

Design and Evaluation of a Sunflower Dehuller to Aid in Precision Planting

By
Lisa Buchholz
Jody Hanson
Janelle Mauch

Project Report
Submitted as part of the course ABEN487: Senior Design Project II

Project Advisor
Dr. Dennis Wiesenborn
NDSU Professor

Dr. Sreekala Bajwa
NDSU ABEN Chair

Project Cooperator
Bob Majkrzak
Chief Executive Officer
Red River Commodities
Fargo, ND

Course Instructor
Dr. Ganesh Bora

Agricultural and Biosystems Engineering
North Dakota State University
Fargo, ND
May 3, 2013

Table of Contents

1.0	Introduction.....	5
1.1	Problem Statement	5
1.2	Rationale.....	5
1.3	Design Objectives.....	5
1.4	Design Constraints.....	6
2.0	Literature Review	7
3.0	Preliminary Evaluation of Potential Designs.....	10
3.1	Definition and Evaluation of Existing Designs.....	10
3.1.1	Curved Vane Centrifugal Dehuller	11
3.1.2	Flash Freeze Process.....	11
3.1.3	Red River Commodities Modification – Gravity Fed.....	12
3.1.4	Red River Commodities Modification – Rubber Rollers	12
3.1.5	Red River Commodities Modification – Vertical Rollers.....	12
3.1.6	Red River Commodities Modification – Corrugated Rolls	12
3.1.7	Red River Commodities Modification – Vacuum Wheel.....	13
3.1.8	Two-Step Process	13
3.1.9	Cutting Knife.....	13
4.0	Final Design Selection	14
4.1	Curved Vaned Centrifugal Dehuller	14
4.2	Straight Vaned Centrifugal Dehuller.....	15
4.3	Almond Dehuller	16
4.4	Counter-rotating Wheel.....	17
5.0	Prototype Testing Methodology.....	18
5.1	Materials.....	18
5.2	Centrifugal Dehullers	19
6.0	Performance Evaluation of Prototypes	20
6.1	Curved Vaned Centrifugal Dehuller	21
6.2	Straight Vaned Centrifugal Dehuller.....	22
6.3	Almond Dehuller	22
6.4	Red River Commodity	22
7.0	Prototype Design Calculations.....	23

8.0	Final Design	26
9.0	Impacts of Final Design	28
10.0	Future Recommendations.....	29

List of Tables and Figures

Tables

Table 1. Decision matrix used to evaluate nine designs based on a weighted percentage. Details about each design can be found in 3.1.1-3.1.9.....	10
Table 2. Decision matrix used to evaluate the preferred designs; 1= most desirable, 4=least desirable.	14
Table 3. Effect of material of construction and shape of vane on dehulling performance for sunflower seed. [2].....	24
Table 4. Effect of moisture content and orientation of loading on rupture force, deformation and energy absorbed at rupture for sunflower seed with standard deviation. [4].....	25
Table 5. Least Significant Difference Statistics for vane configuration, moisture and hertz.[6]..	27

Figures

Figure 1. Design of a centrifugal dehuller developed at NDSU in 2002 for use with flaxseed. [3]7	
Figure 2. Counter-rotating grooved wheel prototype designed by Bob Majkzak ready for evaluation.	8
Figure 3. Configuration of a quasi-static compression system. [4]	9
Figure 4. Forward-Curved Vane Configuration. [2]	11
Figure 5. Cross-section of the centrifugal dehuller. 1) Vane 2) Granite impact stone 3) Motor 4) Collection spout.....	15
Figure 6. Almond dehuller purchased from Kamper Fabrication.	16
Figure 7. Bottom cracker wheel of counter-rotating wheel design with 1/8” groove.....	17
Figure 8. Flow chart of centrifugal dehuller testing.	19
Figure 9. Results from curved vane testing.	21
Figure 10. Results from straight vane testing.	22
Figure 11. Dimensions of curved vane wheel.....	23
Figure 12. Design comparison between original straight vane design and new forward curve design.....	24
Figure 13. Optimum results from the curved and straight vane tests.	26

1.0 Introduction

Currently, in-shell confectionary sunflower seeds are planted using a corn planter. However, as the agricultural community continues with technological advances, the large seed ranges in size from 20/64 inch to 24/64 inch and this variability does not allow precision technology to be utilized. [1]

A sunflower seed consists of a hull and kernel. The kernel is the valuable part of the seed and therefore, is usually separated from the hull. This process is called dehulling.

Dehulling is performed using various methods. These processes are described in more detail in section 3.0. During the dehulling process, the seeds may pass through the rollers several times before being separated. After dehulling, hulls and kernels move forward in separate streams. This paper presents a new mechanism for dehulling confectionary sunflower seeds, as well as oil seeds with some adjustments made to the dehuller.

1.1 Problem Statement

Current precision planters require that seeds be of similar size. Uniformity could be greatly improved by removing the hulls, because the kernels are of similar sizes even when the hulls are not. In addition, the kernels could be coated to be comparable in size with corn to enable the use of existing precision planting technology. However, for planting purposes, the growth tip (acrospires) of the kernel needs to remain undamaged in order for germination to occur. [1] This is a much greater seed dehulling challenge than merely dehulling for snack food use.

1.2 Rationale

By being able to effectively dehull sunflower seeds and reach a high germination rate of 85% from the dehulled seeds, the kernels can then be coated. Coating the sunflower kernel, will in effect, make it approximately the same size as a kernel of corn. A kernel of corn is slightly larger than a sunflower kernel although they have a similar shape, so the seed disks used for planting corn could be used for planting sunflowers as well, if the two kernels were of equal size. Thus, farmers will be able to use their existing equipment to plant sunflowers instead of purchasing new equipment. In addition, removing the hull the plant will emerge sooner from the soil, therefore, the plant will benefit from more growing degree days available for its growth.

1.3 Design Objectives

- Evaluate alternative approaches for a sunflower seed dehuller.
- Test existing sunflower dehullers for performance and modify if necessary.
- Develop and test a bench-scale prototype sunflower dehuller to achieve 95% viability of the kernel when planted.

1.4 Design Constraints

- The moisture content of the whole seed proved to be a constraint in the design process, because as the moisture content varied, the dehulling efficiency did as well.
- The range of existing dehuller designs to research and formulate design modifications also proved to be a constraint. Existing sunflower dehullers cause high kernel breakage, and damage to the growth tip may not be readily detected.
- The amount of available funding for this project was also a constraint for parts fabrication and ordering existing dehuller designs for modification.
- Time needed to fabricate parts and to find unique equipment.
- The percentage of intact kernels, and viability $\geq 95\%$
- The safety of the design, so that pinch points and moving objects are enclosed.

2.0 Literature Review

Studies have shown that aluminum, forward-curved impeller vanes have a higher dehulling efficiency in centrifugal dehullers. In this study, a centrifugal dehuller was used with the following technical specifications. The impeller was driven by a 0.75kW single phase D.C. motor. Two round plates were placed in parallel and separated by a set of three vanes placed 120 degrees apart. Three different materials and shapes were used to make the vanes: aluminum, mild steel, rubber, straight, forward-curved, and backward-curved. This design worked by using centrifugal force to release the sunflower seeds from the impeller vanes at high velocities. The seeds were fed into the dehulling unit by a vibratory feeder, and, after the seeds were forced out of the impeller vanes, the seeds hit a hard-rubber surface in order to create a shear force to remove the hull from the kernel. Two kilograms of seeds were fed into the dehuller with a single pass through the machine. The hulls, kernels, and in-shell seeds were separated and weighed. [2] The equations used in carrying out the calculations can be found in section 7.0.

The results of this study were that the aluminum, forward-curved shape impeller vane had a higher dehulling efficiency in comparison with the other designs. The straight vane yielded a higher non-recoverable fraction of kernel in the hull. Also, the larger the seed sizes, the higher the dehulling efficiency was. [2]

A centrifugal dehuller was developed at North Dakota State University (NDSU), by a senior design group from 2002 in the Agricultural and Biosystems Engineering department. This dehuller was designed for flax seed dehulling. The wireframe model of the centrifugal dehuller is shown in Figure 1. The dehuller prototype has an axially fed rotor. This rotor throws the seed outward to impact the granite surface that surrounds the outside perimeter of the rotor. Once the seeds impact the surface, the hull splits. All fractions of the seed are discharge from the bottom of the machine. The fractions can then be separated by aspirator or gravity table. [3]

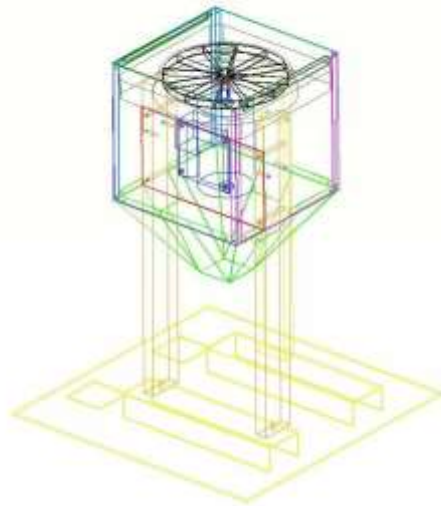


Figure 1. Design of a centrifugal dehuller developed at NDSU in 2002 for use with flaxseed. [3]

A very different approach to sunflower dehulling was designed and developed at Red River Commodities (Figure 2). This prototype is composed of a vibratory feeder that feeds the sunflower seed into the gap between two counter rotating wheels so that the horizontal edge of the hull comes into contact with the wheels (Figure 3a). The bottom wheel has a 1/16" groove cut in the middle of it to hold the seed in the correct orientation. As the wheels turn, they crack the hull and it is separated from the kernel. Red River Commodities loaned this dehuller to the department for evaluation, but did not share any previous test results.



Figure 2. Counter-rotating grooved wheel prototype designed by Bob Majczak ready for evaluation.

A study shows that quasi-static compression tests were carried out to determine whether a vertical or horizontal orientation is better; seed orientation is shown in Figure 3. [4] Within this test, a higher moisture content required less force to crack the hull. The seeds oriented in the horizontal position required less force. [4]

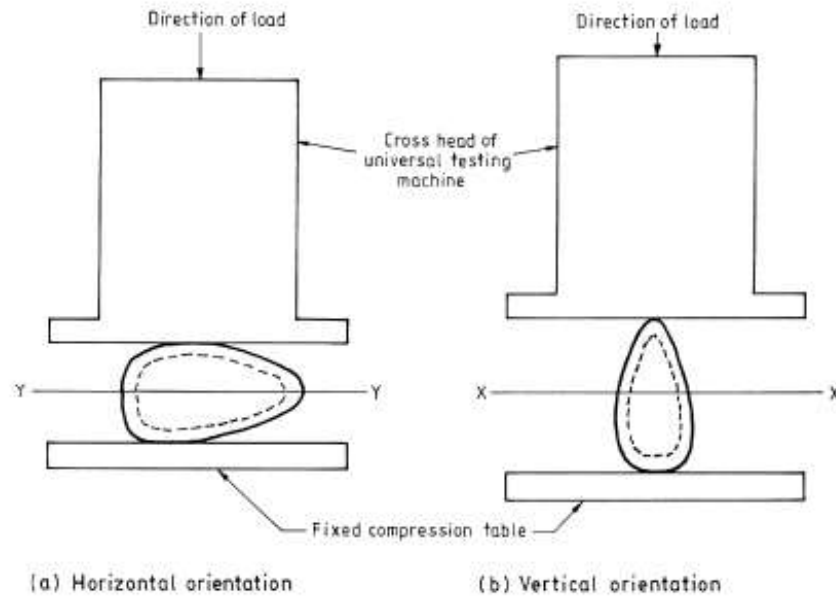


Figure 3. Configuration of a quasi-static compression system. [4]

3.0 Preliminary Evaluation of Potential Designs

The first steps of this project were to identify and evaluate potential designs. The sunflower seeds that were used in this project were obtained from Red River Commodities in West Fargo, ND. A tour of the Red River Commodities was given, and industrial sunflower dehulling equipment was viewed at this time. At the conclusion of the tour the counter-rotating dehuller was demonstrated and brought to the Pilot Plant on North Dakota State University campus for further evaluation.

The next step taken was to study other approaches to dehulling. The types of systems that will be studied include impeller vane configurations, centrifugal shellers and the prototype developed by Red River Commodities.

Evaluation was first based on percent dehulled sunflower seeds. Secondly, dehulled seeds with intact kernels were quantified. The evaluations were conducted at the Pilot Plant on the North Dakota State University campus. Based on these two evaluations, the final design was selected. The final design included modifications to the centrifugal dehuller in section 2.0.

3.1 Definition and Evaluation of Alternative Designs

A decision matrix was created to evaluate nine dehuller designs. A weighted percentage was given to each of the six criteria. For each design a rank from one to nine was given. The scale was based on the design's rank against the others. A rank of one represents the most desirable design and a nine represents the least desirable design for that criteria. A design could receive the same rank as another design. The total rating was calculated by taking the rating of each criteria multiplied by the percentage of that criteria. For example, Centrifugal Dehuller rating was calculated as $(1*0.25)+(1*0.25)+(2*0.05)+(1*0.25)+(6*0.05)+(6*0.15)=2.05$. The results are shown in Table 1.

Table 1. Decision matrix used to evaluate nine designs based on a weighted percentage. Details about each design can be found in 3.1.1-3.1.9.

Rank	Design	Safety 25%	Ease of Use 25%	Portability 5%	Durability &Strength 25%	Use of Standard Parts 5%	Cost 15%	Total 100%
1	Centrifugal	1	1	2	1	6	6	2.05
2	Flash Freeze	1	2	4	1	7	9	2.9
3	Gravity Fed	5	3	1	3	1	1	3
4	Rubber Rolls	3	4	1	3	3	3	3.15
5	Vertical Rolls	6	3	1	3	1	2	3.4
6	Corrugated Rolls	5	3	1	4	2	4	3.75
7	Vacuum Wheel	3	5	1	3	5	5	3.8
8	Two-Step Process	4	3	3	2	8	7	3.85
9	Knife Cutting	2	6	1	5	4	8	4.7

3.1.1 Curved Vane Centrifugal Dehuller

A modification to the centrifugal dehuller that is in the Pilot Plant at North Dakota State University that was previously done as a Senior Design project in 2002. The modification is to change the vanes on the impeller from straight to forward-curved as shown in Figure 4. This design is very safe as all the moving parts are internal. Also very easy to use, the sunflower seeds are put into the vibratory feeder at the top of the machine. It uses an axially fed rotor to bring the seed out to impact the granite stone that surrounds the outside perimeter of the rotor. Once the seeds impact the stone, the hull splits and the hulls, kernels and kernel fractions are collected at the bottom of the machine. From there an aspirator and/or dockage tester is used to separate the kernels and hulls.

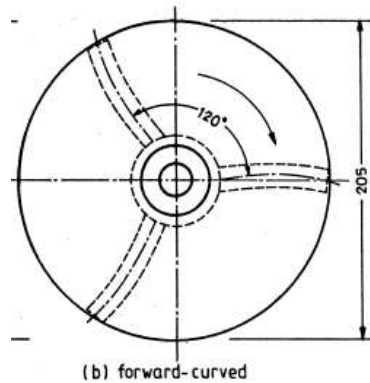


Figure 4. Forward-Curved Vane Configuration. [2]

3.1.2 Flash Freeze Process

A two-step process starting with flash freezing and ending with the centrifugal dehuller designed by the North Dakota State University Agricultural and Biosystem Engineering Senior Design team in 2002. The flash freezer uses fans to blow cold air from pipes with ammonia in them to quickly freeze the sunflower seeds. The quick freeze limits the number of crystals formed in the hull and kernel, decreasing the chance of kernel damage. The freezing process also causes the hull to become brittle. This characteristic decreases the amount of force required to dehull the seed. After the seed is frozen it immediately enters the centrifugal dehuller. This design is very safe as all the moving parts are internal. Also very easy to use, as the sunflower seeds are placed on a belt and then fed into the dehuller at the top. The hulls, kernels and kernel fractions are collected at the bottom. From there an aspirator and/or dockage tester is used to separate the kernels and hulls. The downside of this design is the high cost of the freezing process.

3.1.3 Red River Commodities Modification – Gravity Fed

This modification of the original Red River Commodities dehuller consists of a variation of the impact wheels, to rotating on a horizontal axis instead of a vertical axis. The impact wheels rotate in an opposite direction, to feed the seeds downward. This design includes a vibratory feeder to feed the seeds into the impact wheels; however the orientation of the seeds is not definite every time since this design is mostly gravity fed. The impact wheels are run by a one horsepower motor and the motor is controlled by a DC Speed Controller.

3.1.4 Red River Commodities Modification – Rubber Rollers

This prototype consists of a vibratory feeder that feeds sunflower seeds into two cracking rolls. This modification is to change the wheel material to rubber. Rubber is less abrasive and allows the wheel to be more elastic. A V-shaped groove is cut around the wheel to make a place for the seed to sit in the wheel. Next, an enclosure placed around the cracking wheel, to keep the entire product in one place. Lastly, there would be a brush installed to clean the wheel each pass so that seeds don't stick to the wheel.

3.1.5 Red River Commodities Modification – Vertical Rollers

The seed is fed into the impact wheels by a vibratory feeder with a ten millimeter, flat bottom. The two impact wheels are modified to be the same size, rotating in opposite direction, at the same speed. The orientation of the wheel will be rotated 90° so the shaft operates in the vertical axis. The vibratory feeder modification allows the seed to be fed into the wheels in its natural orientation (horizontal). The wheel orientation allows the seed to be cracked on the edge, where the least amount of force is needed to dehull a sunflower. The impact wheels are run by a one horsepower motor and the motor is controlled by a DC Speed Controller. In addition, surrounding the hardware is Plexiglas, to aid in keeping the debris and seeds within the system and also for safety purposes to shield the moving parts.

3.1.6 Red River Commodities Modification – Corrugated Rolls

The corrugated rolls modification includes changing the wheel type and a 90° rotation of the impact wheels to rotating on a horizontal axis. The wheels are changed from a smooth grind wheel to a corrugated wheel. The impact wheels rotate in an opposite direction to feed the seeds downward. The corrugated wheels are to be spaced such that the seed will get trapped between the corrugated parts to allow the seed to be cracked. This design also includes a vibratory feeder to feed the seeds into the impact wheels; however, the orientation of the seeds is not definite every time since this design is gravity fed and has corrugated rolls. The impact wheels are run by a 1 horsepower motor and the motor is controlled by a DC Speed Controller.

3.1.7 Red River Commodities Modification – Vacuum Wheel

The seeds are fed into the impact wheels by a vibratory feeder. The two impact wheels rotate in opposite direction in order to feed the seeds through. The main driver wheel on the bottom has a modified, larger groove in it to better orient the sunflower seed. The main driver wheel also has a vacuum inside it to aid in holding the sunflower seeds in place in the groove to increase dehulling efficiency. The wheel allows the vacuum to be applied to the seed until it goes past the opposite impact wheel, after cracking the hull, then the vacuum would be released and the hull and kernel can separate and be collected on the bottom side. The impact wheels are run by a 1 horsepower motor and the motor is controlled by a DC Speed Controller. In addition, Plexiglas surrounds the hardware to aid in keeping the debris and seeds within the system and also for safety purposes to shield the moving parts.

3.1.8 Two-Step Process

This approach is utilizing two other designs to create a process. The first step involves the Red River Commodities original prototype. This prototype consists of a vibratory feeder that feeds the sunflower seeds into two cracking rolls. This modification would specify that the cracking wheels would only be far enough apart to slightly crack the shell of the sunflower seed and leave the sunflower seed intact. The sunflower seeds from this step would be moved onto the second step in the process. Then the sunflower seeds would be introduced into the centrifugal dehuller. The centrifugal dehuller consists of a rotating plate with vanes on it. These vanes send the seeds outward towards a granite impact surface. For the two-step process, the speed is lowered to 15 Hertz. By doing this, the damage to the kernel, once the shell breaks off, is minimized.

3.1.9 Cutting Knife

This prototype consists of a vibratory feeder that feeds the sunflower seeds into two cracking rolls. With the modification, the top wheel of the two cracking wheels has a thin blade attached to the center of the wheel going around the circumference of the wheel. This allows for the sunflower seeds entering the cracking wheels to be sliced along the long edge of the sunflower seed. The hull and kernel can then be collected at the bottom of the machine and separated by a dockage tester.

4.0 Final Design Selection

The preliminary design consists of four designs that were chosen based on the evaluation from the decision matrix in Table 2. The decision matrix rates each design against each other based on the weighted values shown. Ratings from one to four are used with one being the most desirable design and four being the least desirable. The total rating was calculated by taking the rating of each criteria multiplied by the percentage of that criteria. For example, the Curved Centrifugal Dehuller rating was calculated as $(1*0.10)+(2*0.40)+(2*0.20)+(1*0.05)+(2*0.25)=1.85$.

The forward-curved vane configuration for the centrifugal dehuller is the best design according to the design matrix. This design is a modification of the straight vane configuration for the centrifugal dehuller which ranks third to the forward-curved vane configuration. The almond dehuller was selected based on literature review and past industry experience. Lastly, the Red River Commodities design was a prototype received from industry.

Table 2. Decision matrix used to evaluate the preferred designs; 1= most desirable, 4=least desirable.

Rank	Design	Safety 10%	Viability 40%	Dehulling Efficiency 20%	Durability &Strength 5%	Cost 25%	Total 100%
1	Curved Centrifugal	1	2	2	1	2	1.85
2	Almond Dehuller	2	1	1	2	4	1.9
3	Straight Centrifugal	1	3	3	1	1	2.2
4	Red River Commodity	4	4	4	3	3	3.7

4.1 Curved Vaned Centrifugal Dehuller

The final design consists of the centrifugal dehuller from the Senior Design Project in 2002. Originally the design from 2002 consists of a straight vane, steel impeller plate, whereas this design consists of a forward-curved vane, aluminum impeller plate. The dehuller prototype has an axially fed rotor, which spins an impeller plate consisting of eight vanes in which the seeds flow through. The seeds flow through these vanes at a high velocity; once they exit the impeller vanes they hit the granite stone impact surface. Once the seed impacts the stone, the hull splits open, thus separating the hull from the kernel. Subsequently all fractions of the seed are gathered at the bottom of the machine. These fractions can then be separated by hand. A cross-section diagram of this dehuller can be seen in Figure 5.

This design was selected based on the statistics found within the literature review shown in Table 3. Table 3 shows that the aluminum, forward-curved vane has the highest dehulling efficiency in comparison with the other variations.

4.2 Straight Vaned Centrifugal Dehuller

The final design consists of the centrifugal dehuller from the Senior Design Project in 2002. Originally the design from 2002 was meant to dehull flax seeds. However, the intent for this design is to dehull sunflower seeds. The dehuller prototype has an axially fed rotor, which spins an impeller plate consisting of twelve vanes in which the seeds flow through. The seeds flow through these vanes at a high velocity; once they exit the impeller vanes they hit the granite stone impact surface. Once the seed impacts the stone, the hull splits open, thus separating the hull from the kernel. Subsequently all fractions of the seed are gathered at the bottom of the machine. These fractions can then be separated by the hand. A cross-section diagram of this dehuller can be seen in Figure 4.

This design was selected based on the statistics found within the literature review shown in Table 3.

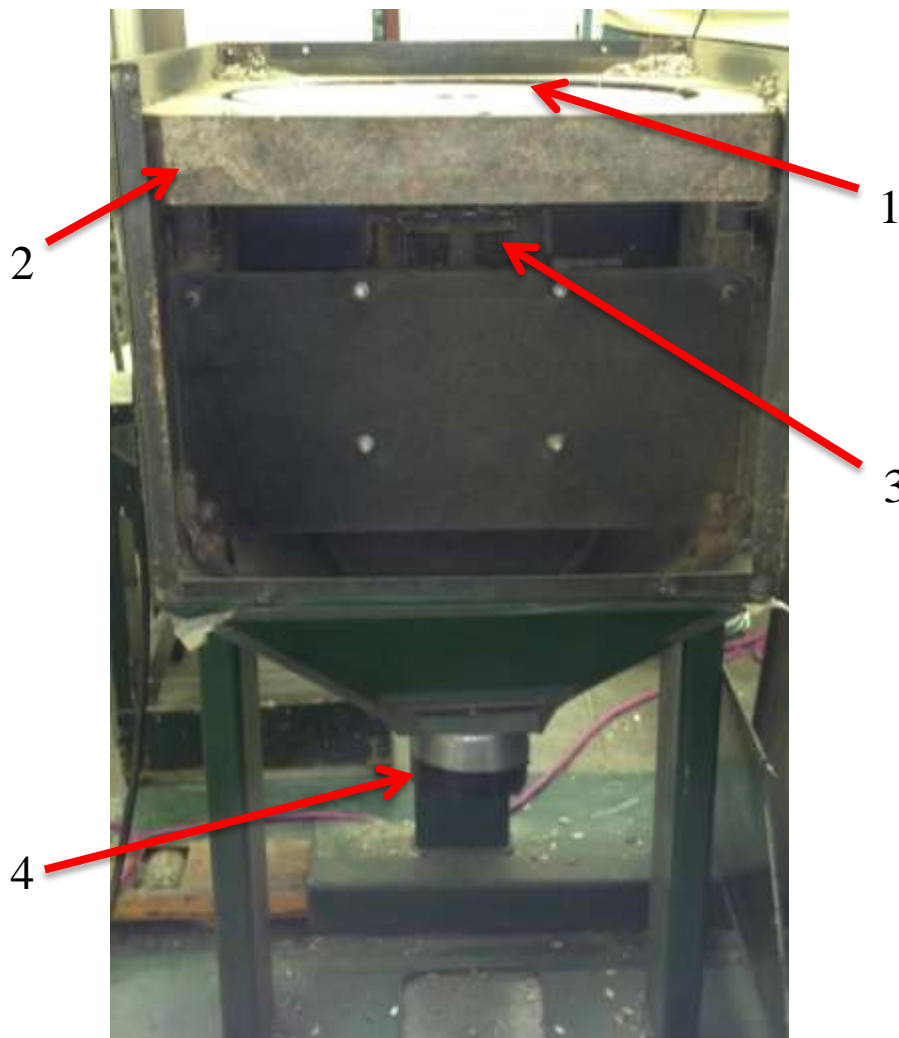


Figure 5. Cross-section of the centrifugal dehuller. 1) Vane 2) Granite impact stone 3) Motor 4) Collection spout.

4.3 Almond Dehuller

This design was ordered in from Kamper Fabrication located in California. The seed is fed into the top feeder and first goes through a cracking roller and then passes through a shearing roller. The rollers are rubber and are run by a 0.75 horsepower motor at 1725 rpm. The motor is connected to a gearing system that changes the speed ratio between the two belts with a maximum input of 3.42 horsepower at 1750 rpm and a maximum torque output of 996 ft-lb.



Figure 6. Almond dehuller purchased from Kamper Fabrication.

4.4 Counter-rotating Wheel

The Red River Commodities final design consists of modifying the original design with a deeper V-groove into the bottom cracking roller and a more accurate speed controller. The V-groove's depth is increased to 1/8" and the speed controller is a Dayton DC, half horsepower speed control, Model Number 1F800. By making the V-groove deeper, the seed is correctly oriented in the horizontal position shown in Figure 3a. The speed controller that was on the original design did not allow for precision speed control, therefore the frequency and rpm's could not be accurately recorded and repeatability was nearly impossible. Also on the original design there was no efficient way to collect the separated kernels and hulls after going through the cracking rollers. So in the new design a channel underneath the cracking rollers was developed from cardboard to help feed kernels and hulls into a collection container at the end of the process.



Figure 7. Bottom cracker wheel of counter-rotating wheel design with 1/8" groove.

5.0 Prototype Testing Methodology

5.1 Materials

Six lots of commercial extra-large confectionary sunflowers measuring from 23/64 inch or larger were acquired from Red River Commodities (Fargo, ND). Lots of seed originated from North Dakota and Kansas. The North Dakota seed was longer, measuring around 25/64 inch. The Kansas seed was 23/64 inch. Moisture content was calculated using a Binder oven and Kolpak refrigerator. The lots of seed were distributed into 1000g samples using 36- 1 gallon zip lock bags. To achieve the desired moisture content distilled water was added to the 1 gallon sample bags. During testing an Accusplit Pro Survivor – A601X stopwatch was used to take consistently timed samples and to measure flow rate from the Powertec (3090 Sample Mill) vibratory feeder. The samples were collected from the dehuller using a OXO strainer. The collected samples were placed in 36 – 1 quart Ziploc bags. A standard 36 - 5 gallon plastic pail with cover collected the excess dehulled seed. An Allen-Bradley PowerFlex 40 variable frequency drive was used to control the hertz output of the dehuller motors. Germination trials were placed on 38 lb. seed germination paper from Anchor Paper Company and placed in a Sterlite 69 liter plastic container to maintain a constant climate.

5.2 Centrifugal Dehullers

Once the prototypes were selected a testing methodology was created to compare the two centrifugal vane configurations. Samples consisting of 1000 gram samples were conditioned into three moisture contents, 6.5 %, 8% and 9.5% to test effect of moisture on dehulling efficiency. Triplicates were created at each moisture level for each hertz setting, to test the effect of speed. In total there were 36 – 1000 gram samples. All the tests were conducted at the same time to eliminate any variables introduced. Refer to Appendix A for a complete procedure for testing. Analysis of variance was performed with SAS and a Fischers least significant difference (LSD) was calculated for main effect and interaction mean comparisons.

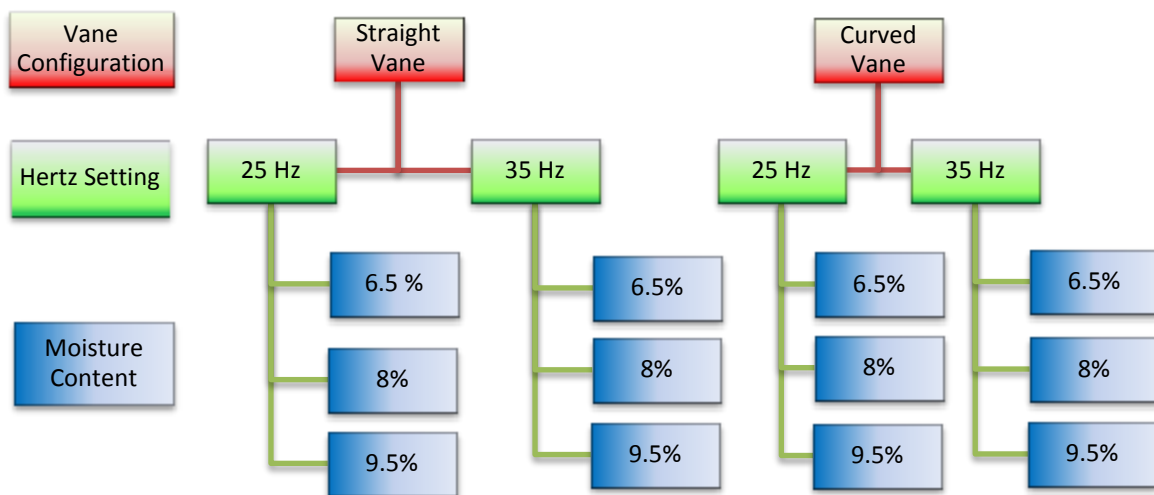


Figure 8. Flow chart of centrifugal dehuller testing.

6.0 Performance Evaluation of Prototypes

To quantify the testing methodology, three performance measures were examined. When sorting the 1000 gram samples, three fractions were separated from each other including percent in shell, percent dehulled with intact kernels and percent dehulled with damaged kernels. Once the fractions were separated, weights were taken and recorded. The weights were divided by the 1000 gram total weight therefore making a percent weight fraction.

Once the weight fractions were calculated, the viability and dehulling efficiency were found. Viability was found using equation 1 found in section 7.0. Dehulling efficiency was found using equation 2 found in section 7.0.

6.1 Curved Vaned Centrifugal Dehuller

Results for the curved vane centrifugal dehuller were collected using Microsoft Excel. A stacked bar graph, Figure 9, was created to visually explain the results. The y-axis represents the percentage of the sample in each fraction. The x-axis identifies the hertz and moisture content.

The blue bar represents seed still in the shell. This fraction is still valuable since it can be passed through the dehuller again. The red and green bars represent seed that was dehulled. The red bar represents kernels removed from the hull with no visible damage. The green bar represents kernels removed from the hull with visible damage.

As the moisture content increases the amount of in shell seeds also increases having a negative effect on the dehulling efficiency. The increased moisture content has a positive impact on the viability as the percent of dehulled damaged kernels decreases.

The 35 hertz setting exerted more force on the seed during impact than the 25 hertz. This led to more damaged kernels with fewer seeds left in the shell. The high amount of damaged kernels seeds decreased the viability but the lower in shell amount increased dehulling efficiency.

The 35 hertz setting and 9.5% moisture was the optimum combination. These samples had the least amount of dehulled kernels with visual damage. On average 51.6% of the seeds were dehulled with no damage. This leads to higher viability which is the main objective of this project. The samples had more in shell seeds than the other 35 hertz settings but these seeds can be passed through the dehuller again.

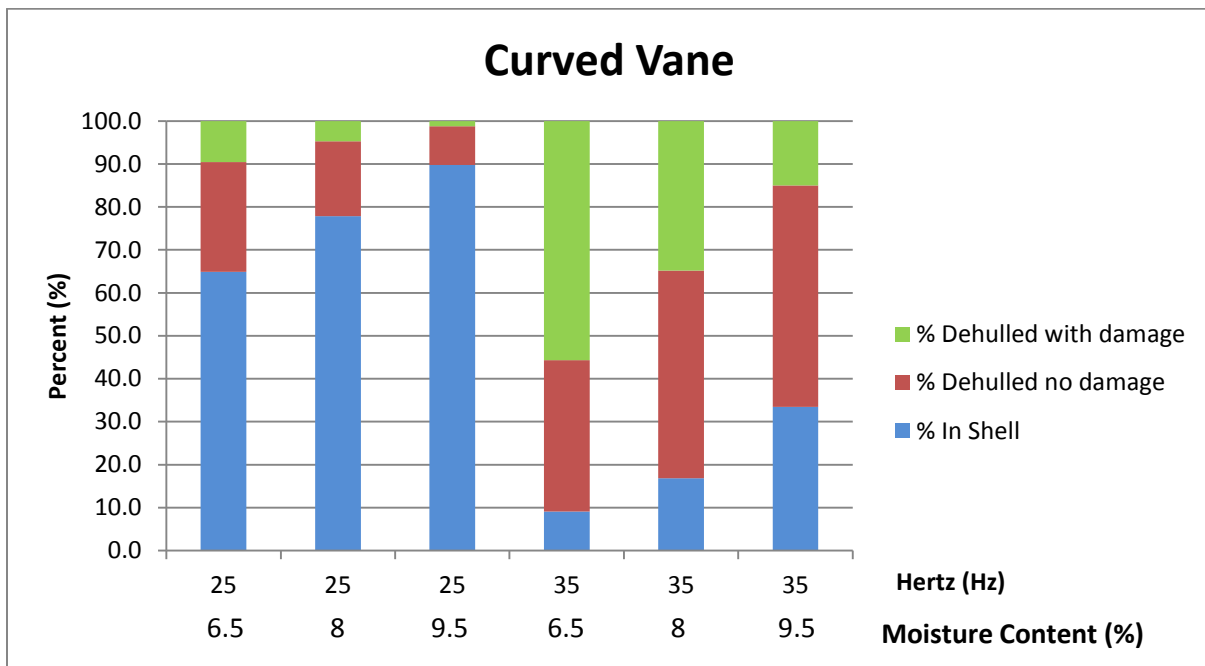


Figure 9. Results from curved vane testing.

6.2 Straight Vaned Centrifugal Dehuller

The straight vaned centrifugal dehuller's performance follows a similar partner to the curved vane design. This design has a higher dehulling efficiency but lower viability. An increase in damaged kernels is due to the way the seed hits the granite impact surface.

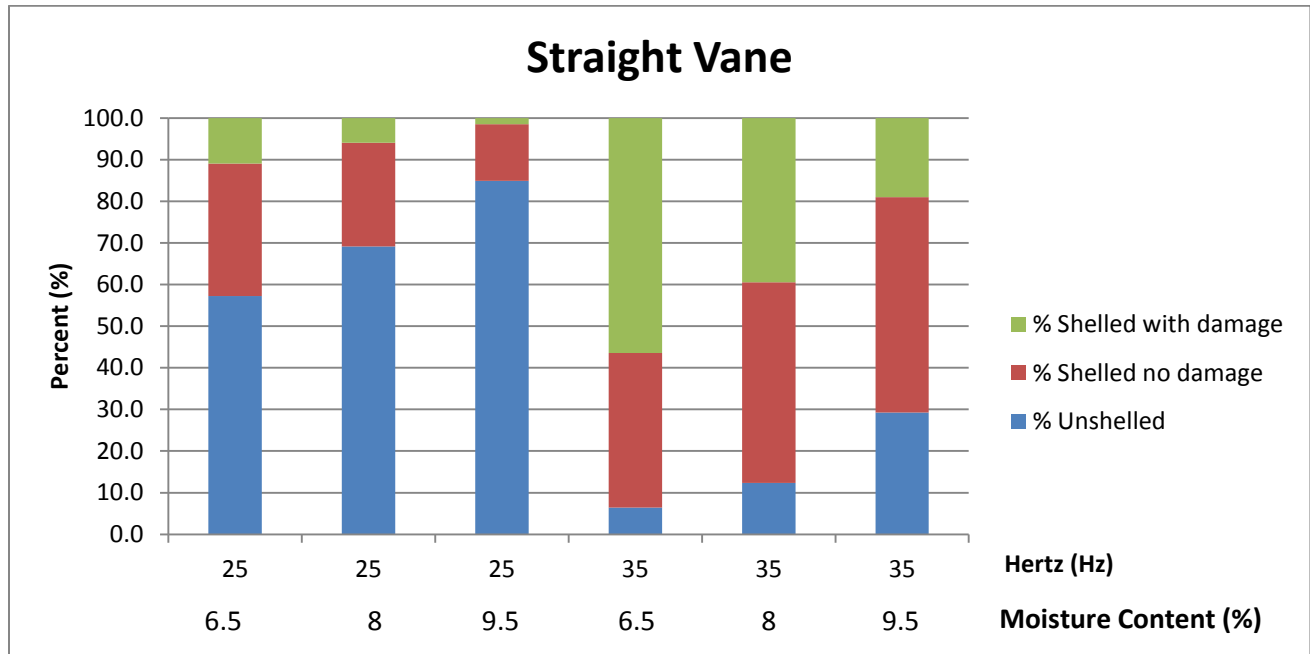


Figure 10. Results from straight vane testing.

6.3 Almond Dehuller

Due to time constraints in the receiving the machine the almond dehuller was not tested for results. Preliminary testing was conducted with promising results.

6.4 Red River Commodity

The performance of the Red River Commodities prototype proved to be very poor and unusable. No data was able to be collected on the dehulling efficiency as no samples were able to be collected. This was caused by the clearance issue between the two cracking rollers. Because the groove was made deeper, the clearance between the two cracking rollers needed to be tighter as the seed sat lower than it had originally.

The shims that allowed for movement between the two cracking rollers did not allow for consistent spacing when removing one shim at a time. The entire top roller was allowed to move up, down, forward and backward when removing or replacing a shim. This caused much inconsistency and when the most optimum spacing possible was achieved, the seeds were in effect completely crushed and the kernels were pulverized. With these results this design was excluded from consideration for further testing.

7.0 Prototype Design Calculations

Literature reviews and research studies have shown that aluminum forward-curved impeller vanes resulted in a higher dehulling efficiency compared to steel straight-vanes which is what the impeller vane from 2002 consisted of. The design modifications are to change the material from steel to aluminum and the vane configuration from straight to forward-curved.

These dimensions remain constant and unchanged with the new design:

- Material thickness of 0.125"
- Overall diameter of 20"
- Inside shaft hole diameter of 1"
- Inside top plate hole diameter of 2"
- Key size of 0.25" X 0.25"

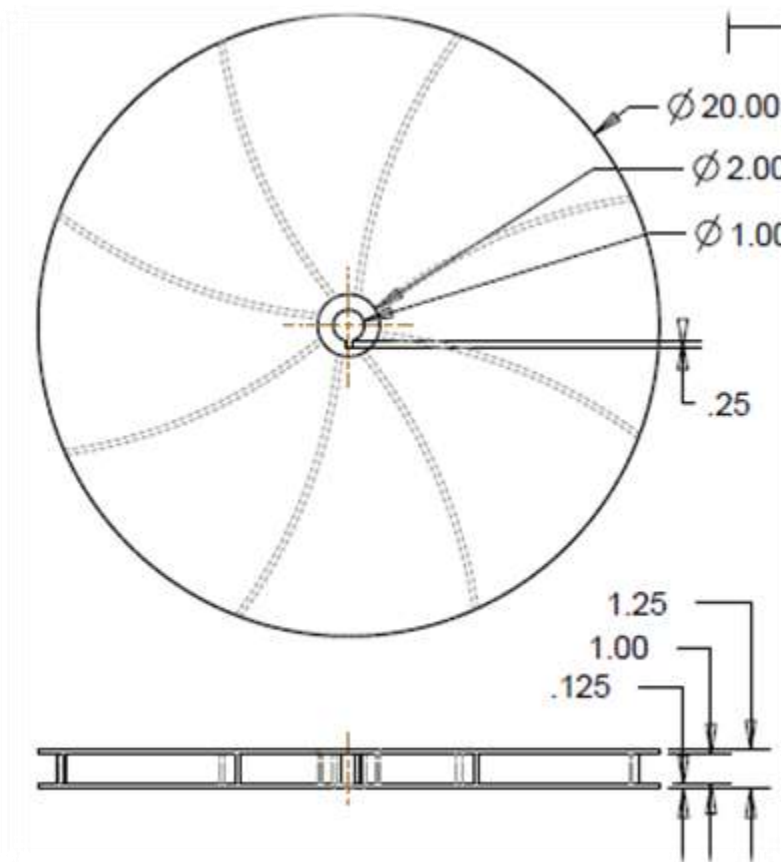


Figure 11. Dimensions of curved vane wheel.

The spacing between the vanes changed from 0.3983” to 0.66”, the curvature changed from straight to an inner radius of 17” spaced 45 degrees apart. The spacing was calculated this way to allow an adequate opening for the seeds to enter the impeller vanes while maintaining the forward-curvature. Figure 12 shows the design change from the straight vane to the forward curved vanes.

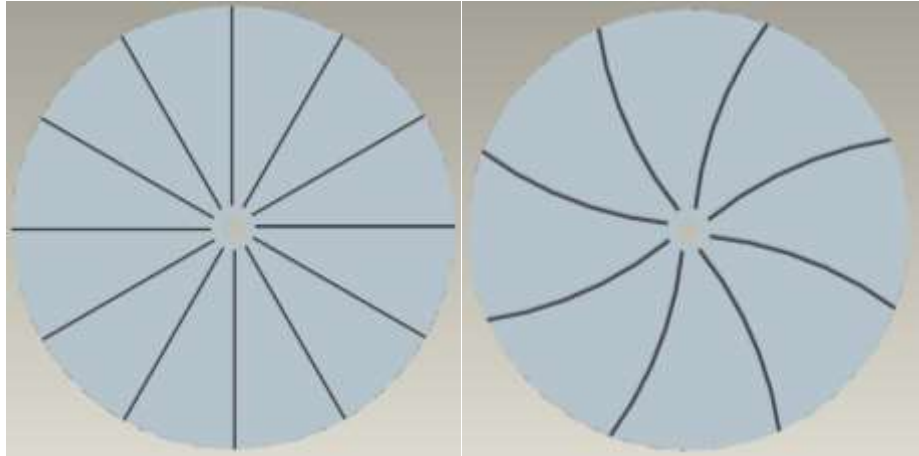


Figure 12. Design comparison between original straight vane design and new forward curve design

The forward curved vanes are to create a greater shearing force between the seed and the impact surface. This will in effect, reduce breakage to the kernels. Whereas the straight-vane configuration causes more of a direct impact force, which could lead to a higher percentage of damaged kernels.

Table 3. Effect of material of construction and shape of vane on dehulling performance for sunflower seed. [2]

Material	Vane	D _e , %	L _k , %	S _e kJ/kg
Aluminum	Straight	58.82	8.18	10.25
	Forward-curved	80.12	6.23	7.82
	Backward-curved.	15.72	7.56	38.14
Mild steel	Straight	49.20	5.87	12.17
	Forward-curved	71.30	4.43	8.20
	Backward-curved.	12.05	5.32	49.86
Rubber	Straight	41.10	6.94	15.24
	Forward-curved	67.02	5.48	9.34
	Backward-curved.	10.42	6.44	58.13

$$\text{Viability (\%)} = \frac{\text{Weight of Dehulled Intact Kernels}}{\text{Weight of Dehulled Damaged \& Intact Kernels}} \quad \text{Equation 1}$$

$$\text{Dehulling Efficiency (\%)} = \frac{\text{Weight of Dehulled Damaged \& Intact Kernels}}{\text{Weight of Total Dehulled \& In Shell Seeds}} \quad \text{Equation 2}$$

Table 4. Effect of moisture content and orientation of loading on rupture force, deformation and energy absorbed at rupture for sunflower seed with standard deviation. [4]

Moisture content (% d.b.)	Rupture force (N)		Deformation (mm)		Energy absorbed (J/m ³)	
	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
Seed						
4.21	50.21 (1.03)	59.12 (1.20)	0.70 (0.02)	0.88 (0.02)	95.18 (0.88)	144.73 (1.28)
8.2	56.36 (1.42)	65.23 (1.61)	0.91 (0.02)	1.02 (0.03)	133.42 (1.44)	157.75 (1.09)
11.84	49.29 (1.29)	58.08 (1.57)	1.15 (0.02)	1.31 (0.02)	164.24 (1.40)	208.81 (1.34)
16.27	38.31 (1.38)	43.36 (1.81)	1.25 (0.02)	1.41 (0.02)	180.48 (1.40)	217.63 (1.52)
20.65	35.26 (1.68)	39.06 (1.38)	1.34 (0.02)	1.46 (0.02)	184.16 (1.35)	222.85 (1.35)

The required force to dehull a sunflower seed will be between 35 and 57 N based on the horizontal rupture force in Table 4.

8.0 Final Design

After looking at the data collected from each vane configuration the optimum results from each vane were compared. In Figure 13, the left column shows the optimum results from the curved vane and the right column shows the optimum results from the straight vane. The curved vane had a lower percentage of damaged kernels and a higher percentage of in shell seeds. Where the in shell seeds can be ran through the dehulling process again, but the damaged kernels are not able to be used and will more than likely be used for bird food. This data shows that the dehulling efficiency is lower for the curved vane; however, the viability is higher because of the smaller percentage of damaged kernels. Since viability is the main focus of this project the curved vane is the final design chosen.

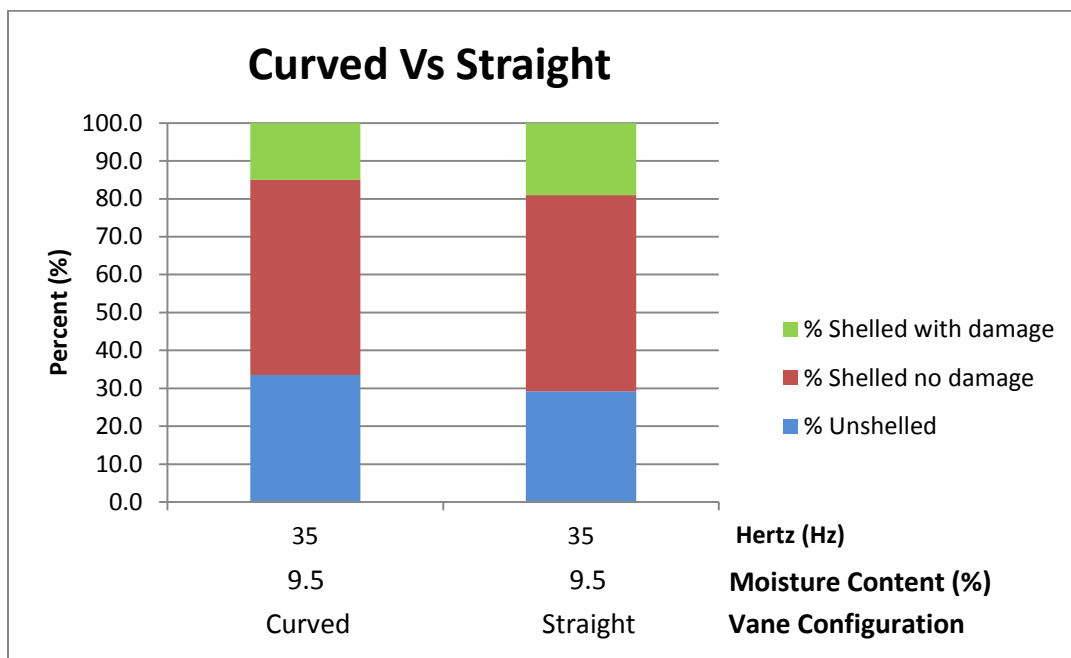


Figure 13. Optimum results from the curved and straight vane tests.

The data was analyzed using analysis of variance (SAS institute, Cary, NC). An *F*-protected LSD ($P \leq 0.05$) was calculated for comparisons of main effect means. Significant differences ($P \leq 0.05$) between means of two way and higher order interactions were determined as twice the standard error of the mean.[6] Standard error of the mean ($n=3$).

Table 5 shows the least significant difference for the two vane configurations, hertz speeds and moisture contents. This shows that the vane configuration was not significant in data variation, signified by having the same letter. However, the moisture content and hertz were significant in data variation, signified by difference in letters.

Table 5. Least Significant Difference Statistics for vane configuration, moisture and hertz.[6]

Vane (V)	Hertz (H)	% Moist (M)	in-shell	dehulled				% damage of dehulled (k+d)		
				Intact kernel (k)		damage (d)				
S	-	-	43.2	b	34.6	a	22.2	a	39.1	a
C	-	-	48.3	a	31.2	b	20.1	b	39.3	a
-	25	-	73.6	a	20.3	b	5.6	b	21.7	b
-	35	-	17.9	b	45.4	a	36.7	a	44.7	a
-	-	6.5	33.8	a	32.3	b	33.1	a	50.6	a
-	-	8	44.1	b	34.7	a	21.2	b	37.9	b
-	-	9.5	59.3	a	31.6	b	9.2	c	22.5	c

To perform germination trials the North Dakota State Seed Department Sunflower Germination Trial Procedure was used. This procedure is talked about in detail in Appendix A. Only preliminary germination tests were completed so no data was yet collected. Seed coating would then be applied to the sunflower kernel to simulate the size of a corn kernel. Since another team is working on the coating aspect there is not any data collected for that. The seed coating allows the sunflower kernel to be used in existing seed discs.

9.0 Impacts of Final Design

Currently there is an increased demand for larger-sized hulled confectionary sunflowers overseas. The development of a dehulled purpose for the larger-sized sunflowers will create an increase in demand that will be offset by an increase in payment to the producers and manufacturers. The new market created by the dehulled seed will increase producer's profitability by offering an outlet for previously discounted seed. The new product will also offer industry a new market and increased margins. The increase in producer and industry profit will lead to a slight increase in community profits with increased spending by both groups.

The final design has several health and safety impacts. These impacts are projectile moving objects, pinch points and dust. The sunflower seeds are discharged from the vanes of the dehuller at a high velocity. If the seed comes into contact with a human, it may cause injury. To eliminate this concern, the vane is placed in a steel enclosure. This enclosure will also eliminate the operator's access to pinch points.

The seed being processed creates dust. Dust can lead to spontaneous combustion in the proper environment. Dust can also cause health problems for operators if inhaled in large quantities. Periodic cleaning can limit the effects of dust.

Dehulled sunflowers may have new standards created based on the development of this machine. The new product may fall under a USDA regulatory agency.

The new design is made of aluminum with a projected lifetime of one year. The most significant wear will be seen on the kernel side of the curved vanes, the impact surface and the top side of the vane collar. Tungsten Carbide could be used to coat the aluminum to increase durability and extend the lifetime to two years. However, this coating is highly expensive, so cost analysis would need to be considered.

The new curved vane dehuller's manufacturability is relatively simple. The motor and vane collar are generic, off-the-shelf models. The vane is laser cut from a wood model in NDSU's possession. The steel enclosure is made from sheet steel with 90 degree angle bends. The granite impact plate is the most difficult part to manufacture because it needs to be complete by an outside vendor. The size, weight and expense of the material also add difficulty to the manufacturing.

There are no significant environmental impacts because the amount of sunflowers currently planted will not change.

There are no political impacts with this design.

10.0 Future Recommendations

Going forward this project will be continued by another team. The future recommendations for this team are to:

- Test the almond dehuller and compare the results to the centrifugal dehuller.
- Test sunflower seed from different regions throughout the U.S.
- Optimize the Hertz setting and moisture content of centrifugal dehuller
- Germination trials
- Seed coating for precision planting
- Germination trials for coated seeds

Preliminary testing of the almond dehuller showed promising results. Once it has been optimized those results should be compared to those of the centrifugal dehuller. Tests should also be completed on seeds from different regions in the United States specifically Kansas and North Dakota. Seed from each area was used through the project and a difference in length and angularity was noticed. The results obtained from the centrifugal dehuller were at two different hertz and three moisture contents. However, further testing should be completed to attain the optimum hertz setting and moisture content.

During the dehuller optimization process, germination tests should be conducted to ensure viability is being achieved. Germination trials are the ultimate test for viability as non-visible damage will become apparent during germination. Once viability has been achieved in the dehulling process and coating should be placed on the seeds. This coating will aid in protecting the kernel tip and enlarge the size of the seed to be similar to that of corn. The size increase will allow existing planter technology such as seed discs to be used. The use of this technology will limit the number of skip and double seed planting. Germination trials will need to be completed on the coated seed as well to verify the coating process does not damage the kernel tip and decrease viability.

Bibliography

- [1] S.P. Clark, G.W. Baker, P.J. Wan and S.W. Matlock, "Separating Kernels and Hulls from Oilseed Type Sunflower Seed", Transactions of the ASABE. 1980
- [2] Susanta Kumar Das and R.K. Gupta, "Effects of Impeller Vane Configurations and Seed Size on Dehulling Efficiency of Sunflower Seeds Using a Centrifugal Sheller", *International Journal of Food Engineering*, vol. 1, article 7, issue 3, pp. 1-7, 2005
- [3] Rémi Sauvage and Matthieu Very, "Testing performances of a new prototype, a flaxseed dehuller at the Pilot Plant in the North Dakota State University", pp. 8, 2002
- [4] Susanta Kumar Das and R.K. Gupta, "Fracture Resistance of Sunflower Seed and Kernel to Compressive Loading", *Journal of Food Engineering*, pp. 1-8, 2000.
- [5] Leonard Cook, Personal Communication, USDA ARS Laboratory, 2012
- [6] Snedecor, G.W., and W.G. Cochran. 1980. Statistical Methods, 7th Ed. Pp 593. Iowa State University Press, Ames, Iowa, U.S.A.

Appendix A – Test Procedures

Centrifugal Dehullers

Preprocessing

1. Weight out 36,000 grams of seed.
2. Dry in oven until below 6.5%.
3. Do oven moisture test on seed to determine moisture content.
4. Calculate how much water needs to be added to each 12,000 gram bag of seed to get it to the correct moisture level.
5. Mix up 90 pound bags of conditioned seed and make sure they are well mixed.
6. Put bags in refrigerator to set for 5 days.
7. Mix bags each day to distribute the moisture.
8. Take the bags out of the refrigerator and weigh out twelve 1,000 gram samples of each moisture and bag them separately with the corresponding treatment number on the bag.

Processing

9. Install straight vane impeller into the centrifugal dehuller.
10. Install sides back on dehuller.
11. Set up vibration feeder to feed product into the dehuller. Set the vibrational feeder to a setting of 6. (Setting 6 corresponds to a feed rate of 387.1 grams/min.)
 - a. Note: Monitor the surface of the vibrational feeder so that dust buildup can be removed, so that it does not affect the flow rate..
12. Set AC inverter to 25 Hz.
13. Turn on dehuller and begin.
14. Pour a 1,000 gram sample into the funnel on the vibrational feeder.
15. With the screen strainer, take three different samples from the dehulled product at different intervals as it is coming out of the dehuller. Each sample should last 10 seconds.
16. Take a sample at 30 seconds, 1 minute and 1 minute 30 seconds.
17. Take the remainder of the sample that was passed through the dehuller and leave it in the pail.
18. Repeat steps 7-9 until the three moistures at 25 Hz have been collected.
19. Change inverter to 35 Hz.
20. Repeat steps 7-9 for the 35 Hz samples.
21. Turn off machine and cut power to the unit.
22. Take straight vane impeller out by taking the key out of the shaft with a hammer and punch.
23. Lift out and put in curved vane impeller.
24. Pound key back into the keyway in the shaft.
25. Repeat steps 7-20.

Postprocessing

1. Select a sample and hand pick out 4 different fractions.
 - a. Intact Kernels
 - i. An intact kernel with a visible undamaged growth tip.
 - b. Intact Seeds
 - i. An intact sunflower seed. Hull completely enclosing a kernel.
 - c. Broken kernels
 - i. Chips of kernel.
 - ii. Hulls
 2. Weigh the 4 different fractions and record the values.
 3. Record a count of how many intact kernels and intact seeds there are.
 4. Input those values into excel sheet provided and compute the weight fractions.

Germination

1. Condition blotting paper. Compute total weight of blotting paper that you will use and add half the weight of the paper, in water to the tub with paper in it.
2. Place 1 piece of blotting paper on a table, count out 45 kernels and space them evenly across the sheet.
3. Cover with 1 piece of blotting paper.
4. Roll up and label the roll.
5. Place in plastic tub and place in a dark place.
6. Take count and pictures at 7 days. Count germinated seeds. Input number into excel worksheet.

Red River Commodity

Preprocessing

1. Mix up 90 pound bags of 7.2 % moisture seed and make sure they are well mixed.
2. Weigh out 136.4 grams of seed from the seed bags.
3. Take a moisture content reading of each sample.

Processing

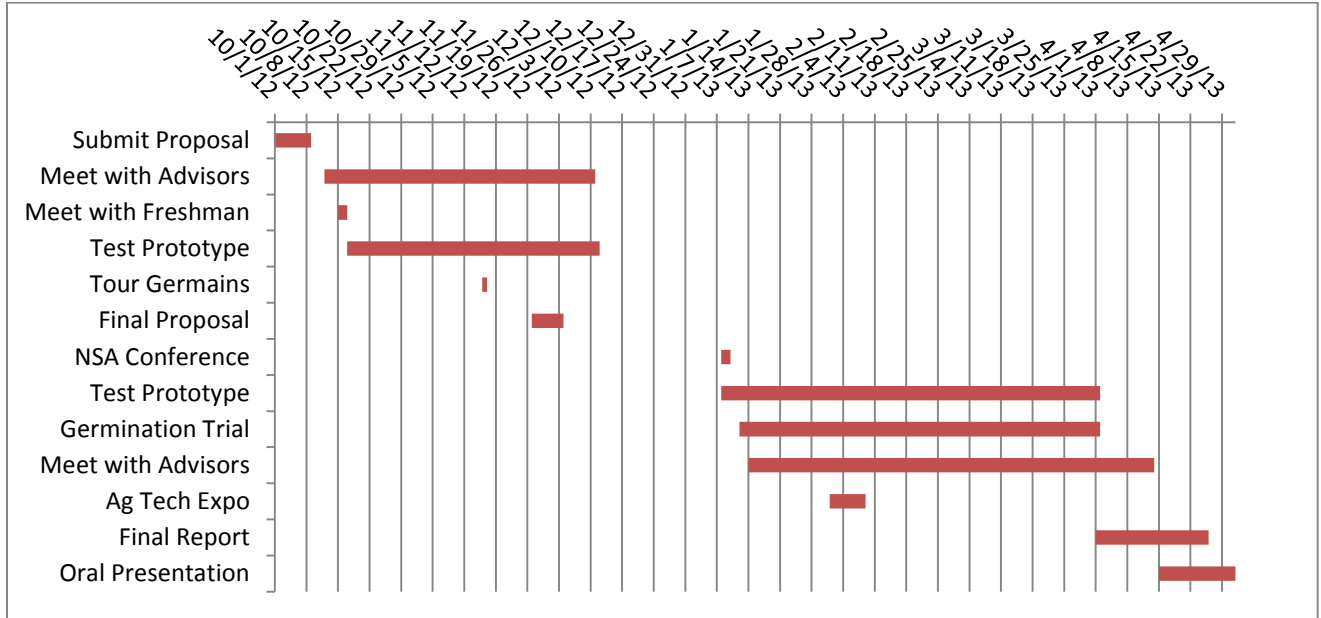
1. Adjust clearance to desired height with shims.
2. Set up vibration feeder so that the seed is feed into groove of the bottom roll. The feed should be within ½” of the top roller. Set the vibrational feeder to a setting of 6. (Setting 6 corresponds to a feed rate of 248.6 grams/min.)
 - a. Note: Monitor the surface of the vibrational feeder so that dust buildup can be removed, so that it does not affect the flow rate.
3. Set up collection box.
4. Set motor to 4.
5. Turn on dehuller and begin.

6. Pour a 136.4 grams sample into the vibrational feeder.
7. Take collected sample and weigh it. Record the values.
8. Put samples into separate bags and label them with the configuration, Hz and moisture.
9. Repeat steps 7-9 until the three samples at motor setting 4 have been collected.
10. Change motor setting to 5.
11. Repeat steps 7-9 for the motor setting of 5.
12. Turn off machine and cut power to the unit.

Postprocessing

1. Select a sample and hand pick out 3 different fractions.
 - a. Intact Kernels
- i. An intact kernel with a visible undamaged growth tip.
 - b. Intact Seeds
- i. An intact sunflower seed. Hull completely enclosing a kernel.
 - c. Broken kernels & hulls
- i. Everything that is left after the two above fractions have been removed.

Gantt Chart



Team Participation

Lisa = 150 hours

Jody = 125 hours

Janelle = 125 hours