanisms. But since this version was not intended as a user-ready device, only as a lab exploratory prototype to figure out the operational space of various parameters, it is not a problem. It could have made manipulations easier.

Another constructive criticism is washing the device. Have in mind cleaning for future developments. For example, some parts should not be exposed to water, like bearings. We had to relubricate them after each use-wash cycle.

This device operates well at 500 RPM. Some parts can break and fly onto the user, with potential harm. We have designed an enclosure for it, but we did not use it, since we need to observe the device in operation and from time to time tweak some adjustments. So we operated it in the open, wearing protective goggles.

Splashing was a problem. Operating the prototype is still messy. We had to use a cardboard wall to prevent splashes in the lab. Splashes come from the collectors, which overflow, and some leakage from the intake manifold.

Log your contribution



One positive note must be mentioned though. The last experiment with the V2 prototype was performed on a rotating/tilting support, mounted on a wheeled chariot. This was much better than on the lab table. First, the normal operation of the device is vertical. But during tweaking we could easily rotate the device in the horizontal position. Moreover, the height of the device was ergonomic, allowing easy operation while standing up, without leaning forward.

Log your contribution

Development process

The development methodology and the refinement of open source, decentralized development and production of physical equipment is an integral part of this project. We are not just after a design for a centrifuge, but one that can be produced in a decentralized way, and also a method of developing such designs in a decentralized, peer 2 peer way, and getting them into the commons in a manner that is economically viable.

The efficiency with which we worked was excellent as this type of development work goes, however we do wonder if we could have learned what we learned a little more easily. Ascertaining the properties of the coagulate/liquid mixture and how it is balanced by the mechanical properties of the machine, and if they are all in range, is not something that can be practically done without building and testing a machine. However it takes a remarkably long time to build equipment like this.

The 3D printing process is rightly regarded as unsuitable for a quality product. However it has great advantages for prototyping, impossible to beat economically. The cost of producing the parts we required through any other means would have been prohibitive. However, the process of finishing and fitting parts with poor dimensional tolerances was still very labor intensive, offsetting part of the cost of parts. A superior manufacturing process would be quite helpful.

The strength of the modified PLA and PETG material was not a major problem. It was adequate when combined with stock metal inserts for high stress areas. However it did limit the practical RPM we were willing to push the machine to, thus far, out of fear of damage and safety concerns.

The printing process itself is also substantially labor intensive when using low cost, low quality machines and input materials, although less so in many ways than competing processes.

We were rarely able to print what we needed in a manner that was fast enough to dynamically overcome problems, but in some cases we were. We were able to print a new seal in a few hours that solved a leakage problem, and to print new motor couplers of superior design when the old ones broke. However, producing any of the large parts on the fly was not very practical, and we opted to modify the ones we had instead.

Community participation has been low, the project is mostly carried forward by a small number of individuals, and there is substantial dependence on funding input to pay for labor, parts and materials.

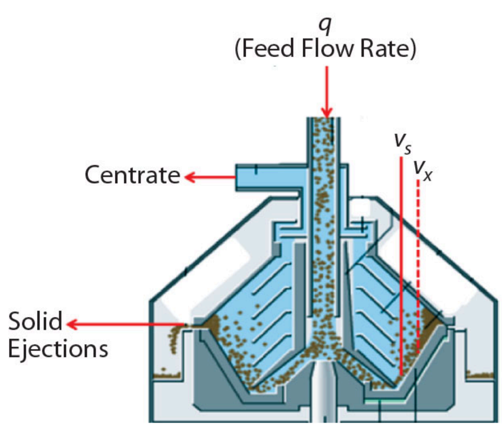
Log your contribution

Further work

Self balancing of the centrifuge would be ideal, we found some papers on this topic, see bibliography.

When we decided to go with this design we underestimated the friction between the screw and the barrel, once the protein paste forms on the inner surface of the barrel and touches the screw. This force ended up being larger than the torque of the motors. Thus, the screw could not scrape the paste out of the barrel through the exit hole. This problem can be overcome by mechanically coupling the screw and the barrel perhaps using a gear with 0.999 ratio, since the rotation of the screw with respect to the barrel should be only of a few RPM.

Another problem we had with this design was that we could not control the speed of the motors very precisely, within one or 2 percent. One solution is to use a single motor with a 0.999 gear between the screen and the barrel, which is hard to find.



We also have a plan for changing the paradigm and abandon the decanter centrifuge design altogether, opting for a simpler device that only requires one motor. This would be a funnel design, similar to the oil clarifying centrifuges, with an escape that can be open and closed at the end of the funnel, when solid matter accumulates, to release it. Clear fluid escapes like in the oil centrifuge. We can monitor the accumulation of solids by eye, using a glass wall on the top.

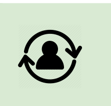
The release can also be automated using optical sensors, when the solid accumulates to a certain level the glass becomes opaque and the solid release is triggered. The solid release is done by opening a small slit. The slit can be activated by centrifugal force, by increasing the RPM slightly. One motor is used.

New parts

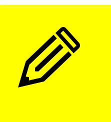
- Pico
- Hollow shaft motor
- Optical tachometer

[Log your contribution]

{Signalization tools}



{symbol for process/status updates - use this to signal important milestones in the process}

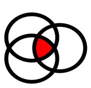


{symbol for notes - use this to post reminders or short messages for self or to collaborators}

{symbol for attention to important information - use this to attract collaborators' attention}

{symbol for ToDos - use this to signal to your collaborators about what they can do}

{symbol for alternatives: enumerates possible solutions to consider}



{symbol for reasoning: presents arguments about possible choices}

{symbol for Information: tells you how stuff works.}

{symbol for Growing consensus: a summary of a section of this report}