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Sustainable Kraft Liner

Jeffrey Hsu, Bryan Lee, Lucas Moyer, Jason Park, Seung Park, Daniel Phung

Project Planning Report Report

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**Abstract**

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In this report, a project plan is outlined describing an agenda for producing liner board from a furnish mix of recycled cardboard, *Arundo Donax*, and virgin softwood pulp obtained from Westrock. The furnish will be processed in 4 unit operations including raw fiber selection, pretreatment, paper production, and conversion. While industry has traditionally strived for stronger grades of liner board, new sources of fiber will be explored as they become economically and environmentally desirable. In addition to furnish optimization, wet-end chemistry will be adjusted to accompany the sustainable sheet. After the sheet is produced with alternatives fibers, a process for statistical analysis is planned and a comparison will be completed against industry liner board.

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# Introduction & background

Nowadays, sustainability and cost are essential factors to keep in mind when producing paper. In order to decrease the amount of deforestation for virgin pulp, more paper industries are trying to maintain a high sustainability that can improve environment quality. The use of recycled paper is becoming more common but there is still a need to achieve a good balance between the amount of recycled paper and paper strength. Recycled furnish lowers the overall paper strength because its fibers are shorter than virgin fibers due to it being processed prior to the pretreatment (Jones, 2016). In addition, using recycled paper conserves resources and produces less pollution and by-products (Bajpai, 2014). Not only does this increase sustainability, but increased uses of recycled paper also lowers costs as well.

This report will outline our plan for our first project. We will produce handsheets of different compositions of recycled, non-wood (*Arundo donax*), and virgin softwood pulp (obtained from WestRock). Before we combine them into one pulp mixture, we will refine each component separately so that the drainage is the same for all three parts. This will be done through a freeness test after the refining step. Once we figured out a matching freeness, we will produce three handsheets for each composition. The focus of our tests will be on strength, as opposed to optical properties. We will perform a STFI, ring crush, and burst tests to determine the compressive and overall strength of the paper. Using an ANOVA analysis, we will optimize paper strength while maximizing the amount of recycled pulp. Then the wet-end chemistry will be optimized using a similar procedure with focus on PAE, ASA, and cationic starch. After the furnish and chemistry have been determined, a full production run will take place to tune the paper making process for our optimized furnish. With the produced sheet, a comparison will be done against industry liner board.

## Objective (A.01)

The objective of this week’s project is to obtain the greatest strength while maximizing the amount of recycled furnish. We want to increase the recycled component in our handsheets in order to increase the sustainability and decrease the cost. However, since recycled paper typically has shorter and weaker fibers, the strength properties of the resulting handsheets will go down. Due to this trade-off, we want to optimize this balance between the recycled furnish and paper strength. The basis composition contains 10% recycled linerboard, 25% *Arundo donax*, and 65% virgin softwood from WestRock. We will vary the composition five times by fixing *Arundo donax* at 25%, increasing the recycled linerboard by 5%, and decreasing the virgin softwood by 5%. Refer to Table 2 for specific compositions. We predict that the reducing the amount of virgin pulp and increasing the recycled pulp will result in a decrease in our final sheet due to recycled pulp having been already processing and having shorter fibers than virgin pulp. The next objective will be to determine a wet-end chemical dosing schedule for our determined furnish. The PFI mill refining will be reevaluated to determine a new target CSF. Our 3rd objective will be to successfully apply our optimum furnish, machine, and wet-end chemistry conditions in a paper machine run. This will lead to our final objective to produce sustainable liner board and evaluate it against industry standards.

## Safety (B.02)

Safety is extremely important in both laboratory and mill settings. In order to minimize damage of any possible accidents, the location of eye wash stations, showers, first aid kits, fire extinguishers, and emergency shut offs should be informed to all laboratory and mill members before any experimentation begins. In addition, personal protective equipment (PPE) should be worn at all times. Such equipment includes closed toed shoes, eye protection, gloves, lab coats, and face shields or hearing protection when necessary.

For this particular experiment, a high speed beater roll will be used for refining the pulp, which spins at 720 RPM. Thus, care should be taken when near it. Anyone operating the machine should fully understand the manual and standard operating procedures before conducting experiments with the high speed beater roll. There is also a possible pinch point between hand lever and the lid that everyone should be aware of when running the beater roll. Also, the operator should not try to force stop the machine before it stops itself after a run as it can be still revolving at a high speed.

## Sustainability (D.04)

Liner production has increased significantly with the trend of package delivery services such as Amazon and Ebay. This increase in demand has been responded to with increased production and is a major focus of the paper industry currently. Liner can be made using recycled material but the doing so compromises strength when it is substituted for kraft fiber. Sustainable development focuses on creating a process that ensures indefinite production, so the need for recycled fiber within the furnish mix of kraft liner is important. Furthermore, using recycled material rather than kraft fibers lessens the chemical output through the kraft delignification process which helps improve the health of the watershed. Also, considerations need to be made towards the use of wet end chemistry that is used to improve the strength of liner. These concerns are addressed directly by group 2’s goal to utilize as much recycled furnish possible to while meeting commercial liner specifications. In addition, 25% of the furnish is sourced from *Arundo donax*, a perennial cane invasive to the Pacific Northwest, to further increase the sustainability of the liner produced. There will be discussions later in the project about the choices of wet end chemistry in regards to strength and drainage while maintaining the goal of a more sustainable production process.

## Schedule (E.05)

Table 1. Papermaking Schedule 1/7 - 3/15

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Days | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
| 1/7-1/13 | -Introduction to class |  | -Obtain recycled fibers | -Pulp recycled fibers and refine arundo donax | -Finish pulping recycled fibers, refine recycled fibers and *Arundo Donax* -Make handsheets | -Work on project planning report | -Work on project planning report |
| 1/14-1/20 | -Presentation & Research  -Testing handsheets for strength properties | -Research | -Refining | -Papermaking machine run #1 | -Testing paper we made for machine run #1 | -Analyzing results and comparing them to our desired specifications -Research | -Research |
| 1/21-1/27 | -Presentation on plan of the week & research | -Research | -Refining | -Papermaking machine run #2 - wet end chemistry testing | -Testing the paper with wet end chemistry | -Analyzing the results of wet end chemistry testing and determining what is needed | -Research |
| 1/28-2/3 | -Pre-production run presentation & research | -Research and refining wet end chemicals for desired product | -Refining | -Production run preparation - preparing wet end and fibers (focus on fillers and retention) | -Research |  |  |
| 2/4-2/10 | -Production run presentation | -Prepare for production run | -Refining | -Production run on paper machine | -Test product and analyze results | -Determine what the next plan of action is |  |
| 2/11-3/15 | TBD (Potentially more trial runs) | | | | | | |

# Method

## Fiber selection & treatment (H.08)

When selecting a furnish mix and fiber treatment method, it is important to consider the strength that is required of liner board. While using 100% virgin softwood would maximize the strength of the finished sheet, the cost of virgin softwood is expensive compared to recycled and alternative fibers. Recycled and alternative fibers also have less of an environmental impact due to their less energy intensive and simple processing compared to virgin softwood. This is why we plan to use a mixture of virgin West Rock, *Arundo Donax*, and recycled cardboard boxes as a furnish mix. Since we do not know the potential strength of a mixture of these fibers, we plan to change the ratio of recycled fiber to virgin fiber while keeping the amount of *Arundo Donax* in the sheet constant.

An initial handsheet trial will be set up to find a ratio of recycled to virgin fiber that maintains the strength properties of liner board. An experiment will be set up as shown in table 2.

Table 2. Experimental Conditions for Handsheet Trial

|  |  |  |  |
| --- | --- | --- | --- |
| Condition # | Recycled % | *Arundo Donax %* | Virgin Softwood % |
| 1 | 10 | 25 | 65 |
| 2 | 15 | 25 | 60 |
| 3 | 20 | 25 | 55 |
| 4 | 25 | 25 | 50 |
| 5 | 30 | 25 | 45 |

A PFI Refiner Curve has been produced for each fiber. Each fiber will be refined to produce a target CSF of 620. Refining is meant to improve the bonding in the sheet without increasing the density. Refining permanently changes the fiber structure by removing the primary and S1 walls of the fiber causing external fibrillation. Due to decreased drainage in the sheet and the usage of recycled fiber that has already been refined, the sheet cannot be over refined or else fiber shortening and cutting will decrease our end strength and yield. This will help improve the environmental sustainability of our sheet due to less steam and fiber demand.

## Wet end chemistry (H.08)

When making liner board, strength is the most important consideration. Optical properties can have some significance, but in this case, we can ignore how the sheet looks and assume that additional packaging would be used to cover the sheets appearance for its final application. Wet end chemistry can also help improve the processability to reduce maintenance on the machine and steam requirement from the dryer cans. In addition, an abundance of chemicals can drive up the cost with marginal improvements in the sheet. Liner board often serves as packaging that may go through wet environments. To address this, Polyamine-epichlorohydrin (PAE) will be used at 1% wt/wt of dry paper. PAE provides a cross linking mechanism to increase the wet strength of a sheet and works in alkaline papermaking conditions. To improve the dry strength of the sheet, cationic starch will be added at 4% wt/wt of dry paper. This starch will enhance the inter-fiber bonding by increasing the amount of coulombic interactions. Starch also helps create a denser sheet which will help the paper dry, reducing the steam requirement. Additionally, Alkenyl succinic anhydride (ASA) will be used as a sizing agent to improve the sheets ability to absorb liquids. ASA gives the sheet surface sizing which is desired for liner boards and works in alkaline paper making. All chemical dosings will be optimized in later trials. The dosings given in this planning report are estimates.

## Trial Matrix (F.06)

The trial is designed to create paper within commercial strength specifications by the end of the quarter. To be able to do this, the team will set up the experiments to utilize one-way ANOVA and two-way ANOVA. The experimental focus will be three part. The first variable that will be optimized is furnish mix, followed by wet end chemistry and refining amounts of each furnish, and then the addition of filler and retention aid. Two-way ANOVA is useful because it will allow statistical significance of two variables on a single dependent variable. This will allow two variables to be changed during paper machine trials to be able to see the effects on strength and drainage. Simply put, our inputs will be furnish mix, wet end chemistry, refining amounts of each furnish, fillers, and retention aid. Our outputs will be burst, STFI, ring crush, and freeness. STFI, also known as short span compressive strength of containerboard is an indication to predict the compressive strength of box compressive strength (TAPPI, 2013**)**. Ring crush is a similar indicator that determines the dynamic compression strength of the final product (TAPPI, 2007**)**. Measuring burst is important because higher bursting strength prevents sidewall punctures which is significant for the final product (TAPPI, 2016**).**

## Paper Production (H.08)

As stated above, we plan to use different ratio of recycled fiber to virgin fiber while keeping the amount of *Arundo Donax* constant. The headbox consistency will be around 0.3% as is in most paper grades. The vacuum level will be strong enough to keep the sheet consistency in the couch to be about 25%. The calendar section will consist of two rolls, applying pressure to the paper sheet passing by. The drying section will be enclosed to conserve heat to increase the rate of drying and the hot air will heat up where the paper sheets separate from the driers. The drier will be operated at 160 psig and 190°C. STFI, burst, and ring crush tests will be done during the production to measure the properties of the paper.

## Finishing (H.08)

For each of the different compositions listed in Table 1, we will produce three handsheets to perform a STFI test, ring crush test, and a burst test. While the STFI and ring crush test will measure the paper’s compression, the burst will provide insight on the strength of the paper when a uniform pressure is applied to all sides. What we expect to happen is that the handsheets with less recycled paper will have greater STFI, ring crush, and burst values.

# References:

The following is the format for end notes;

1. Li, J. (24 july 2015). Rapid method for determination of carbonyl groups in lignin compounds by headspace gas chromatography. Journal of Chromatography A, 1404, 39-43. doi:10.1016/j.chroma.2015.05.055
2. Jones, D., & Glover, D. (2016). The challenges of recycled furnish in the manufacture of premium tissue products. *TAPPSA Journal,5*, 32-35.
3. Bajpai, D. P. (2014). *Recycling and deinking of recovered paper*. ELSEVIER. doi:<https://doi.org/10.1016/C2013-0-00556-7>
4. Bursting strength of paperboard and linerboard. (2016). *TAPPI*. Retrieved January 13, 2019.
5. Ring crush of paperboard (rigid support method). (2007). *TAPPI*. Retrieved January 13, 2019.
6. Short span compressive strength of containerboard. (2013). *TAPPI*. Retrieved January 13, 2019.