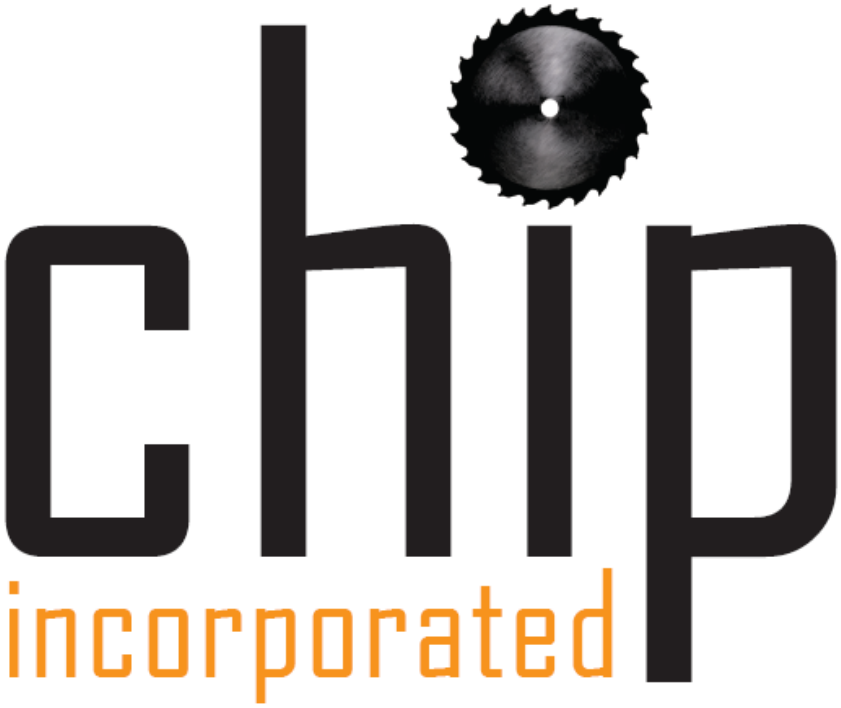

April 29, 2010

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chip incorporated

Introduction

The fall semester proved to be a learning experience for all members of Chip Incorporated. The team received a true taste of the real world when its sponsor stepped away from the project in late November. After considering all options, and after many discussions with our professors and project advisors, the team decided to pursue an idea that stemmed from the research and development conducted during the fall semester. This idea utilizes native Oklahoma products such as Eastern Redcedar mulch and wheat starch to make a mulch tile.

Problem Statement

Chip Incorporated will impact the wood mulch industry by developing an easier, more efficient way to package, ship, and landscape wood mulch.

Statement of Need

In addition to simplifying the application of mulch for homeowners and landscape professionals, the proposed process also utilizes Eastern Redcedar mulch, developing an end product for an invasive species.

Mission Statement

Chip Incorporated will create a value-added mulch product in the form of "mulch tiles" using a native Oklahoma invasive species, Eastern Redcedar (*Juniperus virpiniana L.*), to have a more practical and efficient use of mulch.

Selection of Design

At the end of the fall semester, Chip Incorporated proposed three unique design possibilities for coloring wood mulch to our client, professors and advisors. However, the team's sponsor had withdrawn from the project, leaving the team to decide where to take the project in the spring semester. The team decided to abandon the idea of coloring mulch. Instead the team decided to proceed with the more innovative idea of producing mulch in the form of a rollable strip. The team agreed that this design had the greatest potential for value to the industry, as no similar product currently exists.

The idea of producing mulch in a rollable form was determined to be infeasible, due to the impracticality of the design and weight concerns. The team decided to follow through on an idea suggested by the team's Application Engineer, Shea Pilgreen, and create a square mulch tile.

Patent Review

A patent review was conducted in order to determine if any patents existed on similar products. Chip Incorporated found one patent that was similar to the proposed design, US Patent No. 4,283,445: Non-Woven Organic Mulch Blanket with Polyvinylacetate Copolymer Binder. This patent, filed by Klaus Bartholl, was published on August 11, 1981. Bartholl's patent describes a mulch blanket, which is similar to Chip Incorporated's mulch tile. However, Bartholls' patent uses a polymer binder, unlike Chip Incorporated's wheat starch binder. Bartholl's mulch blanket is held together by the use of a polyvinylacetate copolymer binder on the top surface whereas Chip Incorporated's mulch tile uses starch that is mixed in with the mulch. A copy of the patent, along with a more detailed description, is in Appendix F.

Determination of Design Process

Chip Incorporated's goal was to focus on establishing a process to create a mulch tile. The mulch tile needed to meet a set of criteria. The mulch tile would break apart and appear more natural looking after water had penetrated the surface. In addition, Chip Incorporated wanted to create the mulch tile out of native Oklahoma materials and keep it free of synthetic chemicals. Chip Incorporated, after consulting with Dr. Hiziroglu, a professor in the Natural Resource and Ecology Management department at Oklahoma State University, made the decision to produce the mulch tiles by using a heat press that is most commonly used to create composite panels.

For the team's design process, wood mulch was combined with a starch and subjected to heat and pressure to form mulch tiles. A heat press was chosen because it can be used to quickly and easily form a layer of mulch into a thinly pressed tile.

Eastern Redcedar mulch was chosen to make the mulch tiles. The mulch used was made from whole Eastern Redcedar trees, including the bark and needle-like leaves. A picture of an Eastern Redcedar tree is shown below, in Figure 1.

Figure 1. Eastern Redcedar tree.[1]

Eastern Redcedar mulch was chosen for several reasons. Eastern Redcedar trees are considered a nuisance in the state of Oklahoma. Research from Oklahoma State University has shown that a single acre of Eastern Redcedars can absorb as much as 55,000 gallons of water per year[2]. With the current "Be a Leader, Burn a Cedar" campaigns in Oklahoma, finding another reason to cut down Eastern Redcedar trees would be beneficial for the state of Oklahoma.[3] Another reason Eastern Redcedar mulch was chosen is because it has a strong aroma and has shown to be a natural insect repellant and herbicide.[4] This property is particularly advantageous as introducing starch into the mulch tiles could attract unwanted insects.

Starch was chosen as a binding agent because it is all natural and non-toxic. When mixed with water, the starch forms a glue. This glue sets after drying and remains intact until it is exposed to water. This property allows the mulch tiles to remain in the form of a hard tile during shipping and storage.

Wheat starch and corn starch were chosen for testing as potential binding agents. After the team conducted several experiments, testing mulch tiles created with the two different starches, Chip Incorporated chose to use the wheat starch as the final binding agent. The mulch tiles created with wheat starch met Chip Incorporated's desired expectations in the experiments performed on the tiles. In addition, the wheat starch meets Chip Incorporated's mission statement, as it is a native Oklahoma material.

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[1] Hiziroglu, Salim. "Value-Added Composite Panels Manufactured from Under-Utilized Species in Oklahoma". Oklahoma State University. August, 2006. Microsoft PowerPoint file. 21 April 2010.
[2] "Eastern Redcedar Mapping Project." Biocity News 2, 2009. Web. 15 April 2010. <http://boisecitynews2.wordpress.com/2009/03/03/oklahoma-launches-plan-to-battle-eastern-redcedar>
[3] Stevens, Russell. "Arbuckle Restoration Project Forming in Carter, Johston, Murray Counties". May 2004. The Samula Roberts Noble Foundation. <http://www.noble.org/AG/Wildlife/ArbuckleRestoration/index.html>
[4] "Aromatic Eastern Redcedar: Juniperus Virginiana." Tiny Timbers, 2009. Web. 4 March 2010. <http://tinytimbers.com/specie_cedar.htm>

The combination of Eastern Redcedar mulch and starch forms a relatively strong bond when exposed to the heat and pressure applied by the heat press. When exposed to heat, the oils inside the Eastern Redcedar mulch are activated, forming a resin-like bond which holds the mulch tiles together. The application of pressure forms a smooth, hard surface, which allows for easy packaging and shipping. The combination of these two ingredients, along with the use of a heat press, offers the qualities desired in a mulch tile. Chip Incorporated decided that this was the ideal process to form a mulch tile.

Implementation of Design: Creating Mulch Tiles

The team began testing the process by making small sample-sized mulch tiles using a small heat press in a 4 ¾'' x 4 ¾'' x 4 ¾'' frame. This size was chosen because it fit the small press that was available to Chip Incorporated. Also, the small size allowed the team to be more flexible in altering the formula and process for making mulch tiles. In addition, this size allowed the team to use less material during initial testing.

The use of the small heat press allowed the team to define the process for making the mulch tiles. Initially, the team tested the blend of 120 grams of mulch and 10 grams starch. The mulch and starch were hand mixed and then placed into the square frame. The mulch-starch blend was tamped down using a block of wood. Next, the frame was removed and the mulch-starch blend was placed onto the small heat press. Each tile was subjected to 750 psi. The press was heated on both sides to approximately 350˚F. The mulch samples were pressed for a total of ten minutes. The final thickness of the samples was approximately 0.5 inches.

In order to help determine which type of starch was appropriate for this application, Chip Incorporated conducted several experiments. Corn starch, wheat starch and wheat paste were the starches chosen for testing. The wheat starch and wheat paste were obtained from Hollander's, a decorative paper and bookbinding supply store. The corn starch was purchased from Wal-Mart. The team created the mulch tiles using the following processes and starches in order to determine if the proposed starches would work:

1. Mulch, no starch added, with applied pressure, no heat.
2. Mulch, mixed with corn starch, with applied pressure.
3. Mulch, mixed with corn starch and water, with applied pressure and heat.
4. Mulch, mixed with wheat paste and water, with applied pressure and heat.
5. Mulch, mixed with wheat paste, with applied pressure and heat.
6. Mulch, mixed with wheat starch, with applied pressure and heat.

With these experiments, the team discovered that corn starch did not work as an adhesive, especially when water was added to the mixture. However, the team did not initially test how

well the corn starch worked when heat was applied to the mulch square. Experiments were carried out at a later date to test using corn starch as the binding agent, and can be found in the "Experiment Testing and Validation of Prototype" section of the report.

When testing with the wheat paste, mulch, and water mixture with applied pressure and heat, the team discovered that there was too much moisture in the mixture for the wheat paste to cure. The wheat paste and water mixture was one part wheat paste to five parts water. The resulting adhesive was a white, gooey paste, much like Elmer's glue.

On the team's second attempt with using wheat paste (number 5), the team mixed 10 grams of wheat paste powder together with 120 grams of the Eastern Redcedar mulch. After mixing the wheat paste and mulch together, evenly coating the mulch, the mulch was placed in a square frame, 4 ¾'' x 4 ¾'' x 4 ¾'' The density of the mulch before pressing and applying heat was $\rho \sim 0.30 g/cm^3$. After applying 750 psi at 150°C for ten minutes to the mulch in the square frame, the density was $\rho = 0.65 g/cm^3$ and the thickness of the mulch square was ½ in. From this experiment, it was discovered that there was enough moisture present in the mulch itself to hold it together. Therefore, the team didn't need to add any water to the mulch and starch mixtures when creating the mulch tiles.

When testing with the wheat starch, the same procedure was used. 10 grams of wheat starch powder was mixed with 120 g of the Eastern Redcedar mulch. After mixing the starch and mulch together, the mulch was placed in the same 4 ¾'' x 4 ¾'' x 4 ¾'' wooden frame. After applying 750 psi at 150°C for 8 minutes, another mulch tile was created. This experiment proved that the wheat starch works just as well, if not better, than the wheat paste powder.

From these experiments, the team learned that a mulch tile can be created by using only wheat paste (or wheat starch), mulch, pressure, and heat. No water needs to be added to the mixture before applying pressure and heat.

Once the team proved that the process worked using the small press, the team then tested the process using a larger press. The team used an 18.5"x 18.5" x 8.0" frame in conjunction with a larger press in order to produce mulch tiles on a larger scale. The press used, shown below in Figure 2, was an Erie 24" x 24" - 270 Ton Hydraulic Compression Press produced by Erie Mill and Press Co, Incorporated.

Figure 2.

Before compression, the mulch tile's dimensions were 18.5" x 18.5" x 2.0". Once pressed, the mulch tile's dimensions were 19.5" x 19" x 0.75". Steps 1 through 9 and Figures 3 through 11 show the detailed process of creating the large mulch tiles. Chip Incorporated timed the overall process, and it took twelve minutes to create one 19.5" x 19" x 0.75" mulch tile.

Step 1. Chip Incorporated's team members weighed out the correct amount of mulch and starch and placed them in a bin for mixing. (Figure 3)

Figure 3.

Step 2. After mixing, team members poured the mulch and starch mixture into a wooden frame to shape the mixture into a tile. The frame measured 18.5" x 18.5" x 8.0". Beneath the frame was a metal sheet made of stainless steel, measuring 24" x 24". (Figure 4)

Figure 4.

Step 3. Next, the mulch and starch mixture was spread evenly inside the wooden frame. (Figure 5)

Figure 5.

Step 4. After that, the mixture was tamped down by placing a small block of wood, 18.5” x 6.0” x 0.5” on top of the mulch and stepping on the wood. (Figure 6)

Figure 6.

Step 5. Next, the frame was gently removed. The mixture and the metal sheet were then placed inside the heat press. (Figure 7)

Figure 7.

Step 6. Next, a second stainless steel metal sheet, 24” x 24” in size, was placed on top of the mixture. Steel rods, measuring 26.5” X 1.0” x 0.5”, were then placed on opposite sides of the mulch tile. (Figure 8)

Figure 8.

Step 7. The mixture was then pressed for 5 minutes at 750 psi, 350°F. (Figure 9)

Figure 9.

Step 8. After five minutes, the press was released and the materials inside the press were removed. (Figure 10)

Figure 10.

Step 9. Next, the mulch tile was removed from the metal sheets and the mulch tile was set aside to cool. (Figure 11)

Figure 11.

Experimental Testing and Validation of Prototype

The following experiments were conducted to validate and test the mulch tile prototypes: mulch tile swell tests (non American Society for Testing and Materials standards); mulch swell tests according to ASTM standards; relative humidity tests; modulus of rupture (MOR) tests;

flammability tests; and natural environment (outdoor) tests. In addition, Chip Incorporated tested pressing the mulch tiles at different temperatures as well as tested pressing two other types of mulch, cypress and pine. From these experiments, Chip Incorporated concluded that a mulch tile with a density of 0.65g/cm^3 and 6% wheat starch content was the ideal mulch tile.

Mulch Swelling Tests

A total of eight mulch tile samples, 4.75" x 4.75" x 0.5" in dimension, were subjected to a thickness swelling test on February 16, 2010. Each mulch tile was placed in an individual pan containing a layer of soil in order to simulate outdoor conditions. Figure 12 shows how the experiment was set up. Prior to the start of the experiment, the maximum and minimum thickness measurements of each tile were taken. 200 mL of water was poured over the top of each tile. The thickness swelling of each tile was measured every two hours, from 1 pm to 11 pm, and then once more the following day (February 17 at 10 am). The maximum and minimum thickness measurements of each tile were taken again to determine swelling.

Figure12. Mulch swell tests set up.

The average thickness swelling of each mulch tile was found by using the following equation:

$$Thickness\ Swelling\ (\%) = \frac{Final\ Thickness - Initial\ Thickness}{Initial\ Thickness} * 100$$

Equation 1.

Table 1 lists the properties of the mulch tiles. Column one indicates the sample number. Column two indicates the type of starch that was mixed in with the mulch. The third column indicates the quantity of starch in each mulch tile. All of the samples were subjected to 750psi and a temperature of 350°F by the small heat press.

Table 1. Properties of mulch squares used in the first mulch swell tests.

Sample	Starch Type	Quantity (g)
1	Corn	5
2	Corn	5
3	Wheat	5
4	Wheat	5
5	Corn	10
6	Corn	10
7	Wheat	10
8	Wheat	10

Results from the swell tests are shown below in Figures 13 & 14. Tables depicting recorded swelling measurements for the experiment can be found in Appendix G.

Results of Swell Test

Figure 13 depicts the thickness of one mulch tile before water was applied to it. Figure 14 displays how much one mulch tile swelled after water was applied to it.

Figures 13 & 14.

Results from the mulch tile swelling test indicate that after water was applied, maximum thickness swelling occurred anywhere between two to four hours for the mulch tiles composed of 5g of starch. The mulch tiles composed of 10g of starch experienced maximum swelling from two to eight hours, with three of the tiles experiencing even more swelling at 11 hours.

Some samples shown in Figures 13 and 14 appear to swell, shrink, and swell again, such as is the case with one of the tiles for the Wheat 5g sample, Corn 10g sample and Wheat 10g

sample. This is due to the fact of the mulch tile falling apart as swelling measurements were taken and from mulch pieces falling off of the tiles during handling as well.

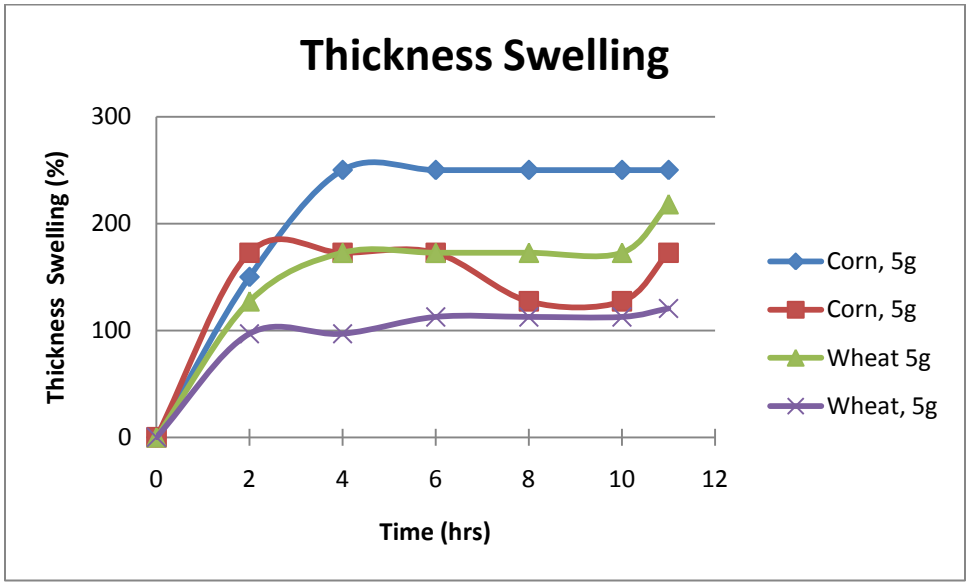

Figure 15. Maximum percent swelling, 5g starch tiles.

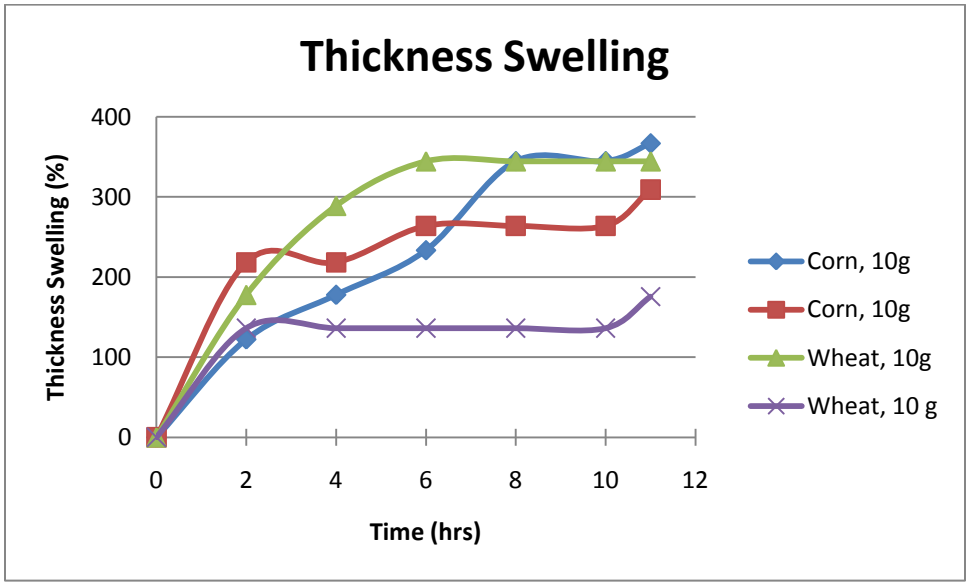

Figure 16. Maximum percent swelling, 10g starch tiles.

ASTM Standard Water Absorption and Thickness Swelling Test

A second experiment was conducted in order to determine thickness swelling and water absorption of the mulch tiles. In this experiment, the "Water Absorption and Thickness Swelling" procedures from ASTM Standard D1037 were followed. Method A 2 Plus 22-h Submersion Period was the method of choice from the ASTM D1037. Prior to water

submersion, each mulch tile was weighed and had thickness measurements taken at four points, midway along each side, one inch in from the edge of the tile.[5] These four points were averaged together, in order to determine initial thickness of each tile.

Following the ASTM standards, each mulch tile was submerged horizontally under one inch of water for two hours. After two hours, each mulch tile was once again weighed and had thickness measurements taken again at the same four points, midway along each side. The average of these four points was taken and used with the initial measurements in order to determine thickness swelling after two hours. The percentage of water absorption, by weight, as well as the average swell in each mulch tile tested can be found in Table 2. The average thickness swelling in the mulch tiles was found using the following equation:

$$Thickness\ Swelling\ (\%) = \frac{Average\ Final\ Thickness - Average\ Initial\ Thickness}{Average\ Initial\ Thickness} * 100$$

Equation 2.

Once these measurements were taken, the mulch tiles were once again submerged under water, this time for a period of 22 hours. After 22 hours had passed, the team attempted to take thickness swelling measurements again. However, none of the tiles held together at the end of the additional 22 hour submersion under water. Therefore, no further measurements were taken.

ASTM Water Absorption and Thickness Swelling Tests Results

Table 2. Results from ASTM water absorption and thickness swelling tests.

Sample Type	Density (g/cm^3)	Water Absorption by Weight (%)	Average Swell (%)
Wheat Starch (3%)	0.65	128.8	71.9
Wheat Starch (5%)	0.65	119.5	74.2
Wheat Starch (6%)	0.65	104.8	82.5
Corn Starch (6%)	0.65	107.2	111.9
Wheat Starch (6%)	0.75	119.2	56.7
Wheat Starch (6%)	0.75	100.3	83.3
Corn Starch (6%)	0.75	100.5	44.5
Corn Starch (6%)	0.75	90.8	43.7

[5]ASTM Standard D1037, 2003. *"Standard Test Methods for Evaluating Properties of Wood-Base Fiber and Particle Panel Materials"*. ASTM International, West Conshohocken, PA, 2006.

Conclusions

As shown in Table 2, the results from this test are varied and show an inconsistent pattern in water absorption and swelling. However, the mulch tiles appear to swell less at a higher density. In order to make the tiles more aesthetically pleasing, it is desired that the mulch tiles swell considerably after water application. Therefore, Chip Incorporated decided that a density of 0.65g/cm^3 should be used when creating the mulch tiles.

Relative Humidity Tests

Tests were conducted in order to see how the mulch tiles reacted to high levels of relative humidity. The mulch tiles were subjected to a relative humidity of 96% in order to simulate a typical, hot Oklahoma summer day. It was desired that the mulch tiles did not swell when subjected to high relative humidity conditions. This was important in regards to temporary storage and shelf life of the mulch tiles before use.

In this experiment, the mulch tiles were placed inside a sealed fish tank under humid conditions. The tiles were placed into three separate stacks, with three 0.65 g/cm^3 tiles in one stack, three 0.76 g/cm^3 in a second stack, and a single 0.75 g/cm^3 tile in the third stack. A hygrometer reading registered a relative humidity reading of 96% and a temperature of 80˚F inside of the fish tank. The experimental setup of the fish tank humidity test is show below in Figure 17 and 18.

Figure 17. Relative humidity test setup, with hygrometer and mulch inside of the fish tank.

Figure 18. View depicting condensation inside the sealed fish tank.

The mulch tiles were kept in the fish tank under these conditions for a period of five days. Initial thickness measurements of each mulch tile, as well as initial weight of the tiles were taken before the test began. The thickness of each mulch tile was measured at four points on the tile, midway along each side one inch in from the edge of the mulch tile, in accordance to ASTM D1037 standards. On the fifth day, the tiles were removed from the fish tank, and the thickness swelling and final weights of the tiles were recorded. The average of thickness swelling was taken from the four measured points on each mulch tile. The percent swelling at each of the four points was calculated using Equation 2.

Relative Humidity Results

Results from the relative humidity tests indicated that the wheat starch mulch tile that contained 6% starch at a density of 0.65 g/cm^3 had the least amount of thickness swelling, 2.04%, over a five day period between March 29 and April 2. The wheat starch mulch tile that contained only 3% starch at a density of 0.65 g/cm^3 had the highest average swelling, 27.3%, over the same five day period.

Table 3. Swelling of mulch tile results from relative humidity test, March 29-April 2.

Sample Type	Density (g/cm3)	Thickness Swelling (%)	Increase in Weight (%)
Wheat Starch (3%)	0.65	27.3	6.14
Wheat Starch (5%)	0.65	4.62	18.7
Wheat Starch (6%)	0.65	2.04	-4.10
Wheat Starch (6%)	0.75	20.4	5.90
Wheat Starch (6%)	0.75	20.8	8.93
Corn Starch (6%)	0.75	5.17	5.63
Corn Starch (6%)	0.75	3.08	7.29

By visual inspection, the mulch tiles showed no change following exposure to high heat and humidity. The quality of the mulch tiles was not compromised from the exposure. Mulch tiles remained intact and inflexible. Also, mulch tiles were dry to touch.

The mulch tiles were placed back inside the fish tank for an additional thirteen days. Each mulch tile was measured again for swelling. The overall amounts of swelling for each mulch tile for the eighteen day relative humidity test are shown below in Table 4.

Table 4. Swelling of mulch tile results from relative humidity test, March 29-April 15.

Sample Type	Density (g/cm3)	Thickness Swelling (%)	Increase in Weight (%)
Wheat Starch (3%)	0.65	30.2	11.2
Wheat Starch (5%)	0.65	30.0	18.7
Wheat Starch (6%)	0.65	22.4	10.8
Wheat Starch (6%)	0.75	27.8	11.0
Wheat Starch (6%)	0.75	9.1	13.0
Corn Starch (6%)	0.75	15.5	10.8
Corn Starch (6%)	0.75	9.2	11.7

The results from the five day humidity test showed that the 6% wheat starch, 0.65 g/cm^3 mulch tile had the least amount of swelling over a five day period. However, there is an increase in swelling for this tile when it was subjected to high humidity and temperature for an additional 13 days. In fact, all the mulch tiles experienced a significant increase in swelling. The mulch tiles felt moist to the touch after they were placed in the fish tank for eighteen days. There were two tiles that appeared to shrink in thickness. Inconsistencies in measurements may explain these results.

Conclusions

Overall, the relative humidity experiment provides evidence that exposure to high heat and humidity in storage and transportation for a short period of time (5 days) will not compromise the quality of the team's mulch tiles. Percent increase in swelling ranged anywhere from 9.1 % to 30.2 % over an eighteen day period.

Modulus of Rupture (MOR) Tests

The modulus of rupture (MOR), also known as flexural strength, a mechanical property for brittle material, is defined as a material's ability to resist deformation under load.[6] In the experiment, rectangular strips of mulch were placed in a Universal Testing Machine to find the MOR, as shown in Figure 19. The strips were supported on both ends and then subjected to an applied load in the middle of the beam until the onset of failure.

Figures 19 and 20. Universal Testing Machine used to test MOR of mulch tiles.

The machine recorded both the current loading stress and the load at the point of fracture. This force, as well as other measurable quantities of the material, was used in equation 3 below to calculate the experimental MOR for the mulch material.

$$\sigma = \frac{3FL}{2bd^2}$$

Equation: 3

The variable F is the load, or the force, at the point of fracture. The load was converted from pounds force into Newtons. L is the length of the support span between the two ends. The

[6] "Flexural Strength" Wikipedia, 3 October 2009. Web. 7 April 2010. <http://en.wikipedia.org/wiki/Flexural_strength>

variable b is the width of the rectangular beam. The variable d is the thickness of the rectangular beam. All length calculations were converted into millimeters. For the modulus of rupture calculations it was necessary to convert into SI units since the majority of our data points were measured in SI units. The MOR is measured in units of stress. The MOR was calculated in MPa.

MOR Results

The resulting MOR calculations were between 0.5 and 3 MPa, as shown in Table 5. Comparatively, particle board has a MOR between 11 and 17 MPa and a rectangular beam of Eastern Redcedar has a typical MOR of 60.7 MPa[7].

Table 5. Bending test results.

Sample Type	Density (g/cm^3)	Average Load (N)	Average MOR (MPa)
Wheat Starch (3%)	0.65	61.4	1.35
Wheat Starch (5%)	0.65	24.7	0.56
Wheat Starch (6%)	0.65	37.8	1.10
Wheat Starch (6%)	0.75	66.7	1.30
Wheat Starch (6%)	0.75	76.1	1.86
Corn Starch (6%)	0.75	31.6	0.89
Corn Starch (6%)	0.75	66.7	2.99

Conclusions

These results were expected due to the pliable nature of the mulch product. Based on the MOR results, there was no discernable correlation between the MOR and the mulch density, nor was there a discernable correlation between the MOR and the percentage of starch used.

Mulch Tile Flammability Test

The concern for the potential fire hazard of the mulch tile was high because Eastern Redcedar mulch is highly flammable.[8] A study conducted by the College of Agriculture and Life Sciences of the University of Arizona evaluated the relative ignition and flammability of eight common mulches. Results from the University of Arizona study showed that organic mulches had the greatest ability to ignite and burn when there was more air space between the particles.[9]

Chip Incorporated conducted a flammability test with one tile of the six percent wheat starch and a density of 0.65 g/cm^3. A propane torch was used to ignite the mulch tile applying a direct

[7] "Wood Technology Fact Sheet" USDA Forest Service, 1996. Web. 7 April 2010. <http://www.fpl.fs.fed.us/documnts/TechSheets/SoftwoodNA/roughhtmlDocs/junipe4.html>
[8] "Landscaping Firewise" SC Forestry Commission, 2005. Web. 24 April 2010. < http://www.state.sc.us/forest/>
[9] "Comparing the Ignitability of Mulch Materials for a Firewise Landscape" Arizona Cooperative Extension, September 2007. Web. 24 April 2010. < http://ag.arizona.edu/pubs/natresources/az1440.pdf>

flame to the edge. It took approximately 30 seconds for the mulch to ignite. After 60 seconds the flame had died down and the mulch tile began to smolder. The mulch tile was then positioned where air could contact directly with the mulch and the open flame. Approximately 12 minutes elapsed and only a small corner of the mulch tile was burned as shown in Figure 21. The reaction was far from highly flammable. It would have taken significantly longer for the entire mulch tile to be consumed by the fire.

Figure 20 & 21. Mulch Flammability Testing.

One explanation for this result was the mulch tile was denser than loose mulch, therefore it was likely to be less flammable. Loose Eastern Redcedar mulch has the density of 0.55 g/cm^3 compared to the 0.65 g/cm^{3}density of the mulch tile. This is a 17.5% increase in density. The denser the mulch particles are in the mulch tile, the less airspace there is between the particles. This allows for less oxygen to be present in the tile to fuel the fire. Also, the starch binder may have had an effect on retarding the flammability of the mulch tile. According to the FDA, wheat starch is a 'Generally Recognized as Safe (GRAS) substance."[10] The material safety data sheet lists the flammability of the substance as a 1, meaning the substance may be combustible at high temperature.[11]

Conclusions

The mulch tile showed relatively low flammability behavior when ignited. Chip Incorporated concluded that high density of the mulch tile is the main cause for the low flammability.

Press Temperature Tests

Chip Incorporated had been pressing all of the mulch tiles used in the experiments at 350°F, as was suggested by Dr. Salim Hiziroglu. However, Chip Incorporated wanted to test pressing the

[10] "Material Safety Data Sheet Starch" Archer Daniels Midland Company (ADM), 22 August 2006. Web. 24 April 2010. <http://www.envirostrip.com/pdfeng/1690msds.pdf>

[11] "Material Safety Data Sheet Starch, Wheat Powder MSDS" Science Lab, 2005. Web. 24 April 2010. <http://www.sciencelab.com/msds.php?msdsId=9924562>

mulch tiles at a lower temperature. A total of three mulch tiles were created using varying press temperatures. The first and second mulch tile had a density of 0.65g/cm^3, and the third mulch tile had a density of 0.75g/cm^3.

Press Temperature Results

The first mulch tile was pressed at the following temperatures and press times: 180°F for two five minute intervals, 200°F for five minutes, and 250°F for five minutes. The mulch tile remained in the press as the temperature was increased each time.

When pressed at 180°F, for five minutes, the mulch tile did not press and the mulch crumbled when touched. The tile was pressed again at 180°F for an additional five minutes. After the second press, the mulch stuck to the metal sheets. Figure 22, shown below, displays what the mulch tile looked like in the press.

Figure 22. Mulch stuck to stainless steel sheets in heat press.

The same tile was pressed again, this time at 200°F, for another five minutes. However, the results were still the same; the mulch still stuck to the sheets. The mulch tile was pressed once more, this time at 250°F, for another five minutes. This time, the mulch only stuck to the bottom of the metal sheet, as is shown in Figure 23.

Figure 23. Mulch tile stuck to sheet after being pressed at 250°F.

When looking at the mulch tile, the tile appeared gooey inside. This allowed for the tile to be very flexible, as is shown in Figure 24.

Figure 24. Flexibility of mulch tile pressed at 250°F.

The second mulch tile in this experiment was pressed at 275°F for a total of five minutes. The resulting tile was identical to the tiles that had been pressed at 350°F, except for the fact that it was slightly more flexible than the 350°F tiles. Pressing at 275°F appeared to be the lowest temperature that the mulch could be pressed at and result in a mulch tile.

The third mulch tile created in this experiment differed from the others because it had a density of 0.75g/cm^3. At this density, the mulch had to be pressed for a total of ten minutes to create the mulch tile. After the first five press minutes, the mulch stuck to the metal sheets. However, after being pressed for an additional five minutes, the mulch tile was successfully created.

Conclusions

The lowest temperature that the mulch could be pressed at, and result in a mulch tile, was 275°F. The temperature had to be this high to activate the natural oils in the cedar mulch and transform them to a resin-like substance to bind the wheat starch to the mulch. If the press temperature is too low, there will not be enough densification on the outer surfaces of the tile. The lack of densification is the reason the mulch was sticking to the metal sheets when pressed at temperatures lower than 275°F.

Outdoor Tests

Chip Incorporated concluded the ideal mulch tile had a density of 0.65g/cm^3 and contained 6% wheat starch. Chip Incorporated then created several samples of the ideal mulch tile that were then tested under the natural elements of the outdoors.

Two mulch tiles (Set 1) were placed outside of the BAE greenhouse, on top of bare soil, on March 31, 2010. Figure 25 shows one of the mulch tiles placed on the bare soil.

Figure 25. Mulch tile and exposed bare soil.

These tiles were left outside until April 22, 2010. Over this time period of 23 days, the tiles experienced a total of 2.68 in of rainfall. Table 6 shows how much rain the mulch tiles received on a daily basis. Data was obtained through the Oklahoma Mesonet which is available online. Mesonet data shows the rainfall, average temperature, and average humidity for each day of the experiment. All days except April 21 data were collected from the Mesonet station in Stillwater, OK. April 21 data from the Stillwater site was unavailable; data from the Perkins, OK site was used in its place.

The rainfall data reflects the rainfall accumulation, in inches, over a 24 hour period. Average temperature is an average of the minimum and maximum temperatures recorded over a 24

hour period. Average temperature is reported in degrees Fahrenheit. Average humidity is the average relative humidity, reported as a percentage. Average humidity is an average of the minimum and maximum relative humidity values recorded over a 24 hour period.

Table 6. Oklahoma Mesonet Data, Stillwater OK, March 31 – April 22, 2010.[12]

Month	Day	Rainfall (in)	Average Temperature (˚F)	Average Humidity (%)
March[13]	31	0.00	74.2	39
April	1	0.00	71.6	58
April	2	0.84	61.8	58
April	3	0.00	57.6	47
April	4	0.00	72.8	52
April	5	0.00	71.4	78
April	6	0.59	72.3	64
April	7	0.00	48.9	68
April	8	0.00	50.5	54
April	9	0.00	60.3	41
April	10	0.00	64.4	43
April	11	0.00	66.1	65
April	12	0.00	68.5	64
April	13	0.00	68.5	53
April	14	0.00	68.5	51
April	15	0.00	68.8	60
April	16	0.45	59.0	89
April	17	0.33	53.7	86
April	18	0.46	51.3	90
April	19	0.00	55.6	74
April	20	0.00	57.2	74
April[14]	21	0.00	62.9	78
April	22	0.01	69.0	73

Two more mulch tiles (Set 2) were placed outside of the BAE greenhouse, on top of bare soil, on April 15, 2010. These tiles were left outside until April 22, 2010. Over this time period of 8 days, the Set 2 tiles experienced a total of 1.25 in of rainfall.

Figures 26 through 41 show how the Set 1 and Set 2 mulch tiles changed in appearance throughout the course of the outdoor tests.

[12] Oklahoma Mesonet. "Mesonet Climatological Data Summary (STIL) Stillwater". Oklahoma Mesonet. April 2010. Web. 18 April 2010. < http://www.mesonet.org/>.
[13] Oklahoma Mesonet. "Mesonet Climatological Data Summary (STIL) Stillwater". Oklahoma Mesonet. March 2010. Web. 18 April 2010. < http://www.mesonet.org/>.
[14] Oklahoma Mesonet. "Mesonet Climatological Data Summary (PERK) Perkins". Oklahoma Mesonet. April 2010. Web. 18 April 2010. < http://www.mesonet.org/>.

Figure 26 & 27. Set 1 mulch tiles on March 31, 2010, prior to receiving any rainfall (left). Set 1 mulch tiles on April 2, 2010, after receiving 0.84 inches of rainfall (right).

Figures 28 through 31 (Clockwise, from upper-left hand corner). Figures 28 and 29 are the Set 1 mulch tiles, on April 15, 2010, after 16 days and 1.43 inches of rainfall. Figure 29 shows the flexibility of one of the Set 1 mulch tiles. Figure 31 is a comparison of a new Set 2 mulch tile to

the Set 1 tiles that have already experienced some weathering. Figure 30 shows the Set 2 mulch tiles, prior to any rainfall or weathering.

Figures 32 and 33 (from left to right). Figure 32 are the Set 1 mulch tiles on April 16, 2010, after 16 days and an overall total of 1.88 inches of rainfall. Figures 33 are the set 2 mulch tiles, on April 16, 2010, after 1 day and an overall total of 0.45 inches of rainfall.

Figures 34 through 37 (Clockwise, from upper-left hand corner, on previous page). Figures 34 and 35 are the Set 1 mulch tiles on April 17, 2010, after 17 days and 2.21 inches of rainfall. Figures 36 and 37 are the Set 2 mulch tiles on April 17, 2010, after 2 days and 0.78 inches of rainfall.

Figures 38 through 41 (Clockwise, from upper-left hand corner). Figures 38 and 39 are the Set 1 mulch tiles on April 18, 2010, after 18 days and 2.67 inches of rainfall. Figures 40 and 41 are the Set 2 mulch tiles on April 18, 2010, after 3 days and 1.24 inches of rainfall.

Figures 42 and 43. From left to right, the Set 1 and Set 2 mulch tiles, dry on April 22, 2010. At this point, Set 1 and Set 2 had experienced an overall total of 2.68 and 1.25 inches of rainfall, respectively.

Conclusions

Results from Set 1 and Set 2 outdoor tests showed that exposure to the weather conditions of the natural environment (ie. rainfall, temperature and humidity changes, wind, and sun exposure) caused noticeable swelling and changes in texture. In addition, the mulch tiles remained intact through the course of the experiment. The mulch neither washed away due to rainfall exposure, nor did it blow away due to wind exposure. After exposure to rainfall, the mulch tiles exhibited noticeable expansion and swelling.

Prior to testing, the mulch tiles had a smooth, hard surface, as shown in Figure 44. After exposure to the elements, the mulch tiles had a rough, uneven surface which resembled that of traditional bagged mulch, as shown in Figures 45 and 46. Swelling and textural changes contributed to a more natural-looking appearance of the tiles. These changes were desirable, as they made the tiles more aesthetically pleasing. Also, results showed that the mulch tiles need not be watered after placement in a landscape. Instead of watering the tiles, the end user could simply wait for a rainfall event.

Figure 44. Close-up of a pressed mulch tile prior to exposure to weather condition of the natural environment.

Figures 45 and 46. Close up of Set 1 and Set 2 mulch tiles, April 22, 2010.

In conclusion, the results from the outdoor test were promising. Results showed that the mulch tiles remain intact and were aesthetically pleasing, even after exposure to the elements.

Cypress and Pine Mulch Tile Testing

In addition to creating mulch tiles out of Eastern Redcedar, Chip Incorporated tested creating the tiles out of cypress and pine mulch. The cypress and pine mulch tiles were created using the small press, following the same procedures as were used with the small Eastern Redcedar mulch.

The process proved to work when using the different types of mulch. No further testing was done with the cypress and pine mulch, as this was not the focus of the project.

Testing Results, Discussion, Conclusions & Recommendations

Experimental results showed that the mulch tiles can withstand humidity and temperature extremes, along with reasonable wear and tear anticipated in shipping, handling, and storage.

The previous experiments showed when exposed to high heat and humidity, the mulch tiles showed no visible expansion or change in texture. Since the mulch tiles can withstand humidity and temperature extremes, they will not need to be stored in a temperature or humidity controlled environment.

Experiments have also shown that the mulch tiles will remain inflexible and have a smooth, hard surface until they have been exposed to water. After exposure to water, the mulch tiles expand and have a rough surface that resembles traditional bagged mulch. These changes make the mulch tiles look natural and aesthetically pleasing.

In addition, the mulch tiles were able to withstand a reasonable amount of force and it is unlikely that they will break during shipping and handling.

In conclusion, Chip Incorporated proved that the mulch tiles can hold up to the extremes in temperature and humidity, along with wear and tear from storage and shipping, without compromising the value of the product for the end user.

Comparison in Storage Requirements Between Mulch Tile and Bagged Mulch

Calculations were made to determine the amount of mulch used in an individual mulch tile. Comparisons were made on both volume and mass basis. A typical bag of mulch has a volume of 2 to 3 ft^3. On a volume basis, a 3 ft^3 bag of mulch is equivalent to seven mulch tiles. Using a mass basis, a 3 ft^3 bag of mulch is equivalent to five mulch tiles. The calculations made in order to determine these values are described in the following paragraphs.

The volume of the mulch tile prior to compression was calculated using the following equation:

$$V = length * width * height$$

Equation 4.

The variable V is equal to the volume of the mulch tile. Length and width are measurements of the surface area of the tile. The height is equal to the thickness of the mulch inside the frame before compression. For a mulch tile with a density of 0.65 g/cm^3, the depth before compression was 2 inches. Using the equation above, the uncompressed volume of one mulch tile is 0.396 ft^3.

Previous experiments showed that when exposed to water, both the length and width of the pressed tile expanded 0.5 inches. The average thickness swelling of a pressed mulch tile, once wet, was 1.2 in, resulting in an overall swelled volume of approximately 0.44 ft^3. After the mulch tile had fully expanded, the density decreased to approximately 0.16 g/cm^3. The density

of one bag of mulch (3 ft^3) was approximately 0.11 g/cm^3, which is 37% less dense than a fully expanded mulch tile.

On a volume basis, one 3 ft^3 bag of mulch is equivalent to seven pressed mulch tiles and one 2 ft^3 bag is equivalent to five pressed mulch tiles. A pressed mulch tile is approximately 500% more dense than loose mulch. When stacked, either during shipping or storage, seven tiles take up approximately 1.13 ft^3 of space. Compared to a bag of mulch, the mulch tiles will save more space in storage and transportation.

One bag of mulch (3 ft^3) weighs approximately 20 lbs. Each individual tile weighs approximately 3.8 lbs. On a mass basis, one 3 ft^3 bag of mulch is equivalent to 5 mulch tiles. The mulch tiles require less space than bagged mulch, but they also weigh more.

Table 7. Comparison of space saved using mulch tiles versus bagged mulch.

Bagged Mulch Volume	Equivalent Amount of Mulch Tiles Per Bag	Mulch Tile Volume	Space Saved Using Mulch Tiles
3 ft^3	7	1.13 ft^3	62%
2 ft^3	5	0.805 ft^3	60%

Figure 47: Top View – Side by side comparison

Figure 48: Front View – Side by side comparison

Business Plan/Financial Analysis

The client encouraged Chip Incorporated to design a "mulch tile" that would simplify the mulching process, reduce shipping cost, save space, and be priced comparably with bagged mulch.

The potential users of the mulch tiles are landscapers who install mulch for homeowners or businesses and retailers that sell mulch to customers. Information on the spending habits and financial strengths of the potential customers, the cost and availability to manufacture the device, the terms secured from the supplier or manufacturer, and the availability to market and sell the device not only on the local market, but state wide and even possibly nationwide would also be considered in the final manufacturing costs.[15]

Chip Incorporated created a list of questions that the team had planned to ask at The Carter County Annual Spring Show in Ardmore, Okla., however the team discovered this was not the right setting for landscapers, and there were very few, if any, in attendance.

Chip Incorporated's mulch tiles are a new idea, and there is not currently a similar product on the market. There is no direct competition from anyone with the same product. However, bagged mulch is not a new idea. The mulch tiles must be priced comparably and offer more benefits to customers to be competitive with the existing bagged mulch market.

Chip Incorporated's business plan would include a mulch product supplier or someone with the time and resources available to potentially manufacture the mulch tiles and distribute them from their location to retailers as needed. For example Green Country Soils in Miami, Okla., would be a potential mulch supplier. They would manufacture them and distribute the mulch tiles to retailers across Oklahoma, where customers would then purchase them. Ultimately, the mulch tiles would appeal to the end customer; however the target market to manufacture the product would be the landscapers and mulch suppliers.

Chip Incorporated has created several different prototypes of mulch tile sizes as well as various mulch varieties. However, the team will not be designing an actual mulch tile press or assembly line for manufacturing the mulch tiles on a large scale. There is simply a proposed process. The team has determined the ratio of mulch to wheat starch needed as well as the amount of heat and pressure required to make the mulch tiles. Therefore, it is somewhat difficult to assign a final number to the actual cost of producing the mulch tiles, most costs are assumed. Chip Incorporated made an assumption that the cost of producing a piece of particleboard will be very similar to producing a mulch tile.

[15] Abrahams, Rhonda. *The Successful Business Plan: Secrets and Strategies.* California, 2003. Text

In an ideal situation, the potential manufacturer of the mulch tiles would not have to invest a large sum of money in input costs such as equipment and facilities, to create the mulch tiles. They would have an existing business and could expand their operations to accommodate manufacturing the mulch tiles easily. However, the team does not know what the situation will be, and producing the mulch tiles could be costly if no previous resources are available.

Proposed and Actual Budget

Chip Incorporated had received a spread sheet from Dr. Rodney Holcomb, an Agricultural Economics professor at Oklahoma State University, with the price of building a particleboard plant which we used to compare the approximate price of making our mulch tiles. The team also used the production rate of 32 tons per day of the plant to base the production scale. Dr. Salim Hizaroglu, gave the team a flow chart of typical particleboard manufacturing and the team modified it for our proposed mulch tiles process. This is in Figure 49, on the next page.

The four major costs associated with the mulch tile facility are going to be a kiln for drying the mulch, the mixing drum to mix the mulch and starch, the press for making the tiles, and conveyor belts to move the material from one place to another. There will be some additional labor cost depending on the design and equipment used in the facility.

The team researched the approximate cost to buy the equipment needed at a used price. With research it was found that a kiln ranges in cost from $18,000-$30,000[16], a batch mixer anywhere from $500-$3,000[17], and a used press from $100,000-$200,000[18]. And the conveyor belt price would strictly depend on the design of the facility and also the amount needed.

Land and facilities to make the actual tiles are another cost. The team spoke with Shea Pilgreen, and determined the approximate cost to build a facility from the ground up. The team assumed a 2,000 square feet facility, at $30 per square foot with additional outside covered storage, making the approximate cost $60,000.[19] However this cost can be greatly reduced if there is any type of existing business in place and land or a facility would not have to be purchased.

The final costs are the input cost of the mulch tiles, mulch and wheat starch. The cedar mulch was donated for our project, but can be purchased from Eastern Redcedar, Aaron Newton, for $20 per cubic yard. Wheat starch can be purchased in 50lbs bags for $58.99 a bag.[20]

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[16] "Access Used Furnace" 20 April 2010. Web 21 April 2010. http://www.usedfurnaces.com/kilns1.html
[17] "Cole-Palmer" 21 April 2010. Web 21 April 2010. http://www.coleparmer.com/products/mixersandoverheadstirrers/industrial-mixers.asp
[18] Dr. Salim Hizaroglu. Forestry Department. Oklahoma State University. 21 April 2010.
[19] Shea Pilgreen. Application Engineer. Oklahoma State University. 18 April 2010.
[20] "Honeyville Food Products" Web 21 April 2010. http://store.honeyvillegrain.com/wheatstarch50lb.aspx

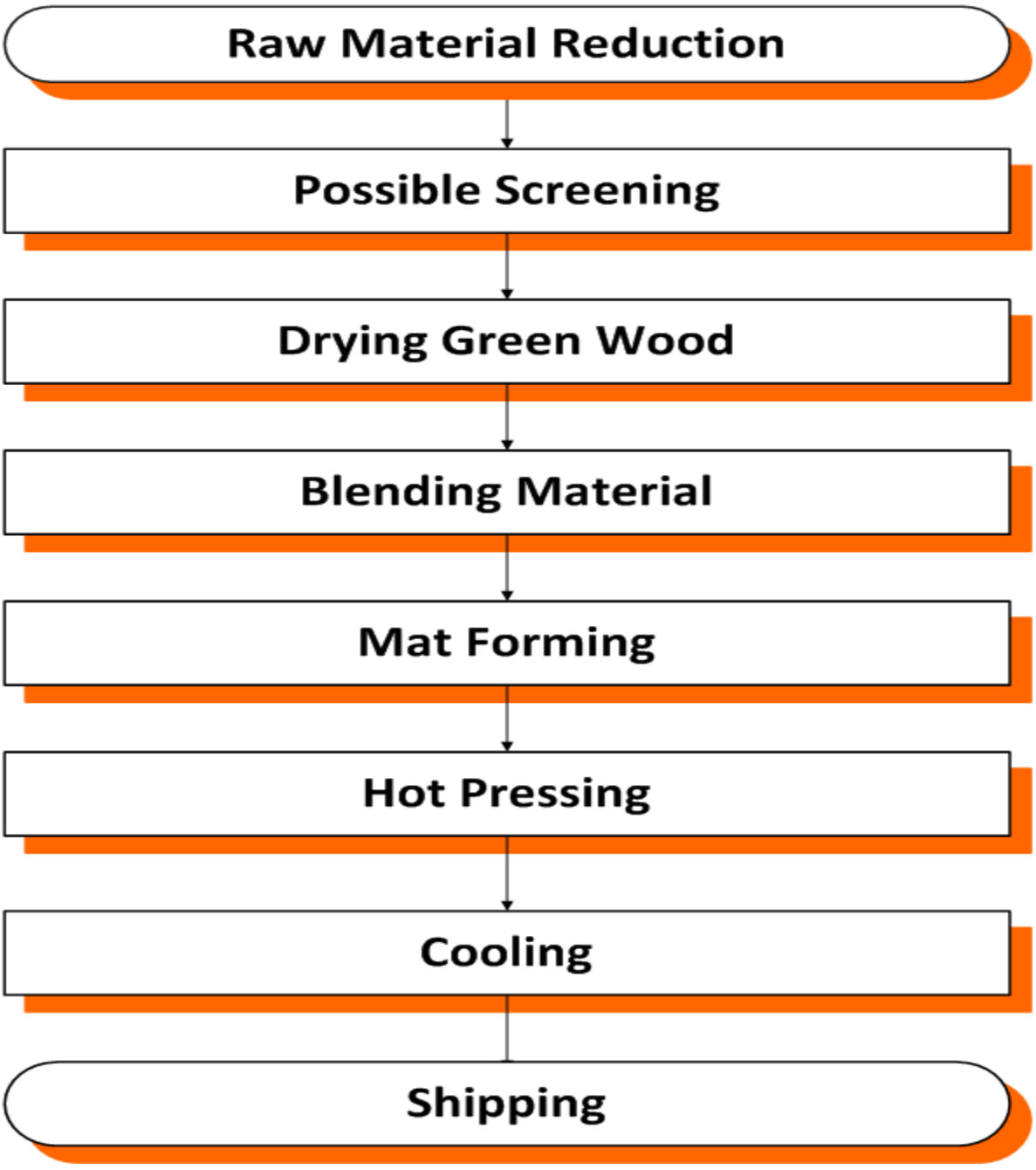

Figure 49. Proposed Mulch Tile Process.

Media and Communications Plan

This project was unique because it did not have an investor or sponsor. A goal of Chip Incorporated was to develop communications materials not only for users, but also for

potential investors. The audience for this product, as determined by Chip Incorporated, was investors, landscape professionals, and homeowners. A budget was not established for communications and marketing materials, however Chip Incorporated took a modest approach when design decisions were made.

The mulch tile was an innovative product with potential in a niche market. Because there is some competition for traditional wood based mulch, marketing the product is key. A cohesive design will help brand our product as a “Mulch Tile”.

The first product developed was the mulch tile logo. The simple design of this logo would be easy for customers to remember. This logo would be used in all communications materials to help achieve a unified design among all materials.

mulchtile

Figure 50. Mulch Tile logo

To promote the product worldwide, Chip Incorporated developed the Mulch Tile website. It is a three page website with an introduction page, an investor page, and a user page. Each page is focused to their specific area providing the viewer with more information on all aspects of the Mulch Tile and its process.

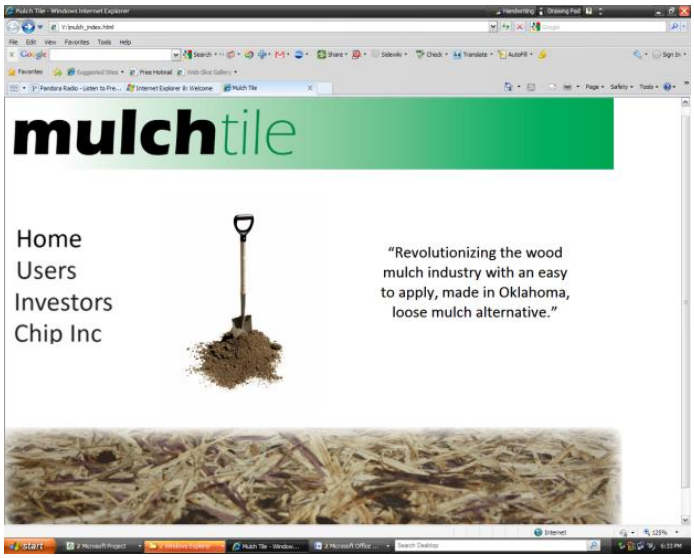

Figure51. Mulch Tile index page

chip incorporated

To address our first audience area, Chip Incorporated developed materials to inform potential investors about the production process. Materials developed include: an informative PowerPoint to be used when pitching the process to potential investors, a mailer-style brochure to send to investors in a bulk mailing, and an investor's page on the Mulch Tile website.

Figure 52. Investor page on Mulch Tile website.

Figure 53. Investor Brochure

The second audience group Chip Incorporated targeted was the homeowners and landscape professionals. A brochure outlining how to use the product was developed. Two forms of this brochure were made. One with a mailer to be sent out to landscape professionals and one with a designed back to be placed in stores and be used at tradeshows. A page was also developed on the Mulch Tile website to display information on where Mulch Tiles could be purchased and how to use the Mulch Tile.

Figure 54. User page on Mulch Tile website.

Figure 55. User Brochure with Mailer

Figure 56. User Brochure with Designed Back.

The materials in the Mulch Tile communications plan had several design concepts to help maintain cohesiveness. Common elements include the Calibri font family, Pantone green color choice, Mulch Tile logo, and the mulch photo. All elements were created using the Adobe Creative Suite.

Media and Communications Budget

The communications plan consists of three separate brochure styles. These brochures can be printed from Fed-Ex Office for $1.23 per brochure[21].

According to the Unites Stated Postal Service website, the cost to mail the mailer-style brochures is $.44 apiece[22].

To purchase the www.mulchtile.com website from Go Daddy, the site will cost $10.69 per year[23].

Users Guide & Safety Precautions

A users' guide was developed as part of Chip Incorporated's communication plan and can be found in Figure 56. Mulch tiles should not be stored close to an open flame. Gloves should also be worn when handling the mulch tiles as the rough edges could cause abrasions on exposed skin. Users with Eastern Redcedar allergies should not handle this product.

Possible Environmental, Society, or Global Impacts

Eastern Redcedars are not just a nuisance; they are a pervasive problem for Oklahomans. Eastern Redcedars are a detriment to farmers as they consume large amounts of water. Research from Oklahoma State University has shown that a single acre of Eastern Redcedars can absorb as much as 55,000 gallons of water per year[24]. This has far reaching implications for Oklahomans. First, they are a threat to Oklahoma's water resources. Their high water consumption limits the amount of water that flows to underground aquifers, as well as lakes and streams. Also, they threaten to starve farmer's crops by competing with them for water.

Another problem with Eastern Redcedars is they are a tremendous fire hazard. The trees have low branches, which are easily ignited by grass fires. In addition, Eastern Redcedars burn hot,

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[21] Fed-Ex Office. Copy & Print. *Full Color Brochure*, 2010. Web. 25 April 2010. <http://fedex.com/us/office/copyprint/brochures/tri-fold_brochures.html?lid=brochures_brochuresindex_brochures >.
[22] United States Postal Service. Products and Services *Prices*, 2010. Web. 25 April 2010. <http://www.usps.com/prices/welcome.htm >.
[23] Go Daddy. Domain Name Search Tool. 2010. Web. 25 April 2010. <http://www.godaddy.com/domains/searchresults2.aspx?ci=16811>.
[24] "Eastern Redcedar Mapping Project." Biocity News 2, 2009. Web. 15 April 2010. <http://boisecitynews2.wordpress.com/2009/03/03/oklahoma-launches-plan-to-battle-eastern-redcedar>

leading to deadly wildfires. These issues have a high cost for Oklahomans, Eastern Redcedars "cost Oklahoma an estimated $218 million dollars annually through catastrophic wildfires, as well as loss of cattle forage, wildlife habitat, recreation and water yield. By 2013 that figure is expected to increase to $447 million if major preventative control steps are not taken"[25]. In order to control Eastern Redcedars, land owners are encouraged to cut down cedars or practice prescribed burning. Many land owners do not heed this advice, as they do not see any economic reasons to do so.

Chip Incorporated's mulch tiles contribute to the preventative control of the Eastern Redcedar population by creating a demand for Eastern Redcedar mulch. This, in turn, encourages land owners to cut down and harvest Eastern Redcedars for mulch. Land owners are far more likely to cut down cedars if they do so for a profit. Not only does this create a market value for Eastern Redcedars, but it effectively reduces their population. A reduction in the Eastern Redcedar population reduces the costs and hazards associated with them. Chip Incorporated's mulch tiles are an innovative solution to the problem of overpopulation of Eastern Redcedars.

Figure 57. Eastern Redcedars overpopulating a field in Oklahoma.[26]

[25] "Eastern Redcedar Mapping Project." Biocity News 2, 2009. Web. 15 April 2010. <http://boisecitynews2.wordpress.com/2009/03/03/oklahoma-launches-plan-to-battle-eastern-redcedar>

[26] Hiziroglu, Salim. "Value-Added Composite Panels Manufactured from Under-Utilized Species in Oklahoma". Oklahoma State University. August, 2006. Microsoft PowerPoint file. 21 April 2010.

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13. "Wood Technology Fact Sheet" USDA Forest Service, 1996. Web. 7 April 2010. <http://www.fpl.fs.fed.us/documnts/TechSheets/SoftwoodNA/roughhtmlDocs/junipe4.html>.
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19. Hiziroglu, Salim. “Value-Added Composite Panels Manufactured from Under-Utilized Species in Oklahoma”. Oklahoma State University. August, 2006. Microsoft PowerPoint file. 21 April 2010.
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23. United States Postal Service. Products and Services *Prices*, 2010. Web. 25 April 2010. <http://www.usps.com/prices/welcome.htm >.

Appendix A: Statement of Work

Objective

Chip Incorporated will create a wood mulch product that utilizes native Oklahoman products to make the task of mulching more efficient**.**

Background

Chip Incorporated wishes to improve the wood mulch industry by developing a product that is easy to ship, pack, and use for both homeowners and landscape professionals.

Scope of Work

Chip Incorporated will turn in a design report on April 29, 2010 that includes a problem statement, statement of need, work breakdown structure, and task list. The work breakdown structures for the Fall and Spring semesters can be found in Appendix B and Appendix C, respectively. In addition, the report will also include the following:

- Competitive analysis report including market and patent research
- Proposed communications plan
- Generation of design concepts
- Gantt chart project schedule
- Proposed budget

Chip Incorporated will present a design proposal oral presentation that will include all material presented in the design report to OSU professors and advisors on April 29, 2010.

Location of Work

Chip Incorporated will conduct research and report development using Oklahoma State University computer labs in Agriculture Hall. Fabrication for the prototype and product testing will be conducted in Dr. Salim Hiziroglu's, of the OSU Forestry Department, labs in Agriculture Hall and in the Food and Agricultural Product Center (FAPC) on the OSU campus. Outdoor tests of the prototype will be conducted at the BAE greenhouse.

Period of Performance

Chip Incorporated will begin work on the project on August 17, 2009 and complete the report on or before April 29, 2010.

Delivery Requirements

Tables 8 and 9 list the delivery requirements for Chip Incorporated, separated into Fall and Spring deliverables.

Table 8. Fall 2009 Semester Deliverables.

Date	Item Due
October 26, 2009	Competitive Analysis Report
October 30, 2009	Statement of Work
November 2, 2009	Work Breakdown Structure
November 6, 2009	Task List
November 23, 2009	Design Proposal Report Draft
December 3, 2009	Design Proposal Report Design Proposal Presentation
December 7, 2009	Team Website
December 8, 2009	Project Notebooks Self and Peer Evaluations
December 8-11, 2009	Team Leader Interviews

Table 9. Spring 2010 Semester Deliverables.

Date	Item Due
March 8, 2010	First Draft of Final Report
March 29, 2010	Second Draft of Final Report
April 5, 2010	Fabrication and Testing Complete
April 12, 2010	Preliminary Presentations in Class
April 19, 2010	Presentation Revisions Due
April 29, 2010	Design Proposal Report Design Proposal Presentation
May 3-7, 2010	Project Notebooks

Applicable Standards

ASTM D 1037 Standard Test Methods for Evaluating Properties of Wood-Base Fiber and Particle Panel Materials will be followed. Standard Test Methods will be used to evaluate modulus of rupture (MOR), water absorption and swelling.

Acceptance Criteria

The mulch tile will be accepted on the condition that the mulch tile performs as well or better than traditional wood mulch. This requires that after lawn placement and water application, the tile must expand and give the appearance that it has been spread out by hand.

Special Requirements

The following are special requirements needed in order to create the mulch tiles:

- The use of Dr. Hiziroglu's small and large heat presses will be required.

- The use of Dr. Hiziroglu's Universal Testing Machine will be required in order to conduct bending tests on the mulch tiles.
- A fish tank will be needed in order to test how the mulch tiles react to high relative humidity.
- A small plot of land south of the BAE greenhouse will be needed in order to conduct outdoor tests on the mulch tiles.
- Services from the BAE Lab will be required to cut out samples from large mulch tiles for testing purposes.

Appendix B: Fall 2009 Work Breakdown Structure

WBS 1.0 Design a Wood Chip Coloring System

WBS 1.1 Project Oversight

Provide guidance to successfully complete this project by May 4th, 2010, with minimal cost. Develop the standards for the wood chip coloring system and an operation manual. Provide a summary report and presentation to OSU professors and advisors on December 3, 2009. Report to the sponsor the alternative designs for the coloring system.

WBS 1.2 Develop Requirements

Learning from the existing technology for large scale coloring systems, Chip Incorporated will meet expectations to develop a viable wood chip coloring system for homeowners and landscape professionals.

WBS 1.3 Design Wood Chip Coloring System

Design a wood chip coloring systems based on the specification developed in WBS. 1.2.

WBS. 2.0 Background Research
August 2009 - December 2009

WBS 2.1 Patent Research

Conduct patent searches to determine relevant documents and evaluate their importance to our project.

WBS 2.2 Wood Properties Research

Conduct a literature review and consult with wood specialist to learn about the properties of wood relevant to our project.

- Meet with Dr. Hiziroglu to ask questions about the properties of wood and how they affect the dyeing process.
    - Jesi, October 10, 2009 and October 21, 2009
- Read through Understanding Wood A Craftman's Guide to Wood Technology for relevant and useful material
    - Jesi, October 10 – October 28, 2009

WBS 2.3 Dye Research

Research existing dye technologies to determine which processes to use in testing. Consult with specialists knowledgeable in this field.

- Conduct research over existing dyes on the market
    - Colorbiotics and Amerimulch
    - Alex, October 12 – October 28, 2009
    - Find out prices for ordering liquid dye
    - Jesi, November 23, 2009
- Research organic dyes that are on the market
    - Consult with representative from organicdye.com
        - Erin, October 12 – October 14, 2009
    - Look at prices for ordering a 55 gallon drum of liquid dye from organicdye.com and prices for ordering powdered dye
        - Find price for shipping and handling
            - Any special shipping issues: None.
            - Is the material hazardous in any way: No.
            - How is it shipped: Freight.
            - Price dependent on size.
    - Erin, November 4 – 16, 2009

WBS 3.0 Market Research

WBS 3.1 Competitive Analysis

September 2009 - November 2009

Research and determine competitors in Oklahoma and neighboring states in the natural and colored wood mulch market.

- Internet research for mulch producers
    - Jesi, Katie, Erin, Alex, Allison, October 23, 2009
- Internet research for mulch retailers
    - Jesi, Katie, Erin, Alex, Allison, October 23, 2009
- Develop database
    - Katie, October 23, 2009

WBS 3.2 Cost Analysis

September 2009- October 2009

Conduct research over current products and the prices available to consumers of both natural and colored wood mulch. Determine added value of colored wood mulch compared to natural wood mulch.

- Compile list of products and prices from competitors

- Jesi, Katie, Erin, October 23, 2009

- Calculated percent increase on colored wood chips vs. natural
  Erin, October 23, 2009

WBS 3.3 Surveying the General Public

November 2009

Develop survey to be passed out at Stillwater home improvement stores and rental companies to determine demand of product. Develop a telephone survey for landscape professionals in the state of Oklahoma to determine willingness to use product. Present findings to OSU professors and advisors in the December 3 presentation and report.

- Developed survey for Landscape Professionals and Retail Stores
  - Jesi, November 1, 2009
- Research and assign professionals to contact
  - Allison, November 1, 2009
- Develop survey script
  - Allison, November 15, 2009
- Conduct phone survey
  - Jesi, Katie, Erin, Alex, Allison, November 20, 2009
- Compile results in spreadsheet
  - Katie, November 25, 2009

WBS 4.0 Documentation

WBS 4.1 Hand Sketching

August 2009 – February 2010

Brainstorm and hand sketch design ideas.

- Brainstorming:
  August 2009 – September 2009 (completed)
  Create a large amount of possible ideas to potentially solve the problem. Each team member was required to come up with at least two designs.
- Rough Draft:
  September 2009 – October 2009 (completed)
  Using concepts and techniques seen in large scale coloring systems and our own ideas, rough sketches were drawn in our design notebooks.
- Revise Draft:
  October 2009 – November 2009
  After the scope and scale of our project was set our designs had to be modified to accommodate our OSU professors and advisors request.

- Approve Design:
  November 2009 – December 2009
  After OSU professors and advisors reviewed our rough sketches they were not satisfied with our designs. A set of our best, most innovative designs will be presented to him for his approval. The best will be selected and the team will continue to improve the design.
- Finalize Design:
  December 2009
  After the best design has been selected further improvement will be made to it. Certain design specifications will be assigned and the parts will be dimensioned. The design will be ready to be input into Solid Works.

WBS 4.2 Solid Works Drawings
January 2010 – April 2010
Create parts drawings and assembly of product in Solid Works.

- Solid Works Draft:
  December 2009
  Our finalized design will be put into Solid Works as a working model. The prototype will be fabricated based on the Solid Works model.
- Solid Works Assembly:
  January 2010
  Each created part in Solid Works will be assembled into a working system.
- Solid Works Animation:
  January 2010 – February 2010
  Using simulation features in Solid Works our system will be animated.

WBS 5.0 Engineering Review and Approve

WBS 5.1 Review and Approve Engineering
December 2009 – April 2010
This work will be complete when the engineering has approval from OSU professors and advisors.

- OSU Professors and Advisors Approval:
  December 2009 – April 2010
  The engineering will be submitted to our sponsor for approval.

- Applications Engineer Approval:
  The engineering will be submitted to our applications engineer for approval.
  December 2009 – April 2010
- BAE Lab Manager Approval:
  The engineering will be submitted to the BAE lab manager for approval.
  December 2009 – April 2010

WBS 5.2 Review, Approve, and Release Drawings
December 2009 – April 2010
This work will be complete when the Solid Works drawings have approval from OSU professors and advisors.

- OSU Professors and Advisors Approval:
  December 2009 – April 2010
  The engineering will be resubmitted to professors for approval.
- Applications Engineer Approval:
  The engineering will be resubmitted to our applications engineer for approval.
  December 2009 – April 2010
- BAE Lab Manager Approval:
  The engineering will be resubmitted to the BAE lab manager for approval.
  December 2009 – April 2010

WBS 6.0 Manufacture Small Scale Wood Chip Coloring System
February 2010 – April 2010
Present Solid Works drawings and specifications to manufacturer for fabrication of prototype.

WBS 6.1 Fabrication of parts
February 2010 – March 2010
Present Solid Works drawings and specifications to manufacturer for fabrication of prototype.

- Make a list of materials required to build the prototype.
- Purchase materials that are not already available in the BAE machine shop.
- Determine which parts can be fabricated in house and what needs to be fabricated elsewhere.
- For the parts that cannot be fabricated in house, place an order with another manufacturer.
- Once the parts are in, double check the specification sheets for accuracy.

WBS 6.2 Assembly

April 2010

- Assemble the coloring system parts using specifications.

WBS 7.0 Experiments and Testing

WBS 7.1 Testing

January 2009 – April 2010

Test various procedures for dyeing wood mulch. Both powdered and liquid dye will be evaluated. Tests will be conducted to evaluate the effectiveness of heat, pressure, and pulverization when dyeing wood chips. Spray and tumbling methods of dye application will also be assessed. Weathering effects will be evaluated in each experiment. A dehydrator will be used to construct drying curves for experiments.

- *Experiment # 1- Coloring woodchips with a mixing/tumbler device.*
  January 13, 2010 – January 15, 2010
  The team will look at coloring the various mulches with dye using a mixing/tumbler device, such as a mini-cement mixer.

- *Experiment #2- Using heat to aid in the dyeing process.*
  January 18, 2010 – January 22, 2010
  This experiment will look at coloring the mulch in conjunction with heat. Preliminary research has shown that applying heat while dyeing a material, such as wood, will help with the dyeing process. The team will test with a dryer system, an oven, and a kiln, if possible. The mulch will be mixed/tumbled during the experiment.

- *Experiment #3- Pressurized vacuum chamber approach*
  January 18, 2010 – January 22, 2010
  The team will also experiment dyeing the mulch using a pressurized vacuum chamber, which can be easily created with PVC pipe and caps. According the Dr. Bowser, the FAPC also has vacuum tumblers and a pressure retort that can be utilized.
- *Experiment #4- Hand held pressure painter device*
  January 25, 2010 – January 29, 2010
  The team will evaluate coloring mulch using a hand held pressure painter device while having the mulch reside in some sort of container that is either stationary or in rotation. This approach would most likely only work when using liquid dyes.

- *Experiment #5- Pounding powdered dye into mulch*
  February 1, 2010 – February 5, 2010
  The team will look to see if pounding powdered dye into the mulch will have a desired outcome.

- *Experiment #6- Affects of weathering on mulch*
  January 15, 2010 – April 1, 2010
  In addition to coloring the mulch, the team will look at the affects weathering has on the dyed mulch, i.e. rainfall, sunshine, extreme hot and cold temperatures, snow, etc.

WBS 8.0 Evaluate Prototype

WBS 8.1 Testing with Prototype
April 2010
The team will test how well the prototype works.

- Apply methods from experimentation that proved to work the best to the prototype.
- Based on results, the team will choose the final dyeing procedure to use with the small scale wood chip coloring system.

WBS 8.2 Functional Checks
April 2010
The prototype will be tested for functionality.

- Evaluate how well the prototype colors the wood mulch as well as limitations of the prototype.
- Develop standards of use and compile into a user manual. This manual will be evaluated during consumer testing.

WBS 8.3 Consumer Testing
April 2010
The prototype will be tested for product ease. The general public will test the prototype at local home improvement stores.

- Determine locations where testing will be conducted
  - Possible locations: Atwoods, Kinnunen, Tractor Supply and on the OSU campus

- Consult with necessary persons about liability concerns
    - Create a waiver for consumers to sign before operating the coloring system

WBS 9.0 Present Findings to Sponsor

WBS 9.1 December Presentation and Report

December 3, 2009

The team will present experiment results to the sponsor to justify the proposed designs developed for professors. A written report complete with patents, literature reviews, competitive analyses and other relevant documents will also be presented to our professors and Shea Pilgreen.

- Prepare report draft- Jesi, Katie, Erin, Alex, Allison
  Due Date November 23, 2009
- Make changes to report based on critique- Jesi, Katie, Erin, Alex, Allison
  Due Date December 3, 2009
- Develop team webpage- Katie
  Due Date December 7, 2009
- Develop power point- Jesi, Katie, Erin, Alex, Allison
  Due Date December 3, 2009

WBS 9.2 May Presentation and Report

May 4, 2010

The team will present the final design and prototype to professors. A demonstration of the final prototype will follow the oral presentation. A final written report complete with patents, literature reviews, competitive analyses and other relevant documents will also be presented to professors.

- Prepare report draft – Jesi, Katie, Erin, Alex, Allison: Due Date April 23, 2010
- Make changes to report based on critique- Jesi, Katie, Erin, Alex, Allison: Due Date April 29/20, 2010
- Develop power point- Jesi, Katie, Erin, Alex, Allison: Due Date April 29/30, 2010

Appendix C: Spring 2010 Work Breakdown Schedule

WBS 1.0 Design and Produce a Mulch Tile

WBS 1.1 Project Oversight

Chip Incorporated will develop a wood mulch tile to be used by homeowners and landscape professionals. A process will be developed to produce the tiles. Also, Chip Incorporated will survey industry professionals in order to determine market characteristics.

WBS 1.2 Develop Requirements

Chip Incorporated will meet the requirements outlined by our advisors.

WBS 1.3 Create a Mulch Time

Chip Incorporated will develop a mulch tile as outlined in WBS 1.1 and 1.2.

WBS. 2.0 Background Research

August 2009 – March 2010

WBS 2.1 Patent Research

A literature review of related patents was conducted in order to discover relevant documents and evaluate their importance to our project.

- Patents were found at the United States Patent and Trademark Office website, http://www.uspto.gov/.
    - Patent research was conducted from October 5 – October 14, 2009 by Jesi, Allison and Alex and again in February 2010.

WBS 2.2 Logo and Name Research

Research was conducted at the library at Oklahoma State University to determine if our proposed product names are unique.

- Research was conducted with the help of Suzanne Reimer.
    - Katie met with Suzanne Reimer in March 2010

WBS 3.0 Market Research

WBS 3.1 Cost Analysis

January 2010- March 2010

Research was conducted to find current prices for inputs used to create mulch tiles.

- Erin conducted this research in February 2010.

WBS 3.2 Surveying the General Public

January-March 2010

Develop survey to be passed out at Stillwater nurseries and landscape supply outlets to determine demand of product. Develop a survey for landscape professionals at the Ardmore Home Show to determine willingness to use product. Present findings to OSU professors and advisors in the spring presentation and report.

- Developed survey for nurseries and landscape supply outlets
    - Erin and Katie, February 2010
- Develop survey for landscape professionals
    - Erin and Katie, March 2010
- Conduct survey at Carter County Master Gardeners' Spring Garden Show
    - Erin, March 2010
    - Survey was not successful because the show targeted a different audience.
- Research nurseries and landscape supply outlets
    - Erin and Katie, March 2010
    - Outlets were not willing to participate or were not stationed in Stillwater when surveying would be conducted.

WBS 4.0 Documentation

WBS 4.1 Development of Proof of Concept

January 2010 – April 2010

The proof of concept for creating mulch tiles was developed with the help of Dr. Salim Hiziroglu of the OSU Forestry Department.

- Determined type of wood mulch used for tile.
- Determined that starch would be used for the binding agent for the mulch tile.
- Determined what temperature, pressure, and the amount of time necessary in order to create a mulch tile from a particle board press machine.

WBS 5.0 Engineering Review and Approve

WBS 5.1 Review and Approve Engineering

January 2010 – April 2010

This work was completed when the engineering received approval from the Applications Engineer and BAE faculty.

- Applications Engineer Approval:
  The engineering was constantly submitted to our applications engineer for

approval.
January 2010 – April 2010

- BAE Faculty Approval:
  The engineering was constantly submitted to the BAE faculty for approval.
  January 2010 – April 2010

WBS 6.0 Create Mulch Tiles
February 2010 – April 2010

WBS 6.1 Development of Prototype
February 2010 – March 2010

- Purchased and obtained required materials.
- Subjected various blends of mulch and starch to various temperatures and press times to create mulch tile prototype.

WBS 7.0 Experiments and Testing

WBS 7.1 Testing
January 2009 – April 2010

- *Experiment # 1- Mulch Swelling Tests, February 16, 2010*
  A total of eight mulch tile samples were subjected to a swell test on February 16, 2010. A heat press was used to apply 15,000 lbs of pressure (750 psi) at a temperature of 350°F.
- *Experiment #2- Relative Humidity Tests, March 6th, 2010*
  Tests were conducted in order to see how the mulch tiles reacted to high levels of relative humidity. The mulch tiles were subjected to a relative humidity of 96% and temperature of 80˚F in order to simulate a typical, hot Oklahoma summer day. These tests helped to determine an expected shelf life for the mulch tiles.
- *Experiment #3- Modulus of Rupture Tests, March 5th, 2010*
  Seven samples of mulch tiles were placed in a Universal Testing Machine to determine the MOR of each tile.
- *Experiment #4- Water Absorption and Thickness Swelling*
  Mulch tiles were subjected to water absorption and thickness swelling tests, following ASTM D1037 Standards.
- *Experiment #5 – Flammability Tests*
  A mulch tile was subject to a flammability test at the BAE Lab. The purpose of this experiment was to see if the mulch tiles posed a fire hazard.
- *Experiment #6 – Press Temperature Tests*

Mulch tiles were pressed at 180, 200, 250, and 275°F in order to determine if a mulch tile could be made at a press temperarture lower than 250°F.

- *Experiment #7 – Outdoor Tests*
  Mulch tiles were placed outside the BAE Greenhouse on bare soil, for a total of 18 days. The purpose of this experiment was to see what the tiles would look like after being exposed the natural weather elements.
- *Experiment #8 – Cypress and Pine Mulch Tiles*
  This experiment was to test if the same process and starch used to create the Eastern Redcedar mulch tiles would work for other mulch species.

BS 8.0 Present Findings to Applications Engineer and BAE Faculty

WBS 8.1 May Presentation and Report
April 29, 2010

The team will present the final design and prototype to Shea Pilgree, OSU Applications Engineer, with a demonstration following the presentation at the BAE Lab. A final written report complete with patents, literature reviews, competitive analyses and other relevant documents will also be presented to the sponsor.

- Jesi, Katie, Erin, Alex, and Allison will prepare the prepare report draft by March 29, 2010.
- Jesi, Katie, Erin, Alex, and Allison will make changes to report based on criticism from Senior Design professors by April 29, 2010.
- Jesi, Katie, Erin, Alex, and Allison will develop a Powerpoint by April 29, 2010

Appendix D: Spring 2010 Gantt Chart

Appendix E: OSU Invention Record and Report Form

Appendix F: Patent Review

Non-Woven Organic Mulch Blanket with Polyvinylacetate Copolymer Binder

U.S. Patent No. 4,283,445

Aug. 11, 1981

This patent describes a mulch blanket composed of organic fibers held together by a polymer binder. The polymer is non-toxic and biodegradable. Fibers may be composed of straw, hay, or alfalfa, or other organic material. The mulch blanket is formed by randomly arranging organic fibers, then spraying a polyvinylacetate copolymer binder on the top surface. Final product is around ½" thick and 1 to 8 feet in length. Product can be sold as a flexible, continuous roll or a stiff pallet.[27]

[27] Bartholl, Klaus. "Non-Woven Organic Mulch Blanket with Polyvinylacetate Copolymer Binder." Patent 4283445. 11 August 1981.

Appendix G: Experiment Data

Mulch Swelling Tests Data

Table 10. Thickness measurements, in centimeters.

Sample	1		2		3		4	
Time	Min	Max	Min	Max	Min	Max	Min	Max
1:00 PM	0.7	1.0	0.8	1.1	0.9	1.1	0.6	1.3
3:00 PM	1.0	2.5	2.5	3.0	1.5	2.5	1.5	2.5
5:00 PM	1.1	3.5	2.5	3.0	2.0	3.0	1.5	2.5
7:00 PM	1.2	3.5	2.5	3.0	2.0	3.0	2.0	2.7
9:00 PM	1.2	3.5	2.5	2.5	2.5	3.0	1.5	2.7
11:00 PM	1.2	3.5	2.5	2.5	2.5	3.0	1.5	2.7
10:00 AM	1.3	3.5	2.5	3.0	2.5	3.5	1.5	2.8

Table 11. Thickness measurements, in centimeters (cont'd).

Sample	5		6		7		8	
Time	Min	Max	Min	Max	Min	Max	Min	Max
1:00 PM	0.6	0.9	0.5	1.1	0.7	0.9	1.27	1.27
3:00 PM	1.5	2.0	2.5	3.5	2.0	2.5	2.0	3.0
5:00 PM	2.5	2.5	2.5	3.5	2.0	3.5	2.0	3.0
7:00 PM	2.5	3.0	3.5	4.0	2.0	4.0	2.0	3.0
9:00 PM	2.5	4.0	3.0	4.0	1.5	4.0	2.0	3.0
11:00 PM	2.5	4.0	3.0	4.0	1.5	4.0	2.0	3.0
10:00 AM	2.6	4.2	3.5	4.5	1.5	4.0	3.0	3.5

Table 12. Thickness swelling, in percentages.

Sample	1		2		3		4	
Time	Min	Max	Min	Max	Min	Max	Min	Max
1:00 PM	0	0	0	0	0	0	0	0
3:00 PM	54	150	213	173	67	127	136	97
5:00 PM	69	250	213	173	122	173	136	97
7:00 PM	85	250	213	173	122	173	215	113
9:00 PM	85	250	213	127	178	173	136	113
11:00 PM	85	250	213	127	178	173	136	113
10:00 AM	100	250	213	173	178	218	136	120

Table 13. Thickness swelling, in percentages (cont'd).

Sample	5		6		7		8	
Time	Min	Max	Min	Max	Min	Max	Min	Max
1:00 PM	0	0	0	0	0	0	0	0
3:00 PM	150	122	400	218	186	178	57	136
5:00 PM	317	178	400	218	186	289	57	136
7:00 PM	317	233	600	264	186	344	57	136
9:00 PM	317	344	500	264	114	344	57	136
11:00 PM	317	344	500	264	114	344	57	136
10:00 AM	333	367	600	309	114	344	136	176

ASTM Water Absorption and Thickness Swelling Data

2/17 Samples

Start time: 1:25-1:30 PM

Sample 1, ρ= 0.65 g/cm^3, Wheat Starch (6%)

Time	Swelling Point 1	Swelling Point 2	Swelling Point 3	Swelling Point 4	Weight (g)	Length (in)	Width (in)
Initial	1.6	1.7	1.7	1.3	202.01	6.0	6.0
3:30 PM	3.0	3.0	3.0	2.5	413.74	6.5	6.25

Comments: crumbling

Sample 2, ρ= 0.65 g/cm^3, Wheat Starch (3%)

Time	Swelling Point 1	Swelling Point 2	Swelling Point 3	Swelling Point 4	Weight (g)	Length (in)	Width (in)
Initial	1.1	1.5	1.9	1.9	161.82	6.0	6.0
3:30 PM	3.0	2.5	2.5	3.0	370.26	6.5	6.5

Comments: crumbling a lot

Sample 3, ρ= 0.65 g/cm^3, Wheat Starch (5%)

Time	Swelling Point 1	Swelling Point 2	Swelling Point 3	Swelling Point 4	Weight (g)	Length (in)	Width (in)
Initial	1.5	1.9	1.9	1.3	179.02	6.0	6.0
3:30 PM	3.0	2.5	3.0	3.0	393.01	6.5	6.25

Comments: good, not crumbling but still flexible, It was ok at 3:30pm

2/24/10 Samples

Start time: 1:25-1:30 PM

Sample 1, ρ= 0.65 g/cm^3, Corn Starch (6%)

Time	Swelling Point 1	Swelling Point 2	Swelling Point 3	Swelling Point 4	Weight (g)	Length (in)	Width (in)
Initial	1.4	1.8	1.1	1.6	171.50	6.0	6.0
3:30 PM	3.0	3.5	3.0	3.0	355.29	-	-

Comments: crumbling a lot, dropped mulch tile, fell apart

Sample 2, ρ= 0.75 g/cm^3, Wheat Starch (6%)

Time	Swelling Point 1	Swelling Point 2	Swelling Point 3	Swelling Point 4	Weight (g)	Length (in)	Width (in)
Initial	1.7	1.7	1.7	1.6	200.54	6.0	6.0
3:30 PM	2.5	3.0	2.5	2.5	439.59	6.25	6.25

Comments: held together good

Sample 3, ρ= 0.80 g/cm^3, Wheat Starch (6%)

Time	Swelling Point 1	Swelling Point 2	Swelling Point 3	Swelling Point 4	Weight (g)	Length (in)	Width (in)
Initial	1.4	1.7	1.0	1.0	206.26	6.0	6.0
3:30 PM	3.0	3.5	3.5	3.0	412.36	6.25	6.25

Comments: held together good, held together the best at 3:30 and at 1:30 the next day

Sample 4, ρ= 0.75 g/cm^3, Corn Starch (6%)

Time	Swelling Point 1	Swelling Point 2	Swelling Point 3	Swelling Point 4	Weight (g)	Length (in)	Width (in)
Initial	1.83	1.57	1.96	1.77	191.92	6.0	6.0
3:30 PM	2.5	2.5	3.0	2.3	384.74	6.5	6.5

Comments: held together well

Sample 5, ρ= 0.75 g/cm^3, Corn Starch (6%)

Time	Swelling Point 1	Swelling Point 2	Swelling Point 3	Swelling Point 4	Weight (g)	Length (in)	Width (in)
Initial	1.85	1.66	1.6	1.5	175.68	6.0	6.0
3:30 PM	2.5	2.5	2.0	2.5	335.24	6.5	6.25

omments: crumbling a lot

Sample 6, ρ= 0.75 g/cm^3, Wheat Starch (6%)

Time	Swelling Point 1	Swelling Point 2	Swelling Point 3	Swelling Point 4	Weight (g)	Length (in)	Width (in)
Initial	1.5	1.5	1.6	1.4	197.70	6.0	6.0
3:30 PM	2.5	2.5	3.0	3.0	396.66	6.5	6.5

Comments: held together good, flexible, held together the best at 3:30 pm and at 1:30 pm the next day

Modulus of Rupture (MOR) Data

2/17 Samples

Sample 1, ρ= 0.65 g/cm^3, Wheat Starch (6%)

P (lb)	L (cm)	W (cm)	D (cm)	MOR
8.7	30.48	7.5	1.4	1.20

P (lb)	L (cm)	W (cm)	D (cm)	MOR
8.3	30.48	7.6	1.5	0.99

Sample 2, ρ= 0.65 g/cm^3, Wheat Starch (3%)

P (lb)	L (cm)	W (cm)	D (cm)	MOR
7.5	30.48	7.4	1.6	0.81

P (lb)	L (cm)	W (cm)	D (cm)	MOR
20	30.48	7.4	1.7	1.90

Sample 3, ρ= 0.65 g/cm^3, Wheat Starch (5%)

P (lb)	L (cm)	W (cm)	D (cm)	MOR
5.0	30.48	7.8	1.4	0.67

P (lb)	L (cm)	W (cm)	D (cm)	MOR
6.1	30.48	7.4	1.9	.46

2/24/10 Samples

Sample 1, ρ= 0.65 g/cm^3, Corn Starch (6%)

P (lb)	L (cm)	W (cm)	D (cm)	MOR
8.7	30.48	7.4	1.7	0.83

P (lb)	L (cm)	W (cm)	D (cm)	MOR
7.3	30.48	7.4	1.6	0.78

Sample 2, ρ= 0.75 g/cm^3, Wheat Starch (6%)

P (lb)	L (cm)	W (cm)	D (cm)	MOR
17.2	30.48	7.4	1.9	1.31

P (lb)	L (cm)	W (cm)	D (cm)	MOR
12.7	30.48	7.4	1.6	1.36

Sample 3, ρ= 0.80 g/cm^3, Wheat Starch (6%)

P (lb)	L (cm)	W (cm)	D (cm)	MOR
16.1	30.48	7.5	2.0	1.09

P (lb)	L (cm)	W (cm)	D (cm)	MOR
11	30.48	7.6	2.1	0.67

Sample 4, ρ= 0.75 g/cm^3, Corn Starch (6%)

P (lb)	L (cm)	W (cm)	D (cm)	MOR
6.2	30.48	7.6	1.8	0.51

P (lb)	L (cm)	W (cm)	D (cm)	MOR
8.0	30.48	7.6	1.3	1.27

Sample 5, ρ= 0.75 g/cm^3, Corn Starch (6%)

P (lb)	L (cm)	W (cm)	D (cm)	MOR
22	30.48	7.2	1.1	5.14

P (lb)	L (cm)	W (cm)	D (cm)	MOR
8.0	30.48	7.5	1.6	0.85

Sample 6, ρ= 0.75 g/cm^3, Wheat Starch (6%)

P (lb)	L (cm)	W (cm)	D (cm)	MOR
16.0	30.48	7.6	1.4	2.18

P (lb)	L (cm)	W (cm)	D (cm)	MOR
18.2	30.48	7.4	1.8	1.54

Oklahoma Mesonet Rainfall Data

Appendix H: Literature and Resources

Appendix I: Spring 2010 PowerPoint Presentation

Eastern Redcedar Mulch Tile

Meet the Team

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Overview

- Mission Statement
- Statement of Need
- Mulch Tile
- Eastern Redcedar and Starch as Binding Agent
- Mulch Tile Process
- Experiments and Results
- Business Analysis
- Communications Campaign

http://www.greenforestproducts.com/gallery_01.html

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Mission Statement

Chip Incorporated created a value-added mulch product in the form of “mulch tiles” using a native Oklahoma invasive species, Eastern Redcedar (*Juniperus virpiniana L.*), to have a more practical and efficient use of mulch.

Statement of Need

Simplified the application of mulch for homeowners and landscape professionals, the proposed process also utilized Eastern Redcedar mulch, which developed an end product for an invasive species.

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Mulch Tile

- 19.5” x 19.0” x 0.75” mulch tiles
- Eastern Redcedar
- 6% Wheat starch
- Panel density of 0.65 g/cm^3
- Press parameters
  - Temperature: 350˚F
  - Pressure: 750 psi
  - Press time: 5 minutes

Eastern Redcedar Mulch Tiles

Eastern Redcedar Logs

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Eastern Redcedar

- Native but invasive
- Threat to OK water resources
  - Can consume 55,000 gallons of water in a year over a 1 acre plot
- Fire hazard
- Cost OK $218 million dollars annually in damages
- “Be a Leader, Kill a Cedar”
- Mulch tile will provide a beneficial end use for Eastern Redcedar

http://www.forestry.ok.gov/Websites/forestry/Images/ERC%20as%20Hazard%20Fuel.pdf

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Starch as Binding Agent

- All natural, non-toxic, wheat starch
- Starch binds with natural oils in mulch when heated and pressed
  - Gelatinizes with heat
  - Forms resin-like bond with oils
- Holds mulch tile together until exposed to water

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Process to Create Mulch Tile

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Experiments

- Thickness swelling of mulch tiles
- ASTM D1037 Water Absorption and Thickness Swelling
- Humid Swelling
- Modulus of Rupture (MOR)
- Ignition & flammability
- Outdoor tests
  - Weather elements
- Press temperatures
- Different mulch types
  - Cypress
  - Pine

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Thickness Swelling of Mulch Tiles

- Eight mulch tiles were tested for thickness swelling as a function of time
- Placed on bare soil
- 200mL water was applied over top of each tile
- Swelling of the samples were measured every two hours for a total of eleven hours

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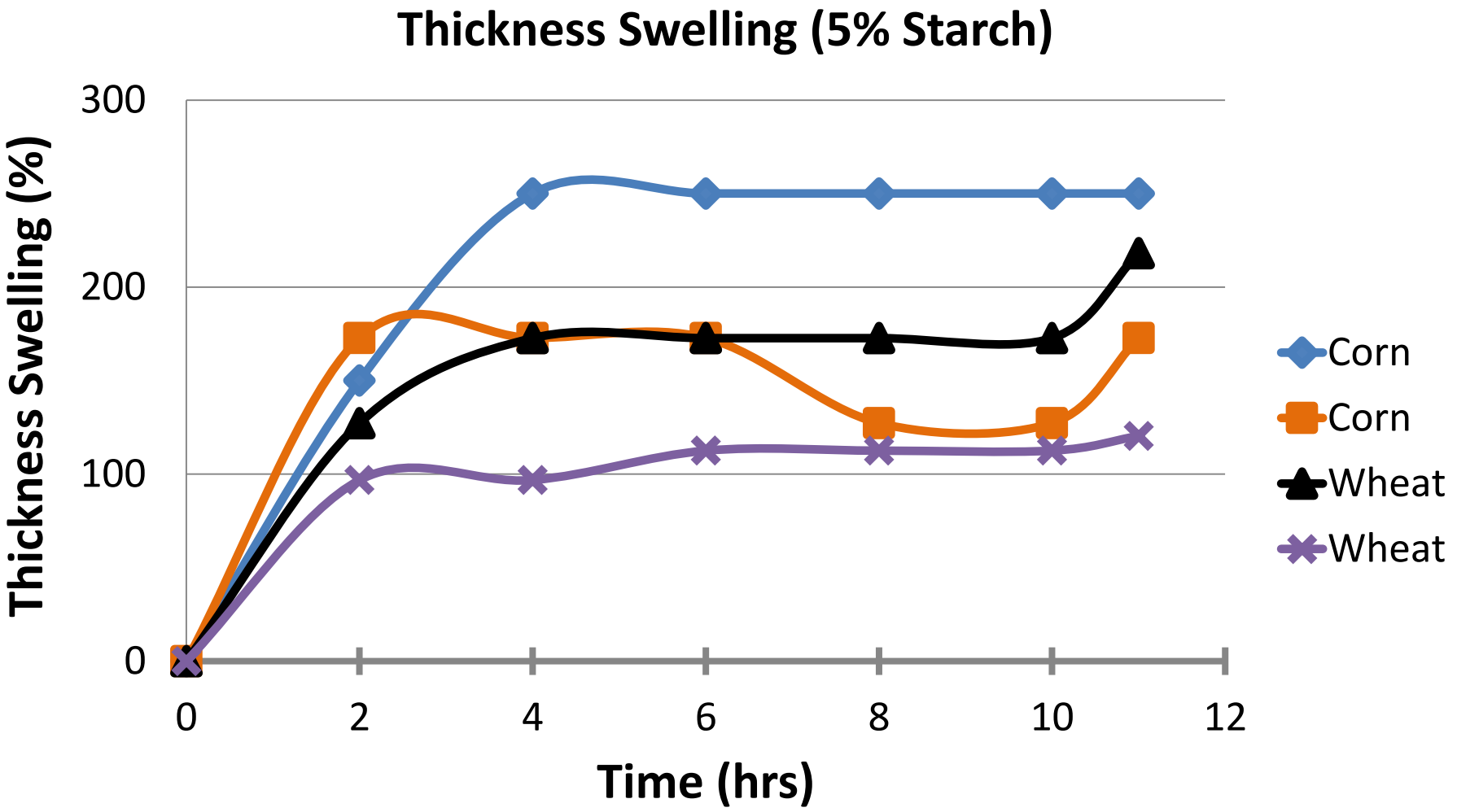
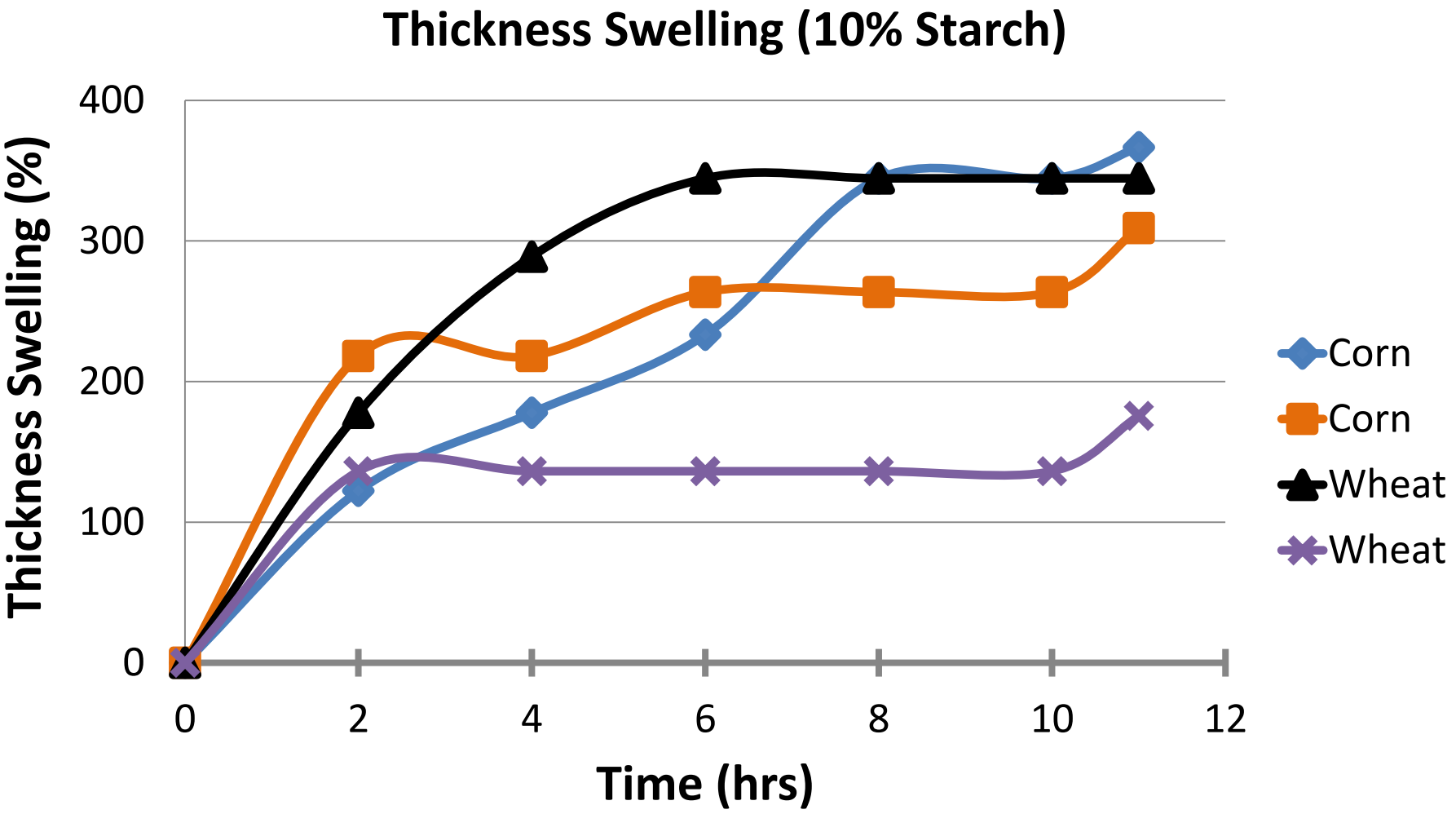

Thickness Swelling (5% Starch)
Thickness Swelling (%)
300
200
100
0
0
2
4
6
8
10
12
Time (hrs)
Corn
Corn
Wheat
Wheat


Thickness Swelling (10% Starch)
Thickness Swelling (%)
400
300
200
100
0
0
2
4
6
8
10
12
Time (hrs)
Corn
Corn
Wheat
Wheat

Thickness Swelling Results

- 5 grams starch
  - Maximum swelling occurred after 2 to 4 hours
- 10 grams starch
  - Maximum swelling occurred after 2 to 6 hours

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Water Absorption & Thickness Swelling Test – ASTM D1037

- Method A 2 Plus 22-h Submersion Period
  - Weighed tiles
  - Thickness measurements taken at four points, midway along each side of tile, 1 in. in from edge of tile
  - Submerged horizontally under 1 in. of water for two hours
  - Weighed tiles and took thickness measurements again
  - Submerged again for 22 hours
- None of the tiles held together after 24 hours

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Water Absorption & Thickness Swelling Test – ASTM D1037 Results

Starch Type	Panel Density, g/cm^3	Water Absorption by Weight, %	Average Swelling, %
Wheat, 3%	0.65	129	85
Wheat, 5%		120	
Wheat, 6%		105	
Corn, 6%		107	
Wheat, 6%	0.75	119	57
Wheat, 6%		100	
Corn, 6%		101	
Corn, 6%		91	

- Tiles appear to swell less at higher density; not desirable
- Need more swelling for aesthetic purposes
- Ideal density is 0.65 g/cm^3

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Humid Swelling Tests

- Test to determine if tiles swelled under humid conditions
  - Storage and shelf life
- Placed in a sealed fish tank, over open water source
  - Approximately 100% humidity
- 5 and 18 day periods
- Tested 0.65 and 0.75 g/cm^3 mulch tiles made with both wheat and corn starch

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Humid Swelling Results

Sample Type	Panel Density, g/cm^3	Average Swelling, % 5 Days	Average Swelling, % 18 Days
Wheat, 3%	0.65	11	27
Wheat, 5%			
Wheat, 6%			
Wheat, 6%	0.75	12	16
Wheat, 6%			
Corn , 6%			
Corn, 6%			

- 5 days: dry to touch
- 18 days: moist to touch

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MOR Tests

- Modulus of Rupture
  - Ability of a material to resist against a maximum load

$$\sigma = \frac{3FL}{2bd^2}$$

F = load at point of fracture, N

L = length of support span, mm

b = width of rectangular beam, mm

d = thickness of rectangular beam, mm

Com-Ten Testing Machine

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MOR Tests Results

Starch Type	Density, g/cm^3	Average Load, N	Average MOR, MPa
Wheat, 3%	0.65	61.4	1.35
Wheat, 5%		24.7	0.56
Wheat, 6%		37.8	1.10
Wheat, 6%	0.75	66.7	1.30
Wheat, 6%		76.1	1.86
Corn, 6%		31.6	0.89
Corn, 6%		66.7	2.99

- Variation in MOR due to heterogeneity of samples
- MOR Eastern Redcedar particleboard = 60.7 MPa

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Flammability Test

- Eastern Redcedar mulch highly flammable
- Tested ignition and flammability of the mulch tile
- Check to see if mulch tile posed a fire hazard for end users
- Propane torch was used to ignite mulch tile

Will the mulch tile burst into flames?

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Flammability Test Results

- 30 seconds to ignite; smoldered
- Flame height increased with wind exposure
- Image on lower right shows mulch tile after 12 minute time lapse
- Mulch tiles do not pose a fire hazard
  - More dense than loose mulch

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Outdoor Test

- Two sets of mulch tiles placed outside on bare soil
- Set 1 outside for a total of 23 days, 2.68 in. rainfall
- Set 2 outside for a total of 8 days, 1.25 in. rainfall

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Time Lapse of Outdoor Tests, Set 1

April 3, 2001; Day 1

April 12, 2001; Day 10

May 3, 2001; Day 31

May 16, 2001; Day 44

May 30, 2001; Day 58

June 13, 2001; Day 72

July 3, 2001; Day 92

July 18, 2001; Day 107

August 1, 2001; Day 121

August 15, 2001; Day 135

August 29, 2001; Day 149

September 12, 2001; Day 163

October 3, 2001; Day 184

October 17, 2001; Day 198

November 1, 2001; Day 213

November 15, 2001; Day 227

November 29, 2001; Day 241

December 13, 2001; Day 255

January 3, 2002; Day 276

January 17, 2002; Day 290

February 1, 2002; Day 305

February 15, 2002; Day 319

March 1, 2002; Day 333

March 15, 2002; Day 347

March 29, 2002; Day 361

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Time Lapse, Set 1 & Set 2

Day 14 April 28, 2010 Day 0

Conclusion of Outdoor Tests

- Noticeable thickness swelling and changes in texture
- Remained intact and did not wash away
- Flexible once wetted and could tear apart easily

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Press Temperature Testing

- Originally pressed at a temperature of 350°F
- Pressed mulch at lower temperatures
- Undesirable results at 180°F, 200°F and 250°F
- Acceptable results at 275°F

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Cypress and Pine Mulch Tiles

- Tested creating mulch tiles out of Cypress and Pine mulch
- Proof of concept used for Eastern Redcedar mulch also worked on the Cypress and Pine raw material
- No further work was carried out in this area since it was outside the scope of this project

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Target Market

- Manufacturing facility would produce tiles
  - Landscape professionals would install mulch tiles for homeowners/ businesses
  - Retailers would sell mulch tiles to end consumers

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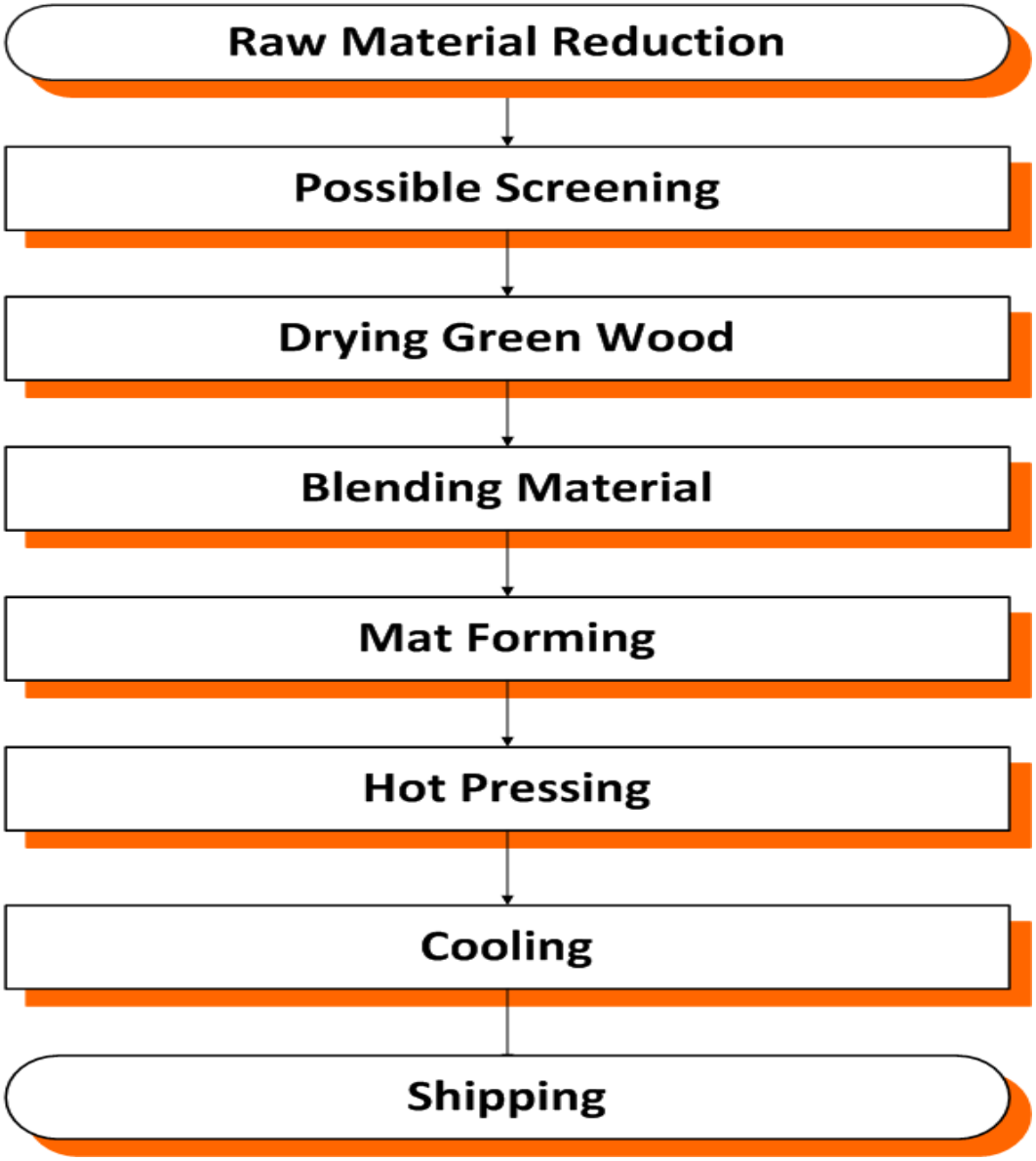

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Cost Assumptions

- All Used Equipment
  - Kiln $18,000-$30,000
  - Batch Mixer $500-$3,000
  - Hot Press $100,000-$200,000
  - Land/Facility 2,000 ft^2 at $30/$ft^2$, $60,000
- Consulted with Dr. Hiziroglu, Shea Pilgreen, Dr. Tilley for cost assumptions

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Variable Costs

- Eastern Redcedar available for $20/$yd^3$
- Assumed 360 yd^3/day production rate; $7,200
- Wheat starch 50 lb bags available for $59

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Material Cost per Tile

- 50 lbs wheat starch will produce approximately 225 tiles
  - $0.26/tile
- 1 yd^3 of Eastern Redcedar mulch will produce approximately 50 tiles
  - $0.40/tile
- Total variable cost per tile
  - $0.66
- 50 tiles = 1 yd^3 of mulch
  - $33
  - Compared to $20
- Additional fixed cost
- Profit margin

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Benefits

- Simplified mulching process
- Potential reduction in shipping cost
  - Able to ship more mulch per load
- Desired that price will be comparable with bagged mulch
  - Dependent upon manufacturing process chosen and resources available

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Communications Campaign

- Audience
  - Investors
  - Landscape Professionals
  - Home Owners
- Design
  - Cohesive design
  - Common design elements

mulchtile

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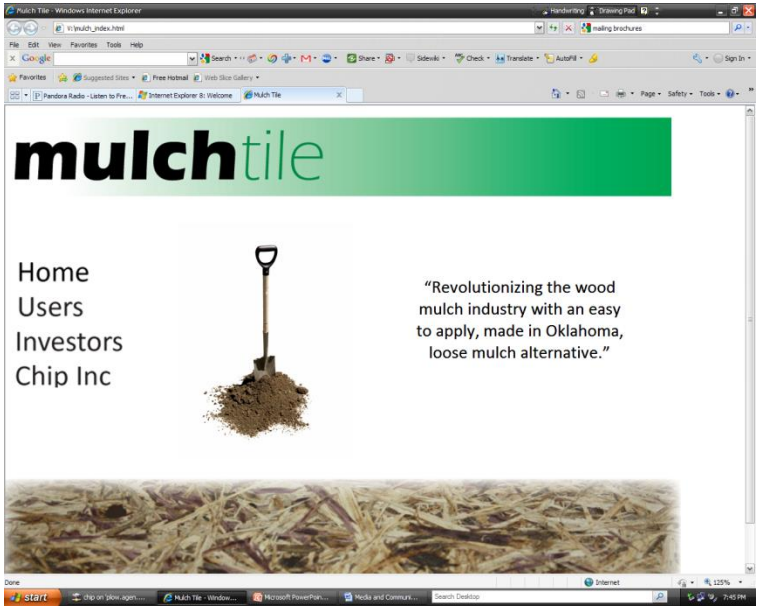
Communications Campaign

- Design Elements
  - Website
    - 3 page website
  - Brochures
    - 3 versions
  - PowerPoint
    - Focused toward potential investors



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Investor Brochures

Why invest?

Chip Incorporated produced a product that utilizes native Oklahoma materials such as Eastern Red Cedar mulch and wheat starch. The starch mixes with natural oils in the mulch to form a binding agent.

When pressure and heat are applied a mulch tile is formed. This tile is less messy, easier to apply, and lighter than the traditional bags of mulch.

With nothing like this on the market, the mulch tile is revolutionizing the landscape industry.

Mulch Tiles save time, space and money buy making the mulching process more efficient.

Producing a mulch tile

1. Measure materials according to specific mulch to wheat starch ratio.
2. Mix ingredients together to promote even distribution of starch on mulch.
3. Deposit mulch and starch mixture in forms to create the tile.
4. Insert tile in heat press to cure at a specific psi and temperature.
5. Remove from press and insert next tile.

User Brochures

How to use a **mulch**tile

How does it work?

Mulch tiles evolved from a colored mulch roll to the eco-friendly and easy-to-use mulch tile.

Chip Incorporated produced a product that utilizes native Oklahoma materials such as Eastern Red Cedar mulch and wheat starch.

When the wheat starch mixes with the water in the mulch a glue type substance is formed. Pressure and heat are applied, and a mulch tile is formed.

While the bond will withstand shipping and packaging, it breaks down after being saturated with water from a hose or through natural precipitation.

This tile is less messy, easier to apply, and lighter than the traditional bags of mulch.

1 Layout tiles in area that you are mulching to determine if any partial tiles are necessary.

2 Lay tiles so the edges match up and cover the ground completely.

3 Water the tiles to promote breakdown of starch glue. Or, the tiles will breakdown naturally when exposed to weather elements.

4 Lightly rake over tiles to fill in any cracks.

Acknowledgments

- Dr. Salim Hiziroglu, OSU NREM Department
- Faculty of the Innovations Senior Design Course
- Dr. Tim Bowser, BAE Department
- Wayne Kiner and the BAE Lab
- Aaron Newton, Eastern Redcedar Company
- Shea Pilgreen, OSU Applications Engineer
- Kay Watson, OK Alliance MEA

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December 3, 2009

Team Members:
Katie Allen, Jesi Lay, Allison Miller, Erin White, and Alex Wilson

Table of Contents

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APPENDICES

Problem Statement

The wood mulch industry will be impacted by developing an affordable wood chip coloring system.

Statement of Need

This type of machine will cater to those who seek home improvement and landscaping projects. This product will also be beneficial to landscape professionals, providing them with a competitive edge and a unique service to offer clients.

Mission Statement

Chip Incorporated will create a wood chip coloring system that is affordable, efficient, and effective in coloring woodchips to be promoted to rental agencies and landscape professionals.

Statement of Work

Objective

Chip Incorporated will create a wood chip coloring system that will be available to homeowners through a rental service and to landscape professionals through direct purchase.

Background

Chip Incorporated wishes to add to the industry by promoting a machine that would be available to homeowners through rent, and to landscape professionals through direct purchase. This product will produce colored woodchips.

Scope of Work

- Chip Incorporated will turn in a design proposal on December 3, 2009 that includes:
    - Problem statement, statement of work, work breakdown structure, task list
    - Competitive analysis report including market and patent research
    - Definition of customer requirements and development of engineering specs
    - Proposed communications plan
    - Generation of design concepts
    - Gantt chart project schedule
    - Proposed budget
- Chip Incorporated will present a design proposal oral presentation that will include all material presented in the design report to OSU professors and advisors on December 3, 2009.
- Chip Incorporated will turn in self and peer evaluations on December 8, 2009.
- Chip Incorporated will turn in a website on December 7, 2009.

- Chip Incorporated will turn in individual project notebooks on December 8, 2009.
- The team leaders will conduct a one-on-one interview with Dr. Weckler.
- Chip Incorporated will turn in a prototype followed by a final design to OSU professors and sponsors in April 2010. Steps taken will include:
    - Checking relevant patents to avoid infringements
    - Inspecting all standards to insure the machine meets code
    - Create drawings to show client best options
    - Conduct testing on different dyes and coloring processes
    - Test the machine

Location of Work

Chip Incorporated will conduct research and report development using Oklahoma State University computer labs. Design development using Solid Works will be done in the Biosystems and Agricultural Engineering (BAE) Computer Labs in Agriculture Hall 208 or 210. Fabrication for the prototype will be conducted at the Biosystems and Agricultural Engineering Design and Manufacturing Lab found on the OSU campus. Dye and product testing will take place at the BAE Lab.

Period of Performance

- Initiation Date: August 17, 2009
- Completion Date: May 7, 2010

Delivery Requirements

Date	Item Due
October 26, 2009	Competitive Analysis Report
October 30, 2009	Statement of Work
November 2, 2009	Work Breakdown Structure
November 6, 2009	Task List
November 23, 2009	Design Proposal Report Draft
December 3, 2009	Design Proposal Report Design Proposal Presentation
December 7, 2009	Team Website
December 8, 2009	Project Notebooks Self and Peer Evaluations
December 8-11, 2009	Team Leader Interviews

Applicable Standards

- The dyes used cannot be toxic.

Acceptance Criteria

The wood chip coloring system will be accepted when the system can successfully color small batches of wood chips affordably, efficiently and effectively.

- The coloring system will be simple and easy to operate for the average homeowner or landscape professional.
- The coloring system will be affordable, either for rent or purchase.
- The coloring system should dye bagged or freshly chipped (green), mulch, regardless of the tree species.
- The coloring system must be easy to clean.

Special Requirements

- In order to build a prototype of the wood chip coloring system, Solid Works and Pro-Engineer computer software will be required to create the drawings for use in fabrication of the parts.
- Services from the BAE Lab will be needed to fabricate parts, and an outside manufacturer may be required to build parts the BAE Lab cannot.
- Training will be required to operate a chipping machine when testing freshly chipped mulch in the coloring system.
- The team will also need cooperation from the Plant and Soil Science Department in order to use the rainfall simulator for experiments.

Work Breakdown Structure

WBS 1.0 Design a Wood Chip Coloring System

WBS 1.1 Project Oversight

Provide guidance to successfully complete this project by May 4th, 2010, with minimal cost. Develop the standards for the wood chip coloring system and an operation manual. Provide a summary report and presentation to OSU professors and advisors on December 3, 2009. Report to the sponsor the alternative designs for the coloring system.

WBS 1.2 Develop Requirements

Learning from the existing technology for large scale coloring systems, Chip Incorporated will meet expectations to develop a viable wood chip coloring system for homeowners and landscape professionals.

WBS 1.3 Design Wood Chip Coloring System

Design a wood chip coloring systems based on the specification developed in WBS. 1.2.

WBS. 2.0 Background Research
August 2009 - December 2009

WBS 2.1 Patent Research

Conduct patent searches to determine relevant documents and evaluate their importance to our project.

WBS 2.2 Wood Properties Research

Conduct a literature review and consult with wood specialist to learn about the properties of wood relevant to our project.

- Meet with Dr. Hiziroglu to ask questions about the properties of wood and how they affect the dyeing process.
    - Jesi, October 10, 2009 and October 21, 2009
- Read through Understanding Wood A Craftman's Guide to Wood Technology for relevant and useful material
    - Jesi, October 10 – October 28, 2009

WBS 2.3 Dye Research

Research existing dye technologies to determine which processes to use in testing. Consult with specialists knowledgeable in this field.

- Conduct research over existing dyes on the market
    - Colorbiotics and Amerimulch
    - Alex, October 12 – October 28, 2009
    - Find out prices for ordering liquid dye
    - Jesi, November 23, 2009
- Research organic dyes that are on the market
    - Consult with representative from organicdye.com
        - Erin, October 12 – October 14, 2009

- Look at prices for ordering a 55 gallon drum of liquid dye from organicdye.com and prices for ordering powdered dye
  - Find price for shipping and handling
    - Any special shipping issues: None.
    - Is the material hazardous in any way: No.
    - How is it shipped: Freight.
    - Price dependent on size.
- Erin, November 4 – 16, 2009

WBS 3.0 Market Research

WBS 3.1 Competitive Analysis
September 2009 - November 2009
Research and determine competitors in Oklahoma and neighboring states in the natural and colored wood mulch market.

- Internet research for mulch producers
  - Jesi, Katie, Erin, Alex, Allison, October 23, 2009
- Internet research for mulch retailers
  - Jesi, Katie, Erin, Alex, AIlison, October 23, 2009
- Develop database
  - Katie, October 23, 2009

WBS 3.2 Cost Analysis
September 2009- October 2009
Conduct research over current products and the prices available to consumers of both natural and colored wood mulch. Determine added value of colored wood mulch compared to natural wood mulch.

- Compile list of products and prices from competitors
  - Jesi, Katie, Erin, October 23, 2009
- Calculated percent increase on colored wood chips vs. natural
  Erin, October 23, 2009

WBS 3.3 Surveying the General Public
November 2009
Develop survey to be passed out at Stillwater home improvement stores and rental companies to determine demand of product. Develop a telephone survey for landscape

professionals in the state of Oklahoma to determine willingness to use product. Present findings to OSU professors and advisors in the December 3 presentation and report.

- Developed survey for Landscape Professionals and Retail Stores
  - Jesi, November 1, 2009
- Research and assign professionals to contact
  - Allison, November 1, 2009
- Develop survey script
  - Allison, November 15, 2009
- Conduct phone survey
  - Jesi, Katie, Erin, Alex, Allison, November 20, 2009
- Compile results in spreadsheet
  - Katie, November 25, 2009

WBS 4.0 Documentation

WBS 4.1 Hand Sketching

August 2009 – February 2010

Brainstorm and hand sketch design ideas.

- Brainstorming:
  August 2009 – September 2009 (completed)
  Create a large amount of possible ideas to potentially solve the problem. Each team member was required to come up with at least two designs.
- Rough Draft:
  September 2009 – October 2009 (completed)
  Using concepts and techniques seen in large scale coloring systems and our own ideas, rough sketches were drawn in our design notebooks.
- Revise Draft:
  October 2009 – November 2009
  After the scope and scale of our project was set our designs had to be modified to accommodate our OSU professors and advisors request.
- Approve Design:
  November 2009 – December 2009
  After OSU professors and advisors reviewed our rough sketches they were not satisfied with our designs. A set of our best, most innovative designs will be presented to him for his approval. The best will be selected and the team will continue to improve the design.

- Finalize Design:
  December 2009
  After the best design has been selected further improvement will be made to it. Certain design specifications will be assigned and the parts will be dimensioned. The design will be ready to be input into Solid Works.

WBS 4.2 Solid Works Drawings
January 2010 – April 2010
Create parts drawings and assembly of product in Solid Works.

- Solid Works Draft:
  December 2009
  Our finalized design will be put into Solid Works as a working model. The prototype will be fabricated based on the Solid Works model.
- Solid Works Assembly:
  January 2010
  Each created part in Solid Works will be assembled into a working system.
- Solid Works Animation:
  January 2010 – February 2010
  Using simulation features in Solid Works our system will be animated.

WBS 5.0 Engineering Review and Approve

WBS 5.1 Review and Approve Engineering
December 2009 – April 2010
This work will be complete when the engineering has approval from OSU professors and advisors.

- OSU Professors and Advisors Approval:
  December 2009 – April 2009
  The engineering will be submitted to our sponsor for approval.
- Applications Engineer Approval:
  The engineering will be submitted to our applications engineer for approval.
  December 2009 – April 2009

- BAE Lab Manager Approval:
  The engineering will be submitted to the BAE lab manager for approval.
  December 2009 – April 2009

WBS 5.2 Review, Approve, and Release Drawings
December 2009 – April 2010
This work will be complete when the Solid Works drawings have approval from OSU professors and advisors.

- OSU Professors and Advisors Approval:
  December 2009 – April 2009
  The engineering will be resubmitted to professors for approval.
- Applications Engineer Approval:
  The engineering will be resubmitted to our applications engineer for approval.
  December 2009 – April 2009
- BAE Lab Manager Approval:
  The engineering will be resubmitted to the BAE lab manager for approval.
  December 2009 – April 2009

WBS 6.0 Manufacture Small Scale Wood Chip Coloring System
February 2010 – April 2010
Present Solid Works drawings and specifications to manufacturer for fabrication of prototype.

WBS 6.1 Fabrication of parts
February 2010 – March 2010
Present Solid Works drawings and specifications to manufacturer for fabrication of prototype.

- Make a list of materials required to build the prototype.
- Purchase materials that are not already available in the BAE machine shop.
- Determine which parts can be fabricated in house and what needs to be fabricated elsewhere.
- For the parts that cannot be fabricated in house, place an order with another manufacturer.
- Once the parts are in, double check the specification sheets for accuracy.

WBS 6.2 Assembly

April 2010

- Assemble the coloring system parts using specifications.

WBS 7.0 Experiments and Testing

WBS 7.1 Testing

January 2009 – April 2010

Test various procedures for dyeing wood mulch. Both powdered and liquid dye will be evaluated. Tests will be conducted to evaluate the effectiveness of heat, pressure, and pulverization when dyeing wood chips. Spray and tumbling methods of dye application will also be assessed. Weathering effects will be evaluated in each experiment. A dehydrator will be used to construct drying curves for experiments.

- *Experiment # 1- Coloring woodchips with a mixing/tumbler device.*
  January 13, 2010 – January 15, 2010
  The team will look at coloring the various mulches with dye using a mixing/tumbler device, such as a mini-cement mixer.

- *Experiment #2- Using heat to aid in the dyeing process.*
  January 18, 2010 – January 22, 2010
  This experiment will look at coloring the mulch in conjunction with heat. Preliminary research has shown that applying heat while dyeing a material, such as wood, will help with the dyeing process. The team will test with a dryer system, an oven, and a kiln, if possible. The mulch will be mixed/tumbled during the experiment.

- *Experiment #3- Pressurized vacuum chamber approach*
  January 18, 2010 – January 22, 2010
  The team will also experiment dyeing the mulch using a pressurized vacuum chamber, which can be easily created with PVC pipe and caps. According the Dr. Bowser, the FAPC also has vacuum tumblers and a pressure retort that can be utilized.
- *Experiment #4- Hand held pressure painter device*
  January 25, 2010 – January 29, 2010

The team will evaluate coloring mulch using a hand held pressure painter device while having the mulch reside in some sort of container that is either stationary or in rotation. This approach would most likely only work when using liquid dyes.

- *Experiment #5- Pounding powdered dye into mulch*
  February 1, 2010 – February 5, 2010
  The team will look to see if pounding powdered dye into the mulch will have a desired outcome.

- *Experiment #6- Affects of weathering on mulch*
  January 15, 2010 – April 1, 2010
  In addition to coloring the mulch, the team will look at the affects weathering has on the dyed mulch, i.e. rainfall, sunshine, extreme hot and cold temperatures, snow, etc.

WBS 8.0 Evaluate Prototype

WBS 8.1 Testing with Prototype
April 2010
The team will test how well the prototype works.

- Apply methods from experimentation that proved to work the best to the prototype.
- Based on results, the team will choose the final dyeing procedure to use with the small scale wood chip coloring system.

WBS 8.2 Functional Checks
April 2010
The prototype will be tested for functionality.

- Evaluate how well the prototype colors the wood mulch as well as limitations of the prototype.
- Develop standards of use and compile into a user manual. This manual will be evaluated during consumer testing.

WBS 8.3 Consumer Testing

April 2010

The prototype will be tested for product ease. The general public will test the prototype at local home improvement stores.

- Determine locations where testing will be conducted
    - Possible locations: Atwoods, Kinnunen, Tractor Supply and on the OSU campus
- Consult with necessary persons about liability concerns
    - Create a waiver for consumers to sign before operating the coloring system

WBS 9.0 Present Findings to Sponsor

WBS 9.1 December Presentation and Report

December 3, 2009

The team will present experiment results to the sponsor to justify the proposed designs developed for professors. A written report complete with patents, literature reviews, competitive analyses and other relevant documents will also be presented to our professors and Shea Pilgreen.

- Prepare report draft- Jesi, Katie, Erin, Alex, Allison
  Due Date November 23, 2009
- Make changes to report based on critique- Jesi, Katie, Erin, Alex, Allison
  Due Date December 3, 2009
- Develop team webpage- Katie
  Due Date December 7, 2009
- Develop power point- Jesi, Katie, Erin, Alex, Allison
  Due Date December 3, 2009

WBS 9.2 May Presentation and Report

May 4, 2010

The team will present the final design and prototype to professors. A demonstration of the final prototype will follow the oral presentation. A final written report complete with patents, literature reviews, competitive analyses and other relevant documents will also be presented to professors.

- Prepare report draft – Jesi, Katie, Erin, Alex, Allison
  Due Date April 23, 2010
- Make changes to report based on critique- Jesi, Katie, Erin, Alex, Allison

Due Date April 29/20, 2010

- Develop power point- Jesi, Katie, Erin, Alex, Allison
  Due Date April 29/30, 2010

Industrial Analysis

Colored mulch is a relatively new landscaping solution. Mulch has been available for years and is used not only as a "finished touch" in landscaping, but it also provides protection from water erosion and as a soft ground covering for playgrounds.[1] Producing a device that will custom color wood mulch to sell to landscape professionals, home owners and rental companies is a new niche market in the wood mulch landscaping industry.

There are currently a large number of registered landscapers in the state of Oklahoma. According to the Oklahoma Secretary of State *SoonerAccess*[2] database, there are 721 landscapers in Oklahoma. Because of this, the potential for market growth with a new wood chip coloring device. There is nothing on the market, as of now, that can be purchased or rented that will color wood chips at home.

There are a large amount of landscape organizations across the state and country. For example, American Society of Landscape Architects, American Nursery and Landscape Solutions, and Professional Landscape Network are just a few examples of the organizations.[6,7] There are also landscaping expos that would allow the proposed device to be easily marketed and made available to landscapers as well as homeowners, such as the Landscapers and Contractors Expo[8], and the California Expo[9].

One major standard affecting dyed mulch production is the fact that it needs to be environmentally friendly and also non-toxic.[10] Because this product can possibly be used in

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[1] Iannotti, Marie. "Mulch- What Is It and Which Mulch Should You Use Where?" *About.com: Gardening.* About.com, 2009. Web. October 16, 2009. <http://gardening.about.com/od/gardenmaintenance/a/Mulch.htm>.

[2] "Business Entities Search Results." *Secretary of State SoonerAccess*. Oklahoma Secretary of State. 25 Oct. 2009. <https://www.sooneraccess.state.ok.us/corp_inquiry/corp_inquiry-find.asp.>.

[6] American Society of Landscape Architects. "About Us." *American Society of Landscape Architects.* American Society of Landscape Architects, 2009. Web. 22 October 2009. <http://asla.org/AboutJoin.aspx>.

[7] *Plant Professional Landcare Network*. Plant Professional Landcare Network, 2009. Web. 22 October 2009. <www.landscapecarenetwork.org/cms/home.html>.

[8] "Landscapers & Contractors Expo 2010." Big Feats Management & Logistics, n.d. Web. 24 October 2009. <http://www.landscapingexpo.net/>.

[9] *CalExpo.* CalExpo, n.d. Web. 24 October 2009. <http://www.calexpo.com/>.

[10] Dr. Salim Hiziroglu. Personal Conversation. 7 October 2009. Stillwater, Oklahoma.

playgrounds, it needs to be safe enough for children to put in their mouths[11]. The team will also need to consider safety standards and liability issues that may arise from selling or renting a device to a customer that has moving parts and could potentially be harmful.

Key resources for this device are wood chips that are not colored or treated. Another resource would simply be landscapers promoting the device that would custom color your woodchips. If a device was produced, the resources would be existing mulch that the customer either chipped themselves or untreated, uncolored mulch they purchased from a local retailer.

Customers/Buyers

Currently, there is not a "do-it-yourself" device to produce colored woodchips. Colored woodchips can only be bought through a retail outlet or dealer. There are also no contractors that color their own mulch to be used at a customers' home or business. Purchases of colored mulch are made from an outside company that colors the mulch off site.

The buying decisions that are made on the customer level of the device are: is the device worth owning or worth the trouble of coloring my own mulch? Currently, customers buy their mulch from a local nursery or home improvement store. These stores get mulch that has been produced by an outside company.

The current market size for colored mulch is large, and has potential to continue to grow. With the production of the right device, that can be marketed to landscapers or rental companies the market has the potential to possibly grow.
There are many businesses that could benefit from selling mulch. For example Lowes already sells colored mulch, but they sell a limited selection of colors[12]. There is potential for a broadened colored mulch market. Also, school systems with playgrounds are also a potential customer base.

The customers for custom colored mulch generally have a higher economic status. They are somewhat wealthy with money to spend on their homes or businesses[13].

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[11] "Playmate®Play Area Wood Chips®". Ever-Green Landscape Nursery & Supply Inc., 2008. Web. 16 October2009. <http://www.playmatewoodchips.com/>.
[12] *Lowes*, 2009. Web. 22 October, 2009. <http://www.lowes.com/lowes/lkn?action=productList&N=4294961544&Ne=4294967294&Ntk=i_products&Ntt=mulch>.
[13] "Innovations in Mulch Colorization." *Biocycle*. Biocycle, 2007. Web. 23 October 2009. <http://www.jgpress.com/archives/_free/001389.html>.

The demographics of the consumers who purchase mulch vary. However, one characteristic that is similar is they are in a good financial situation. They also have the money and time to devote to their landscapes.

Mulch is used to enhance landscapes, as well as to protect against water erosion. With the use of colored mulch, the customer can customize their landscape to make it unique to the customers' tastes and desires.

There is currently a large market for colored wood chips. Virtually all of the landscapers we spoke with use mulch as a part of their services almost on a daily basis. However the option for a landscaper to color the mulch is almost non-existent.

Client Company/Agency and its Resources

The management team is composed of OSU professors along with Shea Pilgreen an OSU Application Engineer, and Kay Watson an Oklahoma Alliance MEA will act as a consultants to our senior design team. These are the groups that we will be communicating with.

Oklahoma Mulch retail Analysis

Table 1. Retail competitors.

Retailer	Supplier	Product	Size	Price
Lowes[14]	Green Country Soil	Natural Cyprus Mulch	3 yd^3 bags	$3.68
		Red Cyprus Mulch	3 yd^3bags	$3.68
		Natural Cedar Mulch	3 yd^3bags	$4.28
		Red & Black Dyed Mulch	2 yd^3bags	$2.97
Atwoods[15]	Green Country Soil	Pine	2 ft^3 bags	$2.99
		Cypress	2 ft^3 bags	$2.99
		Cedar	2 ft^3 bags	$3.49
		Red Mulch	2 ft^3 bags	$2.99

[14] Personal Conversation. Lowes. Stillwater, OK 23 September 2009.
[15] Personal Conversation. Atwoods. Stillwater, OK. 23 September 2009.

Home Depot[16]	Scott's	Color Enhanced Mulch (Sierra Red, Deep Forest Brown)	2 ft^3 bags	$3.97
	Timberline	Bag Cypress Mulch	2 ft^3 bags	$2.67
		Bag Pine Mulch	2 ft^3 bags	$2.75
		Bag Red Mulch	2 ft^3 bags	$3.33
Wal-Mart[17]	Green Country Soil	Cypress Mulch	2 ft^3 bags	$2.88
		Cedar Mulch	2 ft^3 bags	$2.88

Information for this table was collected by the team members in September. The team conducted research by looking up retailers in the surrounding states. The team then collected the product specifications and prices for each company from their website or by telephone inquiry.

Mulch Industry Analysis by State

Table 2. Industry competitors, by state.

State	Supplier	Product	Size	Price
Texas	Mulch King Tomball, TX[18]	Native Mulch	yd^3	$24
		Fine Native Mulch	yd^3	$26
		Red Hardwood Mulch	yd^3	$27
		Brown Hardwood Mulch	yd^3	$26
		Golden Pine Mulch	yd^3	$24

[16] "Shop Products: Barks & Mulches." The Home Depot, 2009. Web. 18 September 2009. <www.homedepot.com>.
[17] Personal Conversation, Wal Mart. Stillwater, OK. 30 September 2009.
[18] "Products and Pricing." Mulch King. 18 September 2009. <http://www.mulchking.org/>.

	Mulch X-Press Houston, TX[19]	Shredded Hardwood	yd^3	$24
		Premium Hardwood	yd^3	$26
		Cedar	yd^3	$28
		Cypress	yd^3	$48
		Shredded Hardwood	½ yd^3	$14
		Premium Hardwood	½ yd^3	$15
		Cedar	½ yd^3	$16
		Cypress	½ yd^3	$26
		Red Colored Mulch	yd^3	$26
		Black Midnight Mulch	yd^3	$28
		Red Colored Mulch	½ yd^3	$15
		Black Midnight Mulch	½ yd^3	$16
	Dirt Cheap Mulch Co. Humble, TX[20]	Natural Brown Hardwood	yd^3	$20
		Cedar Mulch	yd^3	$26
		Black Mulch	yd^3	$28
		Red Dye Hardwood	yd^3	$26
Arkansas	Green Forest Products	Aromatic Cedar Mulch	yd^3	$15.35

[19] "Mulch." *Mulch X-Press Your Local Landscape Material Headquarters*. Mulch X-Press, 2006. Web. 18 September 2009. <http://mulchx-press.com/>.

[20] "Mulches." Dirt Cheap Mulch Co, n.d. Web. 18 September 2009. <http://www.dirtcheapmulch.com/index.ivnu.>.

	Green Forest, AR[21]			
		Colored	yd^3	$18.50
		Oak Sawdust	yd^3	$12.00
		Cedar	3 ft^3 bags	$2.25
		Cedar	2 ft^3 bags	$1.75
		Cypress	3 ft^3 bags	$3.00
		Colored	2 ft^3 bags	$1.75
Oklahoma	Green Country Soil[22]	Red Cedar Mulch	2 ft^3 bags	$2.99
		Eucalyptus Mulch	1.5 ft^3 bags	$3.54
		Cyprus Mulch	2 ft^3 bags	$2.05
		Cedar Mulch	2 ft^3 bags	$2.55
			3 ft^3 bags	$2.95
		Hardwood Mulch	2 ft^3 bags	$1.90
		Pinebark Mulch	2 ft^3 bags	$2.05
			3 ft^3 bags	$2.60
		Pinebark Nuggets	2 ft^3 bags	$2.15
			3 ft^3 bags	$2.75
		Red Colored Mulch	2 ft^3 bags	$2.05
		Midnight Black Mulch	2 ft^3 bags	$2.15
		Cocoa Brown Mulch	2 ft^3 bags	$2.05
	Bulk Sizes	Cedar Mulch	Yards/load	$21/yd

[21] Personal Communication. Denise Estepp. Stillwater, OK. 23 September 2009.
[22] Lay, Jesi. "RE: Question regarding prices of mulch." Email to Jeff Potter. 26 October 2009.

		Hardwood Double Ground	Yards/load	$12/yd
		Red Colored Mulch	Yards/load	$16.50/yd
		Black Colored Mulch	Yards/load	$16.50/yd
		Cocoa Brown Mulch	Yards/load	$16.50/yd
		Brilliant Red Aromatic Cedar Mulch	Yards/load	$26/yd

Information for this table was collected by the team members in September. The team conducted research by looking up suppliers in the surrounding states. The team then collected the product specifications and prices for each company from their website or by telephone inquiry.

Price Analysis

A price analysis was performed comparing the sale prices of natural, uncolored mulch to colored mulch. The percent increase in sale price can be found in the far right columns in Table 3 and Table 4. The data used in these tables was also included in Table 1 and Table 2.

Table 3. Retail competitor price analysis.

Retailer	Size	Natural	Price	Colored	Price	%Increase
Lowe's	3 yd^3	Natural Cyprus Mulch	$3.68	Red Cyprus Mulch	$3.68	0%
Atwoods	2 ft^3	Pine Cypress	$2.99 $2.99	Red Mulch	$2.99	0%
Home Depot	2 ft^3	Cypress	$2.67	Red Mulch	$3.33	25%

Table 4. Industry competitors, by state, price analysis.

State	Supplier	Size	Natural	Price	Colored	Price	% Increase
Texas	Mulch King	yd^3	Native Mulch	$24	Red Hardwood Brown Hardwood Golden Pine	$27 $26 $24	12% 8% 0%
	Mulch X-Press	yd^3	Shredded Hardwood	$24	Red Colored Black Midnight	$26 $28	8% 16%
	Dirt Cheap Mulch Co.	yd^3	Natural Brown Hardwood	$20	Black Mulch Red Dye Hardwood	$28 $26	40% 30%
Arkansas	Green Forest Products	yd^3 $2ft^3$	Aromatic Cedar Mulch Cedar	$15.35 $1.75	Colored Colored	$18.50 $1.75	21% 0%
Oklahoma	Green Country Soil	$2ft^3$ $2ft^3$	Cedar Mulch Hardwood Mulch	$2.55 $1.90	Red Cedar Mulch Red Colored Midnight Black Cocoa Brown	$2.99 $2.05 $2.15 $2.05	17% 8% 13% 8%
	G.C.S. Bulk Sizes	yd/load	Hardwood Double Ground	$12	Red Colored Black Colored Cocoa Brown	$16.50 $16.50 $16.50	38% 38% 38%
		yd/load	Aromatic Cedar Mulch	$21	Brilliant Red Aromatic Cedar	$26	24%

Technical Analysis

Currently, there are no small-scale woodchip coloring systems on the market. However, there are large scale woodchip coloring systems. Colorbiotics ®, Amerimulch ™, Fecon, Morbark, Bandit Industries Inc., and Rotochopper Inc. each sell large scale wood chip coloring systems.[26,27,28,29,30,31]

[26] "Colorant Equipment." Colorbiotics. 2009. Web. 16 September 2009. <http://www.colorbiotics.com/ColorantEquipment.html>.

[27] "Mulch Equipment Line." Amerimulch. 2007-2009. Web. 16 September 2009. < http://amerimulch.com/mulch_equipment.php>.

The advantage to using large scale systems is that large amounts of woodchips can be colored at once. One disadvantage of large scale systems is that large batches of dyed woodchips have to be produced and sold in order to compensate costs of operation. Specification sheets for the large scale systems can be found in Appendix A.

Moisture Content

According to Dr. Salim Hiziroglu, wood scientist in the forestry department at OSU, the moisture content of the green mulch will easily be 30-40% moisture content (M.C.). Lower density wood species, such as softwoods, will have higher moisture content than higher density species, i.e. hardwoods.

Dyes

The major concerns the team needs to address when looking at dyes is the possible toxicity and the pH level associated with them. It is ideal to stay as close to neutral pH (7) as possible. Looking at what is already on the market, Colorbiotics, for examples, states that its dyes are pH 9-10.[32] Dr. Hiziroglu said that is ok, but again, the dye should be as close to neutral pH as possible, so as not to affect plant structures when the mulch is placed in a flower bed. Another issue with liquid dyes is the runoff that would occur when dyeing the mulch. Some dye could be washed away during the dyeing process, as well as after the dye is applied during a storm event, fed into the sewer inlets, and into nearby streams and waterways, leading to environmental health issues.

When the team consulted with Dr. Hiziroglu, he suggested the team stay away from liquid dyes and instead focus on powdered dyes. Dr. Hiziroglu said that with the mulch M.C. at 30-40%, it should be enough for powdered dyes. Some water may need to be applied, but not much. To help the dye stick to mulch, the team will look at using starch as a surfactant. The team chose starch because it is cheap and readily available.

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[28] "Mulch Coloring, Mixers & Conveyors. Fecon. 2009. Web. 18 October 2009. < http://www.fecon.com/mixers/default.asp>.
[29] "Dry Colorant Processing System." Morbark. 2009. Web. 21 November 2009. < http://www.morbark.com/Equipment/SpecSheets/DryColorant.pdf>.
[30] "Color Critter II." Bandit Industries Inc. 2009. Web. 21 November 2009. < http://www.banditchippers.com/index.php?option=com_models&task=view&itemId=15&lineId=9&modelId=32>.
[31]" CP-118." Rotochopper Inc. 2009. Web. 21 November 2009. < http://www.rotochopper.com/equipment/chip-processors/cp-118.html>.
[32] "Material Safety Data Sheet." Colorbiotics MSDS. 2009. Web. 16 September 2009. < http://www.colorbiotics.com/SafetyMSDS.html>.

The team found organic powdered dyes available from Organic Dyestuff Corporation.[33] Erin spoke with a representative from Organic Dyestuff Corporation over the phone, and he told her about the process that they use when they color wood products. They use a fire application to apply the dry powder dye by heating the wood to a specific temperature that would allow the powder, along with water, to coat the wood. The representative also mentioned using some sort of surfactant (not specifically mentioned) to make the powder last longer on the mulch. He told Erin the basic colors with their organic powders were blonde, red cedar, black and any color combinations of those. He also mentioned the carbon black and iron oxides color has a scale within the gray and red families that can also be achieved. The team is looking at purchasing some of these dyes to experiment with.

The colored mulch industry has two primary types of companies making mulch - land clearing companies and waste recycling companies.[34] There are two basic types of colorants on the market today, liquid and powdered dye. The two largest colored mulch producers Amerimulch and Colorbiotics both use their own line of liquid colorants.[35,36] The primary coloring material in red dyes is iron oxides. The primary coloring material in black dyes is carbon black – almost like burnt charcoal.[37] Liquid dyes are able to coat and penetrate the wood more efficiently than powdered dye but the main setback with using liquid dye is the drying time is significant. Powdered dyes can be ground into the wood as it is being mulched to create a continuous production where the drying time is significantly less.[38] However, the powdered dye is less effective at penetrating the pores of the wood.

Many dyes used in the mulch business are solvent based. Typically, wood based stains and lacquers are also solvent based dyes. Another type of dye is a water based dye that provides greater viscosity and penetration. Also, surfactants or mordants are used to improve the fastness or adherence of the dye to the surface.[39] Mold resistance additives are added to some mulch dyes to decrease the temperature of the mulch to reduce the likelihood of mold

[33] "Dyes." Organic Dyestuff Corporation. 2006. Web. 14 October 2009. < http://www.organicdye.com/dyes.asp>.
[34] "Trouble With Colored Mulch." Garden Web. 2006. Web. 28 October 2009. <http://forums.gardenweb.com/forums/load/newgard/msg071838525191.html>.
[35] "Mulch Colorant Line." Amerimulch. 2009. Web. 16 September 2009. < http://amerimulch.com/color-enhanced-mulch.php>.
[36]"Mulch Colorant." Colorbiotics. 2009. Web. 16 September 2009. < http://www.colorbiotics.com/MulchColorant.html>.
[37] "Trouble With Colored Mulch." Garden Web. 2006. Web. 28 October 2009. <http://forums.gardenweb.com/forums/load/newgard/msg071838525191.html>.
[38] "Dry Colorant Processing System." Morbark. 2009. Web. 21 November 2009. < http://www.morbark.com/Equipment/SpecSheets/DryColorant.pdf>.
[39] "Dye." Wikipedia. 2009. 28 October 2009. <http://en.wikipedia.org/wiki/Dyes>.

developing on the mulch.[40] The colorants used are permanent meaning once the dye has dried there should be no runoff or leaching.[41] These dyes are tested and found to be safe and non-toxic.[42]

Table 5. Cost of Liquid and Powdered Dyes

Company	Quantity	Cost
Colorbiotics	55 Gallon Drum	$500
	35 Gallon Drum	$300
Organic Dyestuff	30 Gallon Drum	$600
	5 Gallon Bucket	$280
Procion MX Dyes	1 lb	$22.00
	5 lbs	$69.00
	10 lbs	$114.00
	20 lbs	$200

Dyeing the Mulch

The heartwood of the log is treated naturally with chemicals.[46] Because of this naturally occurring chemical treatment, heartwood will not be able to absorb dyes as easily as sapwood.[47] Also, when looking at heartwood vs. sapwood, the heartwood will be darker when dyed. Sapwood will be easier to dye due to lack of natural chemicals. So when dyeing the mulch, some pieces may be darker than others, depending on if the mulch is sapwood or

[40] "Mulch Colorants" T.H.Glennon company inc. 2009. Web. 28 October 2009. <http://www.mulchcolorjet.com/mulch.htm>.
[41] "Mulch Colorant." Colorbiotics. 2009. Web. 16 September 2009. < http://www.colorbiotics.com/MulchColorant.html>.
[42] "Mulch Colorant Products." Earth Shades. 2009. Web. 28 October 2009. <http://www.mulchdye.com/>.
[46] Personal Conversation. Dr. Salim Hiziroglu. Stillwater, OK. 21 October2009.
[47] Personal Conversation. Dr. Salim Hiziroglu. Stillwater, OK. 21 October2009.

heartwood. When comparing softwood versus hardwood in general softwoods will be easier to dye, due to their cellular structure.[48]

Table 12.2 from Understanding Wood shows the ease of penetration, by preservatives, of the heartwood of various softwood and hardwood species.[49] This, however, is under the condition of a vacuum, pressurized treatment, and it is using a whole log, not woodchips. As was stated by both the book and Dr. Hiziroglu, penetration of the wood is much higher when it is pressurized.

Patent Searches

Pat No *Title*

7381271 *Colorant dispensing system for adding colorant to pre-comminuted material and method of coloring same (2008)*

Inventor: Royce A. Farmwald & P.J. Farmwald

This patent involves a method of adding color to pre-chipped wood. Dry colorant is dispersed in a controlled manner onto the wood chips and then ground into the wood chips. Water is sprayed on after the grinding, allowing the process to use less water than other systems.[50]

WO2005016606(A1) Wood treating formulation (2005)

Inventor: Marc H. Schneider

Assignee: Sam Briddes et al.

This patent details the process that Kebony[51], a Norwegian company that produces innovative wood products, uses to treat and color wood. This process involves a polymerization of wood that improves the durability of wood as well as imparting color. Furfuryl alcohol, a waste product from sugar cane production, is used in the process.[52]

6672114 B2 *Apparatus for batch dyeing (2004)*

Inventor: Benjamin H. Glover, R.D. Nabow, B.R. Edwards, & S.K. Stewart

Assignee: Milliken & Company

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[48] Hoadley, R. Bruce. *Understanding Wood a Craftsman's Guide to Wood Technology.* Newtown: The Taunton Press, 2000. Print.

[49] Hoadley, R. Bruce. *Understanding Wood a Craftsman's Guide to Wood Technology.* Newtown: The Taunton Press, 2000. Print.

[50] Farmwald, Royce A. and P.J. Farmwald. "Colorant Dispensing System for Adding Colorant to Pre-Comminuted Material and Method of Coloring Same." Patent 7381271. 3 June 2008.

[51] Brochure. Kebony ASA, 2008. Web. 1 September 2009. <http://www.kebony.com/enu/index.cfm.>

[52] Schneider, Marc H. Wood Treating Formulation." Patent WO2005016606(A1). 24 February 2005.

This patent describes the machinery used to efficiently batch dye various materials and liquids. A granular or powder additive is combined with liquids to create a colorant solution. At various times during the batch process dye is added to the liquid. Once the batch of materials is dyed the liquid is drained from the chamber leaving a permanently died product.[53]

6321804 *Process for grinding and coloring wood chips (2001)*
Inventor: Christopher Mangold
Assignee: Mangold Recycling Inc.
This device grinds wood to an appropriate size, sieves it, and then sprays it with a wet dye. The wood chips and dye are then mixed by use of counter rotating augers. Multiple augers allow for the wood chips to be colored twice. Dyed wood chips are then dried after being fed through the auger. [54]

5562956 *Wood chipping and dyeing processes and products thereof (1996)*
Inventor: Haves R. White Jr.
This method uses coloring agent added to a wetting fluid to color wood chips. The wood is colored under the process of a heated dye bath. Wood chips are rinsed with hot water bath to ensure fastness of the dye, and then set aside to dry.[55]

5308653 *Method for coloring wood chips using a screw conveyor (1994)*
Inventor: Greg Rondy
Assignee: Kurtz Bros. Inc.
Coloring is achieved through the use of continuous process auger system. Wet colorant containing iron oxide and/or carbon black pigment is applied in a controlled amount onto the wood chips. The wood chips and dye are mixed as they move up the auger. Dyed wood chips exit the chute for further drying. [56]

5242464 *Method of bleaching wood (1993)*
Inventor: Donn R. Armstrong R.P. Anderson & S.S. Borys
Assignee: Pyxis Corporation

[53] Glover, Benjamin H., R.D. Nabow, B.R. Edwards, and S.K. Stewart. "Apparatus for Batch Dyeing." Patent 6672114 B2. 6 January 2004.
[54] Mangold, Christopher. "Process for Grinding and Coloring Wood Chips." Patent 6321804. 27 November 2001.
[55] White Jr., Haves R. "Wood Chipping and Dyeing Processes and Products Thereof." Patent 5562956. 8 October 1996.
[56] Rondy, Greg. "Method for coloring wood chips using a screw conveyor." Patent 5308653. 3 May 1994.

This patent includes a method of bleaching wood through the use of a hydrogen peroxide solution. The benefits of this process are that the bleaching can be achieved in a single application which takes 10 to 15 minutes. This process produces brighter and whiter wood than previous methods. For maximum bleaching, the solution must be moved back and forth on the surface of the wood by the use of an abrasive pad. An additive can be used to help prevent the hydrogen peroxide from degrading too quickly. Addition of dye into the bleaching solution allows for bleaching and dyeing in a one step process. [57]

4932156 *Method of controlling the color of mulch (1990)*
Inventor: Roger C. Underwood
Assignee: Becker-Underwood, Inc.
This patent makes claims on a method to enhance the color of mulch by applying a colorant composition to the product. This gives the mulch; even old and faded chips a long-lasting new appearance. The additive solution slows the effects of weathering and browning of the mulch. This results in having to reapply mulch less often.[58]

4788790 *Method of making a dark uniformly-colored, hardwood mulch (1988)*
Inventor: Charles B. Zeager
This method uses recycled water to saturate the wood completely to penetrate the wood pores. The process is continued until uniformly-colored mulch is obtained.[59]

4062145 *Mulch carpet and method for making same (1977)*
Inventor: Lester Gidge
Assignee: Terra-Tex Corporation
This patent describes a method of making flexible mulch carpeting. The mulch carpet is composed of a synthetic, open mesh fabric sandwiched between two layers of bark. Mulch is mixed with liquid resin and iron oxide to color and coat the bark. The fabric and mulch are held together by resin.[60]

All patents can be found in Appendix B.

[57] Armstrong, Donn R., R.P. Anderson, and S.S. Borys. "Method of Bleaching Wood." Patent 5242464. 7 September 1993.
[58] Underwood, Roger C. "Method of Controlling the Color of Mulch." Patent 4932156. 12 June 1990.
[59] Zeager, Charles B. "Method of Making A Dark, Uniformly-Colored, Hardwood Mulch." Patent 4788790. 6 December 1988.
[60] Gidge, Lester. "Mulch Carpet and Method for Making Same". Patent 4062145. 13 December 1977.

Lab Experiments to be Conducted

For the following experiments, both powdered dye and liquid dye will be tested. The team will also run separate tests that include mixing starch into the dye, to help the dye stick to the mulch. Various brands and types of bagged mulch, green mulch, and pre-treated lumber that have been turned into mulch will be used in all the experiments. By testing various types of mulch, the team will determine how the moisture content and wood type (i.e. hardwood vs. softwood, green vs. treated) affects the coloring process.

Experiment # 1- Coloring woodchips with a mixing/tumbler device.

The team will look at coloring the various mulches with dye using a mixing/tumbler device, such as a mini-cement mixer.

Experiment #2- Using heat to aid in the dyeing process.

This experiment will look at coloring the mulch in conjunction with heat. Preliminary research has shown that applying heat while dyeing a material, such as wood, will help with the dyeing process. The team will test with a dryer system, an oven, and a kiln, if possible. The mulch will be mixed/tumbled during the experiment.

Experiment #3- Hand held pressure painter device

The team will evaluate coloring mulch using a hand held pressure painter device while having the mulch reside in some sort of container that is either stationary or in rotation. This approach would most likely only work when using liquid dyes.

Experiment #4- Pressurized vacuum chamber approach

The team will also experiment dyeing the mulch using a pressurized vacuum chamber, which can be easily created with PVC pipe and caps. According the Dr. Bowser, the FAPC also has vacuum tumblers and a pressure retort that can be utilized.

Experiment #5- Affects of weathering on mulch

In addition to coloring the mulch, the team will look at the affects weathering has on the dyed mulch, i.e. rainfall, sunshine, extreme hot and cold temperatures, snow, etc.

Experimental Procedures

The following are the procedural write ups for the experiments to be conducted.

Experiment # 1

Title: Coloring woodchips with a mixing/tumbler device

Experiment Date(s): January 13, 2010 – January 15, 2010

Objective: In this experiment, the team will study the effects of wood species, mulch properties, and type of dye on colorization of mulch. The team will look at coloring the various mulches with dye using a mixing/tumbler device, such as a mini-cement mixer.

Materials Required:

Cement mixer
Liquid dye
Powdered dye
Bagged mulch, various species of hardwood and softwood
Green mulch (freshly chipped), various species of hardwood and softwood
Dried mulch, various species of hardwood and softwood

Procedures:

Apply these procedures to each variety and species of mulch used, using both powdered and liquid dye.

1) Insert the mulch into cement mixer
2) Apply the dye
3) Run mixer for ten minutes
4) Remove mulch and set aside for drying
5) Evaluate the mulch

Experiment # 2

Title: Using heat to aid in the dyeing process

Experiment Date (s): January 18, 2010 – January 22, 2010

Objective: This experiment will be conducted to determine the effect of heat on the dyeing process compared to a process without heat. Preliminary research has shown that applying heat while dyeing a material, such as wood, will help with the dyeing process. The team will test with a dryer system, an oven, and a kiln, if possible. The mulch will be mixed/tumbled during the experiment.

Materials Required:

Mixing/tumbler device with heating element
Liquid dye
Powdered dye
Bagged mulch, various species of hardwood and softwood
Green mulch (freshly chipped), various species of hardwood and softwood
Dried mulch, various species of hardwood and softwood

Procedures:

Apply these procedures to each variety and species of mulch used, using both powdered and liquid dye.

1) Insert mulch into tumbler with heating element
2) Apply the dye
3) Run mixer for ten minutes
4) Remove mulch and set aside for drying
5) Evaluate the mulch

Experiment # 3

Title: Pressurized Vacuum Chamber approach

Experiment Date (s): January 18, 2010 – January 22, 2010

Objective: Quantify the effectiveness of a vacuum in facilitating the colorization process

Materials Needed:

Bagged mulch, various species of hardwood and softwood
Green mulch (freshly chipped), various species of hardwood and softwood
Dried mulch, various species of hardwood and softwood
Powdered Dye
Liquid Dye
Unpressurized Chamber (PVC pipe and cap on one end)
Pressurized Vacuum Chamber (PVC pipe and caps)

Procedure:

Apply these procedures to each variety and species of mulch used, using both powdered and liquid dye.

1. Assemble both unpressurized and pressurized chambers.
2. Apply equal an amount of wood chips into each chamber.
3. Add equal parts liquid colorant to each chamber.
4. Apply pressure to one chamber and cap it closed while leaving the other open.
5. In the same manner allow the colorant to permeate the wood chips for an equal amount of time.
6. Observe the results of the two chambers noting the penetration, richness of color and overall color coverage.

Experiment # 4

Title: Hand Held Pressure Painter Device

Experiment Date(s): January 25, 2010 – January 29, 2010

Objective: Determine the effectiveness of a pressure painter in facilitating the colorization process.

Materials Needed:

Bagged mulch, various species of hardwood and softwood
Green mulch (freshly chipped), various species of hardwood and softwood
Dried mulch, various species of hardwood and softwood
Liquid Dye
Hand held pressure painter
Wooden container

Procedure:

1. Assemble the wood container and ready it for use.
2. Ready the pressure painter device by filling it with liquid dye.
3. Put the wood chips into the container.
4. Use the pressure painter device to apply the dye to the wood chips.
5. Allow the dye to saturate the material.
6. Repeat the above steps but with rotation of the wooden container.
7. Evaluate and compare the mulch.

Experiment # 5

Experiment Date(s): January 15, 2010 – April 1, 2010

Title: Affects of weathering on mulch

Objective: To determine what affects weathering has on the dyed mulch, i.e. rainfall, sunshine, extreme hot and cold temperatures and snow.

Materials Needed:

Dyed mulch
Rainfall simulator
Metal Halide Lamp
Heat lamp
Box Plot
Freezer
Snow

Procedure:

Rainfall Simulator or Actual Storm event:

1. Place mulch in a box plot and place underneath rainfall simulator.
2. Run the simulator off and on for one hour.
3. Evaluate the mulch after it has dried.

Or

1. Place mulch in a box plot and place outside during a rainfall event.
2. Evaluate the mulch after the storm is over and the mulch has dried.

Sunshine:

1. Obtain a metal halide lamp.
2. Place mulch in a box plot underneath the lamp.
3. Leave mulch under lamp for two weeks.
4. Evaluate the results every two days.

Extreme Hot:

1. Obtain a heat lamp.
2. Place mulch in a box plot underneath the heat lamp.
3. Leave mulch under lamp for two weeks.
4. Evaluate the results every two days.

Extreme cold:

1. Place dyed mulch in a freezer.
2. Every two days, remove the mulch, let it thaw, and evaluate.
3. Place back in freezer.
4. Leave in freezer for total of two weeks.

Snow:

If there is a snow storm:

1. Place mulch in a box plot and place outside during a snow event.
2. Leave outside until the snow has all melted.
3. Evaluate the mulch.

If no snow storm:

1. Place mulch in a box plot.
2. Place finely ground ice in a layer on top of the box plot.
3. Leave in a freezer for one week.
4. Remove from freezer, allow “snow” to melt and for mulch to dry.
5. Evaluate the mulch.

Experiment Materials

Table 6 lists the equipment and materials that the team will need in order to conduct the experiments.

Table 6. Equipment and materials.

Equipment/Materials Needed	Where Can Be Purchased/Borrowed From
Liquid dye	Colorbiotics, Amerimulch, Organic Dyestuff Corporation
Powdered dye	Jacquard
Starch	Wal-Mart
Mulch (bagged and unbagged)	Chad Gray, Lowe's, Atwoods, Wal-Mart
Heating device: dryer, oven, kiln	FAPC, BAE Lab
Mini-cement mixer	Dr. Weckler, Lowe's
Mini-wood chipper	Kinnunen, Lowe's
Pressure retort	FAPC
Vacuum chamber	FAPC, Lowe's
Dehydrator	FAPC
Large containers/bags for mulch	Wal-Mart, Lowe's, Atwoods
pH testing materials	FAPC, BAE lab
Moisture content measuring devices	BAE Lab, Dr. Jones
Rainfall Simulator	Plant and Soil Science Department

Data Collection

A survey will be taken from the general public at Atwoods, Kinnunen, and Tractor Supply in Stillwater, Oklahoma. The following is a copy of the survey:

Please circle your response. Thank you!

How often do you buy natural wood mulch?
Never 1-2 times a year More than 2 times a year

How often do you buy colored mulch?
Never 1-2 times a year More than 2 times a year

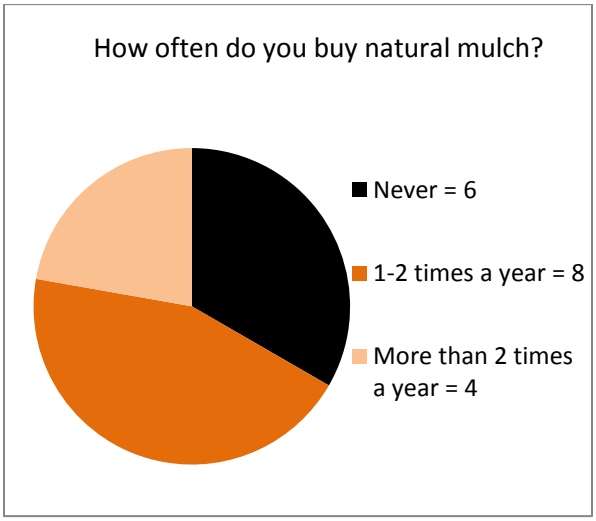
Would you be interested in coloring your own mulch at home?
Yes No Maybe

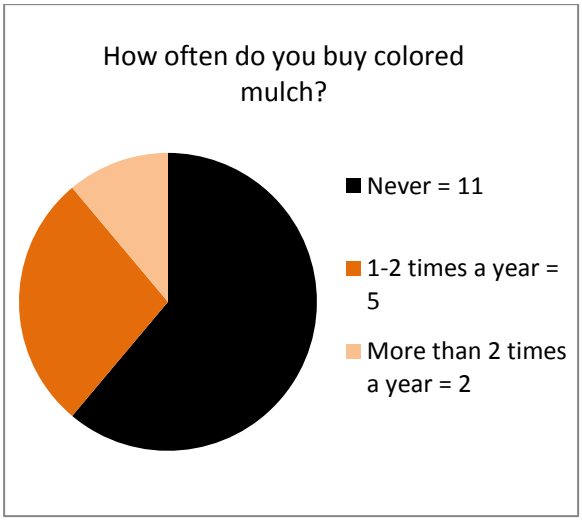
Would you be interested in buying an at-home mulch coloring product?
Yes No Maybe

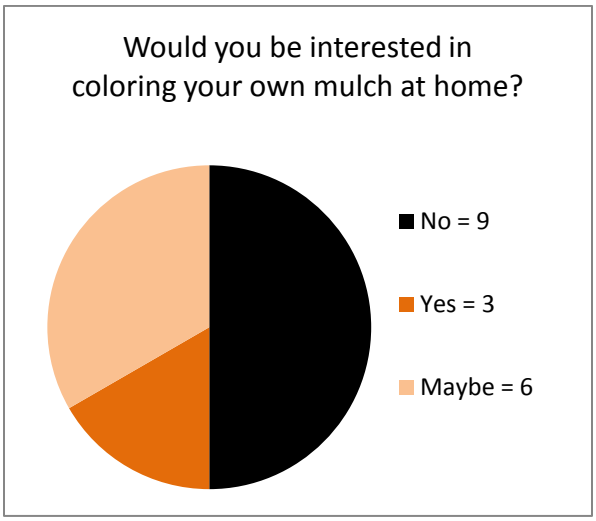
If yes, would you be interested in dyeing mulch to a customized color?
Yes No Maybe

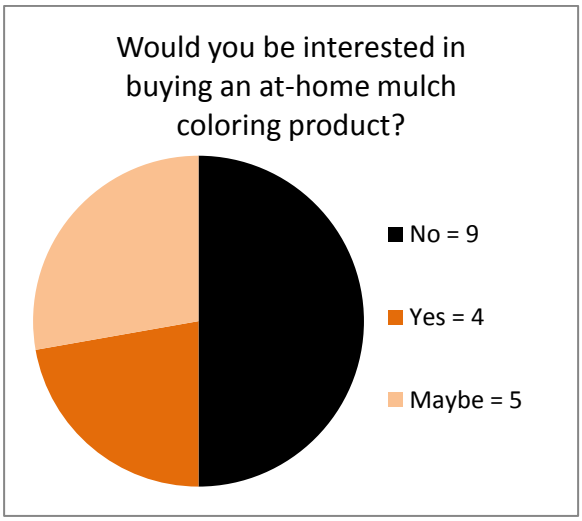
Comments:_____
_____

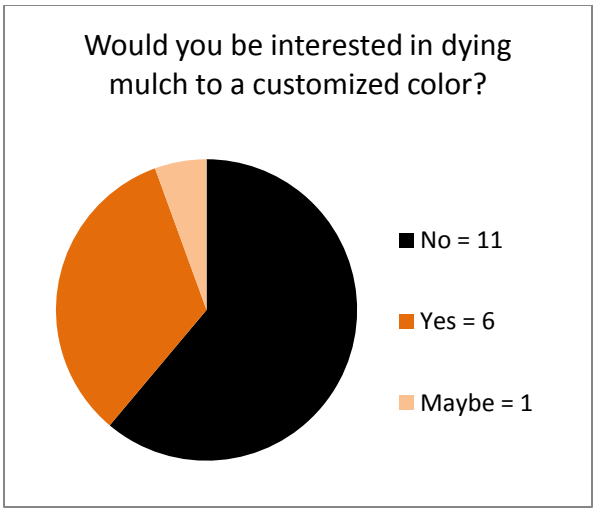
A total of 18 customers turned in surveys at Kinnunen. Tractor Supply and Atwoods did not respond to our request. Results are shown below.











In addition, a survey will be taken amongst Oklahoma landscapers, to see if they would be interested in the small scale coloring device as well. The following is a copy of the phone survey:

Hi, can I speak with your manager please?

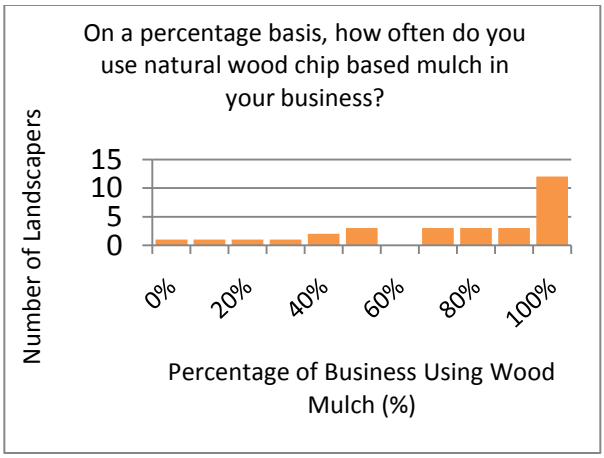
Hi *(manager/owner name)* this is *(your name)*. I am a student at Oklahoma State University. I am conducting research for my senior design project. Do you have some time to answer a few questions?

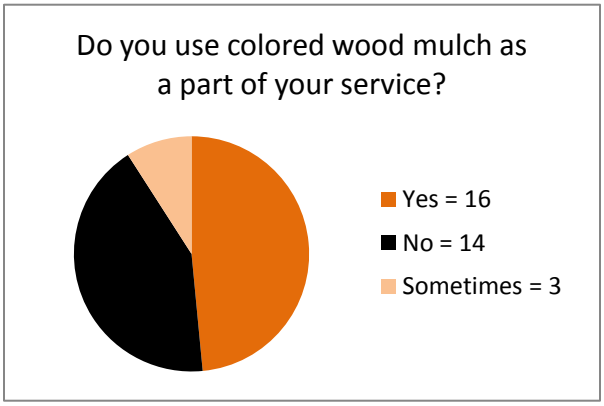
1. First, do you use natural wood mulch as a part of your services?
2. On a percentage basis, how often do you use natural wood chip based mulch in your business?
3. How many pounds of natural wood chip based mulch do you use in a year?
4. Do you use colored wood mulch as a part of your services?
5. Do you make mulch on the job or buy mulch before hand?
6. If it were available, would you be interested in purchasing a small-scale product to color wood mulch for your business?

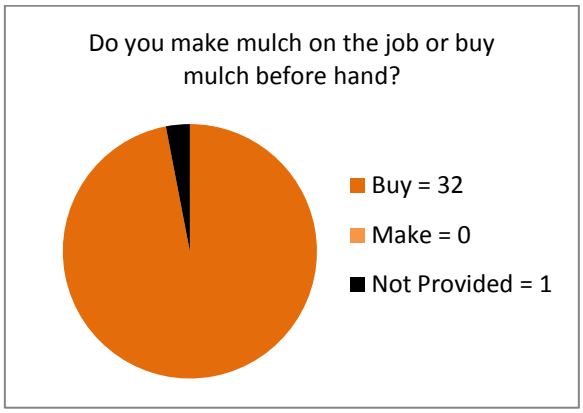
Thank you so much for your time. I appreciate your input. Have a great day.

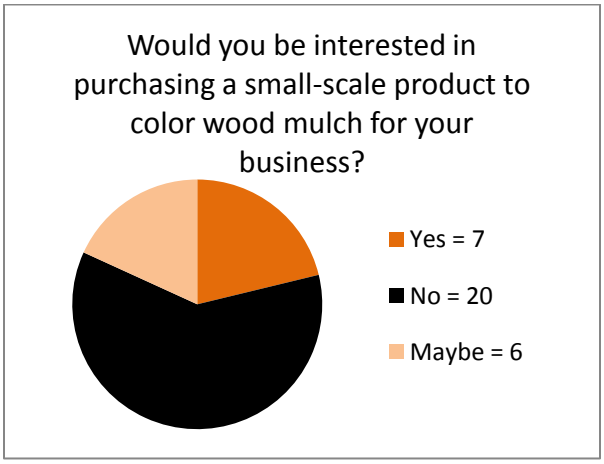
A total of 102 Oklahoma landscapers were called by the team. Out of the 102 landscapers called, only 33 completed the phone survey. Results are shown on the next page:


Do you use natural wood mulch as a part of your services?
Yes = 32
No = 1


On a percentage basis, how often do you use natural wood chip based mulch in your business?
Number of Landscapers
15
10
5
0
0%
20%
40%
60%
80%
100%
Percentage of Business Using Wood Mulch (%)


Do you use colored wood mulch as a part of your service?
Yes = 16
No = 14
Sometimes = 3


Do you make mulch on the job or buy mulch before hand?
Buy = 32
Make = 0
Not Provided = 1


Would you be interested in purchasing a small-scale product to color wood mulch for your business?
Yes = 7
No = 20
Maybe = 6

Design Concepts

55 Gallon Drum Tumbler

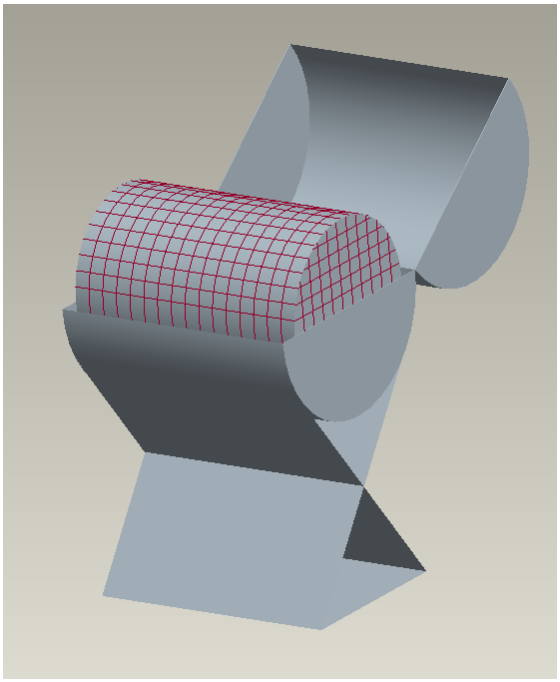


Figure 1. 55 Gallon Drum Tumbler Pro-E Drawing

This design is modeled after a 55 gallon drum grill. This design features using a 55 gallon drum on a stand and a welded wire mesh cylindrical cage placed inside of the drum, approximately 52 gallons in size. The 55 gallon drum will open as a traditional drum grill design. The orientation of the drum and mesh cage is horizontal. The mesh cage will rotate within the 55 gallon drum, powered by an electric, high torque motor, and will feature a large hinged opening for the mulch to be placed in. The cage is large enough to have 6 cubic feet worth of mulch placed inside. The 55 gallon drum will remain stationary.

Dye will be poured in the drum, with the actual required amount being determined at testing. However, there should be enough dye so when the cage is placed inside of the drum, at least 1/3 of the mulch is resting in the dye itself. During the dyeing process, the 55 gallon drum will be closed. The electric motor will power the cage to rotate until all of the mulch has been dyed. Once the dyeing has finished, the cage can be removed from the gallon drum and its contents emptied. There will be a plug with a screen located at the bottom of the drum, where the excess dye can be emptied into a container and used again later.

Another variation of this design is having the welded wire mesh cage raised onto two handles connected to the 55 gallon drum. The cage can be lifted out of the drum case and placed on the handles so that it can drip-dry, with the dye falling directly back into the drum. Yet another variation includes adding heating elements to the drum, so heat the dye during the dyeing process. In addition, electric heat fans can be added to the design to provide a heat drying mechanism to the system.

The 55 Gallon Tumbler design is feasible. Constructing the prototype of this design will not be time intensive. Materials necessary to build the prototype are readily available; no specialized parts will need to be ordered. Services from the BAE Lab can be utilized. Estimated time of building this prototype is projected to be no longer than two days of work.

Vertical Mixing Drum Design

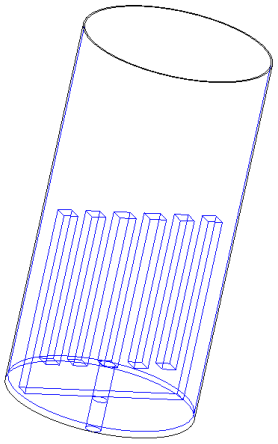


Figure 2. Vertical Mixing Drum Pro-E Drawing

One design possibility is to use the mixing technique but instead of having a horizontal drum, the drum could be turned upright. The basic design is a vertical drum with two sprayer nozzles and a mixing arm. The arm would most likely be powered by an electric motor but for the prototype we may use a hand cranking arm. A liquid pump is needed to pulse the liquid into the bin. Plastic tubing will be required to connect from the pump to the spray nozzles. Finally a stand of some sort will be needed to provide stability to the drum while in operation.

The basic process of this design is to load the wood chips into the drum. Then the sprayers will fill the tank with a know amount of dye and moisture to the desired level. The mechanical

mixing arm then begins to rotate and mix the wood chips as the dyeing processes stains the chips. The mixing arm continues to rotate for a time and then is turned off when the wood chips have the desired coloration and unified appearance. If the arm gets clogged or caught, the arm will have the ability of operating in reverse. Once the wood chips are fully colored the mixing arm will be turned off and the wood chips can be left in the drum or taken out to dry.

This design will be made with easily attainable materials which are relatively inexpensive. Although there are a few moving parts the design is reasonably simple. Since the fundamental concept of this design is used in various applications in diverse fields that proves that the design is valid. It may take several experiments before the specifications of the design can be finalized but the overall feasibility of this design is good. That said this may not be the most efficient way to color mulch.

Mulch Roll Device

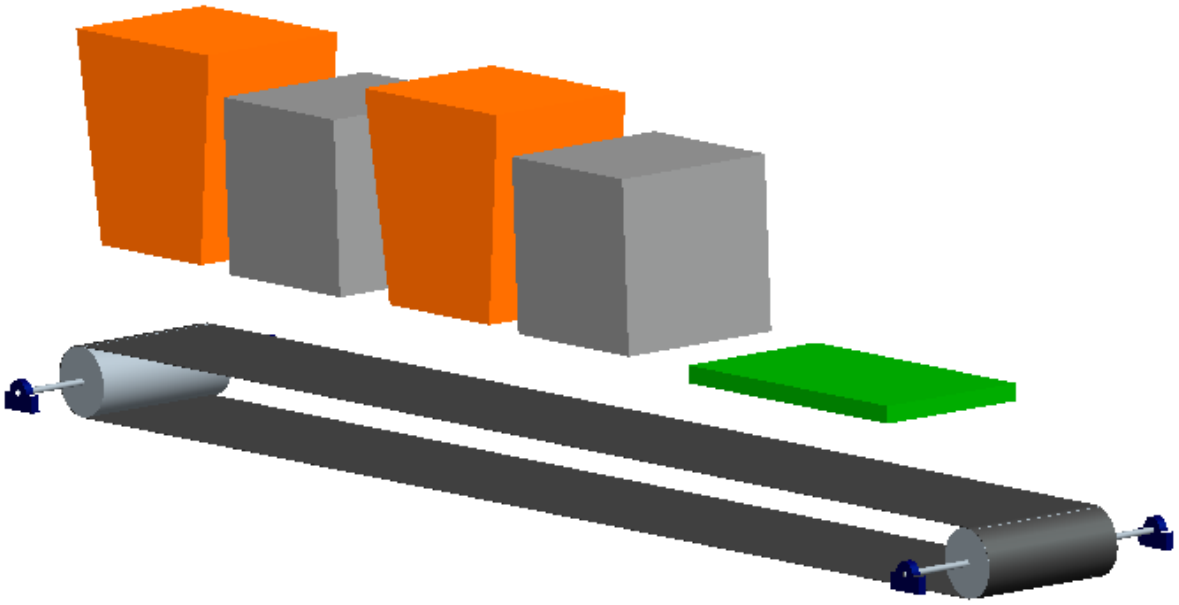


Figure 3. Mulch Roll Device Pro-E Drawing

This device allows for the production of colored mulch strips with a biodegradable fiber backing. The mulch strips can be rolled for ease of storage and used in landscaping. The user can simply unroll the 18" wide strip of mulch and place it in the desired location without having to shovel and rake the mulch into place. Also, the fiber strips will help stabilize soil and

decrease erosion. Mulch strips can be cut to desired length and shaped for placement around trees and other plants.

Mulch rolls are created by using a conveyor belt in combination with a fiber hopper, glue applicator, mulch hopper, dye applicator, and heating device. The steps for the process are:

1) Apply of thin fiber layer
2) Spray glue to bind fiber together
3) Apply thin layer of mulch
4) Spray dye onto mulch
5) Dry with infrared heating element
6) Roll mulch strip

The conveyor belt will be approximately ¼" thick and be made of heat resistant neoprene rubber. The belt will be powered by a hand crank. The conveyor will be supported by two 8" schedule 40 pipes with ¾" 1018 steel rods inside them. Two pillow block bearings will be placed at each end of the rod. The fiber and mulch hoppers will be approximately 18"x18"x24" and have open tops to allow for refilling. The flow of fiber and mulch will be controlled by adjustable shutters similar to venetian blinds. Shutters will be composed of this metal strips linked together with a 3/8" O-1 drill rod. Shutters should be adjusted to allow an even coating of fiber and mulch to fall onto the conveyor belt. The glue and dye tanks will be made from auxiliary fuel tanks. Size of fuel tanks will be roughly 6 gallons each. The tanks will be pressurized with an air compressor or bicycle pump and sealed with a cap. A low pressure, brass nozzle will spray the glue and dye onto the conveyor belt. Infrared bulbs will be used to heat and dry the mulch strip prior to rolling. Porcelain sockets will be used along with the infrared bulbs. An adjustable ramp will be placed at the end of the conveyor belt to allow the mulch strip to slide off of the conveyor. When a desired amount of mulch is made, the conveyor will be stopped and the strip will be cut. The mulch strip will then be rolled by hand for storage or immediate use.

If desired, this device could be used with previously dyed mulch. The dyed mulch could be store bought or dyed by using the Vertical Mixer or the 55 Gallon Drum and Wire Mesh Cage Tumbler. In this case, the process would remain the same except for the removal of step 4.

The fiber and mulch hoppers are relatively simple in construction. They are simply an open topped box with a device to control the flow of fiber or mulch. The flow control device will consist of steel plates about 2" wide and 18" long that will be linked together with a 3/8" O-1 drill rod. A hole will be drilled through each of the plates so that the rod may slide through. By

moving the rod back and forth, you will be able to control how far open the device will be. The strips should be linked together so that they can lie perfectly flush for a closed position. The glue and dye tanks already have female fittings, so that the nozzles may be easily connected to the tanks. The heating element will require a metal frame and mountings for the porcelain sockets. The frame could be made out of scrap metal and welded together. The most challenging piece of the design is the construction of the pipe and rod combination that the conveyor belt rests on. The construction will require small circular plates with holes to be welded to both the schedule 40 pipe and the 1018 steel rod. This will create an 8" diameter pipe with a ¾" rod sticking out at each end. Fabrication of this design will also include the welding of a crank to one of the ¾" rods.

Project Schedule

The following 12 pages are the proposed project schedule as created in Microsoft Project.

Budget

Vertical mixer Cost

Table 7. Vertical Mixer Cost.

Materials	Quantity	Cost
Stainless Steel Sheet*	1	$88.00
Open-head Steel Drum	1	$60.00
Electric Motor	1	$60.00
Plastic Tubing	1	$3.00
Pressure Washer Spray Nozzle	1	$7.00
Utility Pump	1	$60.00
Power-Driven Mixer	1	$23.00
55 Gallon Dolly Drum	1	$40.00

Potential Misc. Cost $25.00 - $30.00

Total Minimum Cost $253.00

Total Maximum Cost $281.00

55 Gallon Drum Tumbler Cost

Table 8. 55 Gallon Drum Tumbler Cost

Materials	Quantity	Cost
55 Gallon Drum	1	$68.00
Galvanized Steel Wire Mesh Sheet ($15ft^2$)	1	$9.00
Electric Gear Motor	1	$22.00
Metal Post	4	$91.00
Hinges	4	$9.00

Potential Misc. Cost $20.00

Total Maximum Cost $218.00

Mulch Roll System Cost

Table 9. Mulch Roll System Cost.

Materials	Quantity	Cost
Auxiliary Fuel Tank	**2**	**$123.00**
Spray Nozzle	**2**	**$10.00**
Infrared Bulbs	**6**	**$16.00**
Porcelain Sockets	**6**	**$23.00**
Pillow Block Bearings	**4**	**$41.00**
1018 Steel Rods	**2**	**$27.00**
Drill Rod	**1**	**$17.00**
Schedule 40 Pipe	**2**	**$239.00**
Rubber Belting	**14**	**$32.00**
	Potential Misc. Cost	**$50.00**
	Total Maximum Cost	**$578.00**

Customer Requirements & Development of Engineering Specs

In order for the customer to be satisfied with the wood chip coloring system, the system will need to successfully color small batches of wood chips affordably, efficiently and effectively. The coloring system will need to be simple and easy to operate for an average homeowner or landscape professional. The system will also need to be able to dye bagged or freshly chipped (green) mulch, regardless of the tree species. In addition, the coloring system must be easy to clean.

Solid Works and Pro-Engineering computer software will be used to create the engineering specs drawings necessary for the development of a prototype of the wood chip coloring system. The team will consult with Shea Pilgreen and Wayne Kiner in developing the specifications. These engineering specs will then be used to fabricate necessary parts. Services from the BAE Lab will be needed in order to fabricate the parts, and an outside manufacturer may be required in order to build parts that the BAE Lab cannot.

Proposed Communications Plan

- Produce a press release on behalf of Chip Incorporated to be sent out to landscape professionals in Oklahoma introducing them to the newest product in the industry.
- Produce a press release on behalf of Chip Incorporated to be sent out to rental companies in Oklahoma introducing them to the product.
- Develop a promotional brochure to be sent out with press releases. The brochure will also be used as handouts at conferences, farm shows, and other industry gatherings.
- Develop a promotional website that provides a more in-depth analysis of the product.
- Develop a booth design to be used at events.
- The booth design, website, and brochure will all be cohesive in an effort to brand the product.

Proposed Business Plan*

The current economic conditions will play a major role in the proposed business plan. There are many factors that will play a role in how successful, or unsuccessful the wood chip coloring device will be. For example the spending habits and financial strengths of our potential customers, the cost and availability of labor to manufacture the device, the terms they are able to secure from the supplier/manufacturer, and the availability to market and sell the device not only in the local market, but state wide, and possibly nationwide[61]. The potential users for this device are homeowners that either rent or purchase and landscapers that do contract work for homeowners or businesses.

In a weak economy often times businesses are very cautious, and spend a great deal of time focused on cost cutting. This leaves a great deal of customers under served or unhappy. Entire target markets are sometimes neglected. This creates a perfect environment for new, more innovative, businesses to thrive[62]. So, the potential to sell our device is there.

Our client would like us to come up with the preliminary ideas for a small wood chip coloring device that can be rented or purchased by homeowners and landscapers. In our proposed business plan it would be best to have the parts manufactured and assembled off site.

[61] Abrahams, Rhonda. *The Successful Business Plan: Secrets and Strategies.* California, 2003. Text
[62] Abrahams, Rhonda. *The Successful Business Plan: Secrets and Strategies.* California, 2003. Text

The team has suggested three potential devices to color wood chips. The Vertical Mixing Drum will cost a minimum of $253.00 depending on the equipment decided to be used in production, and a maximum cost of $281.00. Another device is a 55 Gallon Drum and Wire Mesh Cage. The total cost of parts would be $218.00. And the final idea is a Mulch Roll Device the total cost of parts for this design is $578.00. All of these totals include the cost of the parts to manufacture the product. However, labor is not included. That would be an additional cost to producing the product. That shipping cost would also be placed on the customer and would vary depending on where they live.

The total cost to produce the product and get it on site ready to be sold will depend on the design chosen. The price could then be marked up to the appropriate price. It will be much easier to determine this percentage once we have a clearer idea of the design that we will be using.

Dealing with the financial side of starting new business can often be challenging, however with the existing sawmill, it will be much easier to just expand his financial records rather than starting from scratch. At the beginning of his venture business it might be best to use a cash based accounting system to keep track of income and expenses so that it is easier to see exactly how the business is profiting in the early stages of development.

Based on the phone surveys conducted with landscapers in Oklahoma selling the wood chip coloring device might be somewhat challenging. Team members were assigned approximately 20 landscapers across Oklahoma to contact with a list of questions to ask them. Overall most of the landscapers already had an ordering system in place for their colored mulch and did not have the time or resources to devote to coloring their own wood chips. The market for what our client wants may possibly not be there.

*This proposed business plan is no longer up to date due to the recent events that have taken place. Next semester it will be revised with new information.

Possible Environmental, Society, or Global Impacts

The team's proposed designs will not have a global impact. However, it does have possible environmental and societal impact. The environmental impact lies in the dyes used with the proposed designs. Depending on the toxicity and pH level, the dyes can harm the environment. Disposal of the dyes will need to be handled with appropriate measures by both the team during prototype and experimental testing, and with customers who purchase the team's final product. These designs also have a potential impact on society. Coloring one's own mulch can encourage others to start doing more "do-it-yourself" projects, especially if the results are positive.

Works Cited

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Meet the Team

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Problem Statement

Chip Incorporated will impact the wood mulch industry by developing a new affordable wood chip coloring system.

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Statement of Need

This type of machine will cater to those who seek home improvement and landscaping projects. This product will also be beneficial to landscape professionals, providing them with a competitive edge and a unique service to offer clients.

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Mission Statement

Chip Incorporated will design and build a wood mulch coloring system that is affordable, efficient and effective in coloring wood chips to be promoted to landscape professionals.

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Existing Technologies

- Continuous: Nonstop colorization able to produce significantly more cubic yards per hour than any other method
- Batch: More color consistent for the sacrifice of mass production
- Auger: Used for mixing and processing wood chips

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Existing Technologies

- Conveyor belt: transports colored chips into piles
- Surfactant: used to ensure color fastness to the wood
- Polymerization: protective coating of the wood
- Waste Stream Utilization: i.e. sugar cane

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Amerimulch Equipment

- Color Injection System
  - Spitfire
- Continuous Coloring Systems
  - 1000 Starter System
  - Mini-Mite
  - Middie-Mite
  - Mega-Mite
  - ColorTrom 250

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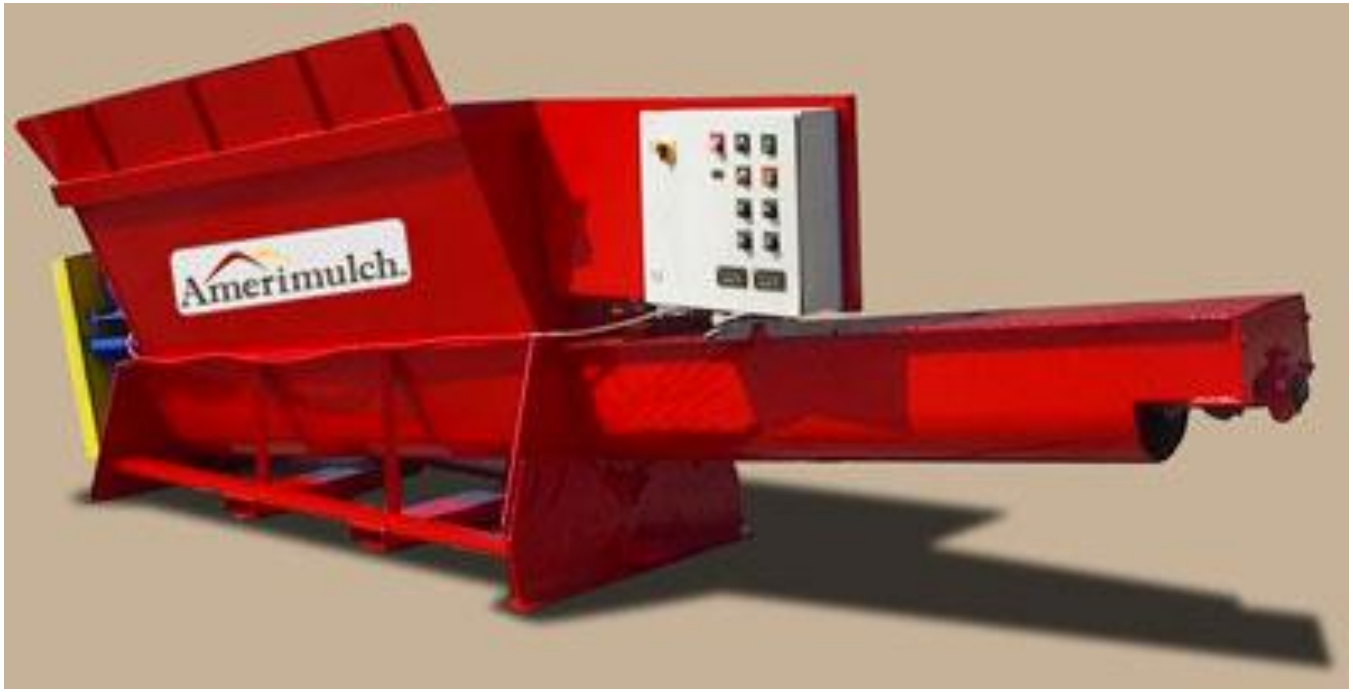
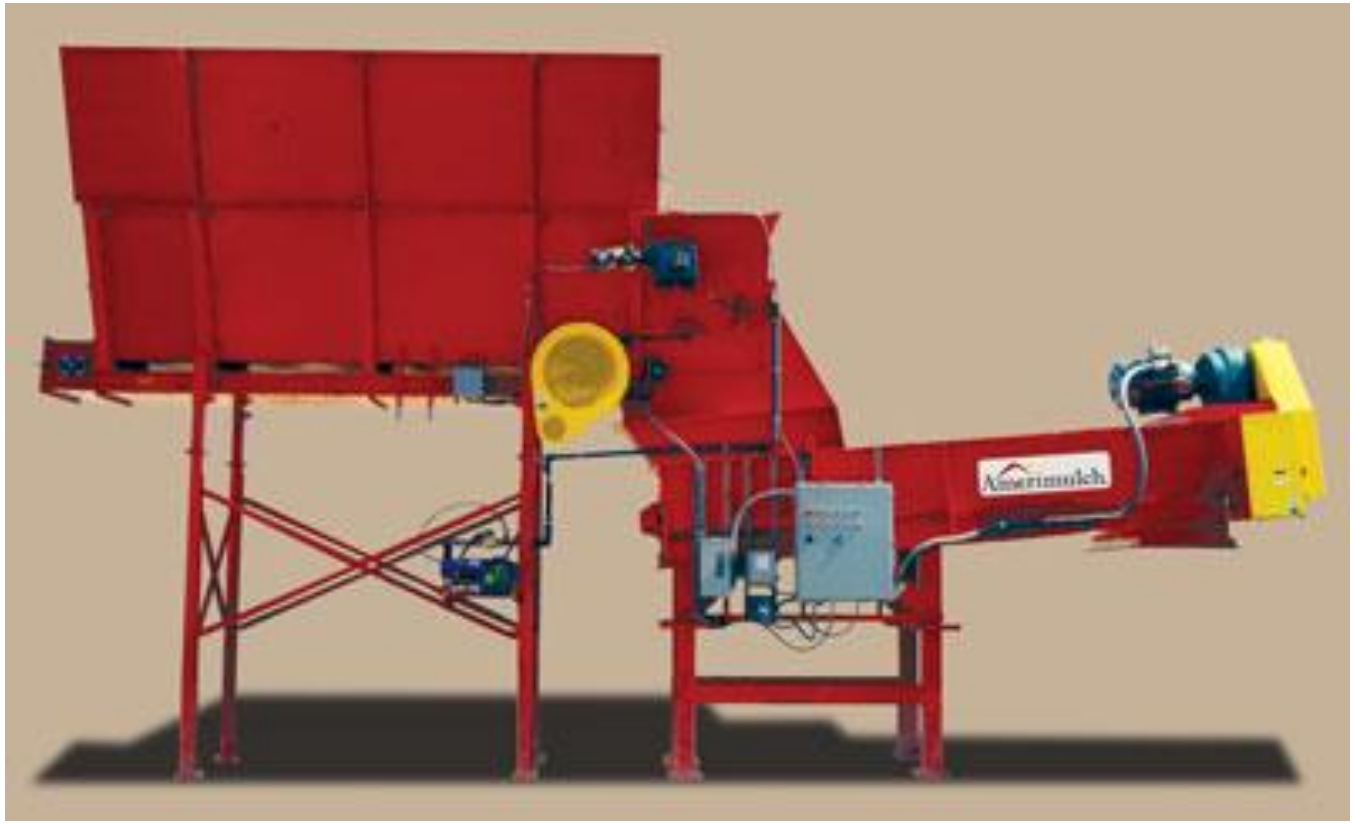
Amerimulch 1000 Starter



Amerimulch Mini Mite

Amerimulch Middie Mite

Amerimulch Mega Mite



Amerimulch ColorTrom 250

Colorbiotics Equipment

- Color Injection System
  - CM200 Color Pump
  - INFUSION
- Continuous Coloring Systems
  - Second Harvester
  - Sahara

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Second Harvester

Sahara

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Fecon Equipment

- Color Injection System
  - Rainbow Mulch Pump Stand
- Continuous Coloring Systems
  - Rainbow Mulch Continuous Mixer
  - Rainbow Mulch Batch Mixer

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Fecon Rainbow Mulch Continuous Mixer

Morbark Drycolorant Processing System

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Rotochopper CP-118

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Bandit Color Critter II

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Common Design Concept

- Coloring systems have the same basic parts
  - Hopper
  - Auger
  - Sprayer
  - Conveyor

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Patent Research

- No. 7381271 Colorant dispensing system for adding colorant to pre-comminuted wood
- No. 6321804 Process for grinding and coloring wood chips
- No. 5308653 Method for coloring wood chips using a screw conveyor
- No. 4062145 Mulch carpet and method for making same

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Dyeing the Mulch

- Heartwood will not easily absorb dyes as sapwood
- Heartwood will dye darker due to natural chemicals

http://www.solarnavigator.net/images/wood_sycamore_taxus_branch.jpg

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Dyeing the Mulch

- When dyeing the mulch, some pieces may be darker than others
- Softwoods will be easier to dye due to their cellular structure
- Toxicity and pH are dye concerns
- Liquid dyes pH 9-10

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Liquid Dyes

Pros

- Even colorization
- Penetrates wood pores well
- Permanent color
- Reusable
- Non-toxic

Cons

- Significant drying time
- Potential for staining

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Powdered Dyes

Pros

- Can be ground into the wood
- Significantly less drying time
- Non-toxic

Cons

- Potential clumping, clogging
- Questionable color fastness
- Tendency to fade or sun bleach

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Liquid vs. Powdered Dye

- Dr. Hiziroglu suggested powdered dye
- Organic Dyestuff Corporation suggested liquid dye
- The team will test both liquid and powdered dye

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Industry Analysis

- Relatively new concept
  - Black, red, blonde, and variations of these
- Large number of registered landscapers
  - 721 according to Oklahoma Secretary of State, *Sooner Access*
- Potential for market growth
  - No at home coloring device as of now

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Retail Competitors Price Analysis

Retailer	Size	Natural	Price	Colored	Price	% Increase
Lowe's	3 yd^3	Natural Cyprus Mulch	$3.68	Red Cyprus Mulch	$3.68	0%
Atwoods	2 ft^3	Pine Cypress	$2.99 $2.99	Red Mulch	$2.99	0%
Home Depot	2 ft^3	Cypress	$2.67	Red Mulch	$3.33	25%

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Customer/Buyer

- Mulch currently only purchased through retail outlet or dealer
  - Lowe's , Home Depot, Wal-Mart, local nurseries
- Is it worth coloring on my own?
  - Is retail price worth having someone else do it?
- Generally in good financial conditions
  - Have funds to spend on landscaping

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Surveys

- Called 102 Landscape Professionals located throughout Oklahoma
- 33 responded to survey
- Left survey boxes at Kinnunen
- ___ responded to survey

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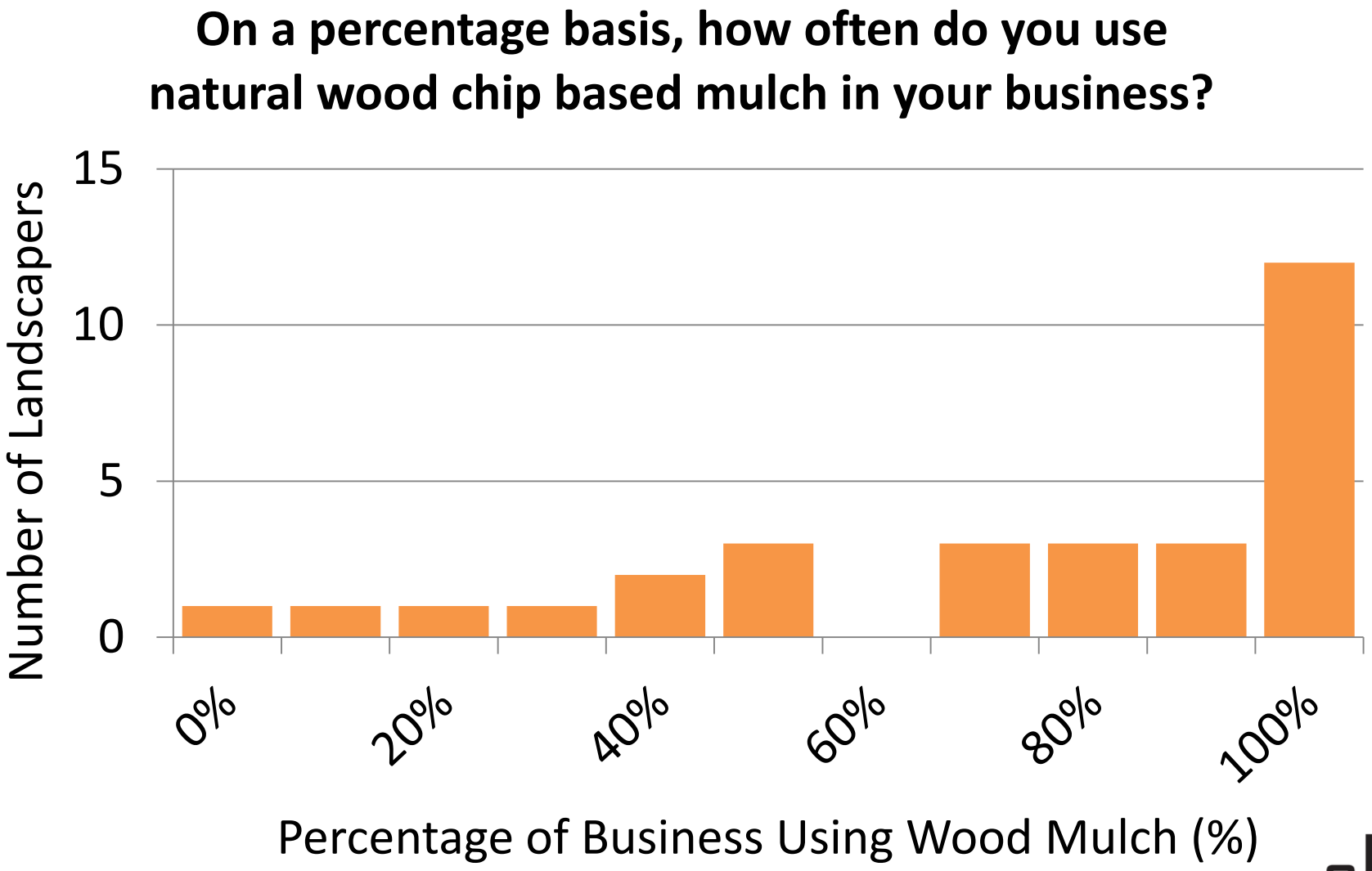
Surveys


Do you use natural wood mulch as a part of your services?
Yes = 32
No = 1

Surveys



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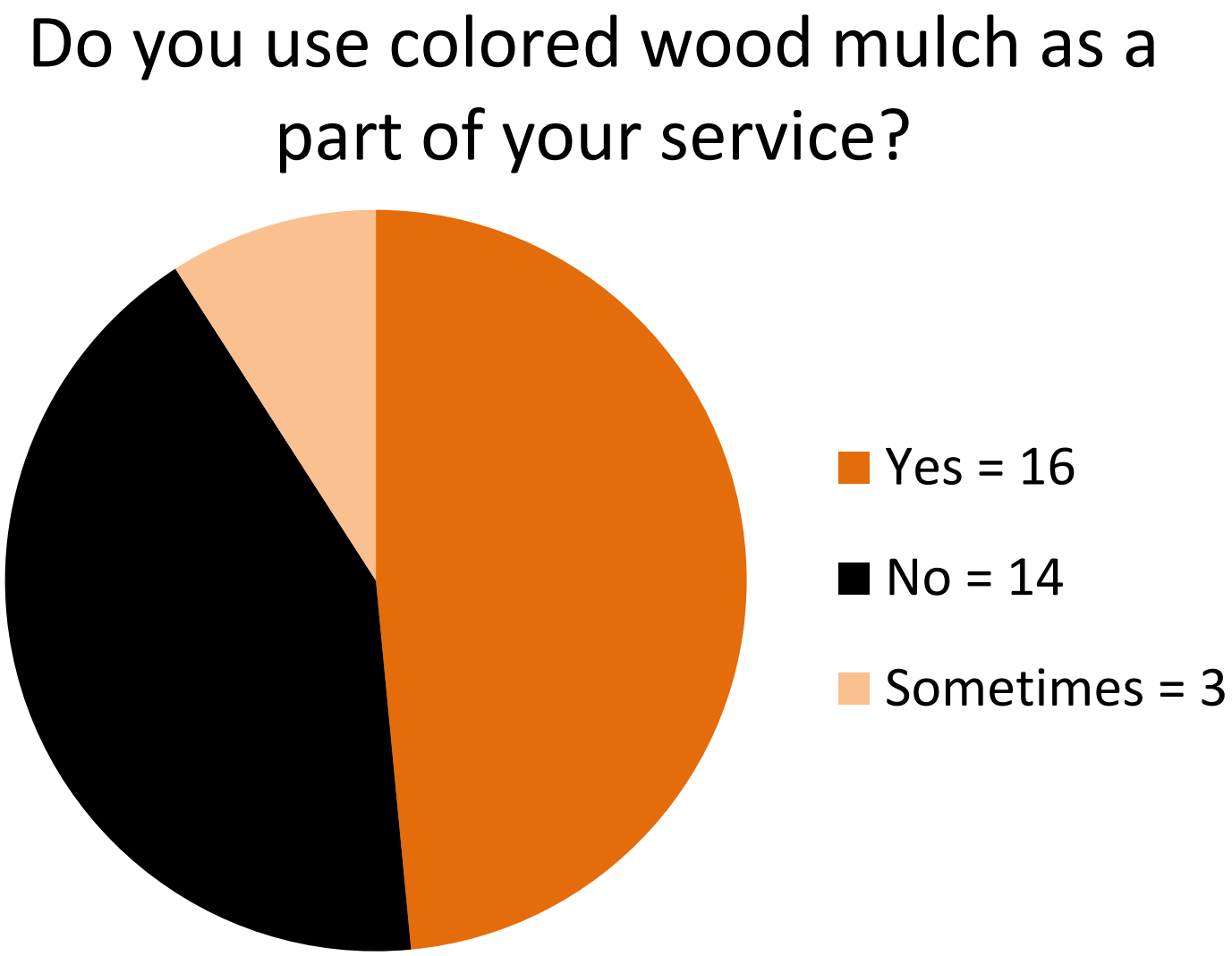
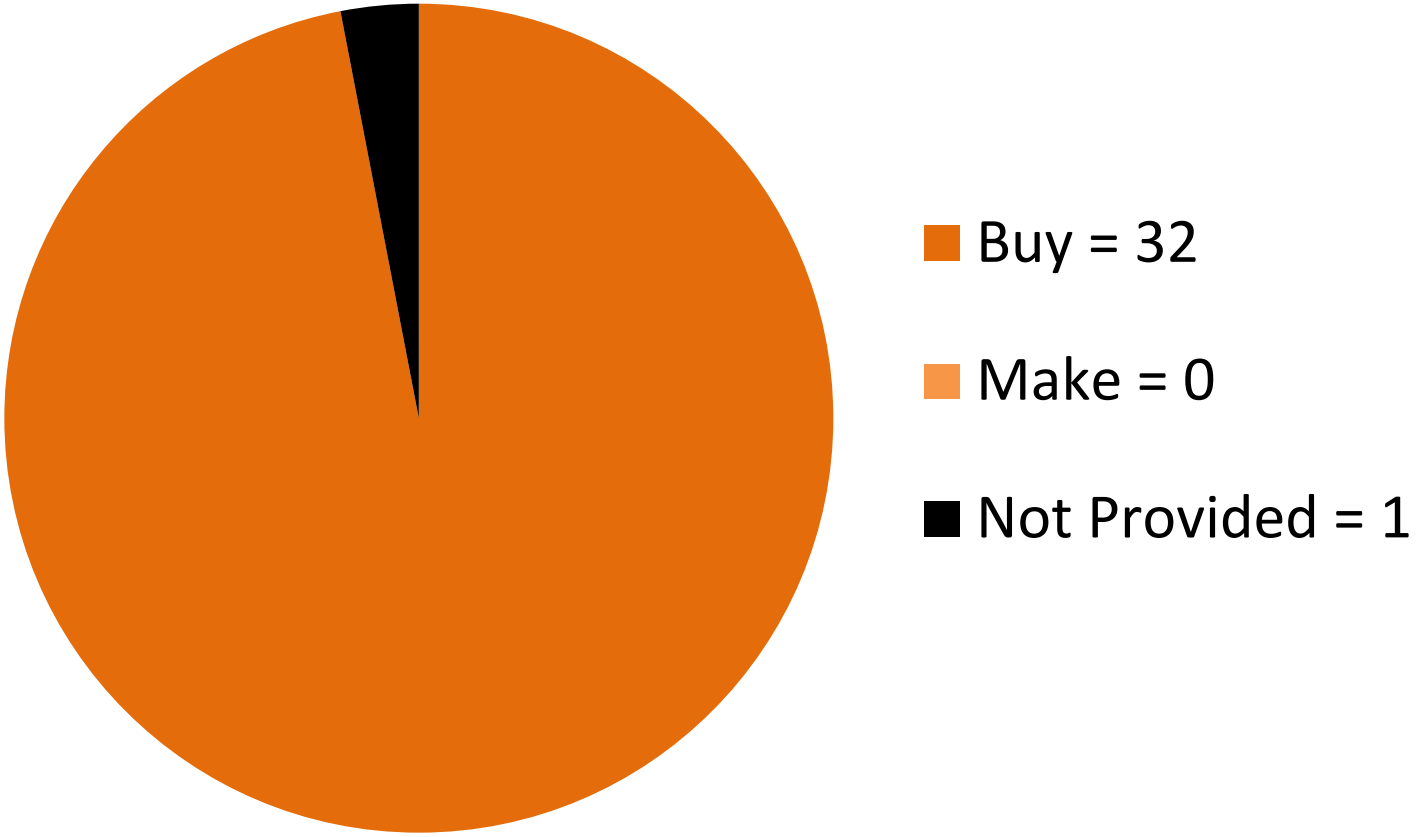
Surveys


Do you use colored wood mulch as a part of your service?
Yes = 16
No = 14
Sometimes = 3

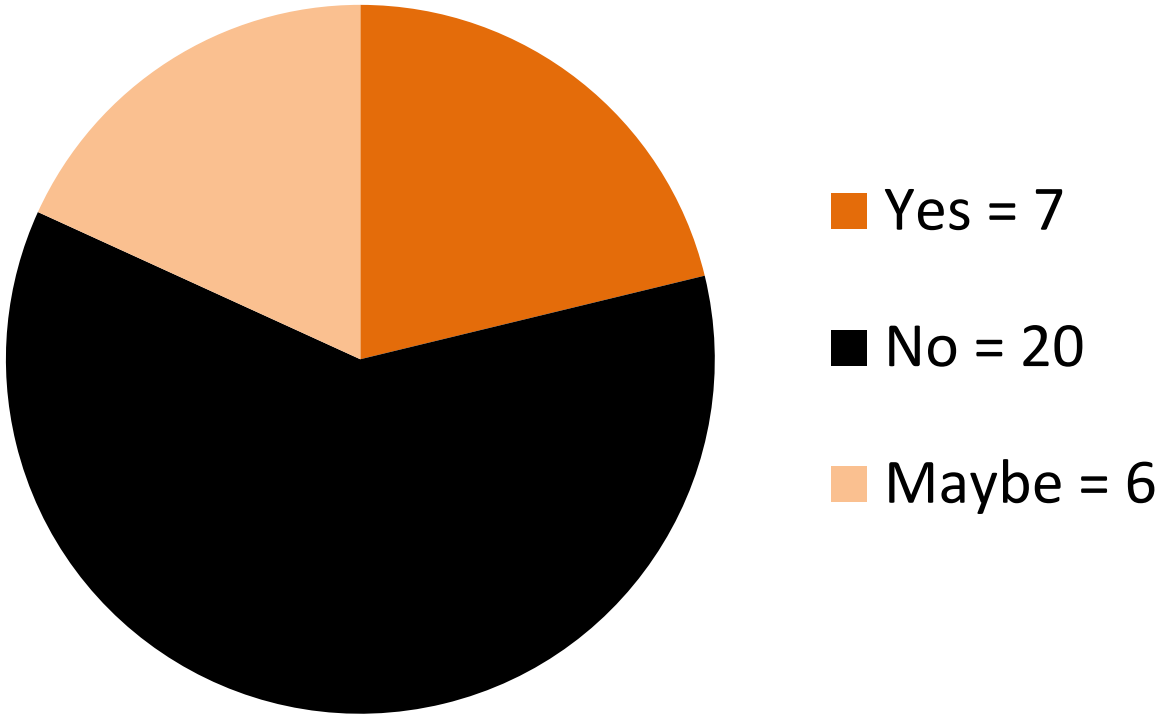
Surveys

Do you make mulch on the job or buy mulch before hand?



Surveys

Would you be interested in purchasing a small-scale product to color wood mulch for your business?



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Target Market Characteristics

- Homeowners
  - Easy and fun to operate
  - Safe
  - Efficient
  - Fast
- Landscape Professionals
  - Outweigh cost of purchasing already dyed mulch and labor

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Experiment 1: Coloring with a Mixing/Tumbler Device

- Study the effects of wood species and mulch properties on the colorization of mulch
- Use a mixing/tumbler device to color various mulches
- Enables the team to determine the specifications for use
  - Wood species and moisture content
  - Time required for dyeing

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Experiment 2: Using Heat to Aid in the Dyeing Process

- Study the effect of heat on the dyeing process
- Use a mixer/tumbler device to color various mulches
- Compare coloring with mixer and heating element to coloring with mixer without heat
- Enables the team to determine whether or not our product should include a heating element

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Experiment 3: Pressurized Vacuum Chamber Approach

- Quantify the effectiveness of a pressurized vacuum in facilitating the colorization process
- Enables the team to determine whether or not our product should include a pressurized chamber for dyeing

<http://www.joewoodworker.com/veneering/vacuum-infusing-chamber.htm>

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Experiment 4: Affects of Weathering on Mulch

- Determine what affects weathering has on dyed mulch
  - Rainfall event
  - Sunshine
  - Extreme Heat
  - Extreme Cold
  - Snow event
- Enables the team to determine how long and under what weather conditions our wood chips will keep their color

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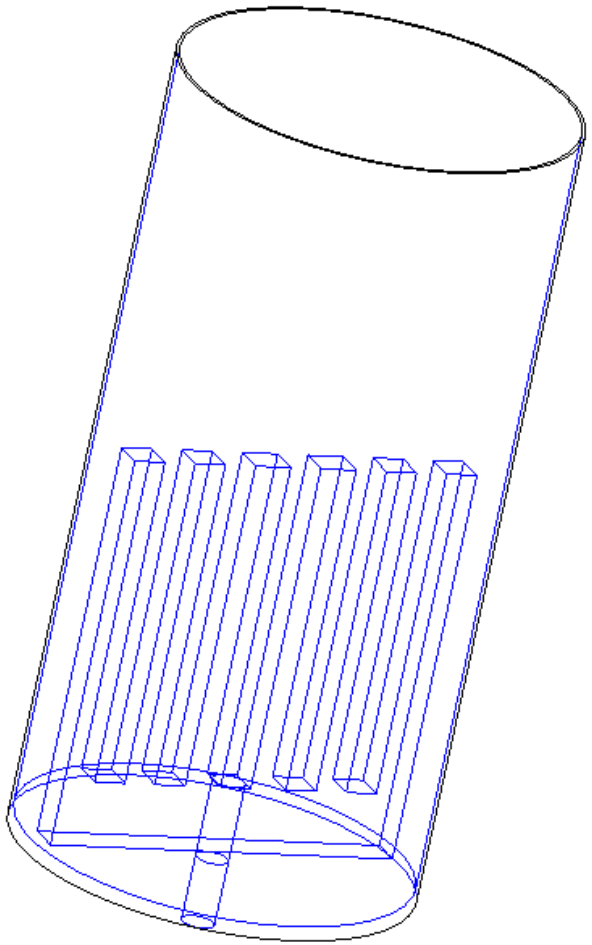
Design 1: Vertical Mixer

- Load wood chips into the drum
- Sprayers fill tank to specified level
- Mixing arm churns the mixture
- When saturated the chips are removed
- Remaining dye is recycled to be reused in next batch



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Vertical Mixer

- 55 gal. Drum OR Stainless Steel Sheet
- Electric Motor
- Plastic Tubing
- Sprayer Nozzle x2
- Pump
- Mixing Arm
- Drum Stand

https://www.khlubes.com/automotive-products-brake-cleaners-c-29_41.html

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Vertical Mixer Cost

Materials	Quantity	Cost
Stainless Steel Sheet*	1	$87.04
Open-head Steel Drum*	1	$59.80
Electric Motor	1	$59.99
Plastic Tubing	1	$2.99
Pressure Spray Nozzle	1	$6.99
Utility Pump	1	$59.99
Power-Driven Mixer	1	$22.54
55 Gallon Dolly Drum	1	$39.99

Total Minimum Cost	**$252.29 - $279.53**
Potential Misc. Cost	**$25.00**
Total Maximum Cost	**$277.52 - $304.76**

*Only one part of the two will be needed

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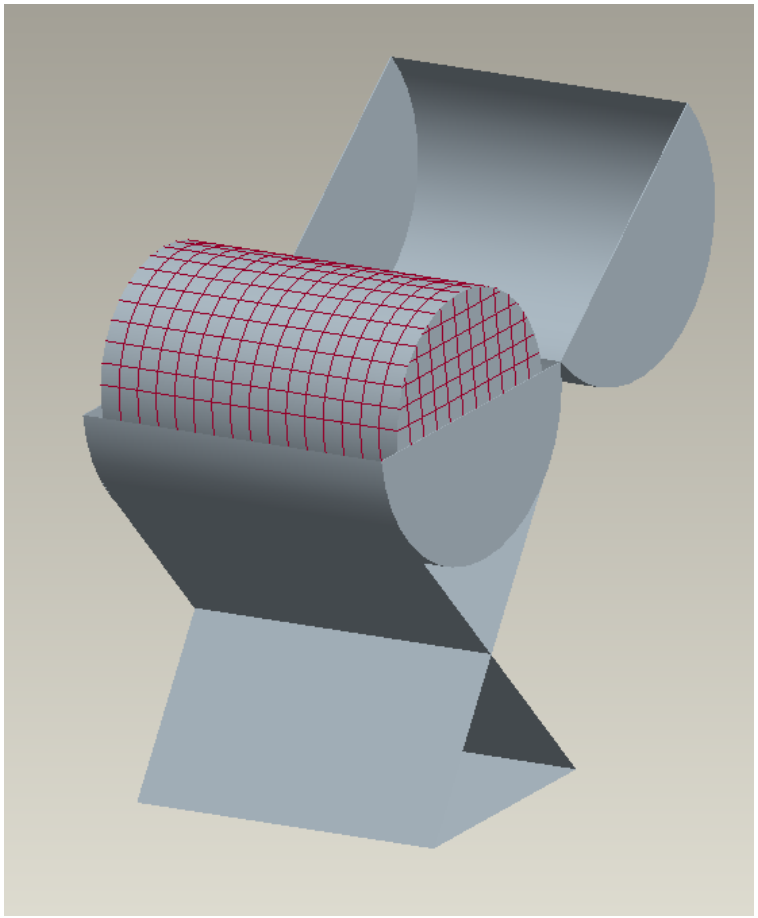
Design 2: 55 Gallon Drum Tumbler

- 55 gallon drum
- 30 gallon cylindrical cage made of welded wire mesh with hinged lid placed inside of drum
- Cage will rotate, powered by an electric, high torque motor
- Cage will have three fins inside to increase tumbling



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55 Gallon Drum Tumbler

- Wire cage removable
  - Lever operation or by hand
- Large enough to dye 3 ft^3 of mulch at a time
- Plug with a screen where excess dye can be drained into a separate container
- Will look at adding heating & drying elements

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55 Gallon Drum Tumbler Cost

Materials	Quantity	Cost
55 Gallon Drum	1	$67.95
Stainless Steel Wire Mesh Roll	1	$75.00
Electric Gear Motor	1	$22.00
Metal Post	4	$90.12
Hinges	4	$8.44

Potential Misc. Cost	**$26.00**
Total	**$290.00**

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Design 3: Mulch Roll System

- Allows for production of colored mulch strips with a biodegradable fiber backing
- Mulch rolls are created using a conveyor belt in combination with hoppers for fiber and mulch along with tanks for glue and dye
- Allows for easy mulch application and storage

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Mulch Roll System

- Mulch strips can be used for soil stabilization
  - Helps prevent erosion
- Mulch strips can be cut and shaped for use around plants
- Product can be rolled
  - Compact storage
  - Easy application
  - No rakes or shovels required
  - Just roll it and go!

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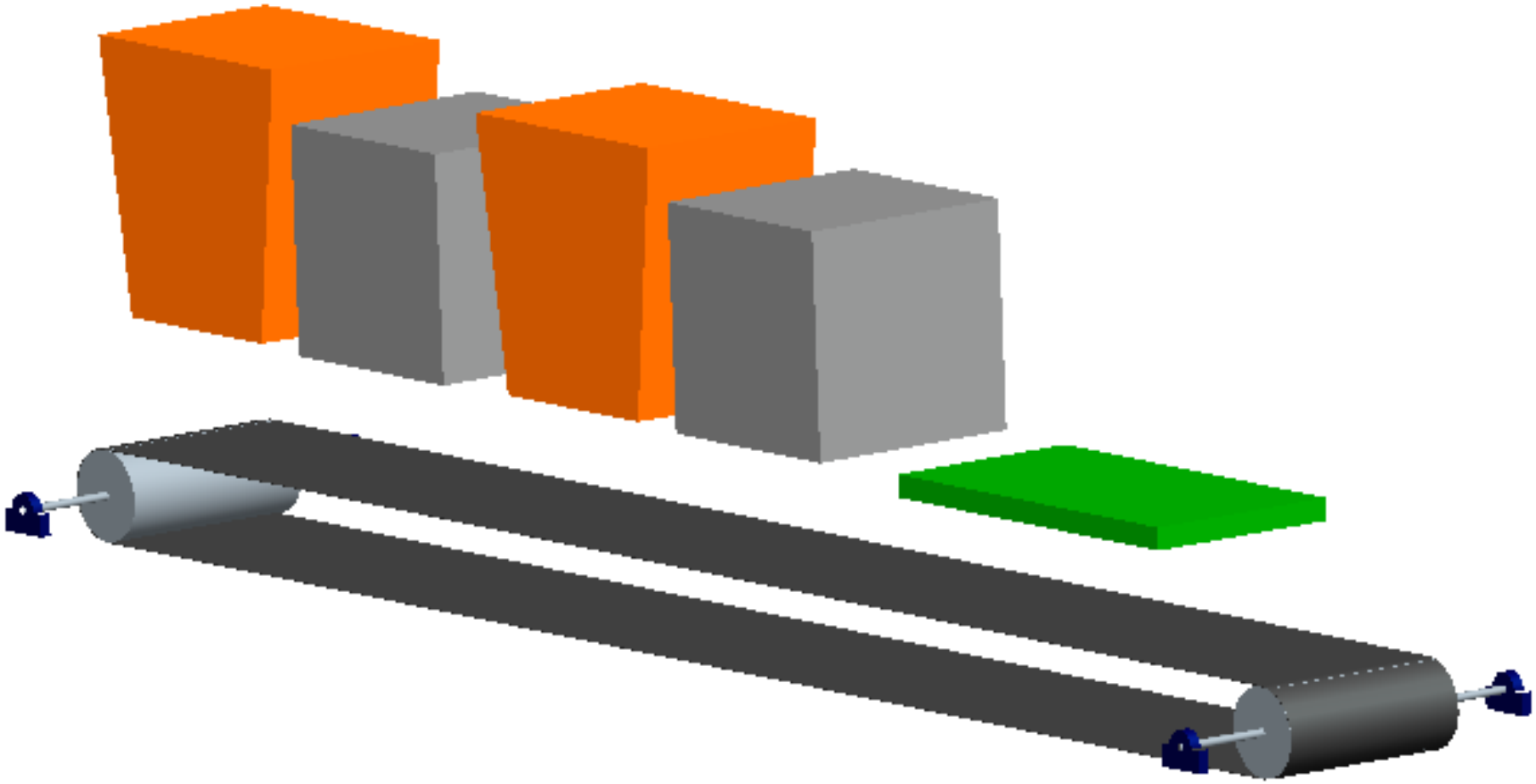

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Mulch Roll Device Cost

Materials	Quantity	Cost
Auxiliary Fuel Tank	2	$0.00
Spray Nozzle	2	$9.50
Infrared Bulbs	6	$15.90
Porcelain Sockets	6	$22.44
Pillow Block Bearings	4	$40.80
1018 Steel Rods	2	$26.96
Drill Rod	1	$16.31
Schedule 40 Pipe	2	TBD
Rubber Belting	1	TBD

Potential Misc. Cost
Total ~ $131.91

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Cost of Dyes for Testing

Company	Quantity	Cost
Colorbiotics	55 gallon drum	~$500
	35 gallon drum	~$300
Organic Dyestuff	30 gallon drum	$600
	5 gallon bucket	$280
Powdered dye???		

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Development of Engineering Specs

- Solid Works to create final drawings
- Drawings will be used to fabricate necessary parts
- Services from BAE Lab will be utilized
- Outside manufacturer may be required for some parts

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Communications Plan

- Develop press releases to distribute appropriately
- Develop promotional brochure
- Develop promotional Website
- Develop booth design to be used at promotional events

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Business Plan

- Have the product manufactured off site
- Total cost depending on chosen design
  - Anywhere from approximately $300-$700
- No existing business in place
  - Must track revenue and expenses to evaluate profit

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