The Effects of Liquid Keratin (Created from Feather Fiber) on the Flexural Strength of a Gel Coat
The Effects of the Amount of Liquid Keratin (Created from Feather Fiber) on the Flexural Strength of a Gel Coat

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ABSTRACT

Feather fiber is a unique product derived from the external outgrowths of Gallus domesticus (chicken feathers). Many uses have been explored for this product because of its unique qualities including water resistance and strength, due to keratin. Recently, scientists have been exploring the possibility of feather fiber being broken down into a liquid keratin form so that applications can be increased. One study suggested that a combination of water, glycerol, and sodium sulfite could break the amino bonds in feathers and create a liquid keratin. This area of study is highly unexplored and, as of today, there is no liquid keratin being produced on a large scale for use. One possible application could be a gel coat. A gel coat is the surface coat that makes up the outer layer of a product such as a composite or other engineered material and provides protection for that product. With the liquid keratin as a component in gel coats, useful space occupied by landfills can be decreased from the average number of 5 billion pounds of dry weight feathers in the United States per year. It is vital that this number be reduced and the exploration of new usages for the waste product could provide the reduction. This project studied the effects of the amount of liquid keratin (created from feather fiber) on the flexural strength of a gel coat.

Two different amounts of liquid keratin were included in a 380 gram gel coat batch: 10% liquid keratin (38g), and 25% liquid keratin (162g). Each of the liquid keratin groups were then compared to a control group with no liquid keratin added, or resin and styrene only. The groups were measured after gel coats were created and placed under flexural strength tests.

The average flexural strength, or peak strength for the 10% liquid keratin gel coat was 15.81 kg. and the average flexural strength, or peak strength, for the 25% liquid keratin group was 10.88 kg. The control group had an average flexural strength or peak strength of 38.24 kg. The results of this study demonstrate that the addition of liquid keratin does not increase the flexural strength of a gel coat. The hypothesis stated that “As the amount of liquid keratin (created from feather fiber) changes, then the flexural strength of a gel coat increases.” Based off the results of the experiment and the statistical analysis applied, the hypothesis was not accepted. Future testing is needed to determine all of the properties of the liquid keratin and gel coats created.
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I. INTRODUCTION OF THE PROBLEM
INTRODUCTION OF STATEMENT OF PROBLEM

Each year billions of tons of fiber fill up the nation’s landfills. These fibers can be found in a wide variety of common waste items including feathers. Missouri is one of the leading feather producers in the United States (“Office Buildings Recycling Tipsheet,” 2004). In fact, about 5 billion pounds of dry weight feather waste is produced in the United States per year (Emery, 2005). This amount would fill enough tractor-trailers to occupy two lanes of interstate from California to Florida (Wagner, 2004).

There have been many new uses discovered for feather fiber by scientists around the country, and research using feather fiber continues. Recently, scientists such as Abe Widra have discovered that hair and possibly other sources of keratin can be broken down into a liquid keratin (alpha keratose) which can be used as a blood plasma expander. Other scientists are also researching the benefits and uses of this liquid keratin because of the keratin’s properties and strength (Widra, 2001) & (Emery, 2005).

A gel coat, however, is basically what makes up the outer layer of a product such as a composite and is first seen on the product’s surface. Generally, gel coats cover boats or even bathroom shower stalls so occasionally they can be colored with pigments but are usually clear. At this time, gel coats are made up of unsaturated polyester polymers that contain glycols and acids (Composites Application Guide, 2006).

The purpose of this problem is to gain knowledge on the effectiveness of liquid keratin made from feather fiber as a component in a gel coat. This might also result in an effective way to use feathers that are not currently being recycled. The project may also help create a stronger, more effective gel coat. Another benefit would be the preservation of useful land that is being utilized by landfills (Gorman, 2003).

This project idea came from previous projects using recycled feather fiber and an interest in creating new uses for the product to reduce the problem of landfills. The experimenter was also interested in the new technique of breaking down keratin to a liquid form. This led the experimenter to the following problem: Does the amount of liquid keratin (created from feather fiber) affect the flexural strength of a gel coat?
A feather is one of the light outgrowths that form the external covering of the body of a bird, for example- *Gallus domesticus* (chicken). Almost every part of a chicken can be used including the feathers (“Want to Save a Tree?”, 2002). Feather fiber is a byproduct of these feathers (Barrodale, 2003).

Walter Schmidt, a scientist with the United States Department of Agriculture (USDA), attempted to make feather fiber by trying to grind chicken feathers into a powder. This form of grinding was too tough to do, so the feathers were cut into short units. Schmidt concluded that the fibers were very tough and wondered why no one had used them before (Barrodale, 2003). Schmidt also discovered that feather fibers have many qualities including a higher absorbency level as feather fibers distribute moisture more evenly than most other types of fibers (Gale Group, 2004). Schmidt and his colleagues developed an efficient mechanical method to separate the more valuable barb fibers (plumage) from the less useful central chaff or quill. Though softer, the keratin fibers in the barbs are stronger and less brittle than those in the quill and therefore have a much broader range of applications (Martindale, 2004). “The new fiber separation process uses less water, energy, and chemicals than for other fibers,” said Schmidt (Gale Group, 2004).

Walter Schmidt and research colleague, Justin Barone, discovered that feathers can be added to various products to strengthen the product while reducing weight (Durham, 2004). Some potential uses for feather fiber are medicines, dashboards, toys, and even as a substance in foods since the fiber has no flavor and takes on the flavor of whatever other material is added (Barrodale, 2003). Other products that may be made with feather fiber include paper, disposable diapers, clothing, and insulation. Recently, scientists have even discovered that recycled feather fibers may potentially have a use in cleaning up radioactive waste because of the product’s potential as an absorbent of heavy metals and even radioactive material such as strontium (Kaplan, 2002).

The technology developed by Schmidt to turn chicken feathers into an industrial fiber recently received a third place award at the “World’s Best Technologies 2004” conference in Arlington, Texas. Three companies- Featherfiber Corporation of Nixa, Missouri; Maxim of Pasadena, California; and Tyson Foods, of Springdale, Arkansas- have licensed the new feather fiber technology from the USDA and are already sending samples to scientists around the world (Durham, 2004).

David Emery’s company, Featherfiber Corporation, is one of three in the nation that has the licensed technology. Emery’s company separates feather from quill, allowing the lightweight but strong feathers to be used. The key to easy separation lies in the fact that quills are bulkier and heavier.
The feathers, dried and sterilized, are shredded and fed into a cylindrical device consisting of an inner and outer tube. The feathers are sucked through the central channel, and the quills are drawn off at the bottom. Air turbulence causes the barbs to float back up between the sides of the tubes (Martindale, 2004). The feather fiber technology has been patented and licensed, and Featherfiber Corporation has built the first fully operational pilot plant to convert feather into feather fiber and keratin quill (Durham, 2004).

The feather fiber is especially strong due to the high level of keratin. The actual feather fiber is 100% keratin because the makeup is completely chicken feathers. Avian feathers contain a form of keratin called beta keratin, or $\beta$-keratin, as well as a thin outer layer of alpha-keratin. Beta keratin (found only in reptiles and birds) is the contrast to alpha-keratin, found in all vertebrates including humans. Beta keratin adds more stiffness to a source where as the alpha keratin found in mammals is soft. The beta keratin also adds waterproof qualities (Prum, 2004).

Alpha keratose is a form of keratin that is broken down to a liquid form. This procedure has been used by scientists such as Abe Widra, who are using the new product in applications such as a blood plasma expander since the keratin is not a foreign substance to humans (Widra, 2001). This new form of keratin is strong and can be cured as a hard substance for practical uses such as pest/termite control (Emery, 2005). Liquid keratin is created from hair using a complex procedure that uses hydrochloric acid, ammonium hydroxide, and peracetic acid and equipment such as a dialysis bag, an Erlenmeyer flask, cellulose tubing and a centrifuge. Other minor equipment and materials are also used. Today, hair is the primary substance that is broken down using this process but feathers and other sources of keratin are being researched (Widra, 2001).

Another procedure that breaks down the actual feather fiber is one developed by the U.S. Department of Agriculture Research Service (ARS). This new technology is performed by combining feather fiber with glycerol, water and sodium sulfite. Then the feathers are pelletized. The result of this procedure is a plastic-like material and the feather fiber reduces the weight of these plastics (Barone, 2006) (Cozier, 2005). Composites have also been reinforced with keratin feather fiber. The feather fiber provides stiffness, but was not as successful with properties such as tensile strength (Barone, 2005). Chicken feather keratin has also been treated with calcium hydroxide (lime) to create a liquid product that contains high levels of Amino acids as well as polypeptides that can be used to feed livestock. This procedure is a simple way to break down parts of the feather to an amino liquid form (Coward-Kelly, 2006). Breaking down the proteins of feather fiber is essential to separating the keratin molecules which will turn into a liquid. Uses for feather fiber and this liquid keratin are growing in labs around the country (Kaplan, 2002).
A gel coat makes up the outer layer of a product such as a composite or other engineered material. The gel coat is the surface coat (colored or clear) that provides cosmetic enhancement and protection for a laminate. A laminate is a panel that consists of multiple layers that are bonded together in a permanent form. A gel coat is the first layer of protection for a laminate and is first seen on the product’s surface. The gel coat also serves to protect the laminate from chemicals, abrasion, etc. during the manufacturing process. Some common forms of gel coats include Isophthalic acid and Neopentyl glycol, but there are a variety of other conventional and specialty types that have been created (Composites Application Guide, 2005).

Generally, gel coats cover boats or even bathroom shower stalls. Gel coats may be clear or colored with pigments. The most common pigment used in gel coats is titanium dioxide because of the simple white color. These pigmentations may change the durability of the gel coat and the properties may change.

Currently, gel coats are made up of unsaturated polyester polymers that contain glycols and acids. Specifically, the gel coat materials include the polymers, inhibitors and promoters, fillers, thixotropic agents, a reactive monomer and pigments. Each of these materials serves a specific purpose that helps to create the gel coat in the finest form. Polymers, for instance, cross-link to the monomer, inhibitors and promoters together create the cure process, fillers create the correct spray properties, thixotropic agents reduce the flow of the liquid gel coat, the reactive monomer reduces the thickness of the liquid gel coat and pigments add color (Composites Application Guide, 2005).

Most conventional gel coats are formed using the open mold process and then applied to the surface of a laminate using spray equipment. The process of creating the gel coat is performed in many different ways. The selection of the materials used to create the gel coat is extremely important since the quality of materials can affect the spray characteristics and in turn, can affect the results of the actual laminate. After the gel coat is initially created and cured, it is sprayed onto the laminate. The thickness of the conditional gel coat layer should be approximately 18 ± 2 mils. and is applied using a spray gun. After the gel coat is cured to the laminate, the product must be evaluated for imperfections including pigment darkening, cracks, air bubbles, blisters, water spotting and many more. These imperfections may then be corrected and the gel coat on the laminate is ready to be tested. Many tests can be performed on the laminate with the gel coat after these steps have been completed, including tests that evaluate the water resistance, UV resistance, flexibility and strength (Composites Application Guide, 2005).
HYPOTHESIS

HYPOTHESIS:
As the amount of liquid keratin (created from feather fiber) changes, then the flexural strength of a gel coat will change.

This was inferred from information gathered during an interview with David Emery, in which he explained feather fibers’ properties of strength after being broken down to a liquid keratin form. Previous experimentation also showed that feather fibers show high properties of water resistance, as well as strength. Based off of this information, the experimenter assumes that as the amount of liquid keratin (created from feather fiber) increases, then the flexural strength of a gel coat will increase.

NULL HYPOTHESIS:
As the amount of liquid keratin (created from feather fiber) changes, then the flexural strength of a gel coat will not change.
II. PROCEDURE OF INVESTIGATION
EXPERIMENTAL DESIGN

**PROBLEM:** Does the amount of liquid keratin (created from feather fiber) affect the flexural strength of a gel coat?

**Independent Variable:** Amount of liquid keratin

**Dependent Variable:** Flexural Strength

**Control Group:** Group with resin, styrene, air release agent, and catalyst only (no liquid keratin)

**Retests:** Ten tests for each amount of feather fiber added and for the control group.

**Constants:**

- Same approximate (percentage) amounts of gel coat ingredients
- Same testing device
- Same environment where tests took place
- Same size of test samples
- Same casting process
- Same percentage amounts of organic peroxide
- Same type of resin
- Same type of catalyst
- Same type/grind of Feather Fiber

**Quantitative Measure:** The flexural strength of a gel coat should be measured in peak strength in kilograms.
**MATERIALS LIST**

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.31 grams 80 micron “UltraClean” feather fiber</td>
<td></td>
</tr>
<tr>
<td>779 grams Unsaturated Polyester Resin</td>
<td></td>
</tr>
<tr>
<td>13.18 grams Methyl Ethyl Ketone Peroxide (MEKP) Initiator</td>
<td></td>
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<tr>
<td>150 grams Glycerol</td>
<td></td>
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<tr>
<td>40 grams Deionized Water</td>
<td></td>
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<tr>
<td>10 grams Sodium Sulfite</td>
<td></td>
</tr>
<tr>
<td>Masking Tape</td>
<td></td>
</tr>
<tr>
<td>14 grams Catalyst (12% cobalt octate solution)</td>
<td></td>
</tr>
<tr>
<td>2.84 grams Air Release Agent</td>
<td></td>
</tr>
<tr>
<td>(6) 34.29 x 34.29cm clear Mylar (polyester) films</td>
<td></td>
</tr>
<tr>
<td>Viton O-ring cord (106.68-114.3 cm)</td>
<td></td>
</tr>
<tr>
<td>Large binder clamps</td>
<td></td>
</tr>
<tr>
<td>Scissors</td>
<td></td>
</tr>
<tr>
<td>Funnels</td>
<td></td>
</tr>
<tr>
<td>Molding Stand</td>
<td></td>
</tr>
<tr>
<td>Dust masks</td>
<td></td>
</tr>
<tr>
<td>Magnetic stir bar</td>
<td></td>
</tr>
<tr>
<td>Fisher Magnetic Stirrer</td>
<td></td>
</tr>
<tr>
<td>Sybron Thermolyne Type 1000 Stir Hot Plate</td>
<td></td>
</tr>
<tr>
<td>Tongs</td>
<td>MTS Model Alliance RT/100 Physical Testing Apparatus</td>
</tr>
<tr>
<td></td>
<td>Electron Caliper (Digimatic Multiplexer MUX)</td>
</tr>
<tr>
<td></td>
<td>Cowles Dispersion Mixer</td>
</tr>
<tr>
<td></td>
<td>Infrared Thermometer</td>
</tr>
<tr>
<td></td>
<td>Vacuum Pump</td>
</tr>
<tr>
<td></td>
<td>120°C ± 2°C Oven</td>
</tr>
<tr>
<td></td>
<td>8 flat glass molds(35.56 x 35.56 x 0.635 cm)</td>
</tr>
<tr>
<td></td>
<td>Glass and plastic beakers</td>
</tr>
<tr>
<td></td>
<td>Pipettes</td>
</tr>
<tr>
<td></td>
<td>Latex safety gloves</td>
</tr>
<tr>
<td></td>
<td>Paper cups</td>
</tr>
<tr>
<td></td>
<td>Tongue depressors</td>
</tr>
<tr>
<td></td>
<td>Electronic scale</td>
</tr>
<tr>
<td></td>
<td>Razor</td>
</tr>
<tr>
<td></td>
<td>Permanent marker</td>
</tr>
<tr>
<td></td>
<td>Stainless Steel spatula</td>
</tr>
<tr>
<td></td>
<td>Safety glasses</td>
</tr>
<tr>
<td></td>
<td>Paper towels</td>
</tr>
<tr>
<td></td>
<td>Paper cutter</td>
</tr>
<tr>
<td></td>
<td><em>Black &amp; Decker</em> Stainless Steel Blender</td>
</tr>
</tbody>
</table>
PROCEDURES

CREATING THE LIQUID KERATIN FROM FEATHER FIBER:
1) Gather materials.
2) Weigh out water (120g) and sodium sulfite (30g) into two separate beakers using electronic scale.
3) Place water, in beaker, onto magnetic stirrer.
4) Using tongs, place stir bar in beaker with water.
5) Turn on the magnetic stirrer.
6) Pour sodium sulfite into the beaker containing water, now mixing.
7) Let the solution mix until completely dissolved (~5 minutes).
8) Weigh out glycerol (150g) in beaker using electronic scale.
9) Pour glycerol into beaker containing water, sodium sulfite, and stir bar on magnetic stirrer.
10) Let liquid mix until thoroughly blended (~5 minutes).
11) Weigh out feather fiber (12.31 g) into plastic beaker using electronic scale.
12) Pour feather fiber into Black & Decker Blender.
13) Take beaker containing liquid solution off of the magnetic stirrer.
14) Turn magnetic stirrer off.
15) Retrieve stir bar from liquid solution in beaker using tongs.
16) Pour approximately ¼ of the liquid solution onto feather fiber in blender.
17) Secure lid on blender.
18) Let feathers and liquid mix 30 seconds.
19) Take lid off of blender.
20) Repeat steps 16-19 two more times or ¾ of original liquid amount has been used.
21) Repeat steps 16-17 once more.
22) Let feathers and liquid (now a slurry) mix on level 1 for ~four minutes.
23) Take lid off blender.
24) Pour slurry into crucible and place on hot plate.
25) Let the slurry heat on Level 5 for 20 minutes (at end, feathers should be liquid).
26) Jar liquid keratin and label.

CREATING THE 10% LIQUID KERATIN GEL COAT
1) Gather materials.
2) Calculate amounts of materials for an estimated 380 gram batch size.
3) Weigh out 162g of resin.
4) Weigh out 38g of liquid keratin.
5) Add liquid keratin to resin in jar.
6) Let keratin and resin mix in Cowles dispersion.
7) Check initial temperature with infrared thermometer.
8) Continue to check temperature every minute until temperature rises 11 degrees Celsius.
9) Add 99g of resin to liquid keratin and resin mixture.
10) Add 81g of Styrene to liquid keratin and resin mixture.
11) Let mix two minutes with Cowles dispersion (until uniform).
12) Weigh out .95 g of air release agent using electronic scale.
13) Add air release agent to the gel coat.
14) Weigh out .38 g of catalyst using electronic scale.
15) Add .38 g of catalyst to the gel coat.
16) Let mix with Cowles dispersion ~4 minutes.
17) Secure lid on jar containing gel coat.
18) Place jar in water bath for 120 hours.
19) Retrieve gel coat from water bath and wipe off excess water on outside.
20) Shake gel coat for ~30 seconds.
21) Place gel coat back in water bath for five minutes.

**CREATING THE 25% LIQUID KERATIN GEL COAT**
1) Gather materials.
2) Calculate amounts of materials for an estimated 380 gram batch size.
3) Weigh out 105g of resin.
4) Weigh out 95g of liquid keratin.
5) Add liquid keratin to resin in jar.
6) Let keratin and resin mix in Cowles dispersion.
7) Check initial temperature with infrared thermometer.
8) Continue to check temperature every minute until temperature rises 11 degrees Celsius.
9) Add 156g of resin to liquid keratin and resin mixture.
10) Add 24g of Styrene to liquid keratin and resin mixture.
11) Let mix three minutes with Cowles dispersion (until uniform).
12) Weigh out .95 g of air release agent using electronic scale.
13) Add air release agent to the gel coat.
14) Weigh out .38 g of catalyst using electronic scale.
15) Add .38 g of catalyst to the gel coat.
16) Let mix with Cowles dispersion ~4 minutes.
17) Secure lid on jar containing gel coat.
18) Place jar in water bath for 120 hours.
19) Retrieve gel coat from water bath and wipe off excess water on outside.
20) Shake gel coat for ~30 seconds.
21) Place gel coat back in water bath for five minutes.

CREATING THE CONTROL GEL COAT
1) Gather materials.
2) Calculate amounts of materials for an estimated 380 gram batch size.
3) Weigh out 257 g of resin in jar.
4) Add 118 g of Styrene to resin.
5) Shake in jar approximately one minute.
6) Weigh out .94 g of air release agent using electronic scale.
7) Add air release agent to the gel coat.
8) Weigh out .38 g of catalyst using electronic scale and add to gel coat.
9) Handshake for one minute.
10) Secure lid on jar containing gel coat.
11) Place jar in water bath for 120 hours.
12) Retrieve gel coat from water bath and wipe off excess water on outside.
13) Shake gel coat for ~30 seconds.
14) Place gel coat back in water bath for five minutes.

PREPARING THE CASTINGS
1) Gather materials.
2) Scrape excess and unwanted materials off glass panels using razor blade.
3) Place Mylar film on top of six glass panels and secure with tape.
4) Tape Viton cord around three edges of three glass panels.
5) Secure two glass plates without Viton cord on top of another with tubing using large binder clamps around three sides (same sides as cord).
6) Place castings in molding stand (side without Viton cord or clamps facing up).
CREATING THE CASTINGS FOR 10% GEL COAT
1) Gather materials.
2) Pour gel coat into plastic beaker.
3) Vacuum air out of gel coat using vacuum pump for five minutes.
4) Weigh gel coat after vacuuming out air.
5) Calculate the amount of initiator for the gel coat.
6) Pipette 4.36 g initiator (MEKP) into gel coat using an electronic balance.
7) Stir in initiator with stainless steel spatula.
8) Repeat step 8.
9) Pour gel coat into 0.57 cm cavity (between glass molds held by clamps sitting vertically in molding stand) using a funnel.
10) Let gel coat being “gelling” vertically in molding stand for 10 minutes.
11) Take gel coat out of molding stand and take off clamps.
12) Pull out Viton cord (if “gelling”).
13) Put clamps back on glass molds exactly as before.
14) Place five gallon bucket on top of gel coat in glass molds.
15) Let cure horizontally for 16 hours with five gallon (~ 24.04 kg) weight on top.
16) Open glass molds and remove Mylar film.
17) Put clamps back on glass molds exactly as before.
18) Place gel coat into oven at 65 degrees Celsius for 4 hours.
19) Take gel coats out of glass molds and let cool two hours.

CREATING THE CASTINGS FOR 25% GEL COAT
1) Gather materials
2) Pour gel coat into plastic beaker.
3) Vacuum air out of gel coat using vacuum pump for five minutes.
4) Weigh gel coat after vacuuming out air.
5) Calculate the amount of initiator for the gel coat.
6) Pipette 4.39 g initiator (MEKP) into gel coat using an electronic balance.
7) Stir in initiator with stainless steel spatula.
8) Repeat step 8.
9) Pour gel coat onto open casting (horizontal, not in molding stand and without clamps).
10) Place top glass plate on top of gel coat (causing a spread across entire glass plate).
11) Place five gallon bucket on top of gel coat in glass molds.
12) Pull out Viton cord after the gel coat begins “gelling” (or approximately 10 minutes).
13) Let cure horizontally for 16 hours with gallon (~ 24.04 kg) weight on top.
14) Open glass molds and remove Mylar film.
15) Secure glass molds.
16) Place gel coat into oven at 65 degrees Celsius for 4 hours.
17) Take gel coat out of glass molds.
18) Let gel coat cool two hours.

**CREATING THE CASTINGS FOR CONTROL GEL COAT**

1) Gather materials.
2) Pour gel coat into plastic beaker.
3) Vacuum air out of gel coat using vacuum pump for five minutes.
4) Weigh gel coat after vacuuming out air.
5) Calculate the amount of initiator for the gel coat.
6) Pipette 4.43 g initiator (MEKP) into gel coat using an electronic balance.
7) Stir in initiator with stainless steel spatula.
8) Repeat step 8.
9) Pour gel coat into 0.57 cm cavity (between glass molds held by clamps sitting vertically in molding stand) using a funnel.
10) Let gel coat being “gelling” vertically in molding stand for 10 minutes.
11) Take gel coat out of molding stand and take off clamps.
12) Pull out Viton cord (if “gelling”).
13) Put clamps back on glass molds exactly as before.
14) Place five gallon bucket on top of gel coat in glass molds.
15) Let cure horizontally for 16 hours with five gallon (~ 24.04 kg) weight on top.
16) Open glass molds and remove Mylar film.
20) Put clamps back on glass molds exactly as before.
17) Place gel coat into oven at 65 degrees Celsius for 4 hours.
18) Take gel coat out of glass molds.
19) Let gel coat cool two hours.
PREPARING THE SAMPLES
1) Gather Materials.

2) Draw 3.11 cm X 10.73 cm rectangle on cured composites (with permanent marker).

3) Cut the samples by hand with a band saw.

4) Sand down each Flex Sample to be 2.54 cm wide.

5) Clean each sample with water.

6) Dry each sample with a paper towel.

7) Label each sample as 10%, 25%, or Cont. with permanent marker.

8) Measure the width and thickness of each sample with an electronic caliper.

9) Record each width and thickness.

TESTING FLEXURAL STRENGTH
1) Turn on the computer.

2) Open TestWorks4.

3) Choose Flex Method according to the thickness of the sample when “Open Method” dialog appears.

4) Enter the width and thickness of sample by using the electron caliper.

5) Set the sample flat on the supporting bars of the MTS Model Alliance RT/100 Testing Apparatus.

6) Lower the crosshead manually by turning the crosshead knob until the top bar is almost in contact with the sample.

7) Press the OK button on the computer.

8) Press the red button on the computer to stop the test when the sample breaks or the VS Displacement curve peaks.

9) Press OK when computer asks to return the crosshead (to release the sample).

10) Click the green Arrow to continue testing.

11) Repeat steps 4-10 for all remaining samples.
III. DISCUSSION OF DATA
RESULTS AND OBSERVATIONS

The average flexural strength, or peak strength for the 10% liquid keratin group was 15.81 kg and the average flexural strength, or peak strength for the 25% liquid keratin group was 10.88 kg. The control group had an average flexural strength or peak strength of 38.24 kg.

The median flexural strength, or peak strength for the 10% Feather Fiber group was 15.55 kg and the 25% Feather Fiber group had a median flexural strength of 10.72 kg. The median flexural strength or peak strength for the control group was 38.62 kg.

The range of flexural strength, or peak strength for the 10% liquid keratin group was 14.69 - 17.18 kg and the range of flexural strength, or peak strength for the 25% liquid keratin group was 9.94 - 13.15 kg. The control group had a range of flexural strength, or peak strength of 34.67 - 42.24 kg. The range difference of flexural strength, or peak strength, for the 10% liquid keratin group was 2.49 kg and the range difference of flexural strength, or peak strength for the 25% liquid keratin gel coat was 3.21 kg. The control group had a range difference of flexural strength or peak strength of 7.57 kg.

For another observation, the experimenter tested the impact strength of each gel coat using the IZOD method. The experimenter found that the control group performed more effectively on the impact strength than the both of the liquid groups. The results were exceedingly similar to the results of the flexural strength test and the control performed nearly twice as well as the 10% liquid keratin group. The 25% performed worse than the 10%. Since the control performed better under this test as well, it is assumed that the liquid keratin’s ability to serve as an effective addition to a gel coat would require further testing. 10 retests were done for this test for each type of gel coat.

Another test was also performed that tested the cure of each gel coat (DSC). The 10% Feather Fiber group was the closest to the control group followed by the 25% Feather Fiber group as the furthest away from the normal cure. These results were also similar to the flexural strength results. Because these results are only shown in graph form, it is difficult to determine the actual comparison of the three gel coats.

Before successfully creating liquid keratin from feather fiber, the experimenter tried several different methods since the procedure is highly unexplored. The experimenter began with ratios received from Walter Schmidt and Justin Barone with the USDA. The original ratio was 60:30:8:2 with 60 grams of feather fiber, 30 grams of glycerol, 8 grams of deionized water, and 2 grams of sodium sulfite. After attempting the original procedure, the experimenter determined that the ratio used an excessive amount of feather fiber and not enough liquid to execute a successful extrusion of feather keratin. An estimated amount of feather fiber (12.31 g) was then tested and the experimenter noted that the one liquid solution of 30:8:2 did not break down the smaller amount of feathers. Liquid solutions, each of the 30:8:2 ratios were added until the feather fiber became a liquid form. Five liquid additions were added in total.
After the feather fibers were in a liquid form, the experimenter noted that the solution hardened and tried heating the liquid to observe the effects. The experimenter observed that the heated liquid solution changed color from the original “milky white” to a light yellow-brown shade. All samples were kept for future observation.

After creating the liquid keratin, the experimenter attempted to remake the solution with all of the amounts at once forming a new ratio of ~12:150:40:10. Even though the ratios were exceedingly different from the original ratios, the feather fiber was effectively broken down to a liquid form. Although the liquefied feather fibers were off-white in color and small grains of feathers could be seen in the liquid, the actual amount of keratin in the liquid is not confirmed.
**Figure 1: Data Table**
The Effects of the Amount of Liquid Keratin (Created from Feather Fiber) on the Flexural Strength of a Gel Coat in Peak Strength in Kilograms.

<table>
<thead>
<tr>
<th>Retests</th>
<th>10% Liquid Keratin</th>
<th>25% Liquid Keratin</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14.94</td>
<td>10.09</td>
<td>39.89</td>
</tr>
<tr>
<td>2</td>
<td>14.69</td>
<td>11.32</td>
<td>37.86</td>
</tr>
<tr>
<td>3</td>
<td>17.18</td>
<td>10.52</td>
<td>38.82</td>
</tr>
<tr>
<td>4</td>
<td>16.85</td>
<td>10.71</td>
<td>38.42</td>
</tr>
<tr>
<td>5</td>
<td>14.76</td>
<td>13.15</td>
<td>38.95</td>
</tr>
<tr>
<td>6</td>
<td>15.4</td>
<td>10.78</td>
<td>42.24</td>
</tr>
<tr>
<td>7</td>
<td>15.31</td>
<td>9.94</td>
<td>39.83</td>
</tr>
<tr>
<td>8</td>
<td>16.75</td>
<td>10.72</td>
<td>35.83</td>
</tr>
<tr>
<td>9</td>
<td>16.57</td>
<td>11.53</td>
<td>35.92</td>
</tr>
<tr>
<td>10</td>
<td>15.69</td>
<td>10.05</td>
<td>34.67</td>
</tr>
<tr>
<td>Mean</td>
<td>15.81</td>
<td>10.88</td>
<td>38.24</td>
</tr>
<tr>
<td>Median</td>
<td>15.55</td>
<td>10.72</td>
<td>38.62</td>
</tr>
<tr>
<td>Range</td>
<td>14.69 - 17.18</td>
<td>9.94 - 13.15</td>
<td>34.67 - 42.24</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.94</td>
<td>0.95</td>
<td>2.26</td>
</tr>
</tbody>
</table>
Figure 2: Individual Graph

The Effects of the Amount of Liquid Keratin (Created from Feather Fiber) on the Flexural Strength of a Gel Coat in Peak Strength in Kilograms

- 10% Liquid Keratin
- 25% Liquid Keratin
- Control

Retests

Flexural Strength in Peak Weight in Kilograms

Retests
Figure 3: Mean Graph
The Effects of the Amount of Liquid Keratin (Created from Feather Fiber) on the Flexural Strength of a Gel Coat in Peak Strength in Kilograms.

Flexural Strength in Peak Strength in Kilograms

Amount of Liquid Keratin

10% Liquid Keratin
25% Liquid Keratin
Control

Values:
- 15.81 (10% Liquid Keratin)
- 10.88 (25% Liquid Keratin)
- 38.24 (Control)
Figure 4: Median Graph
The Effects of the Amount of Liquid Keratin (Created from Feather Fiber) on the Flexural Strength of a Gel Coat in Peak Strength in Kilograms.

- 10% Liquid Keratin: 15.55
- 25% Liquid Keratin: 10.72
- Control: 38.62

Amount of Liquid Keratin:
- 10% Liquid Keratin
- 25% Liquid Keratin
- Control
IV. STATISTICAL ANALYSIS
STATISTICAL ANALYSIS

The statistical analysis applied to the data was the Tukey. This was chosen since more than two test groups were being compared. When the 10% liquid keratin and the 25% liquid keratin groups were compared, the probability of the results, assuming the null hypothesis, is 0.000. This value indicates the amount of liquid keratin did have a significant effect on the flexural strength. When the 10% liquid keratin gel coat and the control group were compared, the probability of the results, assuming the null hypothesis, is 0.000. This value indicates that the amount of liquid keratin did have a significant affect on the flexural strength. When the 25% liquid keratin gel coat and the control group were compared, the probability of the results, assuming the null hypothesis, is 0.000. This value indicates that the amount of liquid keratin did have a significant effect on the flexural strength.
V. CONCLUSION
CONCLUSION

The hypothesis stated that as the amount of liquid keratin (created from feather fiber) changes, then the flexural strength of a gel coat will change. The hypothesis was accepted on all test groups. The inference, however, was not accepted because as the amount of liquid keratin increased, the flexural strength of the gel coat actually decreased. The data collected and the statistics applied shows that the 25% and 10% liquid keratin groups were measurably outperformed by the control group, with the 25% liquid keratin group performing the worst. This indicates that the largest amount of liquid keratin, created from feather fiber, did cause the least amount of weight resistance when testing flexural strength. The null hypothesis was not accepted.

The data showed the control group, (or group with no liquid keratin) performed better than both the other groups. The 10% liquid keratin gel coat, although outperforming the 25% liquid keratin group, did not perform as well as the control (which is commonly used in the industry). This information supports the conclusion that liquid keratin created from feather fiber, in this experiment, is not a viable addition to this type of gel coat.

Although the liquid keratin did not perform as well as the control, it could potentially be a successful component in gel coats. Since the resin used was made to react with the usually used chemicals, it is possible that the resin did not react effectively with the liquid keratin, causing it to not perform as well as the commonly used gel coat. The experimenter is also not aware of the actual make-up of the liquid keratin created and until this is discovered, is uncertain how much keratin was actually extracted from the feather fiber. The process of breaking down feathers to a liquid is highly unexplored, and because of the estimations used to create a liquid successfully, the experimenter drastically changed the ratios proven to be effective in other experiments. Water was also added to the liquid solution, and in high amounts, water has shown to decrease a gel coat’s durability.

Even after the testing, however, the experimenter was still successful in breaking down feather fiber to a liquid keratin. Thus, the procedure used could eventually prove to be a highly effective way to break down feathers to create a liquid containing a large amount keratin. Further testing will need to be performed to determine the amount of keratin within the liquid solution.

In the future, exploration of a process that breaks down feather fiber into liquid keratin could be explored to create an environmentally friendly component that is more practical than its original dry form. Further testing is also needed to determine the most effective combination of liquid keratin in the gel coat or to determine the actual make-up of the liquid keratin used. While this project addressed a method for using recycled feathers to decrease the amount disposed of in landfills, the future of feathers or liquid keratin in the gel coat and plastic industry is still an unknown.
VI. FUTURE STUDY
FUTURE STUDY

1. Does the process by which liquid keratin is created from feather fiber affect the durability of a gel coat?
2. Does the process used to create liquid keratin from feather fiber affect the amount of keratin in the liquid?
3. Does the grind of feather fiber used in creating liquid keratin affect the durability?
4. Does the type of resin used with liquid keratin affect the durability of a gel coat?
5. Does liquid keratin created from feather fiber affect the properties of a blood plasma expander?
6. Does liquid keratin created from feather fiber affect the consumption rate of wood by *Reticulitermes flavipes* (eastern subterranean termites)?
7. Does a bandage made of feather fiber affect the rate of skin growth?
8. Does the addition of liquid keratin to a composite affect the durability?
VII. ACKNOWLEDGEMENTS
ACKNOWLEDGMENTS

The experimenter would first like to thank mentors Kelly Potterf, Lana Vaughn, Dick Fermanian, and John Winfrey at CCP for their expertise and help during the conduct of this experiment. The experimenter would also like to thank Walter Schmidt and Justin Barone with the USDA for providing information on feather fiber and liquid keratin, as well as David Emery from FeatherFiber Incorporated who sent generous amounts of feather fiber and information on the topic. Finally, the experimenter would also like to thank Cook Composites and Polymers (CCP) for allowing the use of their lab and supplies providing the experimenter with lab safety training.
VIII. WORKS CITED
WORKS CITED


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