Scraps To Scrolls:

Can Vegetable Pulp Produce a Sustainable Alternative to Wood Pulp Paper?

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Question: Can fruit scraps be made into a more sustainable option to wood pulp paper?

IDEAS-10/09/23:
-extracting silica dioxide from food waste/expired fruit and vegetables
-turning expired vegetables/fruit/tea leaves (?) into paints
-turning fruit into clothing
-fruit peels into plastic

October 18/2023

-idea?- turning food waste into a paper alternative?

Why is it useful? - turning food waste into an alternative to wood pulp paper and reducing food waste, especially from commercial usages such as grocery store scraps.
How would we do this?- tbd?
IMPORTANT TOPICS TO RESEARCH:

October. 19, 2023

Background

Google search: is paper eco friendly?
result:https://www.bbc.com/future/bespoke/made-on-earth/how-paper-is-making-a-comeback/
Some info on the effects of making paper (direct paragraph):
Indeed, almost every phase of paper manufacturing involves water. Scaled up to the magnitude of the industry today, a vast amount is required. To make just a single A4 sheet, you need between two and 13 liters. In China, which remains one of the leading players in the paper trade, the industry sucked up 3.35 billion tonnes (roughly three trillion litres) in 2014 – enough for about 37 billion baths.

After the pulping and bleaching is over, paper mills end up with water containing a cocktail of organic compounds, alkalis and bleach, which must be treated so that it can be disposed of safely. This can be a huge technical challenge, and some paper mills simply discharge the effluent straight into the local water supply, where it's acutely toxic to fish and other wildlife – even at concentrations of just 2%.

Energy

Another sustainability challenge facing the paper industry is the sheer amount of energy required. One study found that the global paper industry eats up around 6.4 exajoules (EJ) of energy each year – enough to make some 87 trillion cups of tea. All that energy means paper contributes 2% of the world's total carbon footprint.

And finally, there's the trees. Each year, the global paper industry is fed by more than 100 million hectares of forests, which is an area around the same size as Egypt. In some places, the industry is thought to contribute to net deforestation – and therefore yet more carbon emissions, because the felled areas would previously have been locking away carbon dioxide. And while much paper is sourced from sustainably managed forests, some is made from trees in ecologically important forests, contributing to loss of biodiversity.

October. 21, 2023

Google search:why is wood used to make paper as opposed to other materials?

result:https://new.abb.com/pulp-paper/abb-in-pulp-and-paper/articles/characteristics-of-wood-and-papermaking-fibers

softwood

Fibers from softwoods are long and strong, and therefore the strongest paper grades are generally manufactured from chemical pulp made of softwood. Typical important end uses include cardboard boxes and milk cartons, which require high strength to function correctly.

Softwood is composed of up to 90% long, tapering cells called tracheids, which function both for support and water transportation. The hole in the middle of the tracheid is called lumen. The tracheids are connected to each other through pores. Apart from the tracheids, there are other cell types present, for example resin channels storing resin, and ray cells. These cells are principally connected with lignin, forming a stable support structure that holds the fibers in place.

Hardwood

Hardwood fibers are short and thin, giving better paper formation than softwood fibers. They also give paper a smooth printing surface and high opacity. In addition, because there is somewhat less lignin in hardwood compared to softwood, it is also easier to bleach the hardwood pulp to a high brightness.

These qualities make hardwood very suitable for use in printing papers, although these grades generally consist of a blend of hardwood and softwood pulps to meet the combination of strength and the printing surface demands of the customer.

Hardwoods have a more complex structure than softwoods, with different cells for water transport and support. Elongated libriform fibers function for support and are thick-walled in proportion to the diameter. Shorter, wider cells called “vessels” are responsible for water transportation.

Chemical composition

Wood mainly consists of three types of materials: Cellulose, hemi-cellulose and lignin. The relative composition in the wood varies in different species of trees.

Cellulose is the main component of the fiber. It is a straight-chain carbohydrate polymer composed of glucose units and is the structural material on which the fiber is built. Cellulose is insoluble in most solvents, and it is resistant to the action of most chemicals except strong acids. Cellulose is also very important to paper properties because the attraction between cellulose molecules on different fiber surfaces is the principal source of fiber-to-fiber bonding in paper to give strength.

Hemi-cellulose is the second major component in a wood fiber. It is also a polymer built up of branched molecular chains of glucose and other monosaccharides, and it can be removed by mild chemical action. The molecular chains are much shorter than in cellulose. Hemicelluloses are very important in paper making since they promote the development of fiber-to-fiber bonding, because they can help the fibers to take up water during processing, thus directly participating in the bonding.

The third major component of a wood fiber is lignin, the glue which holds fibers together to form the wood structure. It also occurs within the fiber wall. Lignin is a very complex non-uniform molecule and does not dissolve in water or other common solvents, but it can be made soluble by chemical action. The purpose of all chemical pulping processes is to dissolve and remove lignin. However, there is no practical method for complete lignin removal by pulping. The residual lignin gives the unbleached pulp a brown tint, and if white paper is to be made, the remaining lignin must be removed by bleaching. Besides reducing the natural whiteness of pure cellulose fibers, lignin also prevents the formation of fiber-to-fiber bonds in paper, thus reducing the sheet strength.

Google search:is more cellulose better for paper?

result:https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2635603/

A paper based product typically contains **90–99%** cellulose fibers which are the primary structural element and the most important component influencing end use properties.

Google search:is cellulose fiber good for paper?

result:https://www.britannica.com/technology/papermaking/Fibre-sources

Even in the wet state, **natural cellulose fibres show no loss in strength**. It is the combination of these qualities with strength and flexibility that makes cellulose of unique value for paper manufacture. Most plant materials also contain non fibrous elements or cells, and these also are found in pulp and paper

Google search: amount of hemicellulose in paper

Result:https://www.sciencedirect.com/topics/materials-science/hemicellulose

They make up **20–35% of the dry weight of wood**.

November 15 2023

-Come up with research questions:

-why is paper made from wood?

-what is the paper making process?

-Can fruits be used to make paper?

-can you make paper at home?

-what are problems with traditional wood pulp based paper

November.18, 2023

Google search:

-why is paper made from wood?
Results: https://extension.psu.edu/from-the-woods-paper
The ancient Egyptians developed a paperlike substance nearly 4,000 years ago. By weaving together the reeds of papyrus plants into mats, and then pounding them, they produced a thin, tough sheet for writing on. This product was called papyrus, and our English word "paper" has its origin in that Egyptian name. Before papyrus, people used clay tablets, stones, wooden boards, cloths, animal skins, metal tablets, and even leaves to write on.

The Chinese invented the first true paper about 2,000 years ago. Their paper was made from a watery paste of ground-up mulberry bark, hemp, and cloth rags. They pressed this paste to remove the water, then sun-dried the resulting mat of compacted fibers to make a sheet of paper. It wasn't until an invading army captured a Chinese paper mill 600 years later that the papermaking process was carried west to the Middle East, Africa, and Europe.

For many years throughout the Western world, paper was only made from discarded rags and clothing. Cotton and linen fibers produced a fine, strong paper, and the use of other plant fibers for papermaking was forgotten during the Dark Ages. However, paper was always in scarce supply due to the constant shortage of used cloth. The first paper mill in America, established outside of Philadelphia, Pennsylvania, in 1680, also used old rags to produce paper. By 1802, there were nearly 200 such mills in the United States.

During the mid-1800s, European papermakers rediscovered the use of tree fibers for papermaking. Also during this time, various types of machinery and processes were developed in Europe and America for grinding or chemically breaking down wood and producing paper. Wood was in abundant supply, and the use of wood rather than rags made it much cheaper and easier to make paper. This was the beginning of the mass-produced paper industry, an industry that played an important part in the development of our country and the world, and still does!

Today, almost all paper is made from wood pulp; however, some specialty papers are still produced using cotton and linen fibers (for printing things like money and maps). But what exactly is wood pulp? When wood is broken down, either mechanically or chemically, two main things are left: fibers (composed mostly of two kinds of cellulose) and lignin. The fibers are actually the remains of the tree's cells. They are small, about 1/8 of an inch in length and 1/150 of an inch in width (about 1/10 the thickness of a human hair). When a piece of paper is torn, you can see tiny wood fibers along the ripped edge. Lignin is the glue, or cement, that holds the fibers in place in the wood. Wood pulp is nothing more than a huge quantity of individual wood fibers with the lignin removed. The natural color of wood pulp ranges from dark brown to light gray.

November. 19, 2023

Google search:

What is the paper making process?

results:https://extension.okstate.edu/fact-sheets/basics-of-paper-manufacturing.html#:~:text=Typical%20mechanized%20paper%20production%20involves,sheet%20in%20a%20Fourdrinier%20machine.

Before wood pulp is produced from a tree, several steps must be taken. First, trees are cut and transported to a paper mill. Most of the trees used for papermaking in Pennsylvania are smaller trees that have little potential for making lumber. At the mill, the bark is removed from the trees. Lastly, the fibers are either mechanically or chemically extracted from the wood and then separated from the lignin.

In the mechanical method, grindstones tear wood fibers apart in water, or the trees are chipped up into small pieces first and then ground down to fibers. However, chemical methods are more widely used and are more energy-efficient. The chemical methods involve cooking wood chips in large tanks. These tanks, called digesters, are similar to pressure cookers. Various chemicals, called the cooking liquor, help break down wood chips into a mushy mass of fibers. Regardless of the method used to produce pulp, it is always washed and screened (to remove impurities) before it becomes paper.

Wood pulp is also made from chipped sawmill waste wood or from used paper. The recycling process for used paper is similar to making "virgin" pulp directly from wood. In recycling, the wood fibers in the paper must be separated again or "repulped" in water. It is also necessary to remove the chemicals, such as adhesives and ink, on used paper. The recycling process shortens the length of the individual fibers, so wood fibers can only be recycled several times before they are too short for making paper. That's why it is necessary to mix new pulp with recycled pulp to make paper products.

Modern paper machines are nearly as long as a football field and can create a sheet of paper 6-14 feet wide and 40 miles long in an hour.

The papermaking process begins by washing, bleaching (to whiten or "brighten" if necessary), and beating (to soften) wood pulp. Starches, colors, and other chemicals added at this early stage create different types of paper. After mixing the pulp and chemicals with water, this "slush" moves into large paper making machines. Here, the slush is pumped evenly onto a fast-moving (58 feet per second), fine-meshed screen. As water drains off, the slush moves along on the screen and then through a series of heated cylinders to press, dry, and smooth it, ensuring uniform thickness. Rolls of paper are the finished product. They are usually rewound and cut into smaller rolls or packs, then shipped to printers and manufacturing plants to become products. There are thousands of different paper products--everything from coffee filters to facial tissues and magazines. Throughout the papermaking process, tests ensure paper quality. If a roll of paper does not meet quality standards for the desired finished product, it is recycled back into the process.

November. 21, 2023

Here's how paper is made...

1. Pulpwood yard stores the raw material
2. Pulpwood is debarked and chipped
3. At a mill, chips are cooked in a digester and broken down into pulp
4. Pulp is washed, bleached, and softened
5. Pulp is mixed with water and pumped onto a moving screen
6. Paper machines rapidly press, dry, and smooth the pulp
7. Computers monitor the entire process

8. Paper machines produce large rolls of paper
9. Rolls of various weights and colors are stored in warehouses
10. Sheets of cut paper are shipped to buyers

November 23, 2023

Google Search: Non-wood fiber sources for making paper

https://myjafe.com/wp-content/uploads/2020/07/MYJAFE2020-0017.pdf

- Utilization of Empty Fruit Bunches (EFB) from oil palm as a potential substitute for wood fibers in the pulp and paper industry
- Properties of EFB, its suitability for paper production, and explores advanced applications derived from EFB, like nanocellulose and antimicrobial papers
- Malaysia's oil palm industry generates abundant EFB, which, when processed correctly, can serve as an eco-friendly and economically viable raw material for various industries, especially in pulp and paper manufacturing. The paper discusses the morphological properties of EFB fibers, highlighting their potential for paper production due to their thickness and tearing resistance
- EFB, as a non-wood fiber resource, could be a game-changer in the papermaking industry, emphasizing its properties, potential applications, and contributions to sustainability efforts in the palm oil industry
- EFB is a major by-product of the palm oil industry in Malaysia
- The process of oil extraction from fresh fruit bunches (FFB) results in the generation of EFB.
- Approximately 1.07 tonnes of EFB is produced to extract 1 ton of palm oil
- EFB is a type of woody biomass with high moisture content (up to 60%) due to steam from the oil extraction process
- EFB fibers contain cellulose (43-65%), hemicellulose (17-33%), and lignin (13-37%).
- Morphologically, EFB fibers resemble short-fiber hardwoods like eucalyptus
- The fibers have a thicker cell wall compared to wood fibers, leading to higher rigidity and excellent tearing resistance
- Characteristics of EFB fibers include variable lengths (ranging from 0.27 mm to 1.48 mm) and diameters (ranging from 14.00 µm to 16.89 µm)
- EFB utilization contributes to economic growth and creates opportunities for innovative industries, potentially reducing production costs

https://www.sciencedirect.com/science/article/abs/pii/S0315546374738494

- Variability in the content of alcohol insoluble solids (AIS) found in the edible portion of apples
- It emphasizes the sensitivity of the sodium carboxymethyl ether of the isolated cellulose component towards divalent metal ions
- Apple cellulose demonstrates high viscosities in aqueous solutions, suggesting higher molecular weight or steric orientation compared to other cellulose sources

- Cellulose characteristics within apples from different years and potential impacts on processing
- Cellulose is highlighted as a fundamental structural element in various natural materials, usually bound to other structural polymers like hemicelluloses and pectic substances
- Exceptions like cotton and bacterial celluloses exist in almost pure states
- Samples were obtained from apples entering a commercial processing plant, making them non-uniform in source and size
- The process involved mechanical peeling and coring, followed by maceration and juice extraction

November. 24, 2023

Same search as yesterday

http://peer2pickle.weebly.com/edible-paper.html

Method A - Raw Pulp Preparation:

- Uses waste juicer pulp directly, preserving ingredient colors and using no additional water.
- Weaker and crisper results due to dependence on the existing materials to hold together.
- Steps include:
- Adding pulp to a screen, pressing with a microfiber cloth to remove excess water, then carefully transferring to a moistened surface for further drying.

Method B - Boiled Pulp Preparation:

- Involves boiling pulp with baking soda to bind fibers, creating a stronger, more uniform sheet.
    - Steps include:
- Boiling the pulp with water and baking soda, straining, rinsing out brown liquid, creating a saline solution, mixing pulp with saline solution, and draining excess liquid.
- Similar drying process to Method A.

Drying Methods:

- Open Air Drying (Method C): Involves leaving the sheets to dry in open air, noting the likelihood of the paper curling.
- Pressed Under Drying Sheets (Method D): Involves stacking sheets between absorbent materials to compress and absorb moisture, changing the absorbent sheets regularly.

Cost Estimation:

- The cost per sheet is estimated based on time (3 hours) multiplied by the local living wage ($13.50), adding estimated expenses and utilities ($10), and then divided by the number of sheets produced.

Additional Notes:

- Fruit and vegetable fibers tend to produce weak paper sheets due to short fibers, resulting in warping and curling upon drying.
- To achieve flatter sheets, it's suggested to use more skin fibers, and adding other fibers like stems or leaves can strengthen the paper but make it less 'edible.'

https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/papermaking#:~:text=Starch%20is%20used%20as%20a,maize%2C%20wheat%2C%20and%20tapioca.

- Papermaking relies on additives like detackifying agents and dispersants to control deposits on equipment.
- Repulping is essential for mills without integrated pulp mills, dispersing market pulp in water for papermaking.
- Starch, sourced diversely, fulfills multiple roles in paper production, crucially enhancing paper quality.
- Potato starch stands out for its impact on filler retention and paper strength, particularly in wet-end applications.
- Early US papermaking heavily relied on European rag sources, later exploring alternatives like straw and cactus.
- The papermaking process involves forming pulp fibers into a mat, water removal, and drying in machines like the Fourdrinier.
- Specialized papers, like ceramics, leverage papermaking techniques for high-temperature applications.
- Non food specialized applications often require modified starches to enhance specific paper properties, addressing diverse needs.
- Enzyme treatments like pectinase and laccase show potential for improving papermaking properties, especially in mechanical pulp suspensions, offering exciting possibilities for future innovations in the industry.

November 25 2023

Google search: do vegetables or fruits produce the most yearly food waste?

Didn't find answers to my questions, but led me to some environment facts

Forests cover 31% of the world's land, but about 15 billion trees are cut annually, mainly for agriculture, contributing to 90% of global deforestation.

A single tree can absorb 10 pounds of air pollutants yearly and produce 260 pounds of oxygen, while Chicago's 3.5 million trees clear 888 tons of air pollution annually.

Forests are crucial for water sources, supplying more than half of the planet's drinking water and intercepting rainwater to reduce property flooding.

They act as significant carbon storage, absorbing 15% of the US's transportation emissions, with one mature tree absorbing 48 pounds of CO_2 yearly.

Deforestation, responsible for 15% of heat-trapping gasses, highlights the importance of strategic tree planting for energy savings and temperature reduction.

100 million trees around US homes could save $2 billion in energy costs annually.

Recycling paper, using agri-pulp, and repurposing reclaimed wood are key practices promoting tree conservation and eco-friendly manufacturing.

https://www.paperonweb.com ›wood

November 28 2023

Google Search: How to make paper

Result: https://www.artsy.net/article/artsy-editorial-crash-course-basic-papermaking

-most important components of papermaking:

1. Cellulose content
2. Mineral pigments
3. Starches

    -used as a flocculant and retention aid, as a bonding agent, as a surface size, as a binder for coatings, and as an adhesive in corrugated board, laminated grades, and other products

    -The major starch sources are corn, potato, waxy maize, wheat, and tapioca

November 30 2023

-Innovation or experimental?

    -Innovation- taking a blend of fruits and vegetables and tweaking depending a couple tests

    -Experimental: Manipulated Variable- type of fruit or vegetable

December 1 2023

research questions:

-why is paper made from wood?

-what is the paper making process?

-what vegetables have the most similar composition to wood pulp

-can you make paper at home?

-What are the problems with traditional wood pulp based paper?

-what are the most important components of paper?

Extra questions:

(for our knowledge, we are not presenting this as its gets too long)

CHANGE: deciding on experimental and having manipulated variable the type of vegetables

December. 3, 2023

Researching:

Extra basic info:

-Cheapest, most accessible, cellulose high vegetables

Google Search- Cheapest vegetables in Canada

Link 1: https://dfdrussell.org/cheapest-and-healthiest-veggies/

Link 1 list-

1. Cabbage
2. Romaine Lettuce
3. Beet greens
4. Broccoli
5. Zucchini
6. Peas
7. Green Beans
8. Celery

9. Okra

Link 2: https://www.healthstandnutrition.com/healthy-vegetables-on-a-budget/

Link 2 list-

1. Cabbage
2. Bok Choy
3. Carrots
4. Canned tomatoes
5. Peas
6. Zucchini
7. Spinach

Conclusion: cabbage is the cheapest if not the best option, it resembles paper, already containing the water we need to convert its pulp to paper. Reduces our water consumption and costs, and also produces more quantity. The problem with cabbage is that it's quite thin causing the paper to turn out flimsy

December. 4, 2023

Identified controlled, manipulated and responding variables

Controlled: Time of experiment, location, amount of water used, weight of food scraps used, condition of food scraps, processing method, uniformity in pulping, mixing, pressing, and drying, time between each step, time to dry, conditions to dry in, consistency/thickness of the pulp, the pressure put into the pressing of the paper, temperature, humidity, time of day, same tools, cleanliness of the tools used, same timeframe, amount of material used, same type of water, same materials, etc

Manipulated: Type of fruit/vegetable scraps used

Responding: The paper made by each fruit/vegetable and its evaluation the quality of the produced paper, such as tensile strength, thickness, absorbency, and durability

December. 5, 2023

Today I researched the paper making process, didn't do much to start off with, I delved into some videos.

https://www.youtube.com/watch?v=GuMsRWqPc2k

https://www.youtube.com/watch?v=0VEJCWvfhQg

https://www.youtube.com/watch?v=COxB_GvdzWI

Takeaways:

Pulping: Raw materials (like wood) are processed through mechanical or chemical methods to break them down into fibers.

Cleaning and Refining: The pulp undergoes cleaning to remove impurities and refining to improve fiber quality.

Papermaking: Pulp is mixed with water to form a slurry, then formed into sheets, pressed, and dried.

Finishing: Paper may be calendared, cut into sizes, and undergo quality tests before packaging.

Environmental Considerations: Efforts focus on sustainability through recycling, eco-friendly methods, and reduced resource consumption.

<u>December.6, 2023</u>

Google search: How is pulp made?

Pulp is a lignocellulosic fibrous material prepared by chemically or mechanically separating cellulose fibers from wood, fiber crops, waste paper, or rags. Tear the wood by crushing it against a rotating grinding stone or by running chips through a mill. Add cups of shredded paper, to cups of boiling water. To produce pulp, combine the paper and water in a blender or with an egg beater. Soak the food scraps overnight

Ratio- 2 cups of boiling water to ½ of shredded paper

We might have to change this ratio for vegetable scraps

Research:

Wood chips: Kraft pulp (a type of chemical pulp) is made using raw wood (both softwood and hardwood) chips which are pre-steamed in a steaming vessel. Steamed chips are then cooked inside a pressurized digester with a combination of chemicals and heat to dissolve the lignin glue which holds the wood fibers together.

Digester and blow tank: The digester’s pressure is relieved into a blow tank which separates the chips into unbleached pulp fiber.

Screen and Washing: Residual chemicals are removed and recycled in the brown stock washing stage.

Bleaching: The pulp is then bleached to its recognized bright white color in the bleach plant.

Pressing and Drying: The bleached pulp is then diluted to a slurry where it is sprayed across a pulp machine screen to form the pulp mat and begin the dewatering process of pressing and drying in the dryer section.

Pulp Bales: The dried pulp is then cut and baled into 400 kg bales on the baling line in preparation for transport around the world.

Source: https://paperexcellence.com/pulp/how-we-make-pulp/

December. 8, 2023

How will we determine the best fruit/vegetable, what to consider:

- Cost
- Durability of Paper
- Availability of the product
- Environmental Impact
- Waste Utilization
- Processing Ease
- Fiber content
- Cellulose content
- Prevention of rotting
- Sustainability
- Usage
- Ideal amt to use
- Amt of water used

(we will be using the same amount of many of these variables for each test, but this important as it can factor into other things)

December.9, 2023

Brainstorming how we are going to do this, we thought initially an innovation project would be more helpful but decided to move ahead with an experiment. So, why exactly did we choose to do an experimental project, making and thinking of a pros and cons list helped us get started. An innovation project would for sure, create a whole new area to start a nebula of ideas, but going back to it, it wasn't the right decision for us. Refining our project we thought it would be more helpful for us to play around with the certain different fruits and vegetables, in terms of combining them all. This way we can really tell what is better as a substitute for paper by also looking at all the factors we need to take into consideration.

December. 10, 2023

-Worked on science fair proposal

Main problems-Can fruit scraps be made into a more sustainable option to wood pulp paper?

What other issues can this solve:

-This is eco friendly- recycled wood waste, using an alternative to paper

- It also is better than usual recycling as recycling paper itself may not directly lead to environments being damaged bets it consumes a lot of water to recycle even a single sheet of paper

- allows for "unsellable" produce from grocery stores to be repurposed

December.11, 2023

-Google search: does freezing vegetables affect the contents

Summery: it has no effect on structural properties or nutrients

-Google search: lignin papermaking

Results:https://www.sciencedirect.com/science/article/abs/pii/S0960852420309081

-Google Search: lignin removal process from food scraps

1. Pulping:

Chopping or Grinding: Break down the vegetable scraps into smaller pieces to increase surface area.

Boiling or Steaming: Cook the scraps in water to soften them and facilitate lignin separation. This can be done by boiling or steaming the scraps for a certain duration.

Chemical Treatment: Add chemicals like sodium hydroxide (caustic soda) or sodium sulfite to the mixture. These chemicals help break down lignin, separating it from the cellulose fibers.

2. Washing and Bleaching:

Washing: Rinse the pulped mixture thoroughly to remove lignin and chemical residues.

Bleaching (Optional): Use bleaching agents like hydrogen peroxide or chlorine dioxide to further whiten the pulp. This step is often performed in industrial settings for paper used in printing.

3. Fiber Separation:

Beating or Refining: Mechanically process the pulp to separate and align the cellulose fibers, improving paper quality.

4. Paper Formation:

Sheet Formation: Spread the pulp onto a screen or mold to form sheets of paper.

Pressing and Drying: Press the formed sheets to remove excess water and then dry them to create the final paper product.

Source:https://www.sciencedirect.com/science/article/pii/S2238785414000982#:~:text=Extraction%20of%20lignin%20from%20different,consequently%20retrieving%20by%20washing%20them.

Considerations:

Chemical Safety: When using chemicals like sodium hydroxide or bleaching agents, ensure proper handling, use protective gear, and follow safety guidelines. Dispose of chemical residues properly to prevent environmental contamination.

google search: starch in papermaking

The papermaking process consists of several major steps: stock preparation, sheet forming, pressing, drying, and surface finishing. Starch is an important component of many paper grades. Starch consumption by weight in papermaking and paper conversion processes ranks third after cellulose fiber and mineral pigments. Starch is used as a flocculant and retention aid, as a bonding agent, as a surface size, as a binder for coatings, and as an adhesive in corrugated board, laminated grades, and other products. The major starch sources are corn, potato, waxy maize, wheat, and tapioca. Refined starches are supplied in powder form or as slightly aggregated pearl starch. Unmodified (native) starch is rarely used in the paper industry, except as a binder for laminates and in the corrugating process. Most starches for use in papermaking are specialty products that have been modified by controlled hydrolysis, oxidation, or derivatization.

<u>December.12, 2023</u>

Google search: Why is paper made from wood?

- Prior knowledge: I have seen paper being made out of stone, which is apparently water proof and more durable, but this leads to environmental factors that make it much harder to reestablish than trees or plants. Leading it to be more expensive than paper made from wood.

Paper is primarily made from wood due to the widespread availability of pulpwood from trees like pine, spruce, and fir, which serves as an abundant source of cellulose fibers. These wood fibers possess qualities such as length, strength, and flexibility, contributing to the durability and quality of paper. The process of converting wood into pulp for paper production is highly efficient, utilizing well-established technologies and methods optimized for wood fibers. Additionally, paper made from wood pulp can be produced on a large scale, meeting the high demands of various industries like printing, packaging, and writing. Wood pulp is also economically viable compared to other sources of cellulose fibers, making it a cost-effective option for large-scale paper production. However, the reliance on wood for paper has raised concerns about deforestation, environmental impact, and sustainability, prompting exploration into alternative fiber sources like agricultural residues, recycled paper, and certain types of fruit or vegetable scraps to mitigate these issues in the papermaking industry.

Takeaways: cellulose becomes a big thing here; the only reason our idea of turning food scraps into paper works is because vegetables originally came from plants.

Papermaking process

Britcanna quotes, “Papermaking, formation of a matted or felted sheet, usually of cellulose fibers, from water suspension on a wire screen.”

Something to think about: Optical properties and do they matter?The most important optical properties of paper are brightness, color, opacity, and gloss. In an experiment as small as this I don’t think they should necessarily matter. On a larger scale it would definitely be a factor we need to start to incorporate in our thinking but our project doesn’t exactly focus on the consumer.

<u>December. 13, 2023</u>

Worked on the first background research question: why is paper made from wood?

Search: why is paper made from wood?

- Wood is abundant and easily accessible, making it a primary source for paper production
- High cellulose content in wood serves as the main component for papermaking.
- Wood fibers, especially from softwood trees, offer strength due to their length
- Economic viability: Wood pulp is cost-effective for large-scale paper manufacturing
- Technological infrastructure and expertise in processing wood into pulp support its continued use in the paper industry
- Wood-based paper is versatile and can be tailored for different uses
- Efforts to explore alternative fibers aim to diversify sources and improve sustainability in paper production
- Egyptians created the first paperlike material, papyrus, by weaving reeds and pounding them. This led to the word "paper"

- Chinese invented true paper made from mulberry bark, hemp, and cloth rags
- Early Western paper was from discarded rags, but wood pulp later became the primary source due to its abundance
- European developments in the mid-1800s rediscovered tree fibers for paper
- Modern paper production primarily uses wood pulp. Cotton and linen fibers are still used for specialty papers
- Wood pulp contains cellulose fibers and lignin, removed during papermaking

Process:

- Trees are cut, bark removed, and fibers extracted mechanically or chemically at a mill
- Mechanical grinding or chemical methods, like cooking wood chips, are used for pulp extraction
- Recycling paper involves repulping fibers in water and removing impurities
- The papermaking process includes washing, bleaching, and beating wood pulp
- Pulp, chemicals, and water create a "slush" that moves through papermaking machines
- The slush is pressed, dried, and smoothed, producing rolls of paper
- Modern paper machines are highly automated and produce various paper products
- Throughout the process, quality tests ensure the final product meets standards

Source: https://extension.psu.edu/from-the-woods-paper

Key Takeaways: Initially produced from discarded rags, paper transitioned to wood pulp during the 1800s for cost efficiency. Wood pulp, primarily composed of cellulose fibers and lignin, undergoes extensive processing at mills, including washing, bleaching, and refining. Modern paper machines produce a wide array of paper products, emphasizing efficiency and quality control.

December 14 2023

-worked on slideshow (completed some background research slides)

-continued to organize ideas and thought about how to execute the project

-watched video on paper making:https://www.youtube.com/watch?v=E4C3X26dxbM

Key takeaways

-Important to have verity in pulp: straight cut and fibrillated ends to ensure tighter bonds and stronger paper

Google search: https://www.youtube.com/watch?v=5xrWrKIVBgo

December. 16, 2023

-Looked at research questions and decided which ones I needed to further expand on

research questions:

- -why is paper made from wood?
- -what is the paper making process?
- -what vegetables have the most similar composition to wood pulp
- -can you make paper at home?
- -What are the problems with traditional wood pulp based paper?
- -what are the most important components of paper?

-We need to expand on:

- -what vegetables have the most similar composition to wood pulp?
- -What are the problems with traditional wood pulp based paper?
- -what are the most important components of paper?

-Google Search:

- -what vegetables have the most similar composition to wood pulp?

Cellulose is basically plant fiber, and one of the most common sources is wood pulp. Manufacturers grind up the wood and extract the cellulose.

He points to an effort in the late 1990s to establish a cellulose pulp plant using corn stalks, leaves and husks, but it failed.

Sawdust contains only about 40 percent cellulose. Whereas the powdered cellulose used in foods contains about 97 percent cellulose.

Vegetables high in cellulose and green vegetables are high in cellulose

Source:
https://www.npr.org/sections/thesalt/2014/07/10/329767647/from-mcdonalds-to-organic-valley-youre-probably-eating-wood-pulp#:~:text=Cellulose%20is%20basically%20plant%20fiber,turning%20up%20in%20our%20food.

Google Search: Vegetables high in cellulose

Cabbage family of vegetables, for example, arugula, bok choy, Brussel's sprouts, cabbage, cauliflower, collards, kale, kohlrabi, mustard greens, radishes, rutabaga, Swiss chard, turnips, turnip greens and watercress.

High levels of cellulose are found in root and leafy vegetables, legumes, and some fruits such as pears and apples. Lignin content is highest in fruits, particularly strawberries and peaches, whereas pectin levels are highest in citrus fruits and apples.

Cellulose is the most abundant organic polymer on Earth. The cellulose content of cotton fiber is 90%, that of wood is 40–50%, and that of dried hemp is approximately 57%.

Source: https://nap.nationalacademies.org/read/1222/chapter/13#293

Dec. 21, 2023

-Did some research we weren't clear on, this was very minimal as we already had the basic information, just did it to delve on it further

Google Search: what are problems with traditional wood pulp based paper?

Soil erosion, loss of biodiversity, and other environmental problems

Irresponsible harvesting from natural forests, and the establishment of pulp plantations on converted natural forests, can threaten fragile ecosystems and species and cause soil erosion

Natural forests host diverse plant and animal species.

Irresponsible harvesting leads to habitat destruction and fragmentation.

Loss of biodiversity as species lose homes and migration pathways.

Forest ecosystems are intricate and interdependent

Clear-cutting disrupts these systems, causing imbalances Potential collapse of certain species populations

Removal of natural vegetation destabilizes soil. Increased risk of erosion, landslides, and water quality degradation. Impact on surrounding rivers and streams

Forests absorb and store carbon dioxide. Deforestation releases stored carbon, contributing to climate change.

Forests regulate water flow, prevent floods, and maintain water quality.

Tree removal disrupts these processes.

Altered water cycles and increased vulnerability to extreme weather events.

Communities rely on forests for livelihoods and cultural practices. Destruction of forests has profound social and cultural impacts

Facts-

Deforestation is a key factor in the extinction of approximately 27,000 species annually (WWF). 85% of threatened species face habitat destruction, often linked to logging and forest conversion (IUCN).

Logging in tropical rainforests alters ecosystems, impacting species abundance and diversity (Nature). Improper logging practices, such as clear-cutting, lead to soil compaction and nutrient loss, disrupting ecosystems (FAO).

Deforestation and forest degradation contribute to soil erosion, reducing fertility and affecting agriculture (UNEP). Research links deforestation to increased landslide frequency in certain regions (Environmental Management).

Deforestation contributes to 15% of global greenhouse gas emissions, with tropical forests being significant carbon stores (Global Forest Watch). Loss of forests as carbon sinks is a major factor in climate change (IPCC).

Deforestation disrupts water cycles, leading to altered precipitation patterns and increased flood and drought risks (World Bank). Tropical deforestation influences regional and global climate systems, impacting rainfall (Nature Climate Change).

Over 2.2 billion people, including many indigenous communities, rely on forests for their livelihoods (Rights and Resources Initiative). Recognizing and respecting the rights and knowledge of indigenous peoples is crucial for sustainable forest management (World Bank).

Source:
https://www.worldwildlife.org/industries/pulp-and-paper#:~:text=Deforestation%20and%20Forest%20Degradation&text=Irresponsible%20harvesting%20from%20natural%20forests,species%20and%20cause%20soil%20erosion.

https://www.deskera.com/blog/paper-manufacturing-critical-issues-and-challenges/#:~:text=The%20production%20of%20wood%20pulp,biodiversity%2C%20and%20other%20environmental%20problems.

December. 22, 2023

-Last background research question

Google Search: what are the most important components of paper made of wood?

Wood and other plant materials used to make pulp contain three main components (apart from water):

cellulose fibers (desired for papermaking),

lignin (a three-dimensional polymer that binds the cellulose fibers together)

hemicelluloses (shorter branched carbohydrate polymers).

Cellulose Fibers: primary structural component and provides strength, stability, and durability.

Most common source of cellulose fibers.

Derived from various trees, including softwood and hardwood.

Influences paper properties. Longer fibers (softwood) contribute to strength, shorter fibers (hardwood) enhance smoothness.

Calcium carbonate or kaolin clay improve characteristics.

Additives include sizing agents for water control

Water crucial in the papermaking process: suspends and transports fibers for bonding.

Break down raw materials into pulp.

Bleaching agents control whiteness, add color for specific characteristics, used for aesthetic requirements

Includes post-consumer or pre-consumer waste. Reduces demand for new raw materials

The paper industry is actively exploring and adopting sustainable practices, such as using alternative fibers (e.g., agricultural residues) and reducing the carbon footprint of production processes

Source: https://www.paperonweb.com/wood.htm

- Also used some earlier research and sources

Takeaways: Paper is predominantly made of cellulose fibers from wood pulp, influencing its strength and texture. Additives like calcium carbonate enhance specific properties, and water is crucial for bonding during production. The industry is adopting sustainable practices, including chlorine-free bleaching and recycling, to minimize environmental impact. Considerations for fiber length, fillers, and alternative sources showcase ongoing efforts for economic and ecological responsibility in the paper-making process.

-Done all background research

<u>December.31, 2023</u>

-Far behind in science fair, need to make a plan

-List:

-Question: Can vegetables scraps be made into a more sustainable option to wood pulp paper? What is the best fruit/vegetable to turn into paper?

-Hypothesis: If we take the pulp from five different vegetables and make it into paper, the peas will provide the most durable and functional paper because they have the highest cellulose concentration and the fiber content is the most similar to wood pulp.

-Variables:

Manipulated Variable: Type of vegetable scraps used

Responding: The paper made by each vegetable and its evaluation the quality of the produced paper, such as tensile strength, thickness, absorbency, and durability

Controlled Variables: Time of experiment, location, amount of water used, weight of food scraps used, condition of food scraps, processing method, uniformity in pulping, mixing, pressing, and drying, time between each step, time to dry, conditions to dry in, consistency/thickness of the pulp, the pressure put into the pressing of the paper, general size of food scraps, temperature, humidity, time of day, same tools, cleanliness of the tools used, same timeframe, amount of VBA used, amount of material used, same type of water, same materials, etc

-Procedure

-Materials:

-Fresh Vegetables Used: Peas, Cabbage, Cauliflower, Potato, Carrot, Radish

Why we are using vegetables: They typically produce more food waste and are cheaper

Google Search: Which are bought more frequently, fruits or vegetables?

Americans consume a variety of fruits in their everyday lives; a 2022 survey found that vegetables were the most widely purchased fruit among U.S. consumers.

-Making themes for our project to help us decide what experts to contact

Themes

1. Sustainable Materials

2. Waste Reduction

3. Eco-Friendly Paper Production

4. Recyclability

5. Cost-Effectiveness

6. Carbon Footprint

Experts:

3 experts

1. Food waste industry/ food scientist- Mrs Fourie + one more expert
2. Paper making industry
3. University professor to guide us

Timeline

today - december 31

-finish hypothesis

-

Tests to do on our paper (to determine the best paper):

1. Writing tests

2. Folding/durability

Search: How to test paper to see the quality

https://www.deskera.com/blog/quality-control-in-paper-production/#:~:text=Tensile%20strength%2C%20tear%20strength%2C%20and,a%20given%20amount%20of%20time.

January.1, 2024

Why we chose to do this project: We wanted to come up with an ecofriendly way to reuse our food waste, knowing that most of our food waste comes from organic material, usually consisting of fruits and vegetables. As we started to explore we realized that more people consumed and wasted vegetables. They were bought more frequently due to their cost efficiency and nutritional value. Due to this vegetables were wasted more often, with fruits people typically at the whole thing other than the peels and cores, like apples and oranges. With vegetables different cultures use different parts of it to create different culinary dishes. We chose these specific vegetables due to a compromised list containing, the cellulose value, the cost and the amount of food waste.

Type of Vegetable:

Peas- Cultivated Peas/Pisum sativum

Cellulose Levels: High levels of cellulose because of their peels containing the waxy material, the peels are mainly a bigger part of the pea. High levels of hemicellulose when creating starch.

Cost-Effectiveness: Peas are often more cost-effective compared to specialty pea varieties. They are commonly used as food and fodder.

Size: While pea pods are not typically large, peas are often grown in large quantities, providing a decent amount of raw material.

Common Usage: In various culinary dishes and are more commonly available in certain regions.

Cabbage- Green Cabbage

Green Cabbage (Common or Round Cabbage):

Cost-Effectiveness: Green cabbage, especially common or round cabbage varieties, is often more cost-effective compared to specialty cabbages. It's a widely used vegetable in many cuisines.

Size: Common or round cabbage varieties can grow to a substantial size, providing a decent amount of plant material for your experiment.

Common Usage: Green cabbage is a staple in various dishes and is commonly available in most markets.

Cellulose Levels: While cabbage is not particularly high in cellulose, experimenting with different types of cabbage may still yield interesting results. Cellulose contents are still common due to the leafy greens and waxy texture. While other cabbages have higher cellulose content because it is cheaper and more commonly used, due to the common usage it is a bigger factor of food waste produced.

Cauliflower-White Cauliflower

Regular White Cauliflower:

Cost-Effectiveness: Regular white cauliflower is commonly available and is often more cost-effective compared to specialty cauliflower varieties.

Size: While cauliflower heads are not typically very large, choosing regular-sized heads may provide a decent amount of plant material for your experiment.

Common Usage: White cauliflower is a commonly used vegetable in various cuisines and is widely available in most markets.

Cellulose Content: They are fibrous plants, grasses containing agricultural residues, leading to very high to moderate levels of cellulose.

Potatoes-Yukon Gold

Yukon Gold Potato:

Cost-Effectiveness: Yukon gold potatoes are commonly used for various culinary purposes, and their pricing is often reasonable, making them cost-effective for your project.

Size: Typically larger in size compared to some other potato varieties, providing a decent amount of raw material for your experiment.

Common Usage: Yukon potatoes are widely used in the food industry and households, making them readily available in many markets.

Cellulose Content: High levels of cellulose due to the large size and waxy appearance of the fibers.

Carrot- Danvers Carrot

Danvers Carrot:

Cost-Effectiveness: Imperator or Danvers carrots are commonly found in grocery stores and are often more cost-effective than specialty carrot varieties.

Size: These carrots, in particular, are known for their longer length, providing a reasonable amount of raw material for your experiment.

Common Usage: Danvers carrots are commonly used in cooking and are readily available in most markets.

Cellulose Content: Lower than some types but in all aspects this is a perfect carrot. It contains moderate cellulose content amounts. Contains big fibers to bond together the carrot but lower amounts of these fibers.

Radish- Daikon Radish

Daikon Radish:

Cellulose Content: Daikon radishes, particularly when they are grown to a larger size, can have a decent amount of cellulose, which is a key component in papermaking.

Size: Daikon radishes are known for their large size, providing a substantial amount of raw material for your experiment.

Cost-Effectiveness: Depending on your location and the availability of daikon radishes, they can be relatively cost-effective, especially if you can source them locally or from larger suppliers.

Common Usage: Daikon radishes are commonly used in various cuisines, making them more readily available in some markets.

Versatility: Daikon radishes are versatile and can be used in different dishes, which may contribute to their popularity and availability.

Vegetables Price:

Peas: $2.00 per kilogram

Cabbage: $1.50 per kilogram

Cauliflower: $2.50 per kilogram

Potatoes: $2.50 per kilogram

Carrots: $ 2.75 per kilogram

Radish: $3.00per kilogram

Vegetables Cellulose Value:

Peas: Approximately 5.7 grams of fiber

Cabbage: Approximately 2.5 grams of fiber

Cauliflower: Approximately 2 grams of fiber

Potatoes: Approximately 2.2 grams of fiber

Carrots: Approximately 2.8 grams of fiber

Radish: Approximately 1.6 grams of fiber

Waste Produced:

Peas: Waste is often generated from pea pods that are not consumed. The amount of waste can vary based on how peas are harvested and processed.

Cabbage: Outer leaves and cores are commonly discarded, contributing to waste. However, some of these parts may be used in other food products or composted.

Cauliflower: Waste is typically generated from the leaves, stem, and core that are not consumed. The amount of waste can depend on how cauliflower is processed and prepared.

Potatoes: Waste can include peels and parts of the potato that are not consumed. The amount of waste may be influenced by cooking and preparation methods.

Carrots: Waste is often generated from carrot tops and the ends that are trimmed. Carrot tops can be used in recipes or composted.

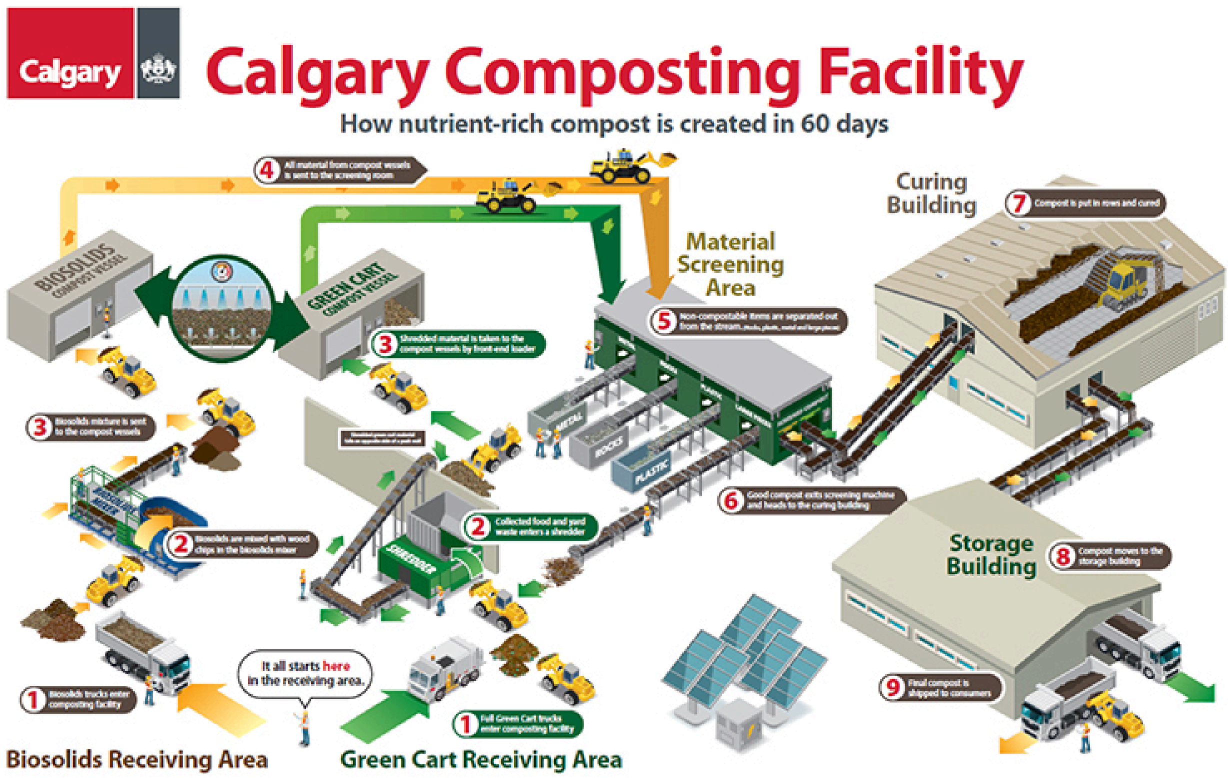
Radish: Waste may include the leaves, stems, and parts of the radish that are not consumed. These can be composted or used in other applications.

January. 3, 2024

-Wanted to see what our city specifically does in regards to composting and recycling

Google Search- City of Calgary Compost Process

- Peak Compost: A Category A compost made from Green Cart food and yard waste; and
- Peak + Compost: A nutrient-rich biosolids based compost that meets Category A criteria.
- Both add valuable nutrients to the soil. The composting process and testing for each variety is the same.



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Step 1: Food and yard waste delivered to the composting facility, emptied onto the tipping floor.

Step 2: Material shredded for optimal decomposition; biosolids added in winter for nutrient enhancement.

In-vessel Composting (Step 3):

Material stays in vessels for 21 days.

Air pumped into material to maintain microorganism activity.

Monitoring for temperature, moisture, and oxygen levels.

Odor control with biofilters.

Pathogen elimination with sustained high temperatures.

Steps 4 and 5 - Screening:

Material from vessels screened for non-compostable items.

Removal of contaminants to produce quality compost.

Steps 6, 7, and 8 - Curing, Cool Down, and Storage:

Curing for 21 days, turning and mixing every five days.

Pipes draw air to enhance decomposition.

Moved to a storage facility after curing.

Final Product Testing:

Category A compost deemed safe for various uses.

Samples sent to CQA accredited lab for analysis.

Sale of Compost:

Bulk sale to companies.

Proceeds reduce processing cost and Green Cart program fee.

Some compost distributed for free to the community.

Composting Facility Expansion:

Introduction of anaerobic digestion system.

Coexists with in-vessel composting.

Anaerobic digester produces biogas and digestate.

Biogas Production:

Captured and upgraded into renewable natural gas.

Revenue supports the Green Cart program.

Digestate Production:

Broken down food and yard waste from digestion.

Mixed with incoming material for composting.

Requires less time in composting vessels.

Benefits of Anaerobic Digestion:

Reduces time in composting vessels, increasing overall capacity.

Lowers greenhouse gas emissions.

Generates revenue through biogas sales.

-Found this on their website

Visit the Composting Facility

Join us for an information session about how Calgary turns green cart food scraps and yard waste into nutrient-rich compost in just 60 days! Our composting facility diverts more than 85 million kilograms of food and yard waste from the landfill each year, producing compost for use in gardens, farms, and City parks.

Call 311 to book.

Where do the materials you toss into your blue cart go? Visit us to learn how recyclables are sorted at the Recycling Facility.

Call 311 to book.

Experts

Categories: Food Scientist, Paper Makers, Paper Sellers, Organic Paper Makers Companies, Recycling and Compost, Forest Resources, Environmentalists, Grocery Stores, Garden Centres, University Professors

Green=Contacted + Received a Response

Yellow= Contacted + not received a response yet

Orange= Contacted some people/ facilities from this category

Red: No contacts yet

University Professors:

- Wrote: https://ifst.onlinelibrary.wiley.com/doi/10.1111/j.1745-4549.2009.00367.x
    - TEL: 862085224357
    - Shiyi Ou
    - EMAIL: tosy@jnu.edu.cn
    - Jinan University (Guangzhou, China) · Department of Food Science and Engineering
    - PhD
- Wrote:https://www.sciencedirect.com/science/article/abs/pii/S0165993603010094
    - Tel.: +34 93 400 61 69
    - S. Lacorte
    - slbqam@cid.csic.es
    - Department of Environmental Chemistry, IIQAB-CSIC, Jordi Girona 18-26, E-08034 Barcelona, Catalonia, Spain

Forest Resources

- Stanford S. Smith- prof. Of forest resource
- Wrote- https://extension.psu.edu/from-the-woods-paper
- email- sss5@psu.edu

Food scientists

- John coupland- food scientist at penn state University
- email- coupland@psu.edu

Jan.4/2024

General Questions to Experts

- Is finding an alternative for wood to make paper a concern for manufacturers as the forestry industry becomes more concerned with the conservation and protection of forests?
- What are problems with other current alternatives to wood pulp paper? Could they eventually replace wood pulp paper in the future?
- What are environmental and ethical concerns with wood pulp paper?
- When finding trees to make paper, is a specific cellulose content essential, or can it be treated in some way to create a stronger and more usable sheet?

-Ordered paper molds/mesh nets

-Contacted 311

January 5, 2024

Questions

- How does Organic Cotton Plus transform recycled cotton and organic materials into paper?
- What challenges have you encountered in the organic paper-making process, and how have you overcome them?
- How does your company ensure the sustainability and environmental friendliness of its paper production?
- Are there any specific considerations or recommendations you would have for a project like ours, focused on utilizing cellulose from vegetable scraps?
- What are the key steps involved in the paper making process at your facility?
- How has technology impacted the paper making industry in recent years?

- What sustainability measures or eco-friendly practices does your company implement in paper production?
- What challenges do you foresee in the future for the paper making industry?
- How does your company manage compost for plants that are not sold or cannot be sold?
- Are there specific steps or practices in place for ensuring sustainable waste management in your plant production processes?
- How does your company approach the reuse or recycling of plant materials to minimize environmental impact?
- Are there any innovative practices or initiatives your company is currently undertaking in the realm of sustainability and waste reduction?
- How does the City of Calgary manage and process recyclables, particularly focusing on waste materials like vegetable scraps?
- Are there specific initiatives or technologies in place to enhance recycling efficiency and sustainability?
- What are the challenges faced by the recycling facility, and how does the city address them?
- How does the City of Calgary manage composting processes for organic waste, including vegetable scraps?
- Are there unique considerations for composting vegetable scraps compared to other organic materials?
- How does the city promote compost use or distribution to the community?

-Contacted Organic Paper Plus (Use recycled cotton to make paper)

-Contacted staples (Paper manufacturing company)

-Contacted White Paper (Calgary based paper making company)

-Contacted Spruce It Up (garden center)

-Contacted Saskatoon Farms (garden center)

-311 got back to us, we have been put on the waitlist for our tours, currently trying to reach experts at the city of calgary

We received these links for videos that could potentially aid us

Compost Facility: How compost is made: Calgary's Green Cart Program (youtube.com)

https://www.youtube.com/watch?v=NGopFxRsQWg&t=1s

Materials Recovery Facility (recycling) - Calgary recycling: How recyclables are sorted (youtube.com)

https://www.youtube.com/watch?v=Zhv-Dv9h3J4&t=3s

-Contacted No Frills (grocery store)

-Contacted Rolland Sustana Group (organic paper producers)

-Contacted Safeway

-Contacted The Paper Seller (paper manufacturer and seller)

-Emailed Professor Shiyi Ou

-Contacted the prof at penn state

January. 2, 2024

Materials Used

- Knife
- Table
- Chopping Board
- Unprocessed potato starch
- Daikon Radish
- Danvers Carrot
- Yukon Gold Potatoes
- White Cauliflower
- Green Cabbage
- Cultivated Peas
- Vat
- Blender
- Computer (Logbook)
- Visio VBA
- Felt
- Mold and Deckle
- Sponge
- Press Bar
- Towel
- Drying Surface
- Measuring Flask
- PPE
- Dropper

- Weights
- Micrometer
- Water
- Flashlight
- Crayola Black Marker
- Sharpie Black Marker
- Cheese Cloth
- Paper Towel

Rough timeline

- today (Jan 6): complete materials, procedure, and finalize what tests to do, email any last people
- Jan 7: extensions, application, sources of errors, bibliography, safety considerations
- Jan 8: Buy groceries, ask Ms. Fourie for her expert's opinion, ask for green/brown trifold paper, organize all background research
- Jan 9: Decide on trifold's themes and fonts, start scripts
- Jan 10: Map out trifold
- Jan 11: Email any last experts & organize all experts opinions
- Jan 13: complete testing, initial observations
- Jan 14(?): more observations, test strength and durability, start analysis/conclusion
- Jan 15: finish analysis and conclusion, add to scripts, start organizing all data for trifolds

Google search:https://starch.eu/ingredient/paper-board/#:~:text=Typically%20 printing%20and%20writing%20 papers,quality%20of%20fibres%20during%20recycling.

Info gathered: Typically printing and writing papers contain 4.1% starch, paper board 2% starch and domestic and industrial papers 1.9% starch

Tests (To see how durable our paper is)- Test alongside normal A4 paper

- Weight- place paper in between 2 things, add weights until failure
- (Sourced by hotzel)
- Writing- test with marker and bleeding (sharpie and crayola)
- Water resistance- Dropper, Measuring flask

Observations

- Opacity- Flashlight

- Thickness- Micrometer
- Textures
- Colour
- Environmental Impact

- Emailed last university professor
- Found another contact (environmentalist)
    - Correspondence to: Department of Chemistry, St. Xavier's College, Maitighar, Kathmandu, Nepal, Email:
    - sapkotanirakar07@gmail.com
    - Nirakar Sapkota

-Food scientist

-Corresponding author. Department of Biomedical Engineering, College of Life Science and Technology, Huazhong University of Science and Technology, Wuhan 430074, PR China.

-Tel.: +86 27 87793025.

-yang_sunny@yahoo.com

-Guang Yang

-Wrote: https://www.sciencedirect.com/science/article/abs/pii/S0268005X13002142

-Food Science Industry

-Gustavo A. González-Aguilar

gustavo@ciad.mx

-Wrote: https://ift.onlinelibrary.wiley.com/doi/abs/10.1111/1541-4337.12005

-Contacted all leftover experts

Questions for Experts continued

- In your article, you explored biodegradable and edible gelatin films for food packaging. How do you see these materials contributing to sustainable practices in the food industry?
- What challenges or opportunities do you foresee in the widespread adoption of biodegradable and edible films in food packaging applications?
- How can projects like ours, focused on utilizing vegetable scraps for paper production, align with advancements in sustainable food packaging?
- In your expert opinion, do you believe our project is a sustainable and environmentally friendly initiative?
- From your experience as an environmentalist, what role do alternative materials, such as vegetable scraps, play in contributing to eco-friendly practices?
- Are there specific aspects or considerations you would recommend for ensuring that our project not only supports sustainability but also actively benefits the environment?
- In your experience, what are the most promising sustainable practices in paper production?
- Are there specific challenges or opportunities that you see in the current landscape of sustainable paper production?
- From your knowledge in food science, do you see any potential synergies or applications between your work on edible coatings and our project focused on making paper from vegetable scraps?
- How do you think innovations in food science, particularly in utilizing by-products, can intersect with sustainable practices in paper production?
- Are there specific challenges or considerations you would highlight for projects like ours that aim to repurpose vegetable scraps for sustainable paper production?
- How do you envision the future of the paper-making industry, considering environmental concerns and the push for sustainability?
- In your experience, have you come across any food-related by-products or waste materials that could be utilized in paper production as an alternative to traditional pulp sources?
- In your research, you explored the characterization of paper and ink from printed paper wastes. Could you share your thoughts on the environmental impact of such wastes in comparison to traditional paper production methods?
- Are there specific challenges or concerns associated with the recycling of printed paper wastes, and how can these be addressed for more sustainable paper production?
- How do you see the future of sustainable paper production, considering advancements in environmental chemistry and recycling technologies?

Safety Considerations: Handling considerations, chemical usage, food safety, cross-contamination, equipment safety, safe workspace, VBA glue handling, proper ppe, knife injuries, allergies, waste disposal, adult supervision

Procedure

1. Gather materials
2. Wash vegetables
3. Cut all vegetables into small pieces on your chopping board
4. Individually, by vegetable, put the pieces into the blender for 30 secs
5. Add ______ml of water to the tub
6. Add processed vegetables to the tub
7. Mix until pulpy consistency
8. Add ____ starch
9. Add _____ml Elmer's glue
10. Soak for 10 mins
11. Hold mould with the screen side up, place deckle on top
12. Dip at a 45 degree angle
13. Dip the frame into the pulp mixture, ensuring the pulp evenly covers the entire screen
14. Scoop up while keeping the mold horizontal
15. Lift the mould and deckle up out of the pulp
16. Let water drain onto the vat from 8-10 seconds
17. Gently tap the frame on the edge of the basin to help the draining process
18. Carefully lift the mould from the deckle
19. Gently place the mould onto the felt, lay down the mould with the paper facing the felt
20. Place a piece of nylon or cheesecloth over the pulp layer
21. Use a sponge to press out excess water
22. Place another felt piece on the paper
23. Put the press bar on top of the felt, and sit for 1 minute.
24. Transfer to paper towel
25. Make nine sheets of paper for each vegetable
26. Let it dry for 1-2 days
27. Rinse mould and deckle after every use, wash off any fibers by hand
28. Repeat steps 2-26 for all trials and vegetables
29. After drying, make observations (smoothness and color)
30. Hold the handmade paper up to a light source, such as a flashlight

31. Observe and record any variations in opacity, such as the amount of light passing through the paper
32. Note any patterns or irregularities in the paper's transparency
33. Repeat 29-31 steps for normal A4 paper
34. Use the micrometer or caliper to measure the thickness of the paper
35. Repeat the measurement at different points on the paper for consistency
36. Record the measurements
37. Repeat 33-35 steps for normal A4 paper
38. Place one of the flat surfaces on a stable table
39. Put the handmade paper on top of the surface
40. Add weights gradually to the center of the paper until it fails (tears or breaks)
41. Record the weights added at the point of failure
42. Repeat 37-40 steps for normal A4 paper
43. Grab new sheet of paper with the same vegetable pulp
44. Fold the dried, handmade paper into smaller sections for testing
45. Use the Sharpie marker to write on one section and the Crayola marker on another
46. Observe for bleeding and spreading of ink on the paper
47. Note any differences in the performance of the two markers
48. Repeat 43-47 steps for normal A4 paper
49. Use the dropper to drop water onto one section of the paper
50. Observe how the paper reacts to the water (absorption, beading, etc.)
51. Measure the amount of water absorbed using the measuring flask
52. Repeat 49-51 steps for normal A4 paper
53. Repeat steps 29-52 for other two trials
54. Repeat steps steps 29-53 for all vegetables
55. Record all results and organize into graphs

<u>Sources of error</u>

- Cross-contamination while making the pulp
- Variation in lighting conditions: Changes in ambient light can influence the perception of opacity, affecting the consistency of observations.
- Uneven application of water: If the water is not evenly distributed during the dropper test, it may lead to inaccurate observations.
- Variability in ink composition: Different brands or batches of markers may have variations in ink composition, affecting how they interact with the paper.
- Uneven application: Inconsistent pressure or speed while writing may impact the results.
- Inconsistent distribution of weights: If the weights are not evenly distributed on the paper, it may lead to localized stress and premature failure.

- Variability in paper thickness: Differences in thickness across the paper sheets may affect how they handle weight.
- Uneven blending or inconsistent chopping of vegetable scraps can result in a pulp mixture with varying fiber lengths and textures.
- Insufficient draining of excess water during the paper forming stage can lead to uneven paper thickness and poor structural integrity.
- Uneven application of pulp on the mesh screen may result in areas of the paper with different characteristics, such as thickness or opacity.
- Incomplete pressing of the paper during the water removal stage may result in excess water retention and affect the paper's final properties.
- Failure to thoroughly clean vegetable scraps may introduce contaminants into the paper pulp, affecting its appearance and properties.
- Inconsistencies in the thickness or texture of the paper pulp can lead to variations in the final paper product.

Extensions:

Experiment With and Combine Ingredients:

Explore the use of different types of vegetable scraps or even consider combining them to achieve unique textures and colors in your paper.

Add Natural Dyes:

Enhance the aesthetics of your paper by experimenting with natural dyes derived from fruits, vegetables, or plant extracts.

Incorporate Additives:

Experiment with additives like plant materials to add visual interest and texture to your handmade paper.

Explore Different Fibers:

Consider incorporating additional fibers into your paper-making process, such as recycled paper fibers or fibers from sustainable sources, to create a hybrid paper with unique characteristics.

Artistic Techniques:

Explore artistic techniques like layering or embedding materials within the paper for a more visually appealing and intricate final product.

Educational Initiatives:

Share your paper-making process with others through workshops, educational programs, or online tutorials to promote awareness of sustainable practices.

Continuous Learning:

Stay updated on new developments and techniques in sustainable paper-making. Attend workshops, read literature, and engage with communities interested in eco-friendly practices.

Networking:

Connect with individuals or groups interested in sustainable practices, recycling, and handmade crafts. Networking can open up new opportunities and perspectives.

Standardize Vegetable Scraps:

Issue: Variability in vegetable scraps may affect the consistency of the paper pulp.

Improvement: Standardize the types and proportions of vegetable scraps used to create a more consistent pulp mixture.

Blending Technique:

Issue: Inconsistent blending may result in uneven pulp texture.

Improvement: Pay careful attention to the blending process to ensure a homogeneous pulp mixture. Consider using a high-quality blender for better results.

Paper Forming Technique:

Issue: Uneven application of pulp on the mesh screen may lead to inconsistencies in the paper.

Improvement: Develop a more controlled and systematic technique for dipping the frame into the pulp mixture to achieve a uniform layer of pulp.

Drying Conditions:

Issue: Variations in drying conditions may affect the paper's final properties.

Improvement: Use a controlled drying environment with consistent temperature and humidity. Consider experimenting with different drying times to optimize paper quality.

Pressing Technique:

Issue: Inadequate pressing may result in uneven water removal.

Improvement: Develop a standardized pressing technique to ensure uniform water removal. Use a consistent pressure across the entire surface of the paper.

Consistency in Equipment:

Issue: Different equipment may lead to variations in the experimental setup.

Improvement: Use the same equipment, such as frames, screens, and blending tools, throughout the experiment for consistency.

Repeat Trials:

Issue: Conducting a single trial may not provide sufficient data for robust conclusions.

Improvement: Increase the number of trials to gather more data and calculate averages. This helps improve the reliability of your results.

Quantitative Measurements:

Issue: Some observations, such as opacity, may be subjective.

Improvement: Implement quantitative measurements wherever possible. For example, use tools to measure thickness and water absorption more precisely.

Documenting Environmental Conditions:

Issue: Not considering variations in environmental conditions during the experiment.

Improvement: Document and control environmental factors such as temperature and humidity, as they can impact the paper-making process.

Collaboration and Feedback:

Issue: Lack of external input may limit perspectives on potential improvements.

Improvement: Collaborate with others, seek feedback, and consider alternative approaches from individuals with experience in paper-making or related fields.

Jan.8 2024

- Jan 7: extensions, application, sources of errors, bibliography, safety considerations
- Jan 8: Buy groceries, ask Ms. Fourie for her expert's opinion, ask for green/brown trifold paper, organize all background research
- Jan 9: Decide on trifold's themes and fonts, start scripts

- Jan 10: Map out trifold
- Jan 11: Email any last experts & organize all experts opinions
- Jan 13: complete testing, initial observations
- Jan 14(?): more observations, test strength and durability, start analysis/conclusion
- Jan 15: finish analysis and conclusion, add to scripts, start organizing all data for trifolds

Google search: how much material does it take to make one price of paper

Typical office paper has 80 g/m^2 (0.26 oz/sq ft), therefore a typical A4 sheet (1⁄16 of a square meter) weighs 5 g (0.18 oz).

Using these measurements, we can estimate that we would need about 5g multiplied by 10, or 50 grams of vegetable waste. However, because the cellulose fibers in vegetables are less prominent than wood, it would be safer to create a thicker paper especially when considering the higher water content in produce waste. Because of this, at least tripling the amount of raw pulp should produce the optimal amount of stability as well as flexibility.

Google search: how much starch content is in paper

Typically printing and writing papers contain 4.1% starch, paper board 2% starch and domestic and industrial papers 1.9% starch. The growing use of recycled paper requires more and more starch quantities to avoid deterioration of the quality of fibers during recycling.

From this information, we can use 4.1% of our total material which would be 100g plus the amount of water (2000g) which gives us 86.1 grams of starch.

Important video-https://youtu.be/FOb34_s-K1M?si=sw7awCuP8HuFf6d_

Jan.9, 2024
-Organized all the information
-Looked and sorted all ideas, mapped out all thoughts

January 10, 2024
-Gathered all information from experts
The Paper Seller Company, Organic Paper Plus:

What are the key steps involved in the paper-making process at The Paper Seller?
The paper-making process at The Paper Seller involves several key steps:
Raw Material Preparation: Selection and preparation of raw materials such as wood pulp or recycled paper.
Pulping: Breaking down the raw materials into fibers.
Paper Formation: Formation of a paper sheet from the fibers.

Pressing: Removing excess water from the paper sheet.
Drying: Final drying of the paper sheet.
Finishing: Cutting, coating, or other finishing processes.

How has technology impacted the paper-making industry in recent years?
Technology has significantly impacted the paper-making industry, enhancing efficiency and sustainability. Automation has improved production processes, while innovations like digital printing have opened new avenues. Additionally, technology plays a key role in monitoring and optimizing resource usage, contributing to environmental sustainability.

What sustainability measures or eco-friendly practices does The Paper Seller implement in paper production?
The Paper Seller is committed to sustainability. We incorporate eco-friendly practices such as:
Efficient Resource Management: Optimizing water and energy usage.
Recycling: Maximizing the use of recycled materials.
Sustainable Sourcing: Responsible selection of raw materials from certified suppliers.
Emission Reduction: Implementing measures to minimize environmental impact.
What challenges do you foresee in the future for the paper-making industry?
The paper-making industry faces challenges related to environmental concerns, digitalization, and market dynamics. Striking a balance between meeting growing paper demand and ensuring sustainability remains a key challenge. Adapting to evolving consumer preferences and addressing global environmental issues will be critical for the industry's future.

Superstore, NoFrills, Co-op, Sobeys, Safeway:
(To follow hygiene protocol all big branded grocery stores follow the same protocol according to bylaws and federal laws to sustain their company)
How do you handle composting processes for organic waste, including vegetable scraps?
At grocery stores, we prioritize environmentally friendly waste management. Superstore gets garbage picked up x2 a day whale most stores have their garbage picked up x3 a day. Organic waste, including vegetable scraps, is collected separately in designated bins. We have established partnerships with local composting facilities to ensure that these materials are appropriately processed and recycled into valuable compost.

What steps are taken for produce that is not sold or cannot be sold, particularly in terms of waste reduction and sustainable practices?
To minimize waste and support sustainability, unsold or non-saleable produce undergoes careful evaluation. Edible items that meet safety standards are often donated to local food banks or community organizations. For items unsuitable for human consumption, we explore options such as composting or conversion to animal feed to maximize resource utilization.

Are there specific initiatives or policies in place to minimize food waste and promote environmental sustainability within the grocery store?
Yes, we are committed to minimizing food waste and promoting environmental sustainability. Our initiatives include:
Smart Inventory Management: Utilizing technology to optimize stock levels and reduce overstocking.
Discounts on Imperfect Produce: Offering discounted prices on slightly imperfect but still fresh and edible produce to minimize waste.
Recycling Programs: Encouraging recycling of packaging materials and incentivizing customers to bring reusable bags.

Saskatoon Farms and Spruce Meadows:

How do gardening centers manage compost for plants that are not sold or cannot be sold?
We prioritize responsible waste management. Plants that are not sold or cannot be sold undergo a careful evaluation process. Any plants that are still viable for growth are often donated to local community gardens, schools, or charitable organizations. For plants that are not suitable for transplantation, we implement composting practices to recycle organic materials into nutrient-rich compost.

Are there specific steps or practices in place for ensuring sustainable waste management in your plant production processes?
Our plant production processes adhere to sustainable waste management practices. We focus on:
Efficient Resource Use: Optimizing water and fertilizer application to minimize excess usage.
Recycling Green Waste: Implementing on-site composting for plant trimmings, leaves, and other green waste.
Eco-friendly Packaging: Utilizing sustainable and recyclable packaging materials wherever possible.

What are steps for approaching the reuse or recycling of plant materials to minimize environmental impact?
They are committed to minimizing our environmental footprint. We actively engage in:
Recycling Initiatives: Recycling plant materials through composting and partnering with local recycling facilities.
Mulching Programs: Encouraging customers to use plant materials as mulch to enrich soil and reduce the need for synthetic alternatives.

Are there any innovative practices or initiatives your company is currently undertaking in the realm of sustainability and waste reduction?

We are consistently exploring innovative practices to enhance sustainability. Currently, we are:
Implementing Water-Efficient Irrigation: Utilizing smart irrigation systems to optimize water usage in our plant production areas. Drip irrigation and planting trees under our fruits is something we often practice

Educational Programs: Conducting workshops and educational events to raise awareness among customers about sustainable gardening practices.

January 11, 2024

-Started to work on trifold, made a basic theme

January 13, 2024

-Did our experiment and made the paper today

January 14, 2024

-Made observations before and after drying, slowly analyzed

During the papermaking process:

-the harder vegetables, specifically the root vegetables were much harder to blend into a finer pulp

-it was quite difficult to get a perfect even sheet as the pulp was not evenly dispersed throughout the water

-after making a sheet, we noticed some splitting and cracking where the water was draining from the paper

During the drying process:

-some of the papers began to form cracks

-the felt started to curl up at the edges, causing the paper to become slightly warped

-the paper dried slightly inconsistently, some patches becoming drier faster than others

-most of them were scentless, however the potato had a strong distinct scent

- the root vegetables in particular developed a spongy texture

January 15, 2024

-Did initial testing, thickness, weight, marker, water

-Gathered and recorded results

January 16, 2024

-Made graphs and tables with results contacted experts about our results

January 17, 2024

-Made analysis and drew conclusions

Thickness Test Analysis:

Peas and potatoes exhibited thicker measurements than the control sample, with peas having the thickest measurements in some trials.

Radish, cauliflower, and cabbage showed varying thickness across trials, indicating inconsistency.

Carrot consistently had thinner measurements compared to the control sample.

Peas showed a tendency to have thicker measurements, ranging from 0.6 mm to 1.7 mm, with an average of 0.97.

Radish exhibited a moderate range of thickness, from 0.4 mm to 1.7 mm, with diverse measurements across trials.

Potatoes secured the third spot in thickness, with an average of 1.07 mm, and a range from 0.7 mm to 1.7 mm.
Cauliflower showed variations in thickness but demonstrated moderate consistency in some trials.
Cabbage had thickness values ranging from 0.4 mm to 1.5 mm, exhibiting variability across trials.
Carrot consistently showed thinner measurements, ranging from 0.3 mm to 0.8 mm.

Weight Test Analysis:

Peas consistently showed the highest water-holding capacity across all trials, with Trial 1 reaching 4000g.
Radish displayed a modest weight-holding capacity in the first trial (590g), doubling its capacity in subsequent trials.
Cauliflower exhibited substantial weight-holding capacity in the first trial (1700g), with variability in subsequent trials.
Potatoes consistently showed a moderate to high weight-holding capacity in Trials 1, 2, and 3 (590g, 980g, and 1090g).
Carrots exhibited variability in weight retention across trials, recording 190g, 490g, and 240g in Trials 1, 2, and 3.
Cabbage displayed significant variability in weight retention, ranging from 3200g to 2090g to 3800g across trials.

Marker Bleeding Test Analysis:

Peas exhibited bleeding through in the first trial but improved in subsequent trials.
Radish displayed variability in bleeding characteristics, with instances of bleed through in the first and third trials.
Cauliflower consistently did not bleed in all trials, indicating good performance for papermaking.
Potato showed a tendency to bleed through in the third trial, suggesting potential ink absorption issues.
Carrot exhibited bleeding through in the first trial but improved in subsequent trials.
Cabbage demonstrated variability, with bleeding through in the second trial but good performance in other trials.

Water Test Analysis:

All vegetables performed within a similar water-holding range (0.25-1.5g).
Peas had the highest average water holding capacity (1.25g), almost three times that of the control sample.
Cabbage consistently held 1g of water in all trials, showcasing consistent results.
Potatoes, similar to cabbage, absorb a notable quantity of water.
Radish had an average water holding capacity of 0.625g, outperforming the control sample.
Cauliflower and carrot, while showing water-holding abilities, performed slightly lower than other vegetables.

Overall Analysis:

Each vegetable exhibited unique characteristics, such as thickness, consistency, and durability.
Challenges with thicker materials, like peas and potatoes, may impact ease of manipulation and writing.
Consideration of thickness, water-holding capacity, and marker bleeding characteristics is crucial for specific applications.
Peas, cabbage, and radish demonstrated noteworthy characteristics, providing potential alternatives or enhancements.

Understanding these properties helps in making informed decisions when selecting vegetable materials for papermaking or related applications.

Conclusion

In summary, the paper created by the cabbage pulp performed the overall strongest in comparison to the other vegetables. Not only was it the strongest in the testing, but it produced a paper most similar to the a4 testing alongside as a control, both in texture and appearance. Although it did not perform the strongest overall, it still was very impressive, and considering all factors, it was the best. It also was the most appealing looking paper, as it was an appropriate thickness and remained much flatter than the other tests. The peas and radish also performed sufficiently, however in terms of aesthetics, they appeared less similar to the control than the cabbage. The cabbage and peas were quite white and flat, making it much easier to write on. The choice of vegetable scraps influences paper properties. Further experimentation and optimization may be required. The cauliflower was fairly weaker and thinner than the rest of the vegetables. We came to the conclusion that meaty and leafy vegetables often had higher cellulose content and worked much better for papermaking. Root vegetables are a component that adds thickness and water resistance to the paper, however, they are harder to break down and bind together to make a uniform sheet. However, mushy vegetables and vegetables with a lower water content would not work the best for this experiment.

January 18, 2024

-Identified outliers

-Started to format printouts for trifold

Trial 2 for Peas in the water test, with a weight of 1.5g, is considered an outlier because it deviates significantly from the trend observed in other water tests for Peas. The higher water-holding capacity in Trial 2 stands out compared to the other trials, making it an outlier.

Trial 8 for Peas in the thickness test, with a thickness value deviating from the general trend, is considered an outlier. This discrepancy may be attributed to measurement errors, variations in the pea samples, or other external factors influencing the thickness measurement in Trial 8.

Trial 3 for Radish in the thickness test is considered an outlier due to its thickness value significantly deviating from the typical trend observed in other trials. Factors such as irregularities in the radish sample or measurement errors may contribute to this outlier.

Trial 3 for Peas in the weight test, with a weight of 0.5g, is considered an outlier because it substantially differs from the average weight observed in other trials. This deviation could be attributed to variations in the pea sample or potential errors in the weight measurement during Trial 3.

Trial 1 for Cauliflower in the weight test is considered an outlier due to its weight value deviating significantly from the average weight observed in other trials. Possible factors contributing to this outlier include irregularities in the cauliflower sample or errors in the weight measurement during Trial 1.

January 19, 2024

-Did sources of error, application and extension

Sources of error

There are a couple sources of error that could have occurred during this project, which would affect the outcome of the experiment. Firstly, there may be some error if the measurement equipment is faulty, or if the kitchen scale was inaccurate. Also, due to our mould and deckle method, it was difficult to ensure that every sheet was the same thickness and opacity throughout all of the tests, which can affect its overall performance. Additionally, we noticed some textural inconsistencies throughout the sheets, some parts having more pulp/skin built up than others. This is especially evident when you compare the first test of each vegetable to the last, where the last is significantly thinner due to the pulp being sparse at that point in the experiment. We also noticed some discoloration throughout the samples. For example, the picture below shows a sheet from the radishes, and you can clearly see the patches of lighter color in contrast to the rest of the sheet. (insert picture later) Since we were working on a limited budget, we had only had access to a traditional food processor, which is evidently much weaker then the industrial mixers as you can tell on the pictures and our samples we have here for you. This meant we weren't able to get a completely homogeneous pulp on all of the vegetables, in particular the root vegetables, as they had a harder texture. Lastly, we were not able to press the papers down due to the sample size we had, and this caused the papers to curl upwards and become slightly bent. While this shouldn't affect the paper composition, it is possible that the warping caused inconsistencies in thickness and overall strength.

Application

If certain vegetable scraps prove to be suitable for papermaking, it could contribute to sustainable and eco-friendly paper production. This is especially important as the paper industry often relies on wood pulp, which involves deforestation. Utilizing vegetable scraps for paper production can help in reducing food waste. It provides an alternative use for vegetable scraps that might otherwise be discarded, contributing to a more circular economy. Understanding how different vegetables affect paper properties allows for customization. This could be beneficial in creating specialty papers with unique textures, colors, or other characteristics based on specific vegetable sources.Vegetable-based papers could be used in educational institutions or offices as a sustainable alternative to traditional paper. While there was no direct relationship between thickness and water quantity absorbed, often it was seen that thicker paper was able to absorb more water. Vegetables with a pulpy and watery consistency overall performed better. Root vegetables may have been slightly lower in comparison to others though they exhibited a significant pattern following them throughout being reliable each time.

Extension

- Include more trials

- Test more vegetables
- Explore the use of different types of vegetable scraps or even consider combining them to achieve unique textures and colors in your paper
- Add mixture of vegetables
- Experiment with fruits and others items in found in the green cart
- Conduct more types of tests
- Refine paper in proper industry tools and practices, as well investing in better equipment
- Further refine the papermaking process for each vegetable to achieve consistent results.
- Investigate alternative markers that do not bleed through the paper.
- Explore additional parameters, such as paper texture and durability, to comprehensively evaluate the quality of vegetable-based papers.

January 22, 2024

-Format all bibliography

-Took a look at all resources to check for accuracy and reliability

1. Hampberg, Ava Saffrium. "Is Paper Better than Plastic?" Edited by Ouelyia Nifemi, *BBC News*, BBC, 29 Oct. 2022, www.bbc.com/future/bespoke/made-on-earth/how-paper-is-making-a-comeback/.
2. Chatterjee, Siddharth. "Tree Wood Classification and Composition: Importance of Cellulose, Hemi-Cellulose and Lignin." Pulp & Paper, ABB Group, 8 Mar. 2013, new.abb.com/pulp-paper/abb-in-pulp-and-paper/articles/characteristics-of-wood-and-papermaking-fibers.
3. Sahin, Halil Turgut, and Mustafa Burak Arslan. "A Study on Physical and Chemical Properties of Cellulose Paper Immersed in Various Solvent Mixtures." International Journal of Molecular Sciences, U.S. National Library of Medicine, 1 Feb. 2008, www.ncbi.nlm.nih.gov/pmc/articles/PMC2635603/.
4. Xiao, Sai Yousef. "Fibre Sources." Encyclopædia Britannica, Encyclopædia Britannica, inc., 27 Apr. 2020, www.britannica.com/technology/papermaking/Fibre-sources.
5. Galioeno, James, and Mahyaka Ellia Huakoa. "Hemicellulose." Hemicellulose - an Overview | ScienceDirect Topics, 16 Feb. 2018, www.sciencedirect.com/topics/materials-science/hemicellulose.
6. Baker, N. (2016, July 1). Basics of Paper Manufacturing - Oklahoma State University. Basics of Paper Manufacturing | Oklahoma State University. https://extension.okstate.edu/fact-sheets/basics-of-paper-manufacturing.html#:~:text=Typical%20mechanized%20paper%20production%20involves,sheet%20in%20a%20Fourdrinier%20machin
7. Vougn, Janetly. "From the Woods: Paper!" Penn State Extension, Penn State Univeristy, 2018, extension.psu.edu/from-the-woods-paper
8. Aubrey, Allison. "From McDonald's to Organic Valley, You're Probably Eating Wood Pulp." *NPR*, 10 July 2014, www.npr.org/sections/thesalt/2014/07/10/329767647/from-mcdonalds-to-organic-valley-youre-prob

ably-eating-wood-pulp#:~:text=Cellulose%20is%20basically%20plant%20fiber,turning%20up%20in%20our%20food.

9. Author links open overlay panelDavid Paton 1, Kara, et al. "Cellulose from Apple Tissue: Isolation, Purification and Chemical Modification." *Canadian Institute of Food Science and Technology Journal*, Elsevier, 18 Apr. 2013, www.sciencedirect.com/science/article/abs/pii/S0315546374738494.
10. Author links open overlay panelDereca Watkins, Kalani Pham, and Diana Fanzhu AbstractLignocellulosic biomass has been acknowledged for potential use to produce chemicals and biomaterials. Lignin is the second most abundant natural polymer with cellulose being number one. "Extraction and Characterization of Lignin from Different Biomass Resources." *Journal of Materials Research and Technology*, Elsevier, 28 Nov. 2014, www.sciencedirect.com/science/article/pii/S2238785414000982#:~:text=Extraction%20of%20lignin%20from%20different,consequently%20retrieving%20by%20washing%20them.
11. Author links open overlay panelIzharul Haq a, N, et al. "Recent Advances in Removal of Lignin from Paper Industry Wastewater and Its Industrial Applications – A Review." *Bioresource Technology*, Elsevier, 5 June 2020, www.sciencedirect.com/science/article/abs/pii/S0960852420309081.
12. Author links open overlay panelS. Lacorte, Kie Yun, et al. "Organic Compounds in Paper-Mill Process Waters and Effluents." *TrAC Trends in Analytical Chemistry*, Elsevier, 2 Dec. 2003, www.sciencedirect.com/science/article/abs/pii/S0165993603010094.
13. Author links open overlay panelZhijun Shi a b, et al. "Utilization of Bacterial Cellulose in Food." *Food Hydrocolloids*, Elsevier, 25 July 2013, www.sciencedirect.com/science/article/abs/pii/S0268005X13002142.
14. Black, Collins, and Georgie Hart. "Pulp and Paper Production from Oil Palm Empty Fruit Bunches: A ... - MYJAFE." *MYJAFE*, Jafe, 31 Apr. 2023, myjafe.com/wp-content/uploads/2020/07/MYJAFE2020-0017.pdf.
15. Chen, Aaron. "Preparation of Leafy Vegetable Paper - Zheng - 2010 - Wiley Online Library." *Wiley Library* , 18 Oct. 2023, ifst.onlinelibrary.wiley.com/doi/10.1111/j.1745-4549.2009.00367.x.
16. City of Calgary, director. *Calgary Recycling: How Recyclables Are Sorted*. Youtube, 2013, www.youtube.com/watch?v=Zhv-Dv9h3J4&t=3s.
17. City Of Calgary, director. *How Compost Is Made: Calgary's Green Cart Program*. *YouTube*, YouTube, 20 Mar. 2019, www.youtube.com/watch?v=NGopFxRsQWg&t=1s.
18. Dr. Binocs Show, director. *Invention Of PAPER | The Dr. Binocs Show | Best Learning Video for Kids | Fun Preschool Learning*. Dr. Binocs Show, 2017, www.youtube.com/watch?v=COxB_GvdzWI.
19. Gadgets, Cheddar, director. *How Wood Turns Into Paper*. Cheddar Gadgets, 2019, www.youtube.com/watch?v=GuMsRWqPc2k.
20. Gordenstein, Ava. "Effect of Protein–Starch Interactions on ... - Wiley Online Library." *Wiley Library* , 2013, ift.onlinelibrary.wiley.com/doi/abs/10.1111/1541-4337.13141.
21. Grant, Gander G. "Our Sustainable Kraft Pulp Production Process: Paper Excellence." *Paper Excellence Group*, 17 Jan. 2024, paperexcellence.com/pulp/how-we-make-pulp/.

22. Holwegner, Andrea. “Top 7 Healthy Vegetables on a Budget.” *Health Stand Nutrition - Online Nutritionist Calgary Dietitian Team*, City of Calgary, 17 Nov. 2022, www.healthstandnutrition.com/healthy-vegetables-on-a-budget/.
23. Jaques, Coliques. “How to Make Your Own Paper | Artsy.” *Artsy*, 2019, www.artsy.net/article/artsy-editorial-crash-course-basic-papermaking.
24. Kaur, Sabeen. “Paper & Board.” *Starch Europe*, 19 Oct. 2020, starch.eu/ingredient/paper-board/#:~:text=Typically%20printing%20and%20writing%20papers,quality%20of%20fibres%20during%20recycling.
25. NevermindPaper, director. *How to Make Recycled Paper (+ Mould & Deckle Diy) | Tutorial*. *YouTube*, YouTube, 2 Apr. 2021, www.youtube.com/watch?v=5xrWrKIVBgo.
26. Obeluovi, Mastaru. “Properties of Wood.” *Properties of Wood (for Papermaking)*, Paper Co., 1 Jan. 2024, www.paperonweb.com/wood.htm.
27. Paradis, Gaia. “Edible Paper.” *PEER2PICKLE*, 2 Sept. 2017, peer2pickle.weebly.com/edible-paper.html.
28. Rachael, Simone. “Top 9 Cheapest and Healthiest Green Veggies.” *DFD Russell Medical Centers*, 16 Feb. 2023, dfdrussell.org/cheapest-and-healthiest-veggies/.
29. Samani, Niti. “Paper Manufacturing: Critical Issues and Challenges.” *Deskera Blog*, 15 Mar. 2023, www.deskera.com/blog/paper-manufacturing-critical-issues-and-challenges/#:~:text=The%20production%20of%20wood%20pulp,biodiversity%2C%20and%20other%20environmental%20problems.
30. Science, Mystery, director. *How Do They Turn Wood into Paper?* Mystery Science, 2017, www.youtube.com/watch?v=0VEJCWvfhQg.
31. Shazhou, Darren. “Papermaking.” *Papermaking - an Overview | ScienceDirect Topics*, Oct. 2022, www.sciencedirect.com/topics/agricultural-and-biological-sciences/papermaking#:~:text=Starch%20is%20used%20as%20a,maize%2C%20wheat%2C%20and%20tapioca.
32. State , Penn. “From the Woods: Paper!” *Penn State Extension*, Penn State, Mar. 2015, extension.psu.edu/from-the-woods-paper.
33. Teagan, Reign. “Read ‘Diet and Health: Implications for Reducing Chronic Disease Risk’ at Nap.Edu.” *10 Dietary Fiber | Diet and Health: Implications for Reducing Chronic Disease Risk | The National Academies Press*, 2019, nap.nationalacademies.org/read/1222/chapter/13#293.
34. Team, BioPak. “Compostable vs Recyclable: Which Is Better for the Environment?” *Compostable vs Recyclable | BioPak Australia*, BioPak, 17 Jan. 2024, www.biopak.com/au/resources/recycling-vs-composting#:~:text=Composting%20is%20for%20organic%20matter,to%20produce%20nutrient%2Drich%20compost.
35. Team, Deskera Content. “Ensuring Quality Control in Paper Production.” *Deskera Blog*, 25 Mar. 2023, www.deskera.com/blog/quality-control-in-paper-production/#:~:text=Tensile%20strength%2C%20tear%20strength%2C%20and,a%20given%20amount%20of%20time.
36. Thestu, Matteo. “Why Is Printing Important for Business?” *Cherrill Print*, 8 Apr. 2021, cherrillprint.co.uk/why-is-printing-important-for-business/#:~:text=Printing%20can%20easily%20adapt%20to,that%20you%20might%20be%20based.

37. Tube, Sappi, director. *The Paper Making Process*. *YouTube*, YouTube, 2 Mar. 2012, www.youtube.com/watch?v=E4C3X26dxbM.
38. Xaila, Grande. "Properties of Wood." *Properties of Wood (for Papermaking)*, Paper Co., www.paperonweb.com/wood.htm.
39. Yousef, Anizla. "Pulp and Paper." *WWF*, World Wildlife Fund, www.worldwildlife.org/industries/pulp-and-paper#:~:text=Deforestation%20and%20Forest%20Degradation&text=Irresponsible%20harvesting%20from%20natural%20forests,species%20and%20cause%20soil%20erosion

January 23, 2024
-Converted all jot into paragraphs
January 24, 2024
-Started script
-Finished all formatting for trifold
January 25, 2024
-Continued working on script and trifold
January 26, 2024
-Took out all printouts for trifold
January 27, 2024
-Glued most things to trifold
January 28, 2024
-Finished trifold and script
February 28, 2024
-Went thru and disected all judges feedback and consulted with our mentors and teachers
February 29, 2024
-Did some research
Google Search: Why doesn't paper rot
Paper doesn't degrade quickly because there is a very small amount of nitrogen. Bacteria and fungi need nitrogen to build their bodies and if there is none they do not grow.
Wood Composition and Decay Resistance:

Wood, primarily composed of glucose polymers like cellulose and lignin, forms a unique resistance to biodegradation.
Polymers in wood, with their long molecular chains, provide structural rigidity and mechanical strength to tree stems and branches.
Microbial Decomposition and Water Content:

Biodegradation occurs when microbes break down organic substances.

Processed wood has lower water content compared to fruits and vegetables, making it less susceptible to microbial degradation.
Cellulose and lignin in wood create a dense physical barrier that inhibits microbial penetration.
Factors Affecting Decay:

Wet soil can contribute to the degradation of wood.
Lowering the water activity in fruits and vegetables increases their resistance to microbial decomposition.
Decay Processes Beyond Microbial Action:

Oxidation, another decay process, contributes to the aging of organic matter.
Acid-free paper, lacking lignin, resists oxidation more effectively than lower-grade paper.
Longevity of Wood and Products:

Wood's high cellulose density makes it challenging for microbiology to decompose quickly.
This resistance contributes to the longevity of trees and products made from wood, such as books and furniture.
Material Considerations for Longevity:

Acid-free paper, treated to remove lignin, is less prone to oxidation and offers increased longevity.
Environmental Impact:

Understanding wood decay processes is essential for managing environmental impact and the lifecycle of organic materials.
Overall, the dense structure of cellulose and lignin, combined with low water content, makes wood highly resistant to decomposition, leading to the durability of wooden structures and products.
Source: https://engineering.mit.edu/engage/ask-an-engineer/what-makes-wood-rot-so-slowly/
March.2, 2024
Search: Why is there minimal air in paper products?
Overview:

Industrial gasses (Oxygen, Nitrogen, CO_2) are crucial for various stages in pulp and paper production.
Air Products provides expertise, equipment, and gasses for optimal efficiency.
Benefits of Industrial Gases:

Reduced operating costs and emissions.
Minimized chemical consumption.
Odor control, increased productivity, and fuel savings.
Gas Applications:

Oxygen Delignification: Proven technology for lignin removal, reducing operating costs and emissions.

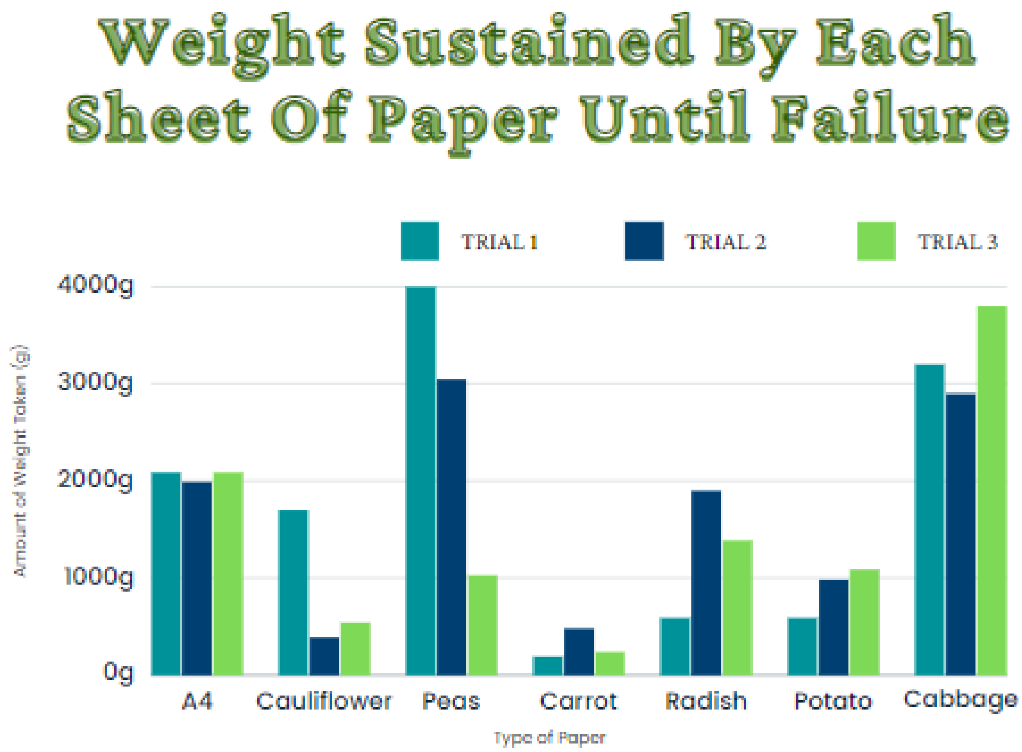
Oxidative Alkaline Extraction: Oxygen addition enhances brightness, saves bleaching chemicals.
Ozone Production: Efficient delignification, reduced chemical consumption, and effluent load.
White Liquor Oxidation (WLO): Economical alkali source, reduces caustic purchases.
Black Liquor Oxidation (BLO): Reduces sulfur losses, alleviates recovery boiler bottlenecks.
Lime Kiln Enrichment: Increases production, fuel savings, reduces emissions, improves kiln stability.
Inerting and Blanketing:

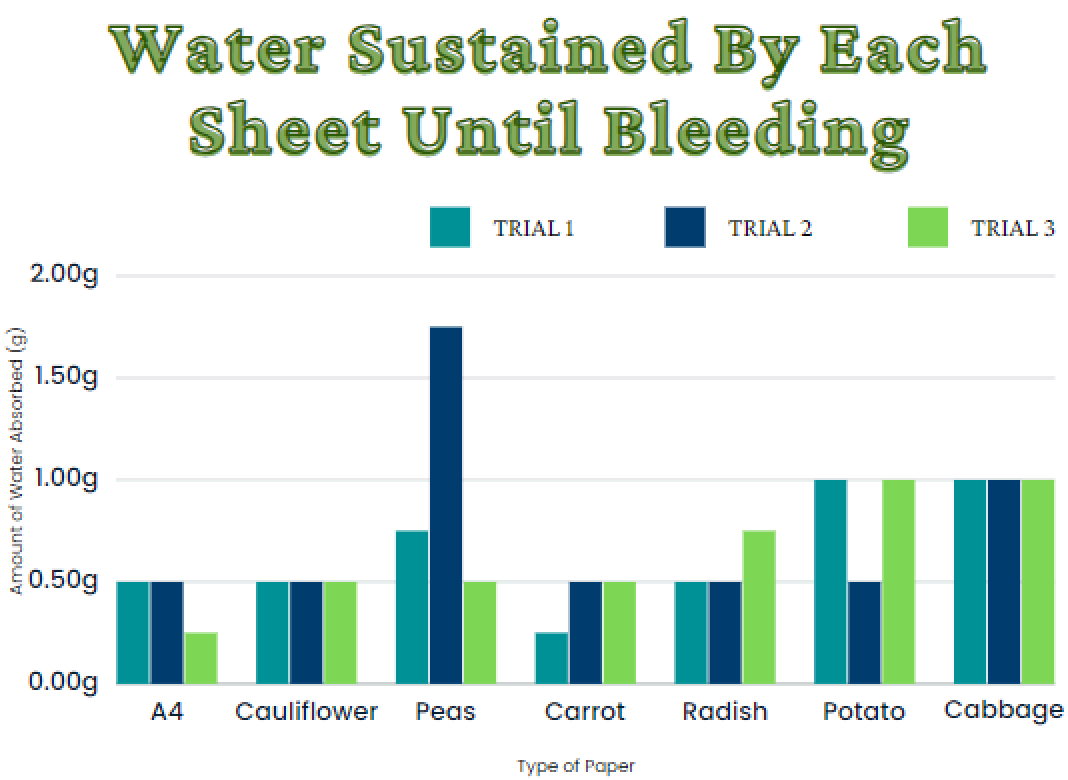
Nitrogen used for inerting and blanketing in tanks, piping, silos, and chlorine rail cars.
Pulp Washing, pH Maintenance, and Wastewater Treatment:

CO_2 for pulp washing, corrosion reduction in paper machines, and pH control.
Oxygen for odor control and improved wastewater treatment.
Gasses Offered by Air Products:

Carbon Dioxide: Applications for environmental performance, product quality, and productivity.
Nitrogen: Inert properties, cooling, and freezing applications across various industries.
Oxygen: Respiratory gas for healthcare and oxidizing properties for improved yields and performance.
Source:
https://www.airproducts.com/industries/pulp-and-paper#:~:text=The%20introduction%20of%20oxygen%20to,bleaching%20chemicals%2C%20reducing%20environmental%20impact.

March 4, 2024
-Fixed all graphs and tables with recommended information
Graphs


Weight Sustained By Each Sheet Of Paper Until Failure
TRIAL 1
TRIAL 2
TRIAL 3
4000g
3000g
2000g
1000g
0g
Amount of Weight Taken (g)
A4
Cauliflower
Peas
Carrot
Radish
Potato
Cabbage
Type of Paper


Water Sustained By Each Sheet Until Bleeding
TRIAL 1
TRIAL 2
TRIAL 3
2.00g
1.50g
1.00g
0.50g
0.00g
Amount of Water Absorbed (g)
A4
Cauliflower
Peas
Carrot
Radish
Potato
Cabbage
Type of Paper

<u>Tables</u>

Marker Tests

Trial	Peas	Radish	Cauliflower	Potato	Carrot	Cabbage	A4
1	Bleed through	Bleed through	Did not bleed	Did not bleed	Did bleed through	Did not bleed	Bleed through
2	Did not bleed	Did not bleed	Did not bleed	Did not bleed	Did not bleed	Did bleed	Bleed through
3	Did not bleed	Bleed through	Did not bleed	Bleed through	Did not bleed	Did not bleed	Bleed through

Thickness Tests

Trial	Peas	Radish	Cauliflower	Potato	Carrot	Cabbage	A4
1	0.6 mm	2.0 mm	0.7 mm	1.7 mm	1.3 mm	0.5 mm	0.2 mm
2	0.9 mm	1.5 mm	0.8 mm	0.8 mm	0.7 mm	0.5 mm	0.2 mm
3	1.1 mm	0.4 mm	0.6 mm	0.9 mm	0.6 mm	1.5 mm	0.2 mm
4	0.8 mm	1.7 mm	0.8 mm	0.9 mm	0.6 mm	0.5 mm	0.2 mm
5	0.9 mm	0.7 mm	1.0 mm	0.9 mm	0.7 mm	0.7 mm	0.2 mm
6	0.6 mm	0.6 mm	1.1 mm	0.7 mm	0.3 mm	0.4 mm	0.2 mm
7	1.4 mm	1.5 mm	0.9 mm	0.9 mm	0.4 mm	0.6 mm	0.2 mm
8	1.7 mm	1.3 mm	N/A	1.3 mm	0.5 mm	0.9 mm	0.2 mm
9	0.7 mm	1.5 mm	N/A	1.0 mm	0.8 mm	0.8 mm	0.2 mm
10	1.0 mm	0.9 mm	N/A	1.6 mm	0.8 mm	0.5 mm	0.2 mm

Average Result for Each Paper

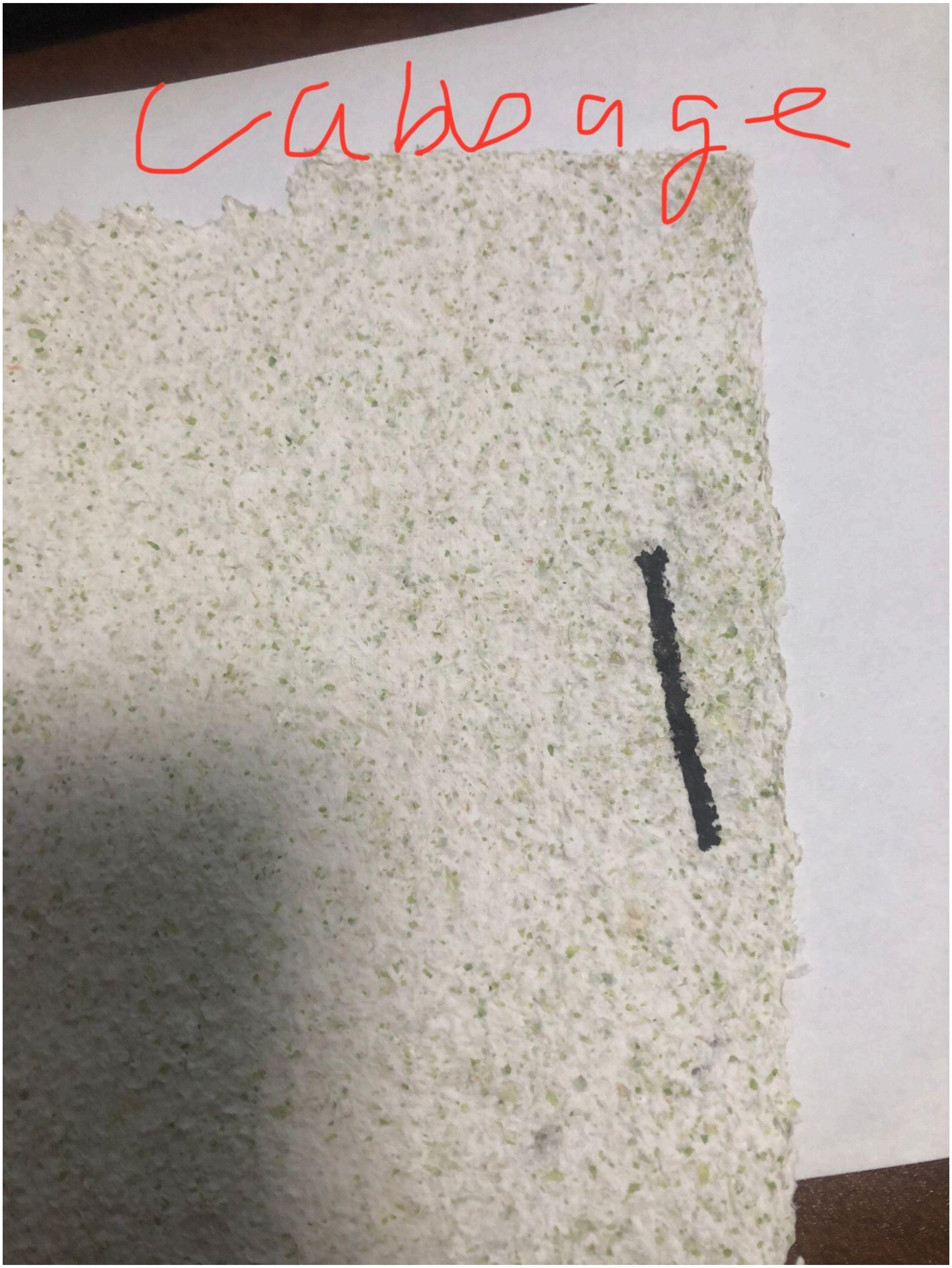
Tests	Radish	Cauliflower	Peas	Potato	Cabbage	Carrot	A4
Thickness	Avg:1.21 Range:0.6-1.7mm	Avg:0.84mm Range:0.6-1.1mm	Avg:0.97 mm Range:0.6 -1.7mm	Avg:1.07 mm Range:0.7-1.7mm	Avg:0.74 mm Range:0.4 -1.5mm	Avg:0.67mm Range:0.3-1.3mm	Avg+ Range: 0.2mm
Weight	Avg: 1693.33g Range: 1030g-3050g	Avg: 2426.33g Range: 1390g-4000g	Avg: 1693.33g Range: 1030g-3050g	Avg: 523.67g Range: 390g-590g	Avg: 440g Range: 240g-590g	Avg: 1223.33g Range: 980g-1700g	Avg: 2056.6g Range:1990-2090g
Water	Avg: 0.625g Range: 0.5g - 0.75g	Avg: 0.875g Range: 0.5g - 1g	Avg: 1.25g Range: 1g - 1.5g	Avg: 0.5g Range: 0.5g - 0.5g	Avg: 0.5g Range: 0.25g - 0.75g	Avg: 0.75g Range: 0.5g - 1g	Avg: 0.41g Range- 0.25g-0.5g

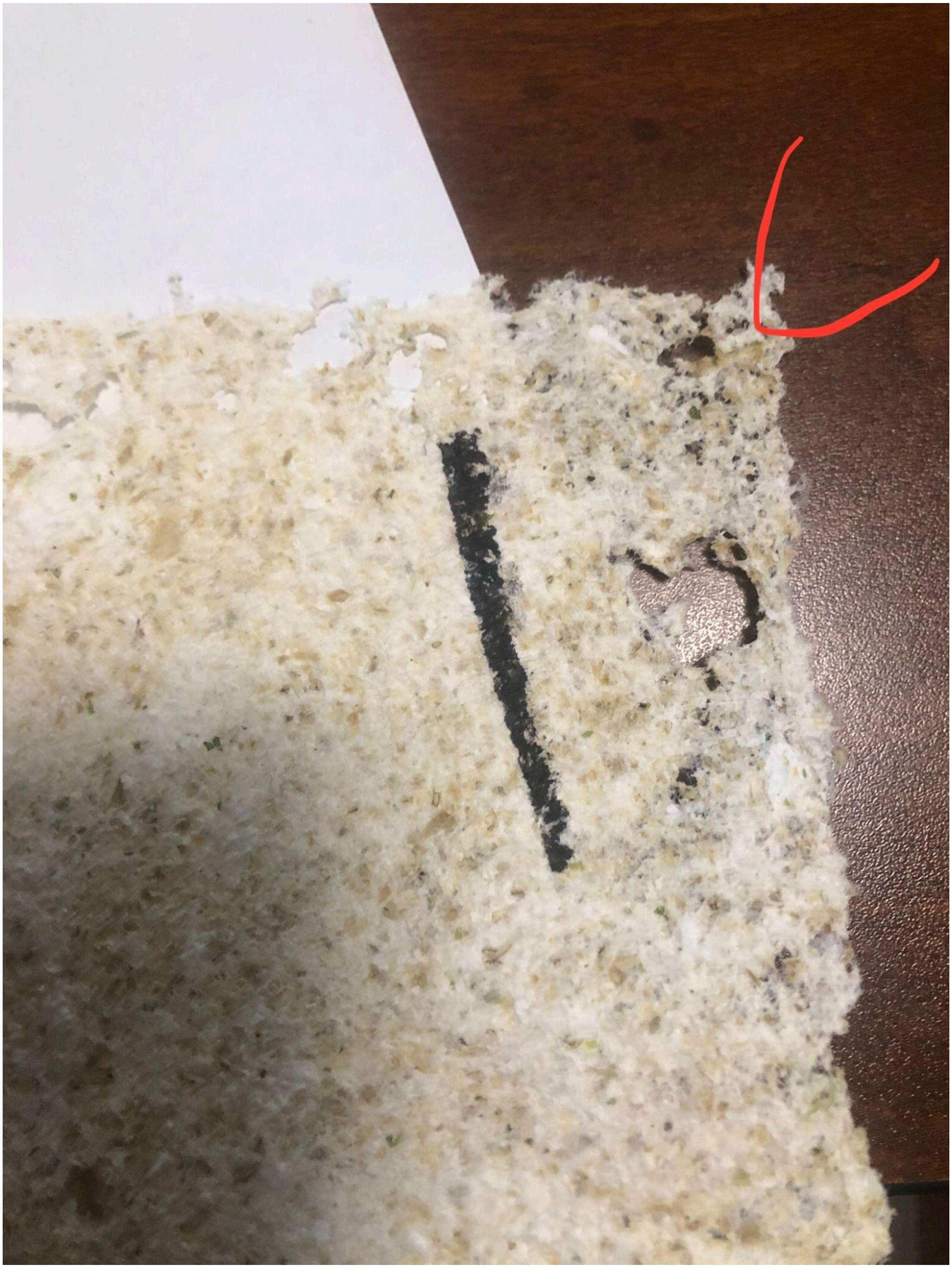
March 5, 2024

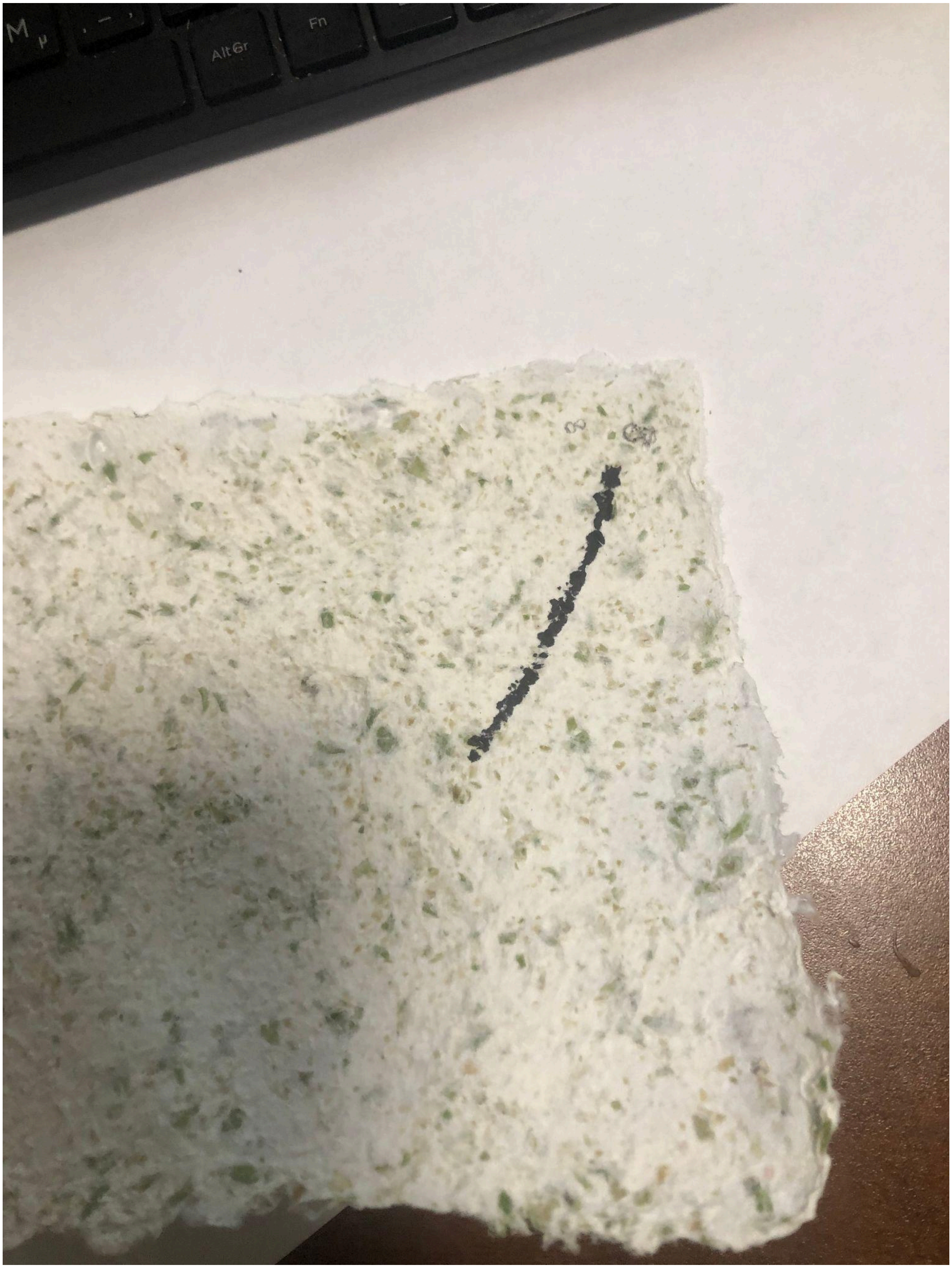
-Edited script

-Uploaded all images

Images

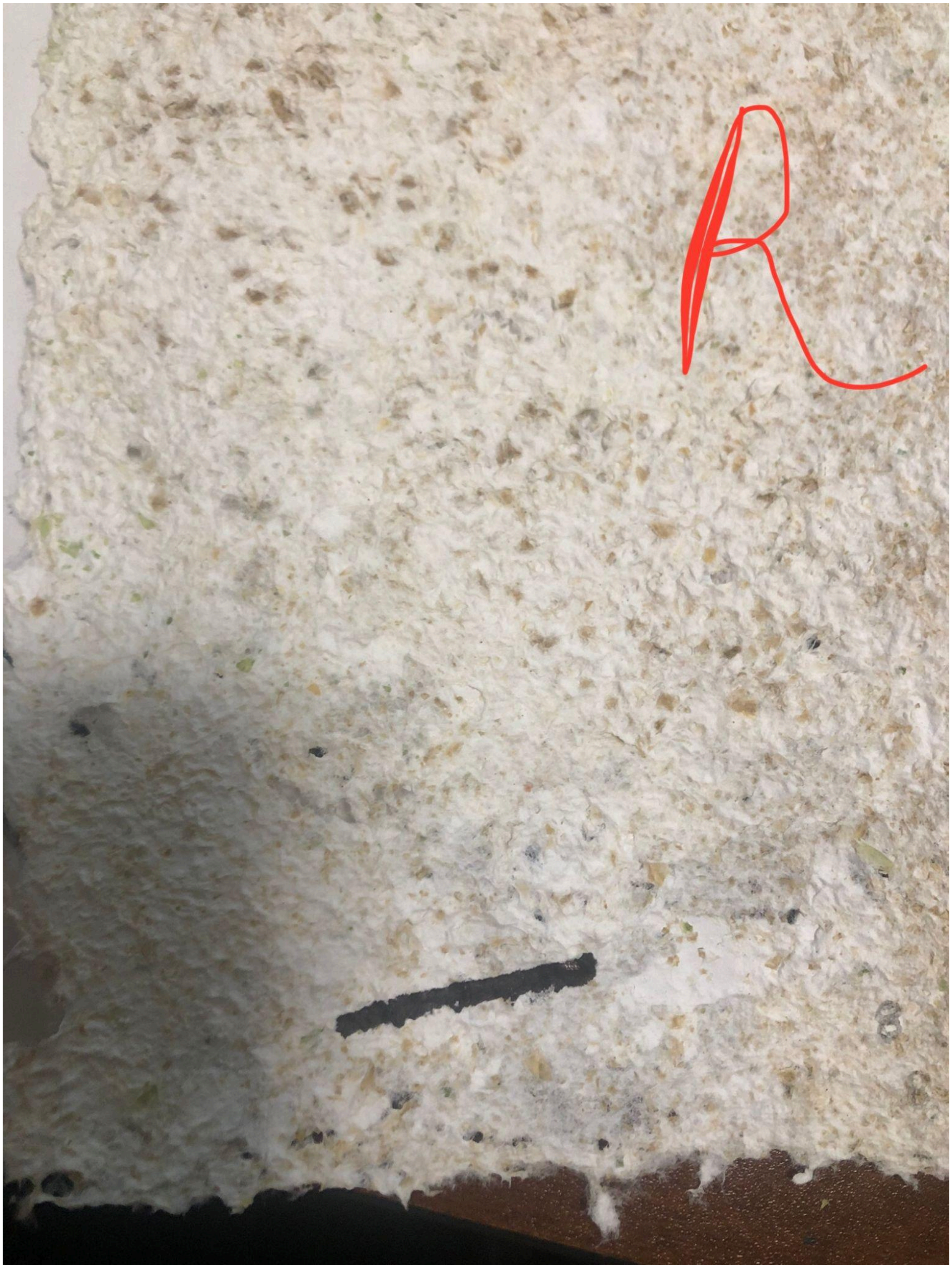

Cabbage






MINNIE
3 YARDS VERGES
CHEESECLOTH
ÉTAMINE
ELMER'S
School Glue
Colle d'école
Cola escolar
Great Value
FELT BOLT
LONGUEUR DE FEUTRE
ROLLO DE FIELTRO
FELT BOLT
LONGUEUR DE FEUTRE
ROLLO DE FIELTRO

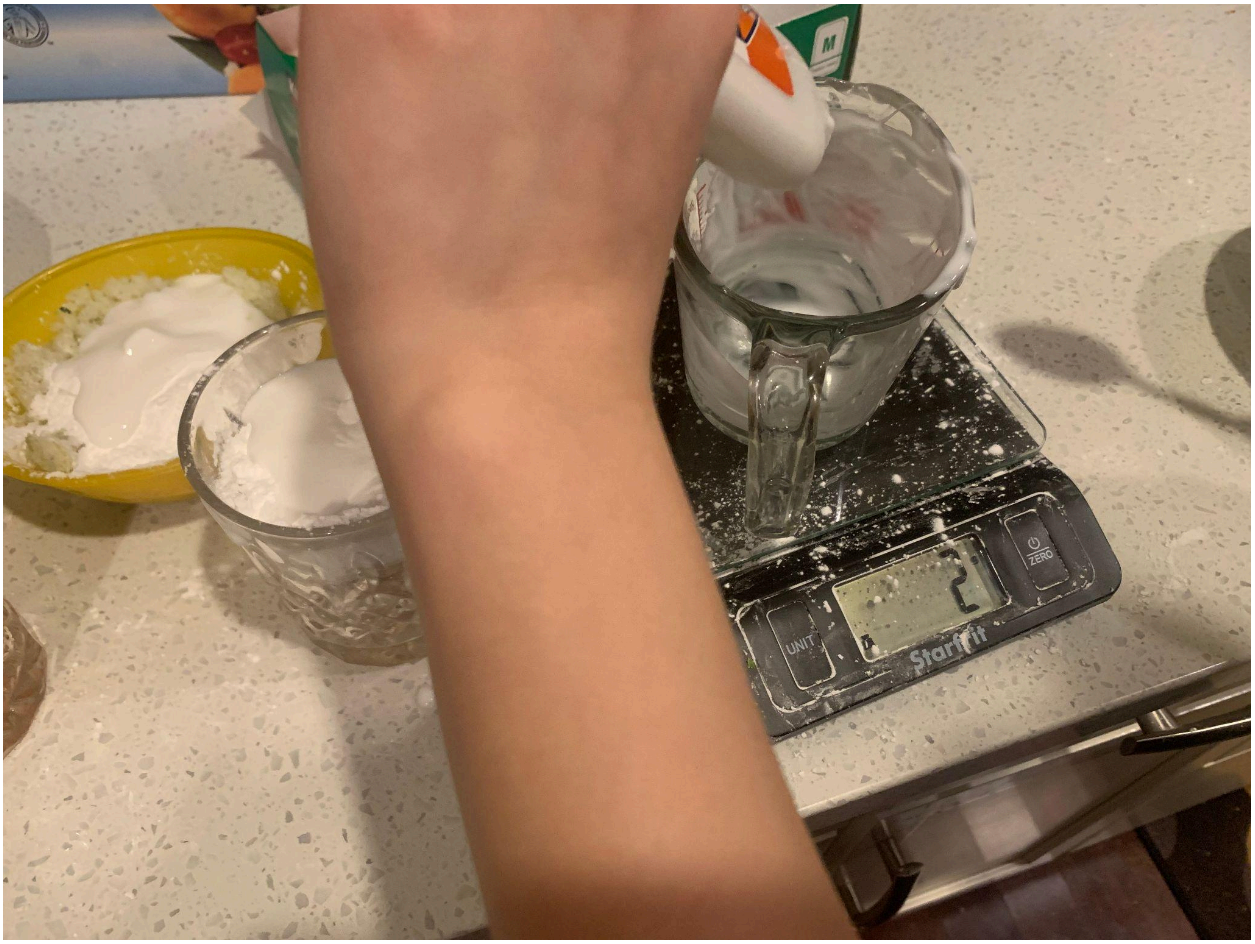

mm/inch
OFF
ON
ZERO
mm


R


mm/inch
OFF
ON
ZERO
mm

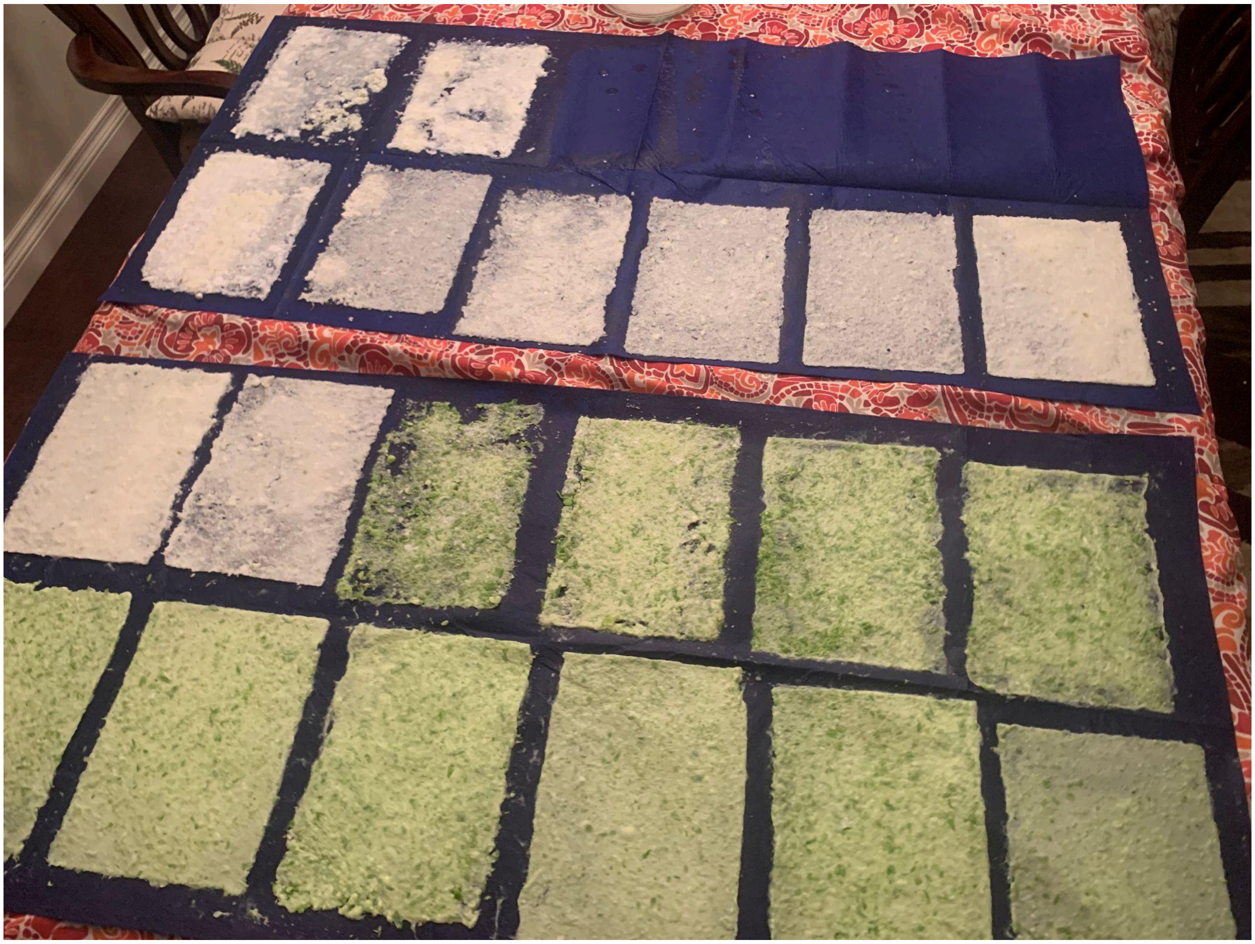

3 YARDS
VERGES
CHEESECLOTH
ÉTAMINE
FELT BOLT
LONGUEUR DE FEUTRE
ROLLO DE FIELTRO
FELT BOLT
LONGUEUR DE FEUTRE
ROLLO DE FIELTRO
Cuisinart

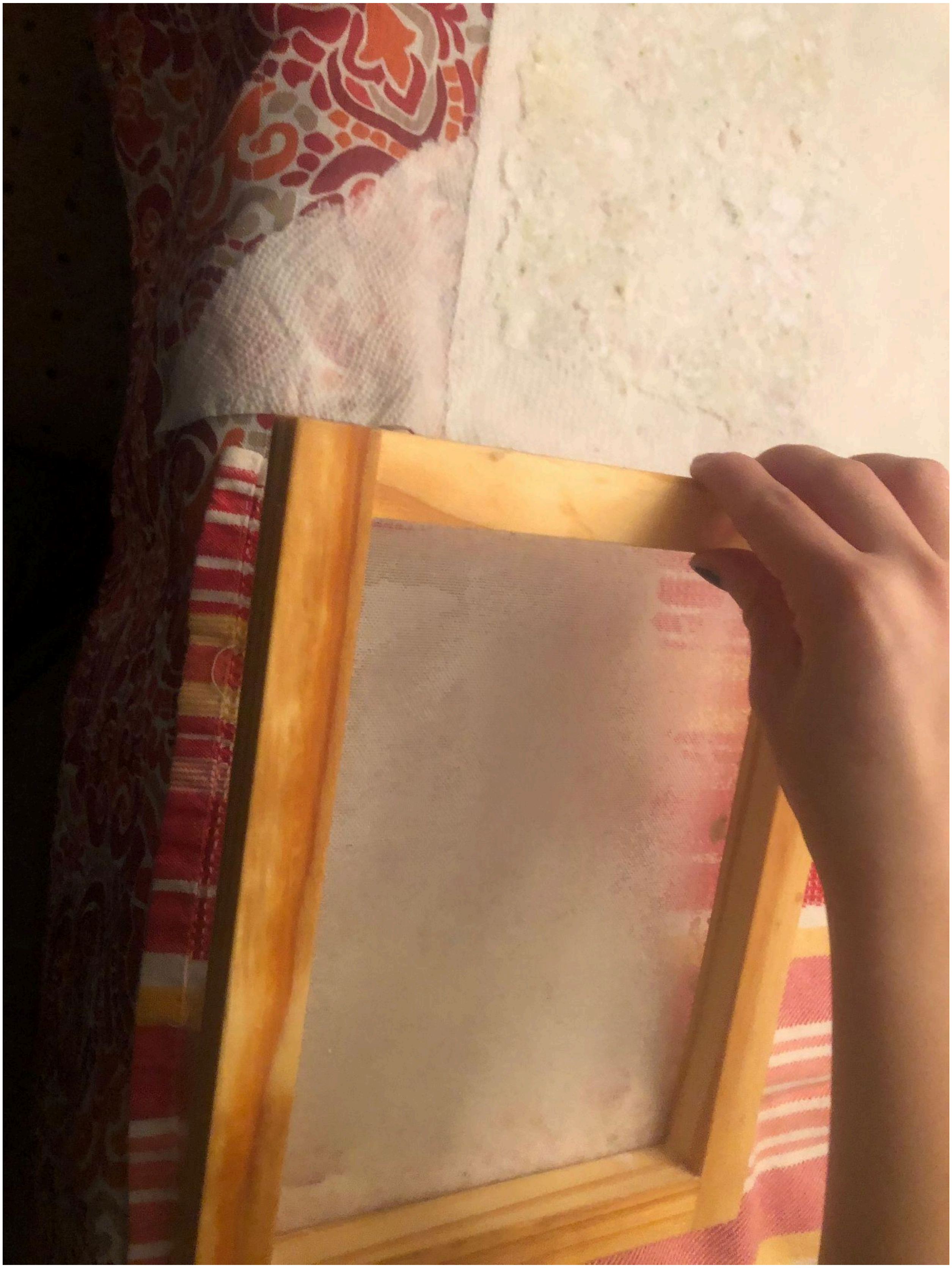

2
UNIT
ZERO
Starfrit


UNIT
ZERO
Starfrit


FUNNY
HERO


32oz
28
24
20
16
12
8





Final Version of Script

Purple=Klaire Plain=Annika

Paper is fundamental to communication in society. Before technology, letters were the most crucial way of communication, and even in modern day, paper products serve as valuable and proven learning tools, permanent records for life's milestones, and secure forms of documentation. It's all around us, even in the production of this project. However, paper is becoming an environmental crisis more than a life changing invention. Paper creation and exportation is becoming a very expensive business, the reality is, we are starting to face major challenges when it comes to finding sustainable ways to produce paper.In contrast, food waste is also a constant problem we must battle as a society every single day, with vegetable waste in particular being a large contributing factor. It's estimated that approximately 20% of produce or more gets thrown out for purely cosmetic reasons like weird shapes, odd colors, or blemishes on a peel you don't even eat. That's 1 in 5 vegetables getting tossed into landfill even though they're just as nutritious and delicious to eat. Although composting is becoming a lot more mainstream, it can attract unwanted pests and wildlife, which can create public health risks and damage property. Additionally, compost can be a breeding ground for dangerous pathogens, and even contaminate our groundwater sources. Improperly managed compost piles can also emit strong odors, which can create problems for nearby residents and businesses. This is where we came up with an innovative science fair project idea that can potentially solve both of these problems with one solution. Good afternoon ladies and gentlemen, my name is Klaire, and this is my partner Annika. Today we are presenting our project, which is creating an alternative to wood pulp paper using vegetable waste. The main question our project surrounds is, what vegetable pulp creates a paper most similar and functional compared to a4 paper, also more commonly referred to as printer paper. For this project, we decided on using 6 different vegetables; cultivated peas, daikon radish, danvers carrots, yukon gold potatoes, white cauliflower, and napa cabbage. After doing some research, we decided on these 6 options primarily because of the high cellulose content, as well as some other factors such as cost and accessibility, which we will further discuss later during this presentation. Our hypothesis for this project is that if we extract the pulp from six different vegetables and produce it into paper, then the peas will provide the most durable and functional paper because they have the highest cellulose concentration and the fiber content is the most comparable to wood pulp. Prior to testing, we formulated 5 project questions to answer to learn more about our topic. Understanding paper's properties and cellulose content is crucial before researching vegetables, which brings us to our first question, "why is paper made from wood." . Wood is abundant, versatile, and cost-effective for large-scale manufacturing, making it a primary source for paper production due to its high fiber content. Selecting wood for paper making involves choosing between hardwood and softwood fibers. Softwood fibers are sturdy, ideal for cardboard boxes, while hardwood fibers provide smooth printing surfaces and high opacity. Manufacturers typically combine these to meet consumer demands.Paper manufacturing involves grinding wood fibers, pressing, drying, and smoothing. Environmental issues like water usage and energy consumption are growing due to global warming. The industry consumes over 100 billion trees annually, causing biodiversity loss and ecosystem destruction. Softer materials and food waste paper could reduce energy consumption and combat deforestation. Professor S. Lacorte in the Department of Environmental Chemistry, at the University of Barcelona believes, “Excessive food waste should be dealt with properly, while food waste compost is a fantastic idea, but alternatives should always be an option, and environmental friendly practices are most in need of, now more than ever. Food waste releases greenhouse gasses that worsen climate change and wastes the resources needed to cultivate, produce, and deliver the food to customers. Reducing food waste and deforestation is a two in one solution contributing to a better life for not only us, but also everything that surrounds us.” The research suggests that collaborating with local grocery stores could help create a waste collection system, as most scraps go to waste. The paper, made from wood, consists of cellulose, hemicellulose, and lignin. Hemicellulose promotes fiber-to-fiber bonding and water absorption, while lignin acts as an adhesive. However, chemical pulping processes can remove lignin, causing a brown tint and hindering bond formation. This research will help create a practical and functional paper.

Papermaking involves the use of starches and polyvinyl alcohol (PVA) as binding agents. Starches aid in flocculation and bonding, while PVA is a water-soluble polymer with high film forming ability. Two methods are used for pulp preparation in wood pulp homemade paper production: blending the material, pressing it with a microfiber cloth, or boiling the pulp with water and baking soda. For this project, we decided to use the first method since we focused on testing the raw pulp, as well as eliminating more sources of error that could be possibilities. This is also so we can try to avoid textural difficulties that we may face with cooked vegetables, helping aid in our controlled variables.

Moving on to variables, our manipulated variable for this experiment is the type of vegetable scraps that we used for each paper, while our controlled variables include time of experiment, location, condition of food scraps, processing method, mixing, pressing, and drying, time between each step, time to dry, conditions to dry in, temperature, time of day, etc. Lastly, our responding variable would be the paper made by each vegetable and its performance, such as tensile strength, thickness, absorbency, and durability.

For this project, we will utilize various materials, including a knife, table, and chopping board for vegetable preparation. Additionally, we'll use 200g of pulp from each vegetable, 42 grams of unprocessed corn starch, a mould and deckle, 25 ml of Elmer’s glue, felt, and a sponge. To fully test the durability of our papers we used, measuring flasks, weights, a micrometer, a dropper, a black sharpie marker, cheese cloth, a blender, a vat, a computer, and personal safety equipment, which are gloves and safety glasses. This project involves gathering materials, washing vegetables, blending them, adding starch and pva, and dumping the processed pulp in a tub with 2 liters of water. Paper sheets are produced by pressing the vegetables into a mould and scooping them up. After drying, the paper is pressed, pressed, and dried for 1-2 days. Observations are made on texture, color, and opacity. Using a micrometer, we measure the thickness of each paper type. Strength testing involves three trials per vegetable, with weights added until failure, and additional observations are noted. Marker testing is conducted by drawing a 5 cm line in 5 seconds, tracing it back, and minimizing outliers. Water absorption tests are performed by dropping water on the paper until it bleeds through, with three tests for each. Results are recorded and analyzed, and the data is presented in graphs and tables for comparison with A4 paper. The procedures are detailed in our trifold, ensuring a controlled environment for accurate and reliable outcomes

.During the papermaking process, it was observed that root vegetables were harder to blend into a finer pulp and achieving a perfect flat sheet was challenging. After making the sheet, minor splits and cracks were observed where the drainage occurred. During the drying process, some papers formed small cracks on the edges, and felt curls up at the edges, causing slight warping. Some papers also dried unevenly, with some patches drying faster than others.The study found that most vegetables had no scent, but the potato had a strong odor during drying. The carrot and potato samples took the longest to dry, taking almost three days. To maximize performance, the researchers decided to wait until all samples were fully dry. Despite dehydration, the potato and carrot samples still had a slightly spongy texture.

The thickness testing was conducted on all samples to gain more accurate results, we compared this the control sample, which is 0.1 mm in thickness. When analyzing our information, we focused on mostly averages and outliers, which if you would like to know more about, you can refer to our trifold which contains all the specific information. The thickness of peas varied throughout the trials, ranging from 0.6 mm to 1.7 mm. With an average of 0.97, our measurement of 1.7mm from the peas sample was a significant outlier and it raised the average significantly. Radish was the second thickest, ranging from 0.4 mm to 1.7 mm, with an average of 1.21. These samples also a fairly large range of data, showing that perhaps there were some inconsistencies between trials. Following radish, the potato samples were the third thickest paper, with an average thickness of 1.07mm, and a range from 0.7 mm to 1.7 mm. All of its trials greatly surpassed the control, indicating its potential for providing a thicker material that may not necessarily work for a4 paper which is what this project is considering, but it could be utilized in a thicker cardboard or specialty paper. Cauliflower had thickness ranging from 0.6 mm to 1.1 mm. Its average was 0.84, which performed quite average compared to the other tests. The cabbage had quite a large range, from 0.4 mm to 1.5 mm, with its average being 0.74. However, most of the papers were quite even, the majority of the trials being 0.5 mm in thickness, despite the significant outlier of the 1.5mm sample. Last but not least, the carrots. Carrot had thickness values ranging from 0.3 mm to 0.8 mm, which was the most similar to the control. However, despite this, the carrot sample did have quite a few holes and tears in it, so while being the thinnest, it also ended up one of the weakest.

During our weight testing, Cabbage had strong weight-holding capabilities, performing the strongest with an average of 3030g. Overall, the most consistent results were found in cabbage, which was superior to some other tests with fluctuating results. Peas also performed strongly, with Trial 1 having the highest value of all the vegetables, being able to hold 4000 g. However, as the tests did not remain as consistent cabbage, dropping down to 3050g, and 1030g in its 2nd and 3rd test, it ended up as the second strongest, with an average of 1693.33g. Radish held a decent capacity with an average of 1293.3g, being the third best. Potatoes had a moderate strength with an average of 886.6g, placing 4th. While cauliflower held 1700g in its first trial, the other trials performed much poorer overall, and it was the second last place, having an average of 876.7. Carrots had the lowest overall performance, with an average of 306.7g. It also had a prominent outlier in one of its tests, which it was only able to support 190g. For comparison, our control results had a range of 1990-2090g, with two tests having identical results.

For our marker tests we decided to draw a single 5 cm line in 5 seconds, and trace the same line back with the same restrictions to ensure measurable and reliable data for our results. Peas, radish, potato, cabbage and carrot all bleed through in one trial, showing some indications of inconsistencies in the fiber composition and thickness. For the cauliflower we noticed, it consistently did not bleed in all trials, indicating good performance in terms of ink absorption, being the most dependable. However the control had bleeding in all trials.

The water tests showed that all vegetables held water between 0.25-1.5g, with peas outperforming the control sample. Peas had the highest average water holding capacity, with an average of 1.25g, which is 3 times the normal printer paper. Cabbage followed, holding 1g of water in all trials. Radish was the third best performer, with an average water holding volume of 0.625g. Cauliflower and carrot also showed permeability, but performed slightly lower than the other vegetables. Cauliflower had an average of 0.875g, both had ranges from 0.5g to 1g, while carrot had an average of 0.75g. Potato had the lowest score but the most consistent, with a score of 0.5g for all three. The results suggest that vegetables like peas, cabbage, and radish can hold significant amounts of water, but their thickness may make it difficult to manipulate and write on.

The project faced potential errors due to issues with measuring equipment and kitchen scale, as well as the mould and deckle method, which led to inconsistencies in thickness and opacity. Textural inconsistencies and discoloration were observed, and due to limited budget, the traditional food processor, which is weaker than industrial mixers, was not able to achieve a homogeneous pulp on root vegetables, causing inconsistencies in thickness and strength. These factors could have affected the overall paper composition and performance.

In conclusion, our hypothesis was incorrect, as the paper created by the cabbage pulp performed the overall strongest in comparison to the other vegetables. Our experiment found that cabbage pulp paper performed the strongest in comparison to other vegetables, producing a paper similar to a4 in texture, appearance, weight, and overall performance. Despite not being the strongest overall, it was the most appealing looking paper, making it suitable for consumers seeking sturdy, flexible, and aesthetically pleasing paper for arts and crafts. Peas, radish, potato, cauliflower, and carrot performed similarly, but with less aesthetic appeal. The potato, cauliflower, and carrot paper was hard to form into a uniform sheet and brittle, making them unsuitable for manipulation or writing.

The project aims to combat environmental and sustainability issues by using vegetable scraps for papermaking. Excessive logging leads to increased greenhouse gas emissions, soil erosion, and habitat disruption. By using vegetable scraps for papermaking, the project can contribute to sustainable and eco-friendly paper production, reducing tree cutdowns. Michelle Dias, a waste facility expert, at City of Calgary, supports this project. She states," I believe this idea is sustainable design, taking innovative practices and combining it with reduce and recycle approaches." We believe that this science fair idea goes hand in hand with reducing our ecological impact and sustainability practices. With the growth and expansion of these papers, we would have a reusability step in between the compost practices, as when contacting the city of calgary waste facilities office, they claimed that our papers could be completely compostable. Converting to these alternatives will decrease the ecological importance of forests that would be cut down.

The experiment aims to extend the project by incorporating more trials and testing different vegetables to explore the use of vegetable scraps or combining them for a perfect pulp blend. The goal is to refine the paper using proper industry tools and invest in better equipment for consistent results. Collaborating with experts in the papermaking field, such as food scientists, paper manufacturers, forest resources, environmentalists, compost and recycling management, grocery stores, and university professors, will help create a more successful model of the product. Additionally, exploring parameters like paper texture and durability will provide a more comprehensive evaluation of the paper's quality.

With that being said, this concludes our presentation. Our bibliography is featured down below/on the back of our trifold, and we would like to thank everyone who provided support to this project, including all of our experts, our parents, the city of calgary, Ms Fourie, Mrs Davis, and Mr Hotzel. We would also like to thank Louis Riel School and CYSF for providing this opportunity for us. At the end of the day sustainability is our main priority, with the environmental crisis being a detrimental issue we must face, together we can change the world, one scrap at a time. Feel free to ask any unanswered questions, and provide constructive feedback. Thank you for listening, your allotted time and consideration.

Extra

Typical office paper has 80 g/m^2 , therefore a typical A4 sheet weighs 5 g. Using these measurements, we can estimate that we would need about 5g multiplied by 10, or 50 grams of vegetable waste. However, because the cellulose fibers in vegetables are less prominent than wood, it would be safer to create a thicker paper especially when considering the higher water content in produce waste. Because of this, at least doubling the amount of raw pulp should produce the optimal amount of stability as well as flexibility. Later we learned that this was not enough to produce 10 uniform sheets, so this materials list is the total amount we ended up using rather than our initial calculations.

Softwood and hardwood are **distinguished in nature in terms of their reproduction rather than their end appearance and attributes**. In general, hardwood comes from deciduous trees which lose their leaves annually. Softwood comes from conifers, which usually remain evergreen

<u>March 6-1o, 2024</u>

-Finalized all information and added into CYSF website

<u>March 11, 2024</u>

-Finished up on slideshow and continued practicing script

-Formatted analysis

To gain insight into the wide range of uses for plant-based materials, we carried out a thorough thickness, marker bleeding technalities weight and water holding capacities testing experiments on different samples. Comparing these materials' potential to a control sample that was the average printer paper, or A4 paper. We investigated the water-holding capacity, thickness, weight, marker performance, of the pulp of certain vegetables. We took and utilized the vegetable scraps, using its pulp and cellulose to create paper. These vegetables included, carrotes, potatoes, cabbage, peas, radish, cauliflower. In an effort to identify special qualities and possible uses for each vegetable-derived material.

In our thickness testing, we sought comprehensive insights by examining all samples to provide a well-rounded comparison against the control sample, which measures 0.1 mm in thickness. The thickness of peas displayed significant variation across trials, ranging from 0.6 mm to 1.7 mm. Despite this range, an outlier measurement of 1.7 mm significantly skewed the average to 0.97 mm. Radish emerged as the second thickest, ranging from 0.4 mm to 1.7 mm, with an average thickness of 1.21 mm. Following closely, the potato samples ranked third in thickness, averaging 1.07 mm, with measurements ranging from 0.7 mm to 1.7 mm. Notably, all potato trials surpassed the control sample, hinting at its potential for thicker materials, suitable perhaps for specialty papers or thicker cardboard rather than standard A4 sheets. Cauliflower exhibited a thickness ranging from 0.6 mm to 1.1 mm, with an average of 0.84 mm, positioning it somewhat mediocrely compared to other samples. Cabbage displayed a wide range from 0.4 mm to 1.5 mm, yet most measurements clustered around 0.5 mm, despite the presence of a significant outlier at 1.5 mm. Lastly, carrots presented thickness values ranging from 0.3 mm to 0.8 mm, closely resembling the control sample. However, despite its thinness, the carrot sample revealed weaknesses such as holes and tears, indicating vulnerability despite its similarity in thickness to the control.

During our weight testing, peas performed the best, with Trial 1 having the highest value of 4000g, its average was also 1693.33g. Radish held a decent capacity of 590g, while cauliflower had 1700g, however, the other trials performed poorly, it was the second last place, having an average of 876.7. Potatoes had a moderate capacity of

886.6g, placing 4th. Carrots had the lowest overall performance, with an average of 306.7g. It also had a prominent outlier in one of its tests, which it was only able to support 190g. Cabbage had strong weight-holding capabilities, with an average of 3030g. Overall, the most consistent results were found in cabbage, which was superior to some other tests with fluctuating results. For comparison, our control results had a range of 1990-2090g, with two tests having identical results.

For our marker tests we decided to draw a single 5 cm line in 5 seconds, and trace the same line back with the same restrictions to ensure measurable and reliable data for our results. Peas, radish, potato, cabbage and carrot all bleed through in one trial, showing some indications of inconsistencies in the fiber composition and thickness. For the cauliflower we noticed, it consistently did not bleed in all trials, indicating good performance in terms of ink absorption, being the most dependable and most comparable to the control.

The water tests showed that all vegetables held water between 0.25-1.5g, with peas outperforming the control sample. Peas had the highest average water holding capacity, with an average of 1.25g, which is 3 times the normal printer paper. Cabbage followed, holding 1g of water in all trials. Radish was the third best performer, with an average water holding volume of 0.625g. Cauliflower and carrot also showed permeability but performed slightly lower than the other vegetables. Cauliflower had an average of 0.875g, with both having range of 0.5g to 1g, while carrot had an average of 0.75g, with a range of 0.5g to 1g. Potato had the lowest score but was the most consistent, with a score of 0.5g for all three. The results suggest that vegetables like peas, cabbage, and radish can hold significant amounts of water, but their thickness may make it difficult to manipulate and write on.

A range of findings have been gathered through our investigation into the water-holding capacity, thickness, weight, and marker performance of materials derived from vegetables. Every vegetable sample has distinct qualities that could be useful in a variety of situations. Peas are strong, but cabbage is the best at supporting its own weight. The most dependable for marker applications is cauliflower, which shows the least amount of ink bleed. These results highlight the delicate balance between thickness, strength, and functionality in vegetable-based materials and provide opportunities for additional study and thought. These analyses provide as a starting point for further exploration of the possibilities, opening the door to creative applications of natural materials across a range of industries.

-Added an abstract to research

<u>March 12, 2024</u>

-Made all final edits

-Prepared to film the video

<u>March 13, 2024</u>

-Filmed and edited the video

-Uploaded all final things

-Drafted acknowledgements:

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Link for slideshow template:https://www.canva.com/p/templates/EAFcBEgfQUs-beige-green-simple-minimalist-social-media-marketing-project-presentation/

Graphs template: https://www.canva.com/templates/EAFWCAaGhhw-white-green-modern-bar-chart-graph/

<u>March 14, 2024</u>

-Edited video
-Final look through
-Took group picture
-Uploaded all attachments and video on CYSF website
-Added banner to project

Picture Citations

Graymont.com, 2024, www.graymont.com/sites/default/files/inline-images/papier-1134070945.jpg. Accessed 14 Mar. 2024.

Slate.com, 2024, compote.slate.com/images/f4181d74-3ad7-4ef5-ba66-76f115ea2205.jpeg?crop=1560%2C1040%2Cx0%2Cy0. Accessed 15 Mar. 2024.

Bendigoadvertiser.com.au, 2024,
www.bendigoadvertiser.com.au/images/transform/v1/crop/frm/silverstone-feed-data/201c28c1-4f41-42c1-bd19-00545d7bb40f.jpg/r0_0_800_600_w800_h600_fmax.jpg. Accessed 15 Mar. 2024.
Psu.edu, 2024, www.e-education.psu.edu/egee439/sites/www.e-education.psu.edu.egee439/files/Lesson05/Images/Lesson5_MaltoseHaworth.png. Accessed 15 Mar. 2024.
Figure 1. Chemical Structure of Lignin.,
www.researchgate.net/figure/Chemical-structure-of-lignin_fig1_323923688
http://education.psu.edu.egee439/files/Lesson05/Images/Lesson5_MaltoseHaworth.png. Accessed 15 Mar. 2024.

Citations

Website Citations

1. Hampberg, Ava Saffrium. "Is Paper Better than Plastic?" Edited by Ouelyia Nifemi, *BBC News*, BBC, 29 Oct. 2022, www.bbc.com/future/bespoke/made-on-earth/how-paper-is-making-a-comeback/.
2. Chatterjee, Siddharth. "Tree Wood Classification and Composition: Importance of Cellulose, Hemi-Cellulose and Lignin." Pulp & Paper, ABB Group, 8 Mar. 2013, new.abb.com/pulp-paper/abb-in-pulp-and-paper/articles/characteristics-of-wood-and-papermaking-fibers.
3. Sahin, Halil Turgut, and Mustafa Burak Arslan. "A Study on Physical and Chemical Properties of Cellulose Paper Immersed in Various Solvent Mixtures." International Journal of Molecular Sciences, U.S. National Library of Medicine, 1 Feb. 2008, http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2635603/.www.ncbi.nlm.nih.gov/pmc/articles/PMC2635603/.
4. Xiao, Sai Yousef. "Fibre Sources." Encyclopædia Britannica, Encyclopædia Britannica, inc., 27 Apr. 2020, www.britannica.com/technology/papermaking/Fibre-sources.
5. Galioeno, James, and Mahyaka Ellia Huakoa. "Hemicellulose." Hemicellulose - an Overview | ScienceDirect Topics, 16 Feb. 2018, www.sciencedirect.com/topics/materials-science/hemicellulose.
6. Baker, N. (2016, July 1). Basics of Paper Manufacturing - Oklahoma State University. Basics of Paper Manufacturing | Oklahoma State University. https://extension.okstate.edu/fact-sheets/basics-of-paper-manufacturing.html#:~:text=Typical%20mechanized%20paper%20production%20involves,sheet%20in%20a%20Fourdrinier%20machin
7. Vougn, Janetly. "From the Woods: Paper!" Penn State Extension, Penn State Univeristy, 2018, extension.psu.edu/from-the-woods-paper
8. Aubrey, Allison. "From McDonald's to Organic Valley, You're Probably Eating Wood Pulp." *NPR*, 10 July 2014, www.npr.org/sections/thesalt/2014/07/10/329767647/from-mcdonalds-to-organic-valley-youre-probably-eating-wood-pulp#:~:text=Cellulose%20is%20basically%20plant%20fiber,turning%20up%20in%20our%20food.

9. Author links open overlay panelDavid Paton 1, Kara, et al. "Cellulose from Apple Tissue: Isolation, Purification and Chemical Modification." *Canadian Institute of Food Science and Technology Journal*, Elsevier, 18 Apr. 2013, www.sciencedirect.com/science/article/abs/pii/S0315546374738494.
10. Author links open overlay panelDereca Watkins, Kalani Pham, and Diana Fanzhu AbstractLignocellulosic biomass has been acknowledged for potential use to produce chemicals and biomaterials. Lignin is the second most abundant natural polymer with cellulose being number one. "Extraction and Characterization of Lignin from Different Biomass Resources." *Journal of Materials Research and Technology*, Elsevier, 28 Nov. 2014, www.sciencedirect.com/science/article/pii/S2238785414000982#:~:text=Extraction%20of%20lignin%20from%20different,consequently%20retrieving%20by%20washing%20them.
11. Author links open overlay panelIzharul Haq a, N, et al. "Recent Advances in Removal of Lignin from Paper Industry Wastewater and Its Industrial Applications – A Review." *Bioresource Technology*, Elsevier, 5 June 2020, www.sciencedirect.com/science/article/abs/pii/S0960852420309081.
12. Author links open overlay panelS. Lacorte, Kie Yun, et al. "Organic Compounds in Paper-Mill Process Waters and Effluents." TrAC Trends in Analytical Chemistry, Elsevier, 2 Dec. 2003, www.sciencedirect.com/science/article/abs/pii/S0165993603010094.
13. Author links open overlay panelZhijun Shi a b, et al. "Utilization of Bacterial Cellulose in Food." *Food Hydrocolloids*, Elsevier, 25 July 2013, www.sciencedirect.com/science/article/abs/pii/S0268005X13002142.
14. Black, Coolins, and Georgie Hart. "Pulp and Paper Production from Oil Palm Empty Fruit Bunches: A ... - MYJAFE." *MYJAFE*, Jafe, 31 Apr. 2023, myjafe.com/wp-content/uploads/2020/07/MYJAFE2020-0017.pdf.
15. Chen, Aaron. "Preparation of Leafy Vegetable Paper - Zheng - 2010 - Wiley Online Library." *Wiley Library* , 18 Oct. 2023, http://ifst.onlinelibrary.wiley.com/doi/10.1111/j.1745-4549.2009.00367.x.ifst.onlinelibrary.wiley.com/doi/10.1111/j.1745-4549.2009.00367.x.
16. City of Calgary, director. *Calgary Recycling: How Recyclables Are Sorted*. Youtube, 2013, www.youtube.com/watch?v=Zhv-Dv9h3J4&t=3s.
17. City Of Calgary, director. *How Compost Is Made: Calgary's Green Cart Program*. *YouTube*, YouTube, 20 Mar. 2019, www.youtube.com/watch?v=NGopFxRsQWg&t=1s.
18. Dr. Binocs Show, director. *Invention Of PAPER | The Dr. Binocs Show | Best Learning Video for Kids | Fun Preschool Learning*. Dr. Binocs Show, 2017, www.youtube.com/watch?v=COxB_GvdzWI.
19. Gadgets, Cheddar, director. *How Wood Turns Into Paper*. Cheddar Gadgets, 2019, www.youtube.com/watch?v=GuMsRWqPc2k.
20. Gorrdenshetn, Ava. "Effect of Protein–Starch Interactions on ... - Wiley Online Library." *Wiley Library* , 2013, ift.onlinelibrary.wiley.com/doi/abs/10.1111/1541-4337.13141.
21. Grant, Gander G. "Our Sustainable Kraft Pulp Production Proccess: Paper Excellence." *Paper Excellence Group*, 17 Jan. 2024, paperexcellence.com/pulp/how-we-make-pulp/.

22. Holwegner, Andrea. "Top 7 Healthy Vegetables on a Budget." *Health Stand Nutrition - Online Nutritionist Calgary Dietitian Team*, City of Calgary, 17 Nov. 2022, www.healthstandnutrition.com/healthy-vegetables-on-a-budget/.
23. Jaques, Colliques. "How to Make Your Own Paper | Artsy." *Artsy*, 2019, www.artsy.net/article/artsy-editorial-crash-course-basic-papermaking.
24. Kaur, Sabeen. "Paper & Board." *Starch Europe*, 19 Oct. 2020, starch.eu/ingredient/paper-board/#:~:text=Typically%20printing%20and%20writing%20papers,quality%20of%20fibres%20during%20recycling.
25. NevermindPaper, director. *How to Make Recycled Paper (+ Mould & Deckle Diy) | Tutorial*. *YouTube*, YouTube, 2 Apr. 2021, www.youtube.com/watch?v=5xrWrKIVBgo.
26. Obeluovi, Mastaru. "Properties of Wood." *Properties of Wood (for Papermaking)*, Paper Co., 1 Jan. 2024, www.paperonweb.com/wood.htm.
27. Paradis, Gaia. "Edible Paper." *PEER2PICKLE*, 2 Sept. 2017, peer2pickle.weebly.com/edible-paper.html.
28. Rachael, Simone. "Top 9 Cheapest and Healthiest Green Veggies." *DFD Russell Medical Centers*, 16 Feb. 2023, dfdrussell.org/cheapest-and-healthiest-veggies/
29. Samani, Niti. "Paper Manufacturing: Critical Issues and Challenges." *Deskera Blog*, 15 Mar. 2023, www.deskera.com/blog/paper-manufacturing-critical-issues-and-challenges/#:~:text=The%20production%20of%20wood%20pulp,biodiversity%2C%20and%20other%20environmental%20problems.
30. Science, Mystery, director. *How Do They Turn Wood into Paper?* Mystery Science, 2017, www.youtube.com/watch?v=0VEJCWvfhQg.
31. Shazhou, Darren. "Papermaking." *Papermaking - an Overview | ScienceDirect Topics*, Oct. 2022, www.sciencedirect.com/topics/agricultural-and-biological-sciences/papermaking#:~:text=Starch%20is%20used%20as%20a,maize%2C%20wheat%2C%20and%20tapioca.
32. State , Penn. "From the Woods: Paper!" *Penn State Extension*, Penn State, Mar. 2015, extension.psu.edu/from-the-woods-paper.
33. Teagan, Reign. "Read 'Diet and Health: Implications for Reducing Chronic Disease Risk' at Nap.Edu." *10 Dietary Fiber | Diet and Health: Implications for Reducing Chronic Disease Risk | The National Academies Press*, 2019, nap.nationalacademies.org/read/1222/chapter/13#293
34. Team, BioPak. "Compostable vs Recyclable: Which Is Better for the Environment?" *Compostable vs Recyclable | BioPak Australia*, BioPak, 17 Jan. 2024, www.biopak.com/au/resources/recycling-vs-composting#:~:text=Composting%20is%20for%20organic%20matter,to%20produce%20nutrient%2Drich%20compost
35. Team, Deskera Content. "Ensuring Quality Control in Paper Production." *Deskera Blog*, 25 Mar. 2023, www.deskera.com/blog/quality-control-in-paper-production/#:~:text=Tensile%20strength%2C%20tear%20strength%2C%20and,a%20given%20amount%20of%20time
36. Thestu, Matteo. "Why Is Printing Important for Business?" *Cherrill Print*, 8 Apr. 2021, cherrillprint.co.uk/why-is-printing-important-for-business/#:~:text=Printing%20can%20easily%20adapt%20to,that%20you%20might%20be%20based

37. Tube, Sappi, director. *The Paper Making Process*. *YouTube*, YouTube, 2 Mar. 2012, www.youtube.com/watch?v=E4C3X26dxbM
38. Xaila, Grande. "Properties of Wood." *Properties of Wood (for Papermaking)*, Paper Co., www.paperonweb.com/wood.htm.
39. Yousef, Anizla. "Pulp and Paper." *WWF*, World Wildlife Fund, www.worldwildlife.org/industries/pulp-and-paper#:~:text=Deforestation%20and%20Forest%20Degradation&text=Irresponsible%20harvesting%20from%20natural%20forests,species%20and%20cause%20soil%20erosion
40. Saini, Sajan. "What Makes Wood Rot so Slowly? Cellulose, a Densely Packed Component of Wood, Slows down This Inevitable Decay…." *MIT School of Engineering*, MIT, 29 Mar. 2011, engineering.mit.edu/engage/ask-an-engineer/what-makes-wood-rot-so-slowly/. Accessed 13 Feb. 2024.

Picture Ciations

1. Graymont.com, 2024, www.graymont.com/sites/default/files/inline-images/papier-1134070945.jpg. Accessed 14 Mar. 2024.
2. Slate.com, 2024, compote.slate.com/images/f4181d74-3ad7-4ef5-ba66-76f115ea2205.jpeg?crop=1560%2C1040%2Cx0%2Cy0. Accessed 15 Mar. 2024.
3. Bendigoadvertiser.com.au, 2024, www.bendigoadvertiser.com.au/images/transform/v1/crop/frm/silverstone-feed-data/201c28c1-4f41-42c1-bd19-00545d7bb40f.jpg/r0_0_800_600_w800_h600_fmax.jpg. Accessed 15 Mar. 2024.
Psu.edu, 2024, www.e-education.psu.edu/egee439/sites/www.e-
4. education.psu.edu.egee439/files/Lesson05/Images/Lesson5_MaltoseHaworth.png. Accessed 15 Mar. 2024.
5. Figure 1. Chemical Structure of Lignin., www.researchgate.net/figure/Chemical-structure-of-lignin_fig1_323923688
6. http://education.psu.edu.egee439/files/Lesson05/Images/Lesson5_MaltoseHaworth.png. Accessed 15 Mar. 2024.

Tables Made on: Word Documents

Graphs and Slideshows Made on: Canva
Canva Slideshow Template:
https://www.canva.com/p/templates/EAFcBEgfQUs-beige-green-simple-minimalist-social-media-marketing-project-presentation/
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