GVI: Straw Stamp and Slicer - BME 200/300

Preliminary Report

BME 200/300 Design

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Abstract

The increase in global demand for animal-derived products has led to a shift towards genomic selection and artificial insemination to reduce environmental harm. Genetic Visions-ST supports this process by conducting a quality control protocol, sequencing bull semen from the straws to ensure the DNA matches the bull listed on the straw. The current process requires individually cutting each straw, pushing the contents into the well plate with a paper clip, and sanitizing the scissors and paper clip after each straw. The procedure is time and labor intensive, taking one hour. The team aims to significantly reduce procedure time by creating a slicer, frame, and stamper. The slicer will mimic a guillotine paper cutter to cut twelve straws at once without cross contamination. The frame will be 3D printed and will have twelve "compartments" to secure twelve straws in the well plate, and clips to attach the frame to the well plate. Lastly, the stamper will have a 3D printed handle and base, 12 steel prongs, and attachments on the side for alignment with the frame. To ensure successful devices, the team will perform compression tests on the slicer and stamper with straws to determine the exact forces required to cut and push the contents out of twelve straws. The team will also perform Genetic Visions-ST's quality control procedure with the new devices to confirm protocol time reduction, and a contamination test verifying minimal cross contamination during the entire process.

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Introduction

Motivation and Global Impact

As the population increases, there will also be an increase in global demand for animal derived products [1]. Genetically improved animals can help this growing issue by providing better meat and dairy products, and also decreasing the environmental harm likely to be caused. To genetically improve animals, artificial insemination is used. At Genetic Visions, they process and control the quality of bull semen to aid the artificial insemination process. However, the current quality control procedure takes around an hour a plate, and eight to ten plates are processed a week, so this procedure can take up to ten hours a week. Decreasing the time to process each plate can help increase the plates processed per week, increasing the efficiency and making the whole artificial insemination process faster.

Furthermore, the semen in each straw is tested to make sure it matches the DNA listed on the straw to make sure no cross contamination occurred. The stamper and slicer must also reduce contamination risk to save time and materials used.

Existing Devices and Current Methods

Currently at Genetic Visions, the clients are using a pair of scissors to cut each straw individually. Then, each straw is stamped individually by using a paperclip to push the cotton down the straw, pushing the contents out of the straw and into the well plate. Although these methods are accurate, this method is quite time consuming as all 96 straws are processed individually.

One example of a competing product is the MiniCutter for Semen Straws by Nasco Education [2]. This is a lightweight product and has an ergonomic handle, increasing the ease of use for the client. To use this product, the straw is placed inside the hole, and a notch is pushed to cut the straw. This straw cutter is able to cut both ¼ and ½ cc straws, which is what the client requested. However, this cutter can only cut one straw at a time, and can not empty the contents of the straw, so a stamper would still be needed. There is not currently a straw stamper on the market that fits the clients requirements.

Figure 1: MiniCutter for AI Straws [2]

The clients at Genetic Visions also provided potential design ideas. The first prototype was a stamper, featuring a top plate, with 96 prongs coming out of it. This prototype is ideal, as it can stamp all 96 straws at once, however, the prongs are too large to fit into the straws.

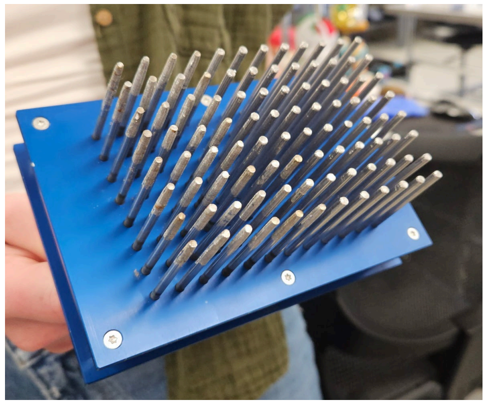


Figure 2: GVI Stamp Prototype

The second prototype was for a cutter. This prototype was a paper cutter-like design, featuring a back wall and an arm that can lift up and down. The front wall has 12 individual holes for each straw so contamination can be minimized. Even so, there is still a contamination risk since each straw is cut using the same blade. Also, the blade would have to be quite sharp to be able to cut all 12 straws at once, which poses a safety risk.

Figure 3: GVI Slicer Prototype

Problem Statement

Currently, quality control procedures investigating quality of bull semen for artificial insemination are time and labor intensive. The process involves cutting and pushing bull semen through a small straw using a straightened paper clip, and transferring the contents to a 96-well plate. This process takes one hour, with 8-10 plates being processed per week. The purpose of the project is to optimize these quality control procedures by designing a straw slicer that should be able to cut 12 straws at a time Additionally, a straw stamper is needed to push bull semen out of the straws in bulk, avoiding cross contamination. All devices should also have removable components for cleaning.

Background

The clients for this project are Sarah Hanson (lab manager), Brett Breidor (lab technician), and Ben Goss (sequencing technician), who are all employees at Genetic Visions-ST. Genetic Visions-ST perform genotyping of production animals as well as sequencing services for a quality control program to ensure the DNA detected from the artificial insemination straws match the bull labeled on the straw.

Genetic Visions-ST uses low-pass sequencing (0.5x coverage), then bioinformatics, to detect if the sperm cells in the straw match the bull that is labeled on the straw with a detection limit of 5%, meaning it can identify contamination if > 5% of the DNA in the sample came from another source [3]. Low pass sequencing is the process of sequencing a genome at a low depth so not every base in the genotype is read, while imputation involves comparison to reference data to form a reconstructed genotype [4]. The low-pass sequencing and imputation combination results in a cost-effective alternative to typical single nucleotide polymorphism arrays, which require more resources and time [4].

To prepare for the low-pass sequencing, a protocol is executed where each artificial insemination straw's ends are cut off and all of the contents in each straw are pushed into a 96-well plate. This requires the creation of three devices: a slicer to cut 12 straws, a stamper to push the contents of the straws into the well, and a frame to hold the straws in place during the procedure. Each device must conform to the dimensions of the 96-well plate used by Genetic Visions-ST: 127.8mm x 85.5 mm x 44.1 mm [5].

A main consideration of Genetic Visions-ST while performing the protocol is the prevention of cross-contamination. DNA sample contamination is a common problem in DNA sequencing and can result in systematic genotype misclassification [6]. Genotype misclassification may lead to inaccurate identification of sperm cells in the artificial insemination straws. The emphasis on lack of cross-contamination influences the prototype components and materials. The slicer, stamper, and frame design must prevent the contents of one straw from seeping into another straw or another straw's designated well on the 96-well plate. Therefore, each device design would benefit from removable components for sanitation and replacement over time.

According to the PDS, the overall goal of the client is to cut down the procedure time from 1 hour to <30 minutes, as 8-10 plates are processed per week. As for design specifications, the slicer must cut 0.20-0.50 inches off the end of each straw, guaranteeing a uniform length for all 12 straws. The slicer must also have a blade guard to cover the blade while not in use. Additionally, the straws must not bend or break during the straw pushing. Each artificial insemination straw has a diameter of 0.002 meters, so 0.32 N of force is required to break the seal and push the contents out of the straw [7]. Furthermore, cross-contamination was heavily emphasized by the clients, so any component of the slicer, stamper, or frame that contacts the inside of the straw must be made of non-porous material and must be removable for sanitation by ethanol or bleach. Finally, each device must have a life-in-service of over one year and there is a

$1000 budget for research and fabrication for all the devices. Additional information regarding the device specifications can be found in Appendix A.

Preliminary Designs

Frame Design 1: The Clamp

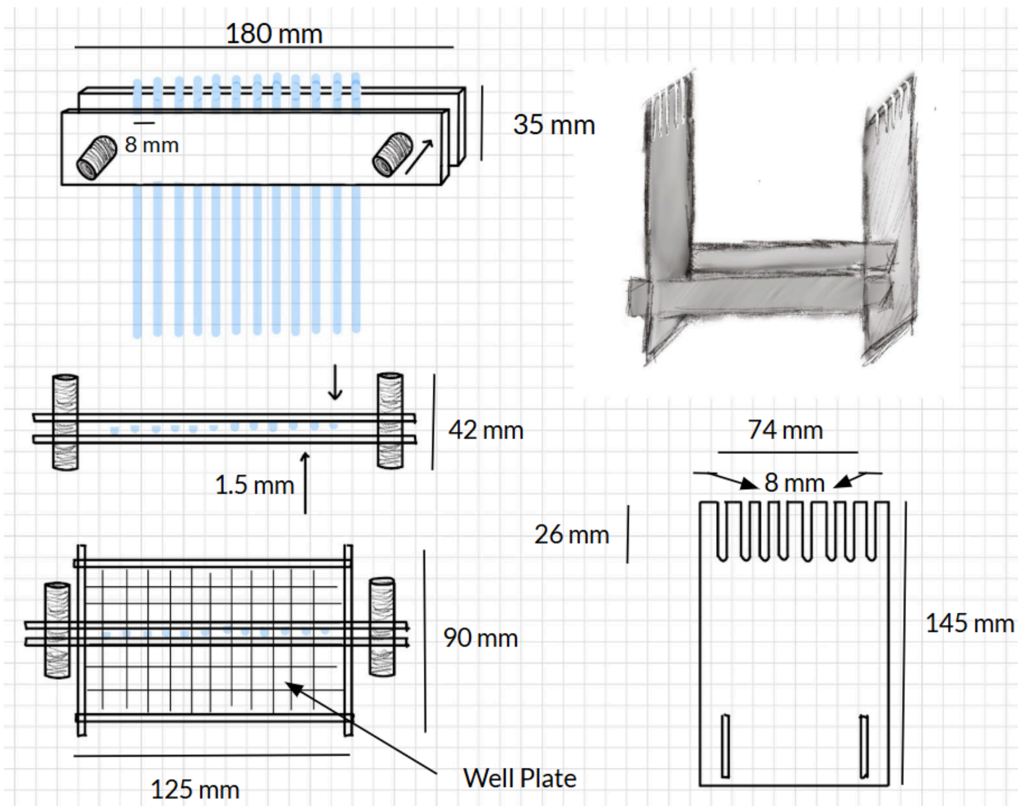


Figure 4: The Clamp

Frame design 1 (Figure 4) incorporates a pinching mechanism that holds 12 straws between two plates, with a consistent 8 mm gap between each straw. The dimensions of the plates are 180 mm in length and 35 mm in height. At both ends of the plates, screws with nuts, approximately 42 mm long, will be placed to bring the plates together and tighten. A separate component of this design is the main frame. It consists of two pieces: two tall walls and two side pieces. The two tall walls are 90 mm in length and 145 mm in height, and the two side pieces are 125 mm.

The process of loading this design is that the clamp piece is initially positioned outside of the well plate. The user will load the straws and then tighten. Next, the whole clamp piece will move the straws to the slicer. Once these two parts are complete, the clamp piece will be placed in the notches in the frame. This is self-tightening, meaning a snug grip can be provided. However, the straws are 2 mm in diameter, and each straw is placed 8 mm apart, meaning it will be difficult to place the straws in their designated position and tighten while maintaining precision.

Frame Design 2: The Stamp

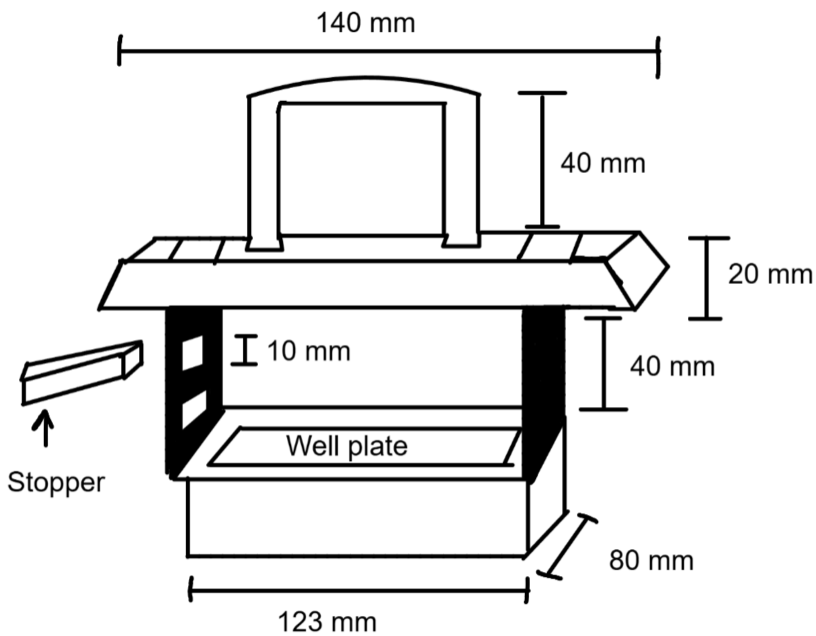


Figure 5: The Stamp

Frame design 2 (Figure 5) utilizes a stamping mechanism to efficiently hold and process all 96 straws simultaneously. The piece that will hold the straws is 140 mm in length and 20 mm in height. On the inside that faces the well plate, there will be caps that are 2 mm in diameter and will fit around the tip of the straw. It features an ergonomic handle of 40 mm in height for ease of operation. There will be a track that sits on two sides of the well plate and spans 40 mm in height. On this track, there are two cutouts approximately 10 mm between each other, which allows the user to place a stopper. The stamper piece that holds the straws will fit on this track and be able to move down until where the stopper is placed.

This frame idea will be loaded outside the well plate, and all 96 straws will be cut in the holder. Once cut and snug in the holder, it will be moved to the frame track and loaded on, where the next step will be to push the contents out. The user can control the height of the holder using the stopper. This design allows all 96 straws to be done at once, improving efficiency. However, due to the close spacing of the 96-well plate slots, it will be challenging to align the straws accurately within their designated area.

Frame Design 3: The Compartments

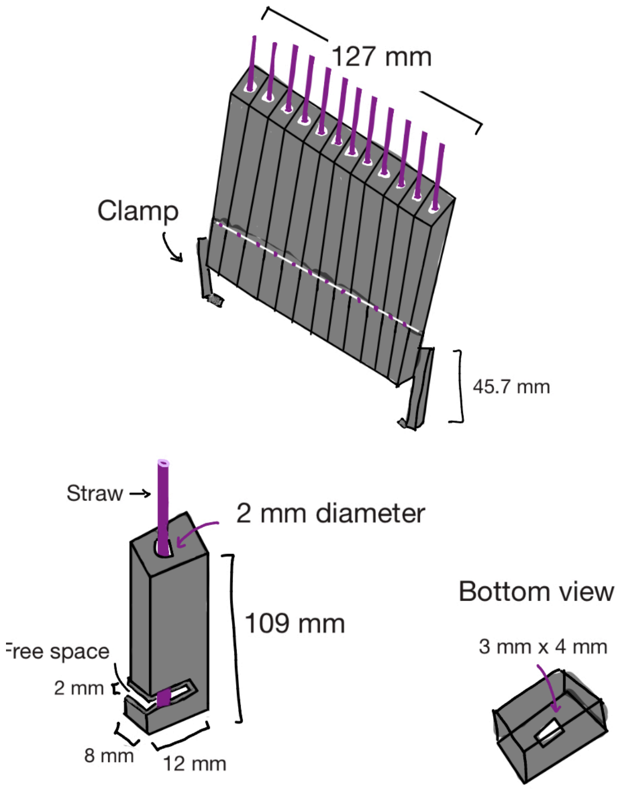


Figure 6: The Compartments

Frame design 3 (Figure 6) has individual compartments to hold 12 straws at a time. Each compartment is 109 mm in height, 12 mm in width, and 8 mm in length. There will be a 2 mm diameter hole for the straw to snugly fit into. A cutout of 2 mm in height will allow a blade to slice the straws, but note that the back wall will be present to allow for a uniform cut. The 12 compartments are arranged together in a single unit, so they have an overall length of 127 mm. At the bottom of the compartments. There will be a 3 mm by 4 mm cutout at the bottom to catch the clippings of the straws. The compartments will clamp onto the well plate by utilizing a 45.7 mm in height piece placed on the bottom of the design.

The process of this design is similar to the other designs since the straws will be placed into their individual compartments, and then a blade will slice the 12 straws. Once cut, the component will be clipped onto the well plate, lining up with the slots of the row, then stamped and the process will repeat. Due to the individual compartments, there is less open space between each straw and therefore less risk for contamination. However, only 12 straws can be done at a time, and it will be difficult to determine the sizing of the hole. The straws need to be snug when stamping, but need to require minimal effort to remove them once complete.

Stamp Design 1: The Retractable Stamper

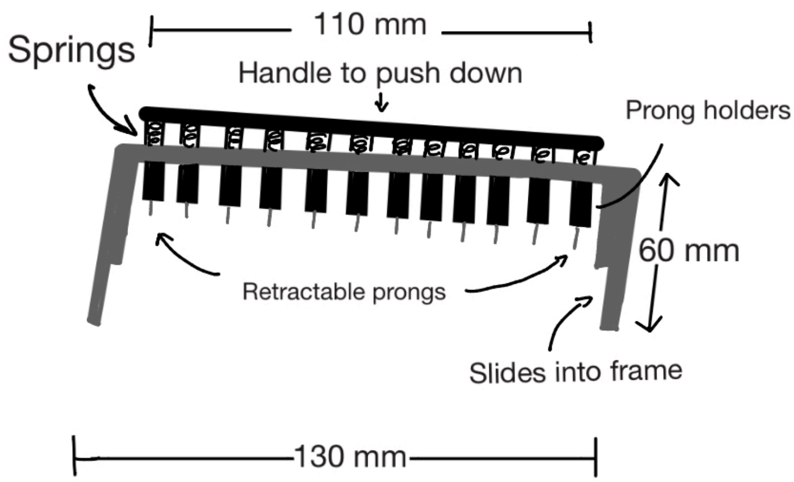


Figure 7: The Retractable Stamper

Stamp design 1 (Figure 7) incorporates 12 retractable prongs, designed to push the contents of the straws out efficiently. The overall design is 130 mm in length and 60 mm in height, while the handle to push the prongs out is 110 mm in length. This design includes side pieces that slide into the existing frame for alignment. The handle would have springs allowing the prongs to sit in the casting when not used, but be brought down when the handle is pushed.

Before using the stamper, the straws would be in the frame and already cut. The stamper would attach to the frame and push the contents out. The user can line up the casting with the straw before retracting the prongs, allowing for an easier alignment. When not in use, the prongs are retractable, reducing contamination risk. The prongs would additionally be removable due to them being fragile. Since the prongs retract when the handle is not pushed, it will be difficult to sanitize after each row. The user would have to support the component while pushing the handle down.

Stamp Design 2: The Removable Prongs

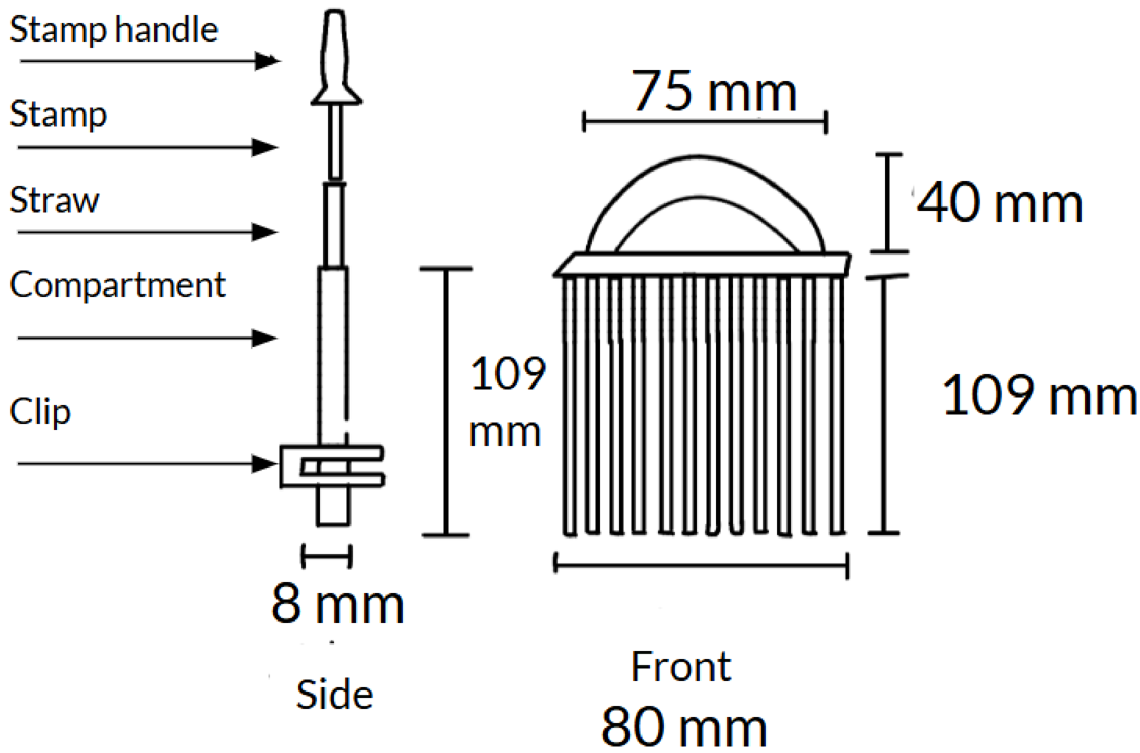


Figure 8: The Removable Prongs

Stamp design 2 (Figure 8) features 12 stationary, removable prongs that remain open to the space. The overall stamp design is 80 mm in length and 149 mm in height. Each prong measures 109 mm in height, while the ergonomic handle is 40 mm in height and 75 mm in length. A clip at the bottom of the design allows it to securely attach to the compartment frame.

Once the cut straws are secure in the compartments and attached to the well plate, the prongs of the stamper will line up with each straw. This process will require the assistance of the user to ensure all prongs are in the designated location. The user will utilize the ergonomic handle to reduce strain and push the contents out. Only 12 straws will be done at a time, and the device will need to be efficiently sanitized. Due to the open nature of the prongs, it will be simple and quick to dip the prongs in a sanitizing liquid. The prongs would be easily removable, allowing them to be replaced as needed. However, the prongs are long and thin, making it difficult to align them in the straws.

Preliminary Design Evaluation

Straw Stamp and Slicer Frame Design Matrix

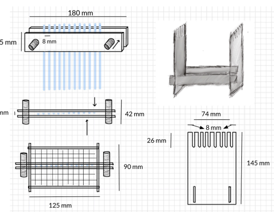
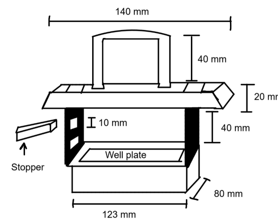
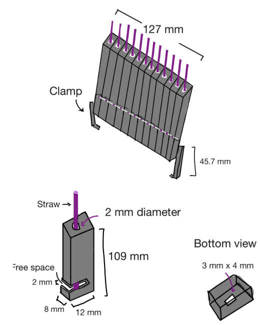
Criteria	**The Clamp** 		**The Stamp** 		**The Compartments** 	
Criteria (Weight)	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Contamination risk (25)	3/5	15	2/5	10	5/5	25
Sanitation (25)	4/5	20	4/5	20	2/5	10
Ease of use (20)	3/5	12	3/5	12	3/5	12
Ease of fabrication (15)	3/5	9	4/5	12	4/5	12
Safety (10)	4/5	8	4/5	8	4/5	8
Cost (5)	4/5	4	4/5	4	5/5	5
Total (100)	68		66		72	

Table 1: Straw Stamp and Slicer Frame Design Matrix

The main criteria chosen were contamination risk, sanitation, ease of use, ease of fabrication, safety, and cost. Contamination risk was identified as a high concern since it is crucial that individual bull semen samples do not come in contact with each other since this can ruin the DNA sequence result. Sanitation additionally was a high determining factor because it is vital that the frame can easily be clean in between uses to prevent contamination. Ease of use was key to the design as the client requested a device that would create a more efficient process while maintaining precision and a simple design.. Thus, the frame should be something simple to hold enough straws without having to manage multiple components. Ease of fabrication was critiqued based on the type of materials required, the mechanism of each component, and the available tools at the university to build the device. Safety was judged based on the frame's ability to prevent the blade from coming in contact with the client's hand. Lastly, cost was ranked last as most of the devices would utilize simple materials, and the cost for each device would most likely not be able to exceed the budget.

Overall, the Compartments scored the highest out of all the devices. One large evaluation was that the compartments would reduce the contamination risk. This design utilizes individual sections for each straw, while the other designs have the straws out in the open. The compartments in the design would be easy to use, as it would have notches on the side to allow the user to align with the straw without worrying about the straw touching the bottom. The other devices would require some adjustment in order for the straw to stay secure. The Compartments also rank higher in ease of fabrication and cost because they would be modeled in AutoCad to 3D print at the Makerspace for around $7.80, which is easily accessible and replicated to create multiple compartments. Since there would be a small gap only for the blade to cut the straws, it is unlikely that the blade would come in contact with the client's hand, which allows us to rank the Compartments high in safety.

Straw Stamp Design Matrix

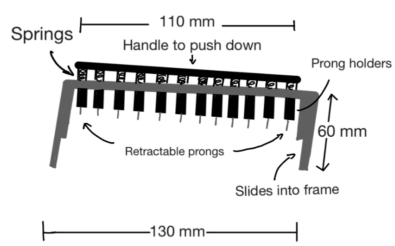
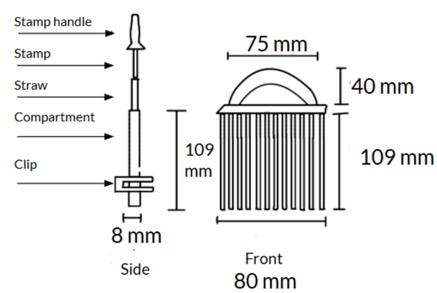
	Retractable Stamper 		**Removable Prongs** 	
Criteria (Weight)	Raw Score	Weighted Score	Raw Score	Weighted Score
Ease of use (25)	4/5	20	3/5	15
Sanitation (25)	4/5	20	5/5	25
Durability (20)	3/5	12	4/5	16
Ease of fabrication (15)	2/5	6	5/5	15
Safety (10)	5/5	10	5/5	10
Cost (5)	4/5	4	5/5	5
Total (100)	72		86	

Table 2: Straw Stamp and Slicer Frame Design Matrix

The main criteria chosen were ease of use, sanitation, durability, ease of fabrication, safety, and cost. Ease of use was identified as one of the highest priorities because it was important that the device can easily push out all the bull semen. This process will be repeated among different rows and multiple times a week and should work without experiencing any issues. It was important that the stamp can be effortlessly cleaned between uses to prevent contamination, so sanitation was additionally ranked as a high concern. Durability was another priority because the client expected to use the device 8-10 times per week for at least a year. Thus, the device should be durable enough to last for a long period of time. Ease of fabrication was determined based on the type of materials needed, the mechanism of each component, and the available tools at the university to build the device. Safety was judged based on the physical strain it would have on the client's hand, as they are expected to use the same motion to push out numerous straws. Lastly, cost was ranked last as most of the devices would utilize simple materials, and the cost for each device would most likely not be able to exceed the budget.

The Removable Prongs was chosen out of the two stamps. It ranked higher in sanitation because the prongs could be easily removed to disinfect, clean, and dry as compared to the Retractable Stamper, which has more components to disassemble to clean. The Removable Prongs were more durable because the prongs could be easily replaced once they are near the end of their lifespan and require less maintenance. However, the Retractable Stamper has more components and mechanisms like springs and casing that require more attention to maintain. The Removable Prongs was ranked higher in cost and ease of fabrication because it could be easily 3-D modeled with the materials at the Markerspace for roughly $4.34, which is significantly less than the set budget.

Final Proposed Design

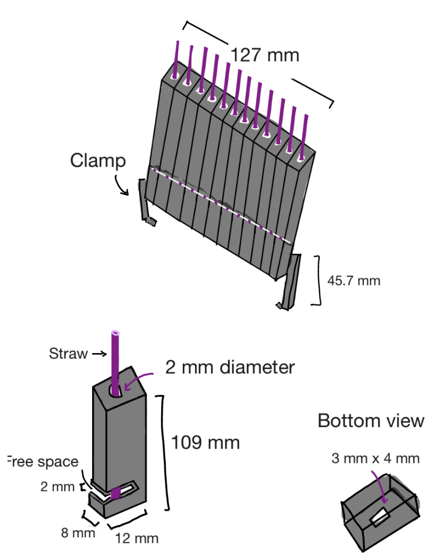


Figure 6: The Compartments

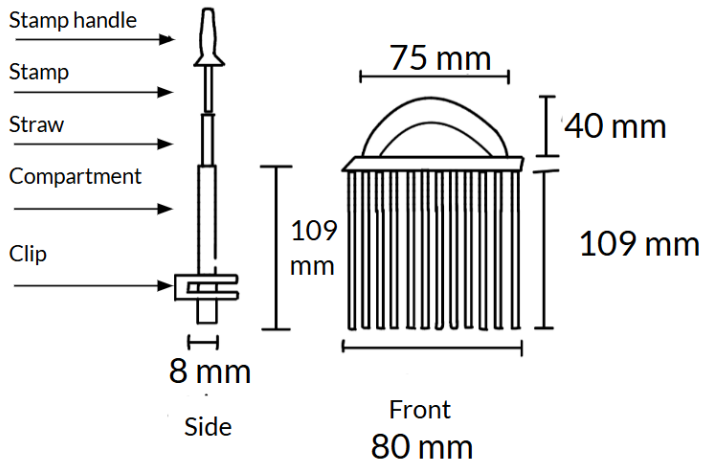


Figure 7: The Removable Prongs

The final proposed design is a combination of the Compartments and the Removable Prongs designs. Both designs sufficiently fulfilled the client's main concern of contamination, sanitation, and ease of use through their ease of separating the straw into their individualized sections and disassembling the devices for cleaning. Each of the straws would be snipped at the crimped edge to create an opening for pushing the bull semen. The frame would first clamp to secure itself to the side of the well plate. Then, the straw would be inserted into the compartments to their indicated height. The Removable Prongs Stamp would sit on top of the compartments and clip to the side to secure them. Once the prongs are properly aligned, the client would be able to push on the handle to push all the bull semen from the 12 straws into the well plate. The client could unclip all the stamps and frames and quickly sanitize them for the next set of straws.

Fabrication

Materials

In order to fabricate the design, both the frame and the handle of the stamper will be 3D printed. For the initial prototyping, ABS and PLA material will be used, which will be printed on the Bambu Printer in the Makerspace. This material was chosen as it's cheap, durable, and easy to print, allowing for multiple iterations to be made in a short time. For final prototyping, however, either Nylon, Polypropylene, or PP GF30 will be used. These materials have better chemical resistance, and will be able to withstand being disinfected with ethanol or bleach without being damaged [8]. The only non-printed component that will be used are the prongs for the stamper, which will be fabricated out of a stainless steel rod that will be cut down to size. The costs for all of the predicted materials are seen in Appendix B. Additionally, the slicing mechanism is still being determined. However, a store-bought guillotine paper trimmer could be a viable option. This mechanism is advantageous as it is able to cut the straws in bulk while reducing contamination. It is also more efficient than the current cutting procedure, as the scissors used need to be disinfected after every use.

Methods

To fabricate the device, the frame will be modeled and printed first, as it is the component holding the straws for the entirety of the procedure. The frame will be modeled on SolidWorks and will feature an opening that will be snug to the straw to hold it while it is being both cut and stamped. For the first iterations, only one straw compartment will be printed as it will take a shorter time to fabricate and will be easier to modify. Once the final iteration is created, it will be duplicated in order to facilitate the full 12 straws. In order to hold the frame onto the well plate, there will be a 3D printed clip attachment, which will connect the frame to the bottom of the well plate.

For the stamper, the handle will also be modeled on SolidWorks, as well as the component that will be holding the prongs in place, which will be a flushed fit to the prongs. To future secure the prongs, they will be glued to the stamper components. Additionally, the ends of the stamper will fit into groves on the side of the frame, helping to solve the problem of any alignment issues.

Testing and Results

To evaluate the efficiency and functionality of the straw stamper and slicer, multiple tests will be conducted. These tests include an MTS test to measure the slicing and stamping force, a timed test to measure process duration reduction, and a contamination test to ensure minimal cross-contamination.

Force Test Procedure - Slicer

1. Place 12 artificial insemination straws on the base of the MTS machine, securing the straws using grips, if necessary.
2. Set up blade by elevating to height within 1 in of the straws, oriented with the sharp side facing the straws.
3. Turn on the MTS machine and TWE software. Setting the correct parameters on the monitor and zero the load and crosshead.
4. Run the compression test.
5. Export data to analyze the force required to slice straws.

Force Test Procedure - Stamper

1. Place 12 straws in the compartment frame on the base of the MTS machine
2. Securely attach stamping device to the grip of the MTS machine

3. Ensure the straws are aligned with the stamping component so as it lowers, the contents of the straw are pushed out
4. Turn on the MTS machine and TWE software. Setting the correct parameters on the monitor and zero the load and crosshead.
5. Run the compression test.
6. Export data to analyze the force required to stamp straws.

Time Reduction Test

1. Lay out 12 straws, the slicer, the stamper, the frame, and the well plate on a lab bench
2. Begin stop watch and start slicing/stamping procedure
3. Attach frame onto well plate and place 12 straws in the first row
4. Slice through the straws
5. Push contents of the straws into the well plate using stamper
6. Stop timer
7. Multiply time by 8 rows to mimic entire experiment duration

Contamination Test

1. Create 2 liquids using equal parts flour and water, and add fluorochrome to one liquid to mimic bull semen
2. Inject every other straw with the liquid containing fluorochrome, injecting the rest with the non-fluorescent liquid
3. Execute entire procedure according to instructions listed in the time reduction test
4. Shine UV light on well plate to identify which wells fluoresce
5. Note if wells other than the original fluorescent wells have been contaminated

These tests will identify areas of improvement for the process and design of the straw stamp and slicer. The purpose of the force tests are to ensure that the device does not add unnecessary efforts needed to use the device. The force needed to slice and stamp the straw should remain around 0.32 N, as stated in the PDS. The time reduction test is necessary to identify if the PDS requirement of a 50% duration decrease is met. If this time is not met, modifications should be made to the process and design of the devices. The contamination test ensures that there is no cross-contamination between straws throughout the duration of the experiment. This test will reveal if the design or procedure should include greater separation between straws to eliminate any chances of cross-contamination. This cross-contamination test was informed by a similar experiment done to assist healthcare workers in their practice of using PPE [9].

Discussion

Results of the three tests will indicate areas of improvement for the fabricated devices. These modifications are necessary to ensure compliance with the requirements stated by the clients in the PDS. Contamination levels as low as 1% can have a significant impact on DNA sequencing results [6], highlighting the importance of performing this test. After each test is executed, an analysis of the causes of the low-performing tests should be performed. After identification of sources of inefficiency or risk factors, modifications shall be made to increase device performance and safety.

Ethical considerations must be assessed when performing the tests listed above. As stated in ISO 12100, when designing machinery, risk assessments must be performed to reduce posed harm [10]. Including blade guards that prioritize user safety is a choice that promotes ethical design for this device.

Looking forward, the ethics of accessibility and environmental consciousness will also play a role in the device's fabrication. In terms of accessibility, the device should be able to be used by all lab members including those with differing hand mobility or size. Additionally, the device should be designed with a minimum shelf life of one year to minimize material consumption during replacements, as stated in the PDS.

Conclusions

The team was assigned to create a device able to hold, cut the ends, and push bull semen out of 96 straws into a 96 well plate through one motion. With the current device, a frame and stamp was developed. The frame has individualized compartments with indicators to demonstrate where to place each straw into each compartment. The frame holds 12 straws at a time and keeps the straws separated during slicing and stamping. The stamp includes removable prongs for easy cleaning and clips on the side to secure itself to the frame as the client pushes on the handle to push out the bull semen.

Future plans include finalizing the slicer design, fabricating the frame and stamp at the Makerspace, selecting materials for both designs, and determining tolerances to identify the most appropriate 3D printing method. In terms of testing, an MTS Electromechanical System will measure the maximum force the frame and stamp can withstand to ensure sufficient force can be applied to push the bull semen out of the straw. The duration of the procedure will also be tested, as the client requested at least a 50% reduction in the total process duration. Future design developments will focus on scaling the system to process 96 straws instead of the current 12. The design will also be refined to improve ergonomics and make the device easier to handle.

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Appendix

Appendix A- GVI: Straw Stamp and Slicer PDS

GVI: Straw Stamp and Slicer - BME 200/300

Product Design Specifications

BME 200/300 Design

September 18, 2025

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Function

Currently, Genetic Visions-ST sequences semen from artificial insemination straws, ensuring that the DNA detected matches the bull that is listed on the straw [1]. This quality control program is intensive, as it takes about an hour to cut and push 96 semen straws per 96-well plate. The clients have requested two devices: a slicer and a stamp. The slicer must uniformly cut the ends of 12 straws without cross-contamination. The components of the slicer must be removable, and a blade guard must be incorporated for safety. The stamp must accurately push bull semen out of 96 straws at once without any punctures or deformation to them.

Client requirements

- A device capable of cutting the ends of 12 insemination straws at a time.
- A mechanism to push the contents of the straws in bulk to a 96-well plate.
- Both devices must have removable components for cleaning.
- Both devices should minimize user error and eliminate any chances of contamination between the straws.
- Reduce the procedure time from 1 hour to a final time of 30 minutes.

Design requirements:

1. **Physical and Operational Characteristics**
    a. **Performance requirements**: The device must consist of a cutting component to cut 12 straws at a time, as well as a stamping component that holds 96 straws and pushes the cotton and semen out of each straw into a well plate. The device is intended to be used 8-10 times per week, and the estimated loading for the device is 0.32 N [2] per use. Design should allow for minimization of cross-contamination, and each component of the device must be able to be disassembled for sterilization [3].

    b. **Safety**: Blade guards must be included to cover blades when the device is not in use to prevent any injury to the user. A warning label may be used to bring awareness to the danger of the blade. Disease transmission during straw slicing and stamping is rare due to lab safety procedures, cattle vaccination, and antibiotic treatment for samples, however a small risk is still posed. If safe practices are not followed, diseases such as Foot-and-Mouth disease or Leptospirosis could infect the user if they were cut by the blade [4]. Utilizing blade guards, wearing gloves, and carefully operating the device are all effective ways to reduce the risk of infection.

c. **Accuracy and Reliability**: The slicing component must cut off at least 0.20 inch and at most 0.50 inch of each straw, and the stamping component should push the entire sample into the well plate to maintain consistency in collection. To maintain precision for slicing and stamping, the straws must be held in place to prevent movement or bending [3].

d. **Life in Service**: This device must function accurately and consistently for a minimum of one year, performing 8-10 procedures per week. The straw cutter will be used 8 times per procedure for about 1 minute per use, while the straw stamp will be used once per procedure for about 10 minutes per use [3].

e. **Shelf Life**: All of the components of the device must have a shelf-life of at least one year. They will be replaced if they show signs of corrosion or decreased functionality. However, since there will be removable components, replacing specific components could increase the device's overall longevity. This device will be used multiple times during the week. When not in use, it will be stored within the Genetic Visions-ST wet laboratory.

f. **Operating Environmen**t: This device will be used in the Genetic Visions-ST wet laboratory and operated by one of the clients. The Food and Drug Administration's regulatory guidelines show that the optimal temperature for wet labs is 68 °F and 77 °F (20°C and 25 °C) with humidity levels between 30% and 50% [5]. The device will come in contact with the filled insemination straws, which are stored in the fridge at ideal temperatures of 4-18 °C to prevent bacteria growth [6].

g. **Ergonomics**: The device should be easily operable by one of the Genetic Visions-ST's employees. For efficiency and user comfort, the device should also be ergonomically optimized to support operators performing this task repeatedly through the week. The main force needed will be the one to overcome the straw's vacuum seal and push the semen into the well plate. Using the pressure equation $P = F/A$, the force needed to push the contents of a 0.002 meter diameter straw is 0.32 N [2].

h. **Size**: The client supplied prototypes to display the functional requirements of the tool. The first prototype, a slicer, measured 11 inches in length and 5 inches in width. It featured a hinge mechanism originating from the base plate and extending upwards approximately 7 inches. The second prototype was a rectangular stamp measuring 5 inches by 4 inches, equipped with spring-loaded pins of 2-inch length. This stamp was designed to interface with straws positioned within a transparent base plate of similar size. When not in operation, both tools are intended to be stored on a personal workbench measuring 3 feet by 2 feet. As the workbench is shared with other tasks, it is essential that the slicing and stamping tools do not obstruct or interfere with daily activities [3].

i. **Weight**: The client has not specified an optimal weight range for the device. If the equipment is placed in a holder, the holder should not exceed more than 20 kg [7]. This is to ensure safe and efficient transport of the holder between floor level to work bench height. The device itself will be placed on a workbench when not in use. It must be sufficiently lightweight to allow operation using the forearms and shoulders without physical strain. For a repetitive task at this height, the maximum weight of the tool should be between 11kg and 14kg [7].

j. **Materials**: The tool must be disinfected after each use, either by immersion in a bleach or alcohol-based solution and through surface wiping. Additionally, the material must be capable of withstanding repeated exposure to these harmful chemical agents. As the client requested, it should be a non-porous material. Various grades of steel exist, including carbon steel, which is susceptible to corrosion when exposed to moisture or oxygen. By applying a chromium oxide coating to the surface, the chances of corrosion can be greatly reduced. Stainless steels in the 300 and 500 series exhibit enhanced corrosion resistance, while those in the 300 series are noted for weldability [8]. The material must withstand harsh conditions, maintain functionality, and prevent cross contamination.

k. **Aesthetics, Appearance, and Finish**: There are no preferences for the appearance of the device, however, the aesthetics of the device should not impede on the function of the device [3].

2. **Production Characteristics**
    a. **Quantity**: The client is aiming to have one straw stamper device and one straw slicer device to work with. The client does not have a preference on whether or not both devices are combined into a singular as long as the devices can be easily disassembled for cleaning [3].

    b. **Target Product Cost**: The overall budget is $1000. The average cost of the jagged tooth blades is around $20 but will need to be modified based on size [9]. Fine pins to push the cotton cost around $5 for a pack of 250 [10]. Currently, there does not seem to be other similar products for the straw stamper. The straw slicers have other similar products at an average cost of $10. ABS Global is selling their straw slicer at a cost of $6.38 [11]. Valley Vet is selling their straw slicer for $13.29 [12]. However, the current straw slicer products only cut one straw at a time.

3. **Miscellaneous**
    a. **Standards and Specifications**: The straw slicer and stamp must follow international standards that correspond to laboratory devices. Since the bull semen goes through a DNA sequencing process, the components that will contact the bull semen should not cause DNA damage and must exhibit biocompatibility. ISO 10993 defines this as “the ability of a medical device or material to perform with an appropriate host response in a specific application” [13].

        In addition to biocompatibility of the device materials, each material’s resistance to corrosion relates to the longevity and accuracy of the device. If corrosion tests are performed on the device materials, they must follow the guidelines set by ASTM F1089, outlining the boil and copper sulfate test, which assess corrosion and copper plating respectively [14].

The safety of the straw slicer and stamp is also a major factor of the design process. ISO 12100, a standard that covers the safety precautions, risk assessment, and risk reductions, must be taken into account when designing the blade and stamp [15]. This will help identify the risks of each design and implement safety components such as a blade guard, better grip material, etc.

b. **Customer**: The main priorities of the client are to reduce the procedure time from 1 hour to < 30 minutes, while maintaining precision of the devices. For the straw slicer, the clients are partial to their proposed jagged-tooth blade to reduce cross contamination between the 12 straws during each cut. The presence of a blade guard with 12 opening holes for the straws and a "straw stopper" to ensure equal cut length (~¼ inch) is favored. They strongly prefer the straw slicer to have removable components, allowing for easier and more thorough sterilization. No preferences were given for the straw stamp other than a light-weight design [3].

c. **Patient-related concerns**: As there is much concern about the risk of cross contamination, the device will need to be sterilized after each use. Because of this, the client would like the device to be easily disassembled for easy cleaning. The product would also need to be able to withstand a cleaning solution, such as bleach after each use. Additionally, the clients value precision the most, over other attributes such as cost and materials [3].

d. **Competition**: Currently the clients are using straws to cut each individual straw, and a paperclip to stamp each straw. There are other competing products on the market. For example, Agtech Inc has a straw cutter also available. To use this product, the straw is inserted and then a button is pushed which turns a disk inside the mechanism to cut the straw. This product can be taken apart to be cleaned, which the clients specified the product needs However, their straw cutter is only for ¼ cc, while the clients requested the product to work for both ¼ cc and ½ cc straws. Also, this straw cutter can only cut one straw at a time, but the client needs to be able to cut 12 straws at the same time [16]. There are many similar products to this plastic semen cutter on the market.

Another product on the market is the MiniCutter for Semen Straws by Nasco Education. This product is lightweight and has an ergonomic handle for easy grip. Similar to the Agtech cutter, this product also has a notch that is pushed for the straw to be cut. However, unlike the Agtech cutter, this product is able to cut both ¼ cc and ½ cc straws. The disadvantage to this straw cutter is that it can also only cut one straw at a time, thus it would not work for the clients needs [17].

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Appendix B- BPAG Table

Item	Description	Manufacturer	Mft Pt#	Vendor	Vendor Cat#	Date	QTY	Cost Each	Total	Link
Frame Materials										
ABS Filament	ABS 256mm/10 in Filament (Bambu Lab) FDM/FFF	-	-	Makerspace	-		150	$0.05	$7.50	https://docs.google.com/spreadsheets/d/125EWYr0aojDuu0BGfzzt-YhfGJA1wojkzE-Vt00tw_M/edit?gid=0#gid=0
Stamper Materials										
Steel Rod	Tight-Tolerance Corrosion-Resistant 316 Stainless Steel	McMaster-Carr	-	McMaster-Carr	2959N14		1	$48.31	$48.31	https://www.mcmaster.com/products/steel-rods/stainless-steel-1~/
PLA Filament	PLA 256mm/10 in Filament (Bambu Lab) FDM/FFF	-	-	Makerspace	-		70	$0.05	$3.50	https://docs.google.com/spreadsheets/d/125EWYr0aojDuu0BGfzzt-YhfGJA1wojkzE-Vt00tw_M/edit?gid=0#gid=0
								TOTAL:	**$59.31**	