Reflective Essay

Our senior design team, EcoBrew Design Group, has always had a passionate interest in the utilization of byproducts in food and beverage production. Many classes in our major, biological systems engineering, focus on the study of recycling waste streams in food and water processing to reduce environmental impacts on natural resources and decrease waste entering landfills and sewage systems. Our research on the collection and implementation of a byproduct produced during beer brewing, known as Trüb, into an animal food product was inspired by our past studies and made possible through Senior Design I, taught by Dr. Edwin Brokesh in the Biological and Agricultural Engineering Department. The goals and topics of this course consist of developing and presenting a design of a process, product, or system that has social, environmental, and economic value in our world today. EcoBrew Design Group conducted research and calculations to develop a process to collect and implement Trüb into animal food products to enhance protein consumption and decrease waste entering the environment through the beer brewing process.

Our team worked directly with our client, Garrett Paulman, co-owner and head brewer at Manhattan Brewing Company. Mr. Paulman values collaborating with organizations at Kansas State University. He put an emphasis on developing a long-lasting collaboration that could help him reduce waste entering the sewage system from his brewery. Based on our client's needs, we decided that the key components of our project would be to research and design a collection system to capture the Trüb as well as design a process to convert this waste product into a nutritional protein additive to animal food products such as dog treats and feed. Our team began creating a project timeline, highlighting important milestones, including research and what topics would be included in our final report. Our team chose APA formatting for our sources, and we used Zotero to properly cite sources used and to keep them organized as the semester went on.

To begin our process design, extensive research on the components of Trüb, including nutritional composition and particle size, as well as different types of food filtration systems needed to take place. *International Journal of Food Science & Technology, FDA,* and *ScienceDirect* were all reliable sources used on the Kansas State University library database to find information on these topics of study. Our team was captivated by different filtering and collection designs found in research. We also learned that specific testing would need to be done on the Trüb that we collected to ensure high nutritional value and safe storage.

We needed to make sure that every source we used was reliable. We ensured this by collecting information from trusted, peer-reviewed articles and websites. Our team used the Kansas State University online library database to find a majority of the articles used in our research. We knew that these sources were reliable and written by professionals. When we needed to use articles outside of the database, our team checked that the articles were written by a professional on the topic being discussed. While this might have added on some extra research time, it was very important that we knew the information could be trusted by Mr. Paulman. We made sure each article was recently written to ensure that the information provided was up-to-date. When discussing food related laws and requirements, our team made sure to collect information directly from government sources including the U.S. Food and Drug Administration.

Out of the many articles we read, the one that resonated the most with our team was "Waste from Brewing (Trüb) as a Source of Protein for the Food Industry," written by the *International Journal of Food Science & Technology*. This article went into detail explaining methods of debittering Trüb and why it was necessary. It was interesting to learn that while Trüb has high nutritional value, it can be overlooked due to its bitterness and variability of bitterness depending on the type of beer being brewed and the type of hops being used. The article also went on to discuss global bitterness analysis as well as all of the specific compounds that Trüb possesses.

When researching the best articles to use on the Kansas State University library database, our team developed key words for each objective that would aid in minimizing the number of articles that would be available. For example, when researching the nutritional composition of Trüb, we used keywords such as nutrition, Trüb, beer, byproducts, and bitterness. It was also very convenient that the Kansas State database allows you to narrow down the amount of material that shows up with a search. We were able to select that we wanted only peer reviewed articles from the past few years, and it immediately gave us the newest journals written on the specific topic. Our team was able to find exactly what was needed because of the database. We also learned through this research that it is important to pull the specific information that we needed by reading only specific parts of the article. There are a few ways to do this that we found the most beneficial. First, we could read the abstract at the beginning of each article to get a generalized understanding of what it was about. If this article was what we were looking for, we would go directly to the table of contents to find the specific information that was needed. We finished by reading the conclusion to see if there were any last bits of information that would be helpful in aiding the topic discussion.

Our team, EcoBrew Design Group, learned that staying on task with the help of our timeline was crucial. Communication with our client was necessary and needed to take place each week for our project to run smoothly. Utilizing the Kansas State University library database helped our team conduct proper research that allowed for the success of our project. Our research skills gained while taking this course will help us as we begin our careers as engineers.

Final Project

For

BAE 536

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Executive Summary

EcoBrew Design Group partnered with Garrett Paulman, co-owner of Manhattan Brewing Company, to develop a system to collect the waste created during the process of brewing beer as well as create a byproduct from this waste. The waste, known as Trüb, is removed from the brew kettle and fermenter, and is sent directly down the drain into the sewage system. EcoBrew assisted Manhattan Brewing Company in creating more collaboration opportunities with Kansas State University, as well as decreasing their environmental footprint on water resources in Manhattan. With the number of breweries in Manhattan growing rapidly, eliminating solids entering the sewage system from breweries alone is a significant issue that needs to be solved to save small brewing businesses money if future costs are implemented by the wastewater treatment plants. Capturing the solid waste before it enters the water system will aid in lowering breweries' environmental impact as well. Through extensive research, calculations, and testing, EcoBrew Design Group was able to develop Trüb collection system designs as well as processes to debitter and dry the Trüb for use as a protein additive in food products such as dog treats and ice cream. The team also communicated with other clubs and organizations at Kansas State University to create a collaboration with Manhattan Brewing Company that would allow this collection, debittering, and drying process to continue in the future. This report includes all research, testing, designs, and solutions that EcoBrew Design Group developed over the semester.

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List of Abbreviations &/or Relevant Definitions

Abbreviations	Definitions
BOD	Biological Oxygen Demand
CFR	Code of Federal Regulations
GRAS	Generally Recognized as Safe
FDA	Food and Drug Administration
FD&C	Food, Drug and Cosmetic
FSMA	Food and Safety Modernization Act
LCA	Life Cycle Assessment
MBC	Manhattan Brewing Company
TSS	Total Suspended Solids

Introduction

Problem Statement

Manhattan Brewing Company produces roughly 4,000 pounds of waste every week, comprised of 3,500 pounds of spent grains and 660 pounds of Trüb. The spent grains are collected and sent to a local ranch where it is utilized as animal feed. This leaves over 600 pounds of Trüb waste that is sent down the drain. To define, Trüb is the remnants of the grain, hops, and yeast that is left after removing the liquid from the brew kettle and the fermenter. As such, the Trüb is comprised of valuable commodities that require many resources to produce, which is expanded upon in the Life Cycle Assessment. The resources put into producing these commodities are important to consider when evaluating the full scope of the waste. The environmental ramifications of underutilization of natural resources are compounded by the further environmental costs of treating the waste. The biological oxygen demand (BOD) and total suspended solids (TSS) of the Trüb require more intensive wastewater treatment. Lastly, the Trüb contains valuable nutritional compounds and high protein content that should be used to generate a product of value.

Customer

The client for this project was Manhattan Brewing Company (MBC**).** EcoBrew Design Group worked with Garret Paulman, co-owner and head brewer. EcoBrew approached Garret in August of 2023 with an idea to utilize the waste they produced. The idea was to collect the waste made from brewing and create a product with it. MBC was eager to work with EcoBrew from the beginning. Garret allowed the team to observe him on a brewing day and walked the team through the entire brewing process.

Project Goals

The goal for this project was to design a collection and utilization method for Trüb, a brewery waste product. The goal was to limit waste from the production process entering the Manhattan sewage system and turn the waste Trüb into a value-added byproduct. Doing so would allow MBC to reduce its environmental footprint and in turn spark a partnership with MBC and Kansas State University.

Project Constraints

It is important to maintain the integrity of the beer product of Manhattan Brewing Company, as such this project will not alter the chemistry, or the mechanics of the brewing process. With that the collection device must fit into the available space in the Manhattan Brewing Company location and be designed to work on the current scale and capture at least 21 gallons of Trüb. For the Trüb product created, all methods used to develop the end material must be food safe and allow for safe consumption.

Review of Literature and Observations

Overview of the Brewing Process

The process of brewing beer can vary depending on the brewery and the type of beer being produced. For this report, EcoBrew discussed the process of making Townie beer at Manhattan Brewing Company. All information was obtained from Garrett Paulman from a site visit that the team made on September 29, 2023. The first step in brewing Townie beer was milling, which involved crushing dried grain through rollers and producing a powder called grist. MBC used dried grain from Briess. Then, the grist, in this case 500 pounds of malt, was added to the mash/lauter tun along with 13 pounds of rice hulls, 13 pounds of wheat, 350 milliliters of lactic acid, and 460 gallons of water. The mixture was stirred and heated until it reached 148 degrees Fahrenheit and had a pH between 5.2 and 5.5. Once this process was complete, the vorlauf, which means recirculation in German, process began. The process involved sending the liquid, called wort, from the mash/lauter tun through a filter and back into the mash/lauter tun twice. This allowed for the removal of bigger solids. The wort was then transferred to the brew kettle, and the leftover grains that remained in the mash/lauter tun were removed. This is called brewers spent grain, and MBC collected the spent grain in large bins for farmers to use as feed.

Once the wort was in the brew kettle, the sparging process began. This involved adding more water to the wort. In this process, 31 gallons of water were added along with zinc for yeast growth and 140 milliliters of fermcap for foam control. The wort was then boiled at 280 degrees Fahrenheit for 1.5 hours, with 2 pounds of hops being added 45 minutes into the boiling. At the end of the boiling, the wort was sent through a heat exchanger where it was cooled to 65 degrees Fahrenheit. It was then sent to the fermenter. What was left in the brew kettle was a solid waste called Trüb, which consisted of all the grains and hops that remained. Currently at MBC, the Trüb is sent directly down the drain into the sewage system from the brew kettle. The wort in the fermenter was left to ferment for 18 days specifically for Townie. 2 liters of yeast and 140 milliliters of fermcap were also added to the fermenter during this process. At the end of the 18 days, all remaining Trüb was sent down the drain. The final product was packaged and transported or was sold on tap at Manhattan Brewing Company. A diagram of the complete brewing process of Townie beer can be seen in Figure 1 below. Since this process does create a large amount of Trüb from the brew kettle that was being sent directly down the drain, EcoBrew Design Group conducted research on different food waste collection methods to capture the Trüb and use it as a byproduct.

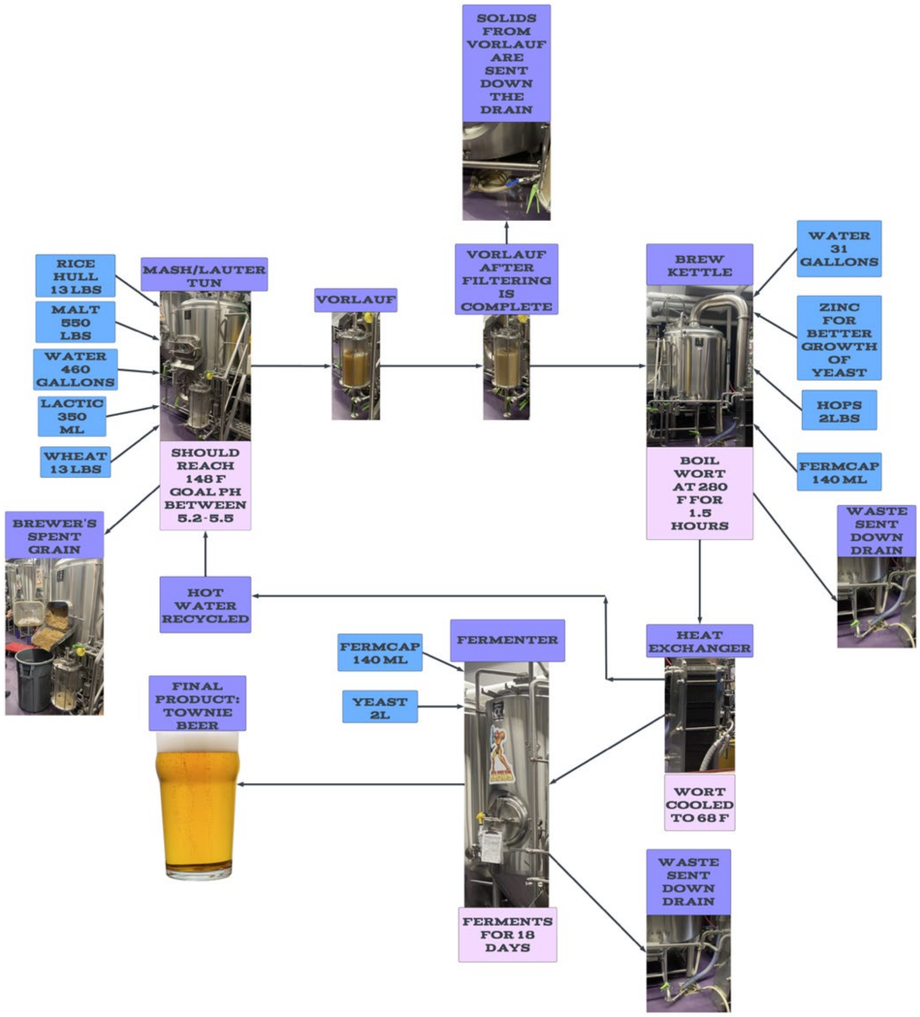

Figure 1: Process of brewing Townie Beer at Manhattan Brewing Company.

Properties of Trüb

Three waste products were developed during the brewing process. These included brewers spent grain and residual yeast, which were both easily incorporated into animal feed (Saraiva et al., 2019). The third waste product was Trüb, which is limited in its additions to animal and human food due to its bitterness from the hops that are added in the brew kettle (Saraiva et al., 2020). However, Trüb does have a significantly high protein content of up to 40-70% along with 1-4% lipids, 20-60% carbohydrates, and 5-10% polyphenols (Santos & Martins, 2024). It also includes both nonessential and essential amino acids, with 28.76% of protein being made of essential amino acids, 15.02% branched chain amino acids, and 70.63% total amino acids (Saraiva et al., 2019). Percentages of specific amino acids can be found in Tables 1 and 2 below. Trüb protein has the potential to be a high protein source that can be added to other food products once bitterness extraction takes place, which can be done based on past research and development (Saraiva et al., n.d.).

Nonessential Amino Acid	Percent of Trüb
Aspartic Acid	5.59
Glutamic Acid	12.20
Serina	4.03
Glycine	3.08
Arginine	3.78
Cystine	1.57
Alanine	4.23
Proline	5.25
Tyrosine	2.14

Table 1: Nonessential amino acid percentages found in Trüb (Saraiva et al., 2019).

Essential Amino Acid	Percent of Trüb
Histidine	1.73
Threonine	2.86
Methionine	1.09
Valine	4.59
Isoleucine	3.29
Leucine	7.14
Phenylalanine	4.21
Lysine	3.16
Tryptophan	0.69

Table 2: Essential amino acid percentages found in Trüb (Saraiva et al., 2019).

Collection Methods

When conducting research on Trüb collection methods, EcoBrew Design Group found that it was essential that the water coming out of the brew kettle was filtered thoroughly with little to no remaining solids in the stream. The filter would also need to be able to catch approximately 21 gallons of Trüb from the brew kettle. This quantity was determined by the following calculation made by EcoBrew, which took into consideration the 410-gallon brew kettle with 3% Trüb per batch plus a 2% correction factor to account for overflow:

- 410 gallons (5% Trüb) = 20.5 gallons of Trüb.

The team researched filters used for food processes and found an example of using a cheese cloth to separate the curd from the water. While a cheese cloth would not be feasible for the amount of Trüb needed to be captured, the idea of using a type of mesh was feasible. The team decided to conduct particle size testing of the Trüb to determine what mesh size would be appropriate to capture the Trüb from the brew kettle and allow the water to pass through. EcoBrew design Group conducted the following steps to test particle size and appropriate mesh size:

1. Collect 2 Trüb samples, each in a 250-milliliter bottle, from Manhattan Brewing Company.
2. In the lab, place a stack of #35, #60, #120, and #230 sieves on top of each other with a pan underneath to capture any remaining Trüb particles, and pour one bottle of Trüb into the stack.
3. Use a steady stream of water to move the Trüb through the sieves.
4. Calculate how much Trüb remains.
5. Repeat with the second bottle.

After conducting this test, the team found that the smallest particles were captured in the #120 sieve and water was still able to pass through with no overflow. However, the Trüb collection system would need to have two layers for the bigger particles to be captured first and not clog the #120 sieve since the flow rate would be much greater than the sink used in testing.
EcoBrew Design Group researched the micron size of the #60 and #120 sieves that were used so that the proper mesh could be ordered for a two-layer Trüb collection system. The following results were found (*Mesh Size, Mesh to Micron Comparison Chart | Kramer Industries Inc*, n.d.):

- 60 mesh = 250 microns = 0.01 inches
- 120 mesh = 125 microns = 0.0049 inches

The team conducted research on how the mesh could be incorporated into the Trüb collection system. After further discussion with Garrett Paulman, it was confirmed that the whole system, including the mesh, would need to be made of stainless steel for food safety measures and to handle the high temperatures and consistent rinsing and washing. Stainless steel was also found to have a very high rust resistance, which made it a widely used food production material (*Food-Grade Metals*, 2016). Once the Trüb is collected, the next step would be to transform the waste into a protein byproduct.

Protein Extraction Methods

To transform the Trüb into a protein rich byproduct, EcoBrew Design Group researched methods of debittering and drying to turn the Trüb into a fine powder that could be added to food products like dog treats and ice cream. The first process would be debittering. One process found consisted of thawing 25 grams of Trüb per Liter of water and homogenizing it at 25 degrees Celsius for 10 minutes (Saraiva et al., 2019). Then, the Trüb and distilled water were heated at 100 degrees Celsius for 60 minutes (Saraiva et al., 2019). After the drying, the sample was filtered and remixed with water, and after another drying at 100 degrees Celsius for 60 minutes, filtration was repeated, water was added again, and the process happened two more times (Saraiva et al., 2019). Once finished, the sample was stored in darkness at 5 degrees Celsius (Saraiva et al., 2019).

Another debittering process found in research was not quite as extensive but proved to remove bittering components since the sample was smaller than the one previously discussed and was also proven based on further testing (Santos & Martins, 2024). The process began by homogenizing 5 grams of hot Trüb with 100 milliliters of water with a magnetic stirrer (Santos & Martins, 2024). The sample was then centrifuged at 8709x g for 10 minutes (Santos & Martins, 2024). The solid fraction was dried at 50 degrees Celsius for 12 hours and obtained a moisture of less than 15% at the end of the drying (Santos & Martins, 2024).

For protein extraction, the debittered Trüb was either dried in an oven at 50 degrees for 12 hours (Santos & Martins, 2024), or at 55 degrees Celsius for 24 hours (Saraiva et al., n.d.). EcoBrew Design Group used the most feasible debittering and drying processes based off research and available resources. The debittering and drying processes that were used by the team are discussed later in this report.

Standards

EcoBrew Design Group had to follow food safety standards relating to food additives and food production equipment. The FDA contained rules and information on procedures for adding new ingredients to food and feed. The FDA also contained information on foods generally recognized as safe (GRAS) for human and animal consumption. Regulations on food production equipment were found in the Code of Federal Regulations.

FDA Food and Safety Modernization Act, Title I, Section 113

In this section of the Food and Safety Modernization Act (FSMA), the procedures for new dietary ingredients were discussed. This section explained that the Secretary decides when the new dietary ingredient is considered new, when the manufacturer or distributor should provide all necessary information on the new dietary ingredient, the safety of a new dietary ingredient, and the appropriate methods of identifying a new dietary ingredient (Nutrition, 2020).

Food, Drug, and Cosmetic Act, Sections 201(s) and 409

The FD&C Act (Commissioner, 2018) is found in the *Code of Federal Regulations* (CFR) and requires that any substance added to or that is expected to become a component of animal or human food must be used in accordance with a food additive regulation unless it is generally recognized as safe (GRAS) for that intended use (Nutrition, 2023). GRAS, found under section 201(s) and 409 of the FD&C Act, is a term used to clarify foods that are safe for human and animal consumption (Nutrition, 2023). For a food to be considered GRAS, it must go through scientific procedures or through experience based on common use in food for foods consumed in the years before 1958 (Nutrition, 2023).

21 CFR 211.65: Equipment Construction

Subpart D of the *Code of Federal Regulations* (CFR) discussed that equipment shall be constructed so that surfaces that come into contact with food or drugs shall not be reactive, additive, or absorptive so as to alter identity, safety, strength quality, or purity of the food or drug (*21 CFR 211.65 -- Equipment Construction*, n.d.).

Safety & Ethical Considerations

EcoBrew Design Group developed some safety considerations for the Trüb collection system and for developing a protein additive from the Trüb collected. Safety considerations included, but were not limited to, the following:

1. The Trüb protein additive would need to follow all food safety guidelines in order to be safe for human and animal consumption.
2. All proper PPE and other safety equipment would need to be worn in the lab while doing debittering and drying procedures to avoid safety risks such as burns or other lab related injuries.
3. When developing the final Trüb collection system out of stainless steel, the system would have no sharp edges to prevent injury.

Ethical considerations were also reviewed during the design and research process. These considerations included the following:

1. The development of the Trüb collection system and debittering and drying process should help Manhattan Brewing Company decrease their environmental impact on local water sources.
2. The development of a byproduct from the Trüb will allow for Manhattan Brewing Company to be an outreach source to different agricultural organizations that create food products at Kansas State University.
3. Creating a protein additive out of the Trüb will benefit both animals and humans by providing another optional protein source, especially as populations and protein demands increase.
4. Recycling the Trüb instead of discarding it will decrease the amount of waste being produced at Manhattan Brewing Company and will therefore decrease the brewery's environmental footprint.

Life Cycle Assessment

When developing new, more sustainable protein sources, it is important to consider food-safe waste products as a potential option. In the case of this Life Cycle Assessment (LCA), the food-safe waste product that was analyzed was Trüb, a solid waste slurry found during the beer brewing process. The environmental impacts of Trüb per kilogram were presented in terms of carbon footprint, land use, water depletion, and energy utilization. The results were compared to soy protein isolate per kilogram. Both consequential LCA results, which give an estimate of how the global environmental burdens are affected by the production and use of the product (Ekvall, 2019), and attributional LCA results, which estimate what share of the global environmental burdens belongs to a product (Ekvall, 2019), were used for the soy protein isolate comparison. Results for carbon footprint revealed that the value for Trüb was smaller at 0.768 kg CO_2e/kg protein compared to the consequential value of 2 kg CO_2e/kg protein and the attributional value of 6 kg CO_2e/kg protein. Trüb had no land use contributions because no excess land was needed to grow or produce it, while soy protein isolate had land use values of 8 square meters a year/kg protein for consequential and 6 square meters a year/kg protein for attributional. Trüb had a higher water depletion value than the consequential value of soy protein isolate, with values being 52.13 L water/kg protein compared to 38 L water/kg protein respectively. However, the Trüb water depletion value was much lower compared to the attributional water depletion value of soy protein isolate which was 205 L water/ kg protein. 0.032 ton-kilometers of transportation were by diesel truck per kg of soy protein isolate, while 0.00502 ton-kilometers were used for driving per kg of Trüb protein. The results of this LCA indicate that utilizing food-safe waste from production, such as brewing beer, can have many environmental and resource benefits. The full Life Cycle Assessment with figures and sources can be found in Appendix C.

Methods

Trüb was collected from Manhattan Brewing Company in Manhattan, Kansas. After collection, the Trüb was stored at 4 degrees Celsius to prevent spoilage if left in room conditions.

Analyzing Material Properties of Trüb

Several analysis methods were employed to determine the material properties of Trüb and how they would impact a collection method design. Firstly, the Trüb was analyzed gravimetrically. To determine the particle size of Trüb the collected sample was passed through sieves ranging in size from 1 centimeter to 75 micrometers. The best sieve size for the collection method was determined through analyzing the balance between amount of Trüb collected and the ease of water passing through. To determine the moisture content of the Trüb it was dried at 100 degrees Celsius for 24 hours. It is important to note that the moisture content of Trüb is inconsistent as varying amounts of water are added to the Trüb during removal from the brewery.

The protein content of raw Trüb was found through the Bradford method (Bradford, 1976). Absorbance of the raw Trüb supernatant was read from a Bradford machine at a wavelength of 595 nanometers. The standard curve was generated using bovine serum albumin.

Debittering Trüb

To debitter the Trüb, it was filtered to remove water (size 75 micrometers), and then combined with water at 50 grams raw Trüb per liter of water. This mixture was heated at 100 degrees Celsius for one hour with constant stirring. After boiling the Trüb was filtered again. This process was repeated for a total of 5 washes. The Trüb was then dried at 50 degrees Celsius for 16 hours. The protein content of debittered Trüb was found in the same Bradford method as raw Trüb.

Design and Implementation of Trüb Collection

EcoBrew Design Group developed different collection methods to capture the Trüb from the brew kettle at Manhattan Brewing Company. The first design created by the team focused on building layers of mesh that could be easily inserted and removed from a stainless-steel tank measuring 36 inches by 24 inches by 7 inches. These measurements were obtained based on the following calculations done by EcoBrew:

- After the gallons of trub was calculated, it was converted using the conversion rate of 1 gallon equaling 0.133681 cubic feet. The design of the system had to hold at least 2.74 cubic feet of material. After looking at the space allowed at MBC the only stipulation was that the design had to be shorter than eight inches for the drainpipe coming out of the brew kettle. Making the design 36 inches by 24 inches by 7 inches gave it 3.5 cubic feet of storage which was enough to meet the design needs.

The isometric view of the Trüb collection system drawn in AutoCAD can be found in Figure 2 below. This first design had a layer of #120 mesh sitting on the braces of the box with a #60 mesh layer laying just above it. This would allow bigger particles to get trapped in the first mesh layer and smaller particles to get trapped in the second layer while still allowing water to pass through the collection system. The tank would be sloped and would lead the water to a hole where a hose would pump it out to the drain that is already used at Manhattan Brewing Company. Advantages and disadvantages of the first Trüb collection system design can be found in the appropriate sections later in this report.

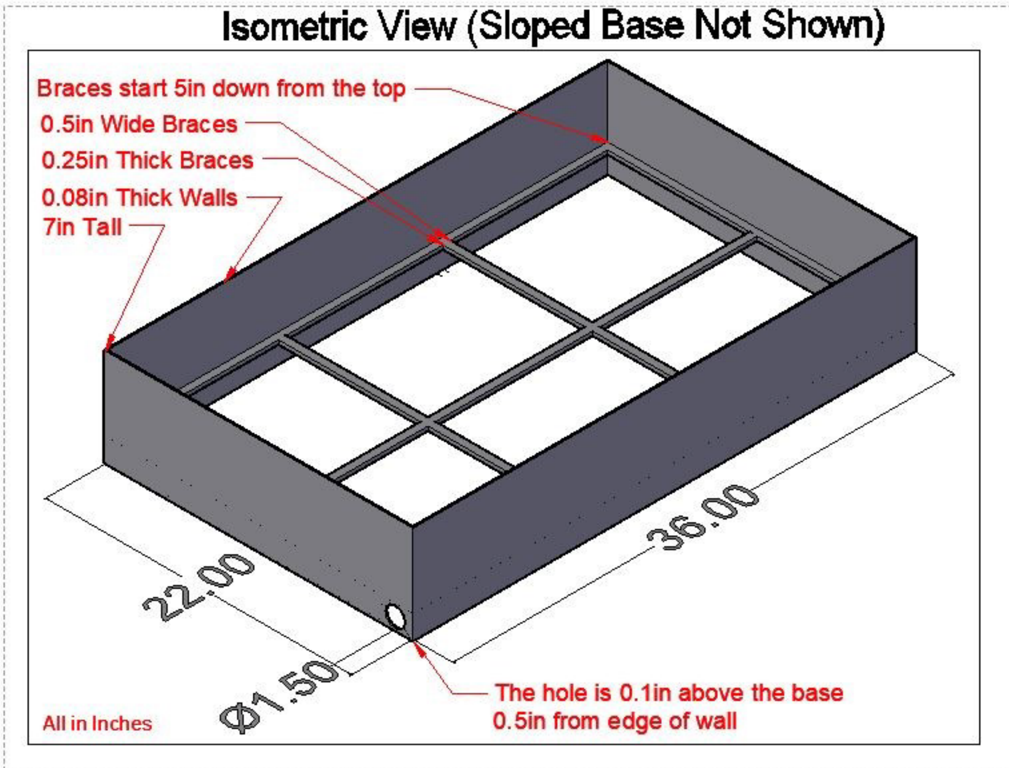

Figure 2: Isometric view of the first Trüb collection system drawing.

The mesh in the collection tank would not be attached to the tank itself. Instead, the mesh would be welded together, making it simple for users to remove the Trüb from the collection tank. It would also make the cleanup process easier for the user, as the mesh and tank could be washed separately. Additionally, handles would be included to make the lifting of the mesh easier. The mesh design can be found in Figure 3 below.

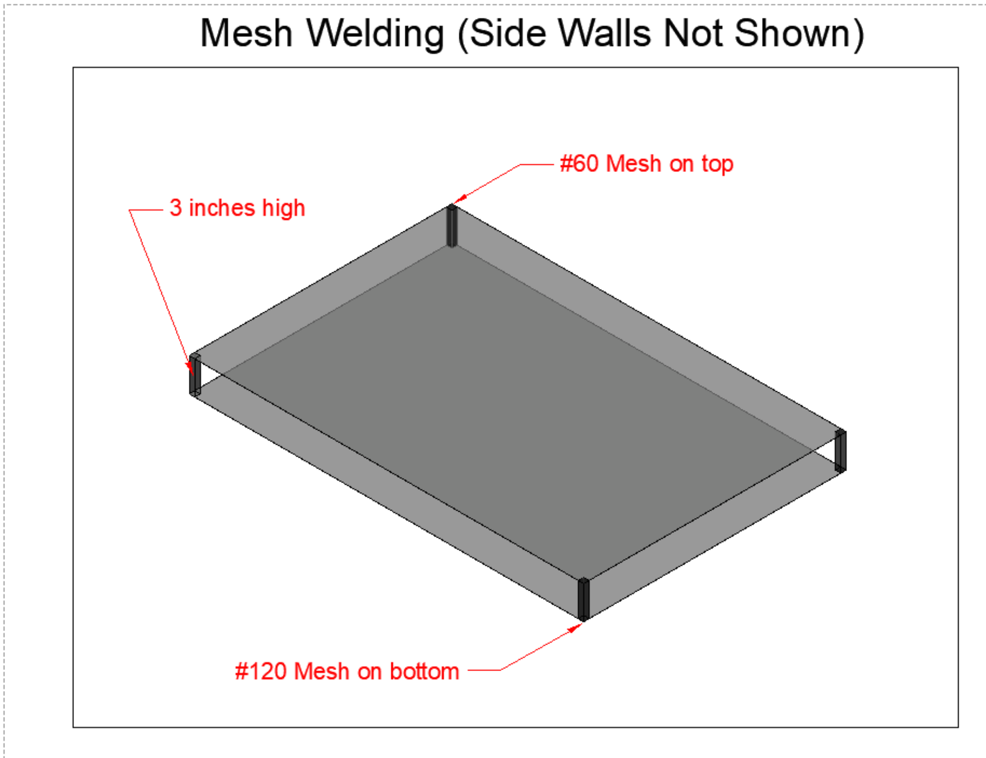

Figure 3: Removable mesh welding in the Trüb collection system.

To test proof-of-concept, EcoBrew Design Group built a $20 model using a plastic tub and two meshes, one #60 mesh and one #120 mesh. The objective was to analyze the adequacy of the mesh size in capturing Trüb particles. The model can be found in Figure 4 below.

Figure 4: Trüb collection prototype built by EcoBrew Design Group.

Initially, the prototype performed as anticipated during testing. However, the design's low quality led to the mesh collapsing midway through the process. This occurred due to the absence of a supportive brace for the mesh. Also, the #60 and #120 mesh sizes were too fine. To enhance drainage efficiency, opting for a larger mesh, such as #30 and #60 sizes, would be more effective. Despite these challenges, the prototype ultimately demonstrated the viability of the original design.

Byproduct Production

EcoBrew Design Group utilized the dried and debittered Trüb by adding it to food products. The team turned the Trüb into a fine powder by blending it, making it easier to incorporate into different food products. EcoBrew decided to add the powder to dog treats that could be sold at Manhattan Brewing Company, as well as to ice cream that could be sold at Call Hall Dairy bar.

Dog Treats

Dogs, like humans, need essential amino acids to support important bodily functions including transporting nutrients around the body, immune system function, and hormone function (*The 10 Amino Acids Your Dog Needs*, n.d.). The essential amino acids that dogs need include arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine (*The 10 Amino Acids Your Dog Needs*, n.d.). Trüb protein contains all of these essential amino acids except for arginine (Saraiva et al., 2019), making it a quality protein source for dogs. Incorporating Trüb protein into dog treats can increase protein consumption while also conserving quality taste. The following recipe from *Taste of Home Magazine* was utilized by EcoBrew to create a prototype of dog treats containing Trüb protein:

- 1 cup of whole wheat flour
- ¼ teaspoon ground cinnamon
- 3/8 cup water
- 1/8 cup peanut butter
- ½ large egg, room temperature
- 1 tablespoon canola oil

1 teaspoon of Trüb protein isolate developed by EcoBrew Design Group was also added to each dog treat. The ingredients were stirred together, cut into appropriate shapes, and placed in a 350-degree oven for 35 minutes. The finished product can be found in Figure 5 below.

Figure 5: Dog treats containing Trüb made by EcoBrew Design Group.

Each dog treat without the Trüb protein contains 61 calories, 3 grams of fat, 8 grams of carbohydrates, and 3 grams of protein ("Dog Biscuits," 2022). The treats would contain 4.3 grams of protein each with the addition of Trüb protein. These calculations can be seen below:

- 2 tbsp peanut butter = 7 grams of protein.
- 1/8 cup peanut butter in one batch = 2 tbsp = 7 grams of protein/batch from peanut butter.
- 1 cup wheat flour in one batch = 16 grams of protein/batch from wheat flour.
- 3 grams of protein in half an egg.
- Total protein in one batch = (7+16+3) grams = 26 grams of protein.
- 26 grams of protein per batch/10 biscuits per batch = 2.6 grams of protein per biscuit which is approximately 3 grams of protein per biscuit as stated in the article ("Dog Biscuits," 2022).
- With 1 teaspoon Trüb per biscuit = 1.7 grams protein per teaspoon (10 biscuits per batch) = 17 grams protein from Trüb in one batch: 43 grams total protein in one batch/10 biscuits = **4.3 grams protein/biscuit.**

For proper storage of the dog biscuits, dog owners should store them in an airtight container for 3 days at room temperature, in the refrigerator for 5 days, or in the freezer for up to 3 months ("Dog Biscuits," 2022). The team also conducted a cost analysis on the ingredients needed for making the dog treats, found below.

Cost Analysis

EcoBrew Design Group calculated the cost of making one batch of dog treats based on the amount of ingredients listed above. The calculations are as follows:

- 80 oz bag of King Arthur Whole Wheat Flour = $5.58 = 7 cents per oz
    - 2 cups (4.5 dry weight oz/1 cup) = 9 oz (7 cents/oz) = **63 cents for whole wheat flour**
- 2.5 oz Great Value Ground Cinnamon = $1.24 = 50 cents per oz
    - ½ tsp (0.18 dry weight oz/1 tsp) = 0.09 oz (50 cents/oz) = **4.5 cents for ground cinnamon**
- Assume cost of water = 0
- 16 oz Great Value Creamy Peanut Butter = $1.84 = 12 cents per oz
    - ¼ cup (8 fluid oz/1 cup) = 2 fluid oz (12 cents/oz) = **24 cents for peanut butter**
- 12 Count Eggland's Best Extra-Large White Eggs = $3 = 25 cents per egg = **25 cents for egg**
- 16 fluid oz Crisco Pure Canola Oil = $3.32 = 21 cents per fluid oz
    - 2 tbsp (0.5 fluid oz/1tbsp) = 1 fluid oz (21 cents/fluid oz) = **21 cents for canola oil**

The total cost of making one batch of dog treats is $1.38.

Incorporating Trüb protein into dog treats is a simple way to increase protein intake for dogs and to utilize the Trüb waste from brewing to create a valuable product. The cost analysis also shows that these treats would be cost effective as Manhattan Brewing Company could create another means of profit at a low production cost.

Protein Additive to Ice Cream

Call Hall Diary Bar, located in Call Hall at Kansas State University, offers products such as milk, cheese, eggs from the KSU Poultry unit, meat from the KSU quality meats lab, and ice cream (*Call Hall Dairy Bar*, 2023). Call Hall dairy products also follow a "farm to spoon" principle, meaning that all production and processing of raw milk happens within a 2-mile radius of their retail locations (*Call Hall Dairy Bar*, 2023). EcoBrew Design Group considered implementing a collaboration with Anthony Fink, food service manager of Call Hall Dairy Bar, and Manhattan Brewing Company to develop a protein ice cream made with Trüb protein. This would give Call Hall Dairy Bar a locally sourced protein powder that could be implemented into one of the current recipes. EcoBrew Design Group developed a mocha protein ice cream prototype using the following recipe:

- 1 tablespoon of cream cheese
- 1/3 cup sugar
- 1 teaspoon espresso powder
- 1 teaspoon cocoa powder
- 1 teaspoon of vanilla extract
- ¾ cups of heavy cream
- 1 cup of whole milk

- 1/6 cup vanilla protein powder
- 1/6 cup Trüb protein isolate

Lemon protein ice cream was also made by removing the instant espresso and cocoa powders from the ingredients listed above and adding 1 tablespoon of lemon extract instead. The mixture was blended and stored in the freezer for 24 hours. The following day, the frozen mixture was blended in a Ninja Creami Ice Cream Maker. The recipe was developed from ideas in the Ninja Creami Recipe Guide. The team used a mocha flavoredand lemon flavored ice cream with the Trüb to help enhance the flavor in case any bitterness were to remain. While the recipe above was used for the prototype, the recipe for the "white mix" used at Call Hall Dairy Bar will be utilized for the ice cream base, along with the addition of Trüb protein isolate, if this idea is passed and further discussion takes place next semester between Garrett Paulman, co-owner of Manhattan Brewing Company, Anthony Fink, food service manager of Call Hall Dairy Bar, and EcoBrew Design Group. The following information was found to calculate protein in a serving of Call Hall vanilla ice cream with the addition of both Trub protein and vanilla protein powder:

- 1 serving of Call Hall vanilla ice cream = 2/3 cup = 6 grams of protein (*Call Hall Dairy Bar*, 2023).
- 1/6 cup of Simple Truth Vanilla Plant Based Protein Powder = 20 grams of protein.
- 1/6 cup of Trüb protein isolate = 8 teaspoons (1.7 grams of protein per teaspoon of Trüb) = 13.6 grams of protein.
- Total protein in one serving of Call Hall protein ice cream = (6+20+13.6) grams protein = **39.6 grams of protein or approximately 40 grams of protein.**

A cost analysis on ingredients was also done for the ice cream as well, which is found below.

Cost Analysis

EcoBrew Design Group calculated the cost of making one pint of both the lemon and mocha flavored ice cream based on the amount of ingredients listed above. The calculations are as follows:

- 8 oz Philadelphia cream cheese brick = $2.98 = 34 cents per oz
    - 1 tbsp (0.5 fluid oz/1tbsp) = 0.5 fluid oz (34 cents/oz) = **17 cents for cream cheese**
- 10 pound bag of Emperial Sugar = $7.68 = 5 cents per oz
    - 1/3 cup (4.5 dry weight oz/1 cup) = 1.5 dry weight oz (5 cents/oz) = **7.5 cents for sugar**
- 2 oz McCormick Pure Lemon Extract = $4.42 = $2.21 per fluid oz
    - 1 tsp (1 fluid oz/6 tsp) = 1/6 fluid oz ($2.21/fluid oz) = **37 cents for lemon extract**
- 8 oz Baker's Imitation Vanilla Flavor = $1.46 = 18 cents per fluid oz
    - 1 tsp (1 fluid oz/6 tsp) = 1/6 fluid oz (18 cents/fluid oz) = **3 cents for vanilla extract**
- 16 oz Great Value Heavy Whipping Cream = $2.78 = 17 cents per fluid oz

    - ¾ cups (8 fluid oz/1 cup) = 6 fluid oz (17 cents/fluid oz) = **$1.02 for heavy whipping cream**
- 64 oz Great Value Whole Milk = $1.97 = 3 cents per fluid oz
    - 1 cup = 8 fluid oz (3 cents/fluid oz) = **24 cents for whole milk**
- 1 Pound Tub Orgain Organic Plant Protein Powder = $22.44
    - 1 pound = 16 oz
    - $22.44 / 16 oz = $1.40 per oz
    - 1/6 cup (4.5 dry weight oz/1 cup) = 0.75 dry weight oz ($1.40/oz) = **$1.05 for protein powder**
- For the purpose of this report, we will assume that the **Trub protein costs $1.05** since it is the same amount as the other protein powder added.
- 1.94 oz Delallo Instant Espresso Powder = $4.77 = $2.51 per oz
    - 1 tsp (0.18 dry weight oz/1 tsp) = 0.18 dry weight oz ($2.51/oz) = **45 cents for instant espresso powder**
- 8 oz Hershey's Cocoa Powder = $4.44 = 56 cents per oz
    - 1 tsp (0.18 dry weight oz/1 tsp) = 0.18 dry weight oz (56 cents/oz) = **10 cents for cocoa powder**

The total cost of making one pint of lemon Trüb protein ice cream is $4.00. The total cost of making one pint of mocha Trüb protein ice cream is $4.19.

Developing a protein ice cream with Call Hall Dairy Bar will allow for the utilization of the Trüb created during brewing at Manhattan Brewing Company. It will also give MBC another opportunity to collaborate with organizations at Kansas State University.

Analysis of Solutions Considered

When considering final solutions, EcoBrew Design Group focused on determining advantages and disadvantages of the debittering method, each Trüb collection method, and of each Trüb protein byproduct developed.

Advantages of Solutions Considered

Debittering Method

The benefits of the debittering method developed by EcoBrew Design Group include the following:

1. Trüb in its untreated state as is when collected from the brew kettle and fermenter is unpalatable due to its bitterness from the polyphenol compounds. Debittering is necessary to utilize the Trüb in food products.
2. Debittering in the manner described in the methods section allows for a food safe method of debittering Trüb without added chemicals.
3. Other alternatives considered involved adding sodium hydroxide to alter the pH of Trüb and completing a lower number of washes. Through the addition of sodium hydroxide, it adds in a potentially harmful chemical to humans and would need cautionary procedures to ensure that those making the materials and those consuming the end powder are safe.

Dog Treats

The benefits of incorporating the process of making and selling dog treats at Manhattan Brewing Company would include the following:

1. MBC had a goal of interacting with students at Kansas State University through academic opportunities. MBC could be an outreach source for the K-State Pet Food Program, run by Dr. Greg Aldrich, that would give students the opportunity to take the Trüb from the brewery and make dog treats with the methods created by EcoBrew Design Group.
2. While students in the K-State Pet Food Program would get hands-on experience, MBC would also benefit from the lower cost of production from utilizing K-State resources and would in turn create higher revenue from dog treat sales.
3. MBC is a dog friendly establishment. Selling dog treats in-store would not only increase revenue for the brewery but would also provide a product that owners could buy for their dogs when they bring them into MBC.
4. MBC is also an environmentally friendly company. They have run various tests to establish a minimum flowrate through their pumps to prevent cavitation and reduce water usage. With the design this will allow for further reduction in their ecological footprint.

Protein Additive to Ice Cream

The benefits of collaborating with Call Hall Dairy Bar to develop a protein ice cream from Trüb created from brewing at Manhattan Brewing Company would be the following:

1. MBC would have another outreach opportunity with Kansas State University by working with students that work at Call Hall Dairy Bar or who are in the agricultural departments that work with Call Hall Dairy Bar.
2. MBC could make some revenue if profits from the ice cream are split between Call Hall Dairy Bar and Manhattan Brewing Company.
3. The Trüb from MBC would get used and would lower the brewery's environmental impact.

Implementing the Trüb Collection System

The advantages of utilizing the first Trüb collection system designed by EcoBrew Design Group and found in Figure 2 above include the following:

1. The system would fit correctly under the pipe that is discharging the Trüb and water from the brew kettle. It was also fit correctly in the desired location and would eliminate any mess created in the collection process with the hose attachment. The small size would allow for easy movement and storage when not in use.
2. The collection tank would be made of stainless steel giving it durability and the ability to withstand washing without being damaged. Stainless steel would also allow the collection tank to last a very long time with little to no replacements needed except if it is damaged.
3. The ability to insert and remove the mesh layers would allow for easy Trüb transport and easy cleaning.
4. Stainless steel mesh was found at a low price online at about $16 for two pieces of 16 by 50-inch mesh for both the #60 and #120 sizes.
5. Having two layers of mesh in the collection tank would allow for smaller particles to be captured, reducing waste in the water stream.
6. The box was designed to simplify handling and operating. The separation of the box and mesh components enhances overall usability, including retrieval of Trüb, cleaning the mesh, and replacing parts of the collection system when necessary.

Disadvantages of Solutions Considered

Debittering Method

The disadvantages of the debittering method developed by EcoBrew Design Group would include the following:

1. The debittering method described in the methods section involves a high amount of water compared to the Trüb in the water mixture. For one tablespoon of finished Trüb protein powder it takes roughly 7 liters of water, just to debitter it. In terms of environmental sustainability, lowering the water and energy usage of the debittering process should be considered.
2. Additionally, with less washes, less water and energy are needed. Finding a way to lower the number of washes could create savings in energy and water.
3. The Trüb at the end stage is not completely debittered and results change depending on the hops content of the beer the Trüb is collected from.

Dog Treats

The disadvantages of incorporating the process of making and selling dog treats at Manhattan Brewing Company would include the following:

4. Students in the K-State Pet Food Program would need to have a means of transportation to transfer the Trüb from MBC to the appropriate lab for debittering and drying the Trüb as well as making the dog treats.
5. The dog treats would need to be properly stored in a fridge or freezer if they are not sold within 3 days. Fridge and freezer space would be taken up by the dog treats.

Protein Additive to Ice Cream

The disadvantages of collaborating with Call Hall Dairy Bar to develop a protein ice cream from Trub would include the following:

1. While the bitterness of the Trüb is removed in the debittering process, slight bitterness might remain, which could negatively affect the taste of the ice cream product.
2. The addition of vanilla protein powder on top of the Trüb protein affects texture of the ice cream, giving it a grittier bite.
3. MBC might not make as much profit since the product would have to be sold at Call Hall and not at the brewery. Profits might not be split evenly.
4. While the Trüb protein isolate would be locally sourced, the vanilla protein powder would need to be purchased elsewhere if it is used in the final recipe.
5. There would be more legal hoops to jump through since humans would be consuming the ice cream and not just animals.

Implementing the Trüb Collection System

The disadvantages of utilizing the first Trüb collection system designed by EcoBrew Design Group and found in Figure 2 above include the following:

1. EcoBrew Design Group spoke with two different organizations to get quotes for the building of the stainless-steel collection system. The first contact, Dan Tumberger with Trieb Sheet Metal, gave the team a quote of $600 for just the tank alone. The second contact, Eli Sheppard, BAE Department Research Engineering Technologist, gave a quote of $1000. The cost estimate list from Mr. Sheppard can be found in Figure 6 below. While stainless steel is already expensive, the cost of building the tank alone without the other attachments included was found to cost far more than anticipated. The team would need to find alternative ways to build the collection tank to lower the overall cost.

INVOICE

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920 N 17th St
1016 Seaton Hall
Manhattan, KS 66506
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Fax: 785-532-5825

Enter Row number for part(s)	Item #	Description	Units	Rate	Price
1	1	Setup Fee		$ 32.50	$ -
	2	8.5 SqFt of .125 304 Stainless Steel	8.5	$ 39.00	$ 331.50
	3	5.5 SqFt of .25 304 Stainless Steel	5.5	$ 62.50	$ 343.75
	4	Plasma table cut time	1	$ 56.00	$ 56.00
	5	Labor for fabrication and welding time	3	$ 90.00	$ 270.00

Invoice Date:
11/8/2023

Invoice Subtotal $ 1,001.25

TOTAL $ 1,001.25

Bill to: QUOTE Brewing Sr Design

Thank You! Please make checks payable to: Payment due within 30 days of receipt.

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Figure 6: Quote from Eli Sheppard on cost of building the first design of the Trüb collection system.

2. Adding a hose and hose attachment to the Trüb collection tank would add on an additional $100 to the overall cost of building.
3. A main problem with the proposed design is its inability to filter Trüb over a given time. It is extremely inefficient when the filter becomes clogged and requires cleaning multiple times per brew.
4. The current design does not allow for particle size variation without the purchase of new mesh sizes. When designing the method of collection this was overlooked by an assumption that every brew would have the same size particles.

Recommended Solution

EcoBrew Design Group developed a list of recommended solutions for the client, Garrett Paulman, co-owner of Manhattan Brewing Company. The following list explains each recommended solution:

1. Further research and outreach must be done second semester to determine whether a collaboration with either the K-State Pet Food Program or Call Hall Dairy Bar would be more feasible. One collaboration should be in place by the end of the spring semester.
2. The recipe for the protein ice cream will need to be modified to enhance flavor.
3. The debittering process, while successful, could still be further modified to decrease bitterness and overall water use.
4. Recommended ideas for enhancing the design of the Trüb collection system are as follows:
    i. To address its inefficiencies, the design needs to be modified to be able to filter faster and with more variety in particle sizes. There are three pivots to the design that would further increase the projects' ability to meet Garrett’s demands. Firstly, an actual pivot to the design in how it operates could be accomplished by creating a way to clear the screen continuously or periodically while continuing the filtering process. This would be accomplished by incorporating aspects from a plate and press filtration system and a rotary vacuum-drum filter, found in Figures 7 and 8 below. The goal would be to press the Trüb into a cake-like material that would then be rotated to a knife that slices the cake off the screen allowing for a cleaning of the screen as it cycles back to the top. This would allow for faster filtration and Trüb collection.

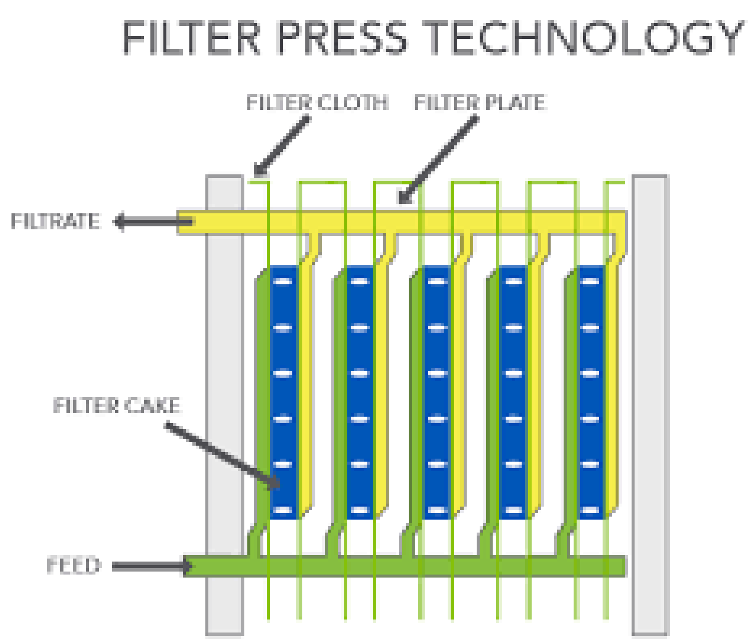

Figure 7: Diagram of a press filter (“Filter Press,” n.d.).

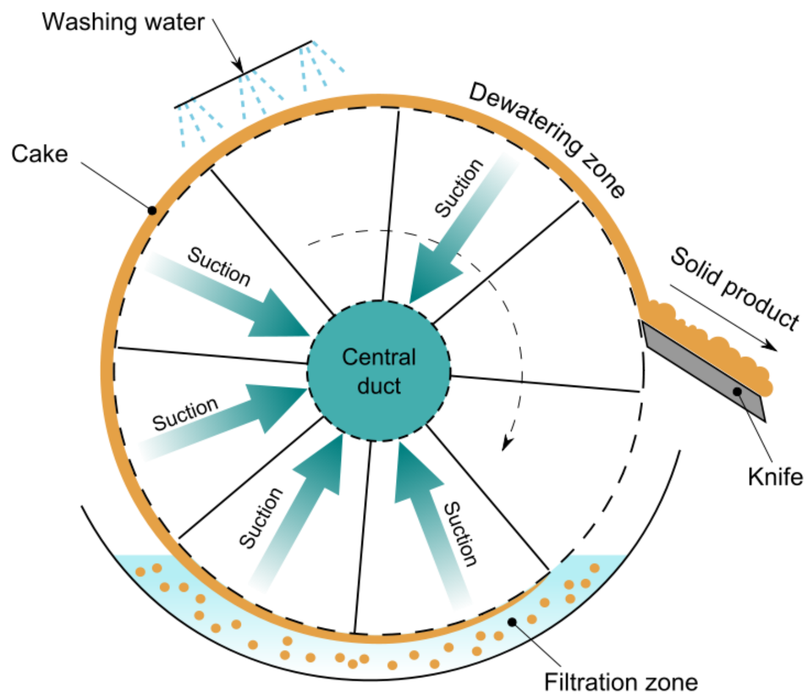

Figure 8: Diagram of a rotary vacuum-drum ("Rotary Vacuum-Drum Filter," 2023).

ii. The second design that can change how this project is viewed is by using a vertical cylindrical filtering tube as seen in Figure 9 below. If sized correctly the idea is that allowing for clogging at the bottom of the cylinder as water passively filters out the sides of the cylinder can increase the efficiency of this design. The upside of this design is that it would be more cost effective and more efficient in filtering as the sedimentation settles to the bottom of the filter.

Figure 9: Cylindrical filter (Cylindrical Filter - Smooth Surface and High Porosity, n.d.).

iii. The last design solution would be to build a settling tank, found in Figure 10. Since this project has a proven concept of a byproduct, it no longer is just focusing on filtering the Trüb. The collection of the material is more important and what is now less important is taking it out of the wastewater. By using a settling tank all the material is captured and taken out of the waste stream. The only constraint with this idea is space in the Manhattan Brewing Company.

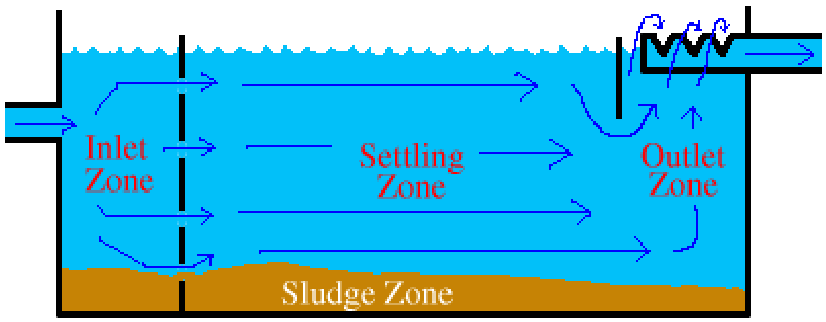

Figure 10: Diagram of settling tank (*Zones of Sedimentation Basin | Water Treatment | Wastewater Treatment | Water Treatment Process & Plant Design,* n.d.).

Conclusions

EcoBrew Design Group worked with Garrett Paulman, co-owner and head brewer of Manhattan Brewing Company, to develop a collection system that would capture the waste solids created during the brewing process, known as Trüb, to prevent waste entering the Manhattan sewage system. With the increasing number of small breweries in Manhattan, Kansas, eliminating the waste entering the city's water system will not only enhance water quality for all of Manhattan's residents, but will also save breweries from having to pay for wastewater treatment once there is an increase of Trüb entering the sewage system. Trüb is a valuable waste product with high nutritional value, especially protein content. Utilizing this protein rich waste to develop a byproduct can provide customers with a plant-based protein source that is also sustainable. Keeping this in mind, EcoBrew Design Group also developed a drying and debittering method to allow for the utilization of the Trüb protein in other food products. The team developed a recipe for dog treats and protein ice cream with the Trüb protein. Developing these byproducts has the potential to benefit Manhattan Brewing Company financially, as the dog treats could be sold in store, and profits could be split among MBC and another collaboration if the ice cream is further enhanced.

The design method of the Trüb collection system did meet Garrett Paulman's needs. However, it can and will be improved next semester. More testing needs to be done to determine which mesh sizes capture the most Trüb without clogging. The other recommendations should also be tested to determine the best action to go forward with the Manhattan Brewing Company. This project has completed the goal of removing Trüb from the wastewater and in the material and size constraints that were given.

As the search for protein sources for the human population continue to become an increasing challenge, developing a process to collect, dry, and utilize Trüb developed during the brewing process at Manhattan Brewing Company proves that protein sources can be found in unusual, but feasible places. While EcoBrew Design Group has only just begun the initial research and design for this process, the team has proven that developing a protein source from Trüb created at breweries can be done. This process not only benefits Manhattan Brewing Company financially, but also benefits customers and people looking to find alternative protein sources.

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Appendix A - Scope of Work

- Project Objectives
  - Develop a process to remove and separate waste streams from the brewing process to reduce the amount of solid waste entering the Manhattan sewage system and create a product from the Trüb.
- Deliverables
  - AutoCAD design and prototype of Trüb collection system
  - Design process of protein extraction and debittering of Trüb
  - Prototypes of products created from Trüb
  - Life cycle assessment comparison of Trüb protein vs. Other plant protein
- Technical Requirements
  - Dr. Wilken will be our advisor
  - Will need access to AutoCAD
  - BEST Lab access
    - Lab safety training
- Milestones
  - Complete background research and observation of brewery facility that will lead to a process design idea.
  - Design the collection and separation process by 10/23/2023.
  - Creation of a prototype of Trüb collection device to use at Manhattan Brewing Company by 10/30/2023.
- Specifications
  - The project will not alter the chemistry or the mechanics of Manhattan Brewing Company brewing process.
  - The project will be based on the current scale of Manhattan Brewing Company.
  - Work on the project will end on 12/10/2023.
  - The collection prototype must be able to capture no less than 22 gallons of Trüb.
  - The final collection system must be made of stainless steel.
- Limits and Exclusions
  - We will only propose a design of the process of creating products from the Trüb and will not implement it into the brewing process.
- Customer
  - Garrett Paulman, Co-Owner of Manhattan Brewing Company

Timeline

- 9/28 & 9/29: Attend Manhattan Brewing Company and observe the brewing process
- 10/2: Midterm Presentation
- 10/4: Create first schematic
- 10/23: based off preliminary research and Manhattan Brewing Company observations, generate multiple collection and separation methods

- 10/30: Complete research to decide on the most feasible option for the collection system
- 11/1: Run first test on Trüb collection using the prototype that is made
- 11/5: Make alterations to design based on testing results
- 11/12: Have final Trüb collection system made
- 11/15: use created process to extract and dry protein from Trüb
- 11/20: Finalize protein extraction process and develop prototypes of products made from Trüb
- 11/30: Final tests and solutions developed and ran
- 12/6: Presentation
- 12/13: Final Report

Appendix B - Full Life Cycle Assessment

Introduction

Plant based protein products provide an alternative protein source that also decreases environmental impacts compared to meat alternatives. However, many plant based protein sources still require an immense amount of land and water to grow and to be processed. Utilizing food-safe solid waste from food production to develop an edible protein source is a necessary step in creating a more sustainable protein production system all across the globe. This Life Cycle Assessment compares the waste solids from brewing beer, known as Trub, as a protein additive to soy protein isolate.

Purpose and Hypothesis

Many food processes produce a waste by-product that could have potential to be used as an alternative protein source. Taking the waste known as Trub from the brew kettle during the brewing process and turning into a powdered protein additive would reduce environmental impacts, especially because it eliminates the process of growing the necessary ingredients that are readily available in the solid waste stream. The purpose of this Life Cycle Assessment is to investigate the environmental benefits of using Trub from beer brewing to create a protein additive versus growing and processing soy for soy protein isolate. The hypothesis is that utilizing Trub to develop a protein additive will have fewer negative effects on the environment compared to growing and processing soy for soy protein isolate.

Investigative Methods

This LCA is used to investigate the environmental impacts of Trub when developed into a protein additive, in this case, a powder similar to soy protein isolate. The reference flow and functional unit are both set at one kilogram of Trub protein compared to one kilogram of soy protein isolate. Data for production of soy protein isolate is used from peer reviewed articles. EcoBrew Design Group has done the calculations for the carbon footprint, land use, water depletion, and energy utilization of Trub with assistance from reliable online articles and sources.

To calculate the carbon footprint of Trub, a food carbon footprint calculator has been used from My Emissions, a leading provider of carbon labeling ("Food Carbon Footprint Calculator," n.d.). My Emissions takes up-to-date data from recognized databases, such as Ecoinvent, to create a Life Cycle Assessment approach of carbon emissions from farming, processing, packaging, and transport of different foods.

When calculating land use, data from other sources is used and analyzed for this LCA. Water depletion and energy utilization data for soy protein isolate is found from other sources, while the water depletion and energy utilization from Trub production is calculated by EcoBrew Design Group using the calculations found in the Results section. It is important to observe that soy protein isolate is 87% protein (Thrane et al., 2017) and Trub is 70% protein (Santos & Martins, 2024).

Product and System Boundaries

This Life Cycle Assessment will specifically focus on Trub produced by Manhattan Brewing Company. The system boundaries will consist of the inputs and outputs of the brew kettle as shown in Figure 7. Data will come from calculations from EcoBrew Design Group. System boundaries for the soy protein isolate include the stages from farming to production as presented in Figure 8. Data for the soy protein isolate will come from LCAs written previously and sited in this report.

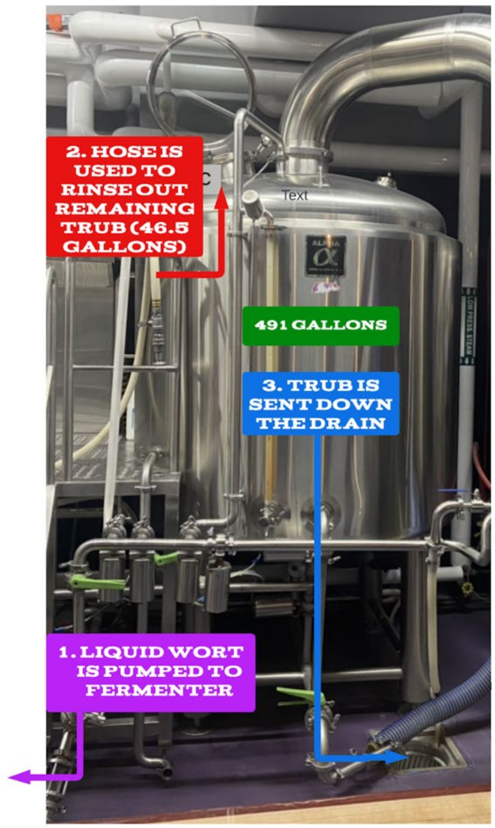

Figure 11: System boundary of Trüb production.

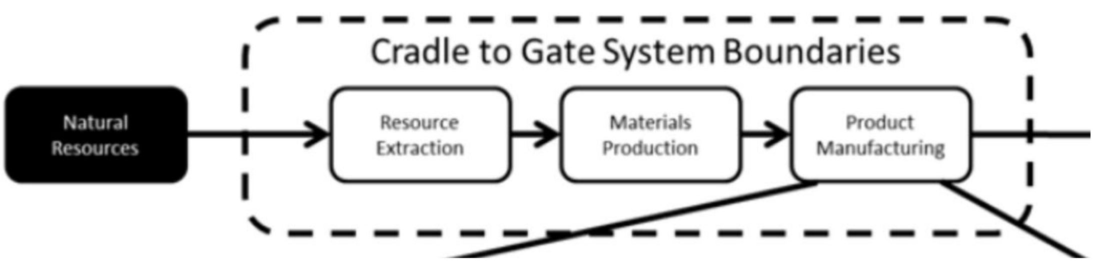

Figure 12: System boundary of soy protein isolate (ISSST et al., 2015).

Results

Carbon Footprint

To test the accuracy of the My Emissions database calculator, data on the carbon footprint of soy protein isolate was researched in other sources to compare results. The consequential carbon footprint was found to be 2 kg CO2e/kg protein in Chapter 2 of Sustainable Protein Sources (Thrane et al., 2017). When soy was selected in the My Emissions database, it also calculated 2 kg CO2e/kg protein. The attributional carbon footprint of soy protein isolate was found to be 6 kg CO2e/kg protein (Thrane et al., 2017). The carbon footprint of Trub was calculated by selecting beer in the database, since Trub is the waste product of beer brewing. The result was found to be 0.768 kg CO2e/kg protein ("Food Carbon Footprint Calculator," n.d.). The consequential carbon footprint of Trub protein is far less than that of the soy protein isolate.

Land Use

Since the waste streams from beer brewing, called Trub, are extracted directly from the brew kettle at a brewing location, no excess land is taken to grow or produce it, making its consequential land use 0 square meters a year/kg protein. However, growing soy for soy protein isolate does involve a significant amount of land use, which was found to be 8 square meters a year/kg protein for consequential land use and 6 square meters a year/kg protein for attributional land use (Thrane et al., 2017).

Water Depletion

When calculating the water use during the brewing process, the brew kettle itself holds 410 gallons, but when considering the excess water entering from the other tanks and the water used for cleaning and rinsing, the total water in the brew kettle reaches 491 gallons, and total use rises to 537.5 gallons/batch, which is what was used in calculations for water depletion found below. Other calculations found in the overall report use 410 gallons of water based off of the brew kettle alone. The calculations for water depletion from Trub production can be found below:

3% of each 491-gallon batch is Trub:
- 0.03(491 gallons) = 14.73 gallons of Trub
- 14.73 gallons of Trub (3.7854 kg/1 gallon) = 55.76 kg Trub/batch

70% of Trub is protein:
- 0.70(55.76 kg Trub/batch) = 39.03 kg protein/batch

Water depletion from Trub:
- 537.5 gallons of water/batch (3.7854 L/1 gallon) = 2034.65 L water/batch
- 2034.65 L water/39.03 kg protein = **52.13 L water/kg protein**

Water depletion from Trub is calculated to be 52.13 L water/kg protein. While this value is higher than the consequential water depletion of soy protein isolate, which is found to be 38 L water/ kg protein (Thrane et al., 2017), it is much lower than the attributional water depletion of soy protein isolate, which is 205 L water/kg protein (Thrane et al., 2017). This is likely because soy uses more water to be grown initially but might use less when it comes to processing. Trub production requires no extra water for growth since it is a waste product.

Energy Utilization

In this LCA, it is assumed that the value for energy utilization for the drying process is about the same because the drying process for both Trub protein and soy protein isolate is similar if not identical. When considering transportation of soy protein in the United States, once the soybeans are grown, they must be transported to a new location for processing. Transportation occurs via diesel truck and railway freight to get soymeal to the manufacturing facility for creating soy protein isolate (ISSST et al, 2020). Typical transportation distances for soy are 20 to 40 miles on highway in a diesel truck and 900 miles on railway in a freight car (ISSST et al., 2020). When converted to ton-kilometers, this means 0.032 ton-kilometers of transportation are by diesel truck per kg of soy protein isolate and 1.448 ton-kilometers of transportation are by freight rail for a kg of soy protein isolate (ISSST et al., 2020). Comparing this information to Trub from Manhattan Brewing Company, the only transport of the Trub is from Manhattan Brewing Company to the Kansas State University food processing lab and back, which is approximately 3.12 miles, or 5.02 kilometers. After calculating, this would be 0.00502 ton-kilometers for driving per kg of Trub protein. The lower mileage leads to lower fuel emissions.

Discussion

While soy protein isolate is a nutritionally dense meat protein alternative, it has more negative environmental impacts when compared to the waste solids from beer brewing, known as Trub. Trub has lower impacts in all the following categories: carbon footprint, land use, water depletion, and energy utilization. The hypothesis is supported by the evidence of this Life Cycle Assessment. Utilization of waste solids from certain food safe processes, like brewing beer, eliminates the process of growing the necessary protein ingredients that are already available in the solid waste stream. Trub has the potential to be a new protein additive with its locality in any state that inhabits a brewery, making it easily accessible for food transportation and production.