Manufacturing Design and Economic Analysis of Powdered Alcohol Production

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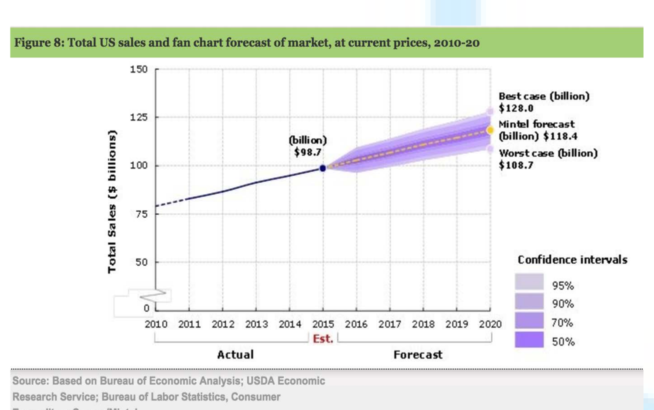
Abstract

The capstone project is focused on developing a student run business that provides consumers with a product, in this case a dissolvable capsule containing alcoholic powder. A preliminary market analysis revealed that the alcohol market is staggering at around $97 billion, and provides a good entrance opportunity ("American Lifestyles: Balance or Bust," 2016). Manufacturing specifications for powderizing alcohol were designed based on the information gathered in the literature review; most notably was a 1974 General Food Corporation patent concerning dry alcohol. To produce the final product, six unit operations were required; a mixer, drum dryer, miller, mixer, spin coater, and an automatic capsuling machine. The mixer utilized a horizontal stirring process to homogeneously mix maltodextrin and water. Once thoroughly mixed, a drum dryer is used to fix the mixture into a crystalline-amorphous solid. A hammer mill was then used to ensure the mixture was broken down into homogenous particle size and density that sufficiently bulked the maltodextrin to increase uptake of alcohol. Once the desired bulk density and size was obtained, a horizontal mixer combined the amorphous maltodextrin with a 90% ethanol solution. To allow the ethanol/maltodextrin to be shelf-stable, the mixture was coated with corn zein, preventing the alcohol from dissolving the capsule. Finally, the mixture is placed within a '000' sized capsule and blister packaged. Once the necessary unit operations and their functions were determined, the team began designing the sizing and operational parameters, as well as economic analyses, based on power requirements needed to meet the set throughput. Sizing was determined by comparing dimensions used in industry as well as using estimations from *Plant Design and Economics for Chemical Engineers*. After the unit operations had been designated sizes, operational parameters, and throughputs, it was possible to calculate the energy balances. These energy balances lead estimations of the cost of operation in terms of required energy and the cost of ingredients per batch. The costs of the machinery was also recorded by calling equipment manufacturers and using methods in *Plant Design and Economics for Chemical Engineers*. It will cost $1,503,600 to begin operation, and then cost $8,634.16 per batch(Appendix B, Table 2). The throughput is roughly 230,000 capsules a batch, and are expected to be sold for around $1 a piece.

Market Analysis



Marketing information was gathered from the database Mintel, which revealed both quantitative and qualitative data. From surveys, it was concluded that 82% of Millennials like to experiment with novel drinks. The trend in the market is steady growth; alcohol is a consistent marketplace and is also being bolstered as more and more Millennials come of drinking age. In 2015, the total sales for alcohol outside of the home was $98.7 billion, and is expected to grow to $128 billion by the year 2020 ("American Lifestyles: Balance or Bust," 2015). If 6-PAC was able to capture just 0.1% of the market it would secure roughly $9.8 million in revenue a year

Economic Analysis

To determine economic success in the long run, 6-PAC has ran extensive tests to calculate the Total Cost of Investment, Total Product Cost, and Return on Investment. Total Cost of Investment incorporates all costs of equipment purchase, installation, building parameters, as well as legal expenses and even yard improvements. Total Product Cost takes into account costs related to raw material purchases, employee wages, standard utilities, and depreciation. Finally, Return on Investment was calculated based on the assumption that our plant will operate at 50% capacity during its first year, 90% capacity its second year, and 100% capacity for the third year and after. This is due to consumers becoming more familiar with our product as the years pass.

Total Cost of Investment
$1.335 million

Total Product Cost
$11.52 million

Return on Investment
1st year: $2 million
2nd year: $7.5 million
3rd and after: $8.8 million

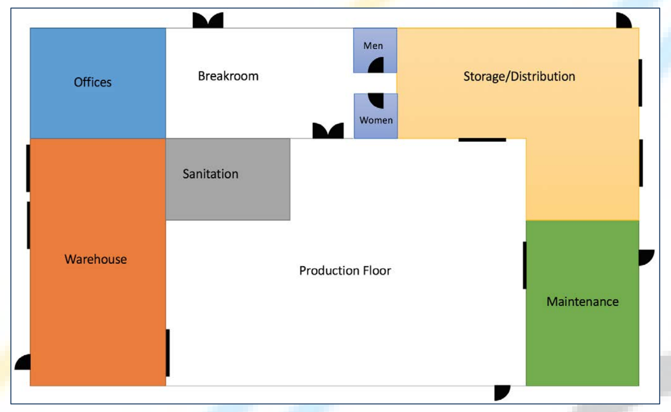
Discounted Cash Flow
For interest rate of 15%:
$108.3 million

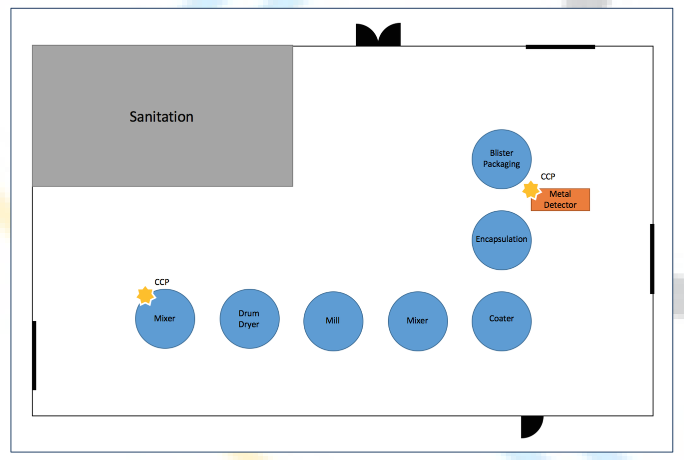
Literature Review

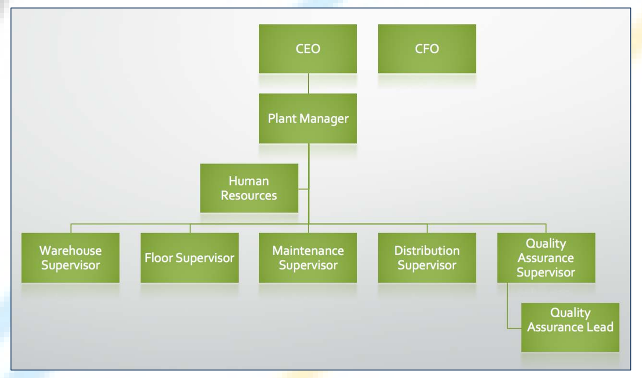
The general procedure that was followed for powderizing alcohol was patented by General Foods Corporation in the 1970s. In the patent, General Foods describes the necessity of proper bulking of maltodextrin to facilitate the encapsulation of ethanol. Maltodextrin was mixed in equal parts with water and then cast as a film and drum dried to a moisture content between 2 and 6%. The maltodextrin was then milled and sieved to pass through sieve size 20 and sit on top of sieve size 60. These processing steps create an amorphous maltodextrin molecule with a bulk density from 0.05 to 0.3 g/cubic cm, perfect for the uptake of alcohol. Maltodextrin and ethanol were then blended together until a dry powder was achieved. The patent claims it can hold 60% alcohol per molecule. Manufacturing design and considerations were extrapolated from this information. Individual unit operations for large scale manufacturing were researched in order to understand common methods to model system behavior.

Manufacturing Process

Raw materials will be unloaded at the warehouse site and move into production. The production floor will run through the necessary unit operations to produce our final product of encapsulated alcohol. The first mixing phase is significantly prone to microorganism growth, so it must be under heavy scrutiny throughout production. Another quality control area is the stage between encapsulation and blister packaging. Prior to packaging, the capsule must be screened by a metal detector to ensure that no heavy metals are contaminating our product. Once the product is approved for consumption, it will be held in storage until distributed to vendors.



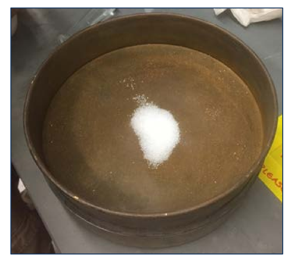


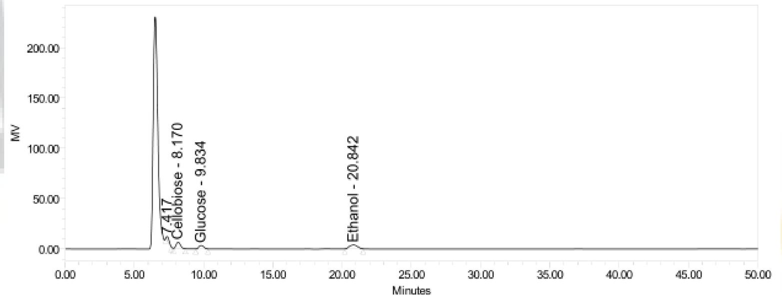


Laboratory Procedure

Powderizing Alcohol

1. Dissolve equal parts of maltodextrin(DE 5-15) in DI water, mix 15 minutes, or until a homogenous solution is achieved.
2. Pour a thin amount of the solution into a glass petri dish to simulate casting a film.
3. Dry the film to a moisture content of 2-6% by placing it on a hotplate at 65 C.
4. Mortar and pestle the dried film so that it passes through a sieve size 20 and sits on top of sieve size 60
5. Prepare an aqueous solution of 90% ethanol.
6. Mix the bulked maltodextrin particles with liquid ethanol drop-wise while maintaining a dry and flowable powder.
7. Vacuum seal the alcohol powder to prevent the hygroscopic properties and evaporation



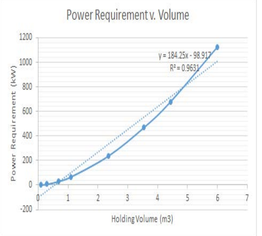


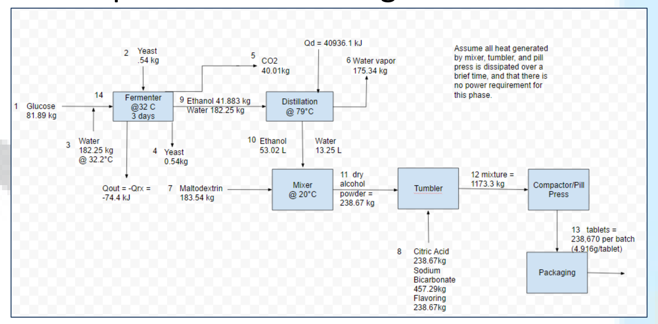
Testing for Ethanol Present

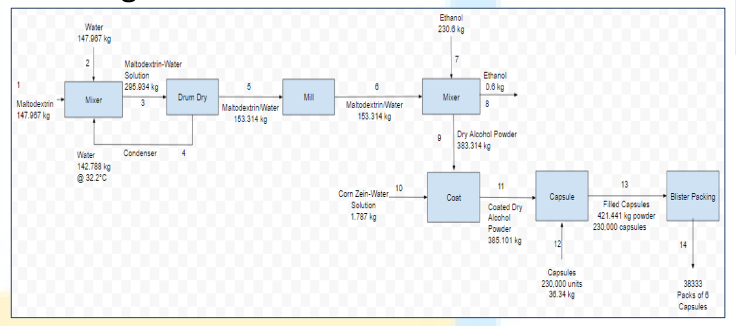
1. Theoretically determine the required mass of alcohol-maltodextrin mixture needed to create a 1g ethanol/ 1L water solution. Scale the ratio to grams of ethanol over 1.5 mL of water.
2. Place mixture into a microcentrifuge tube
3. Vortex for approximately 1 minute or until no solids remain
4. Centrifuge the solution at 16,000 rpm for 5 minutes
5. Draw 1.5 mL of the resulting supernatant out of the microcentrifuge and run through a .2 µm filter
6. Place at least 1 mL of filtered solution into the HPLC vial
7. Cap and label the vial
8. Run HPLC

Final Design

For this capstone project, the initial prototype design that was modeled stemmed from Ooho, a small company's project that creates clear membranes out of seaweed that contains water on the inside. The goal was to expand on this topic by trying to design a type of membrane that would be able to withstand the chemical degradation properties of alcohol. It was quickly realized that the protein's structure in these membranes would never hold up for a quality product to hit the market. From here the design transitioned into trying to convert alcohol into a powder and compressing that powder into a tablet. This initial design incorporated fermenting and distilling alcohol before even considering the actual goal of the project. After analyzing this iteration, it was found that there was too little focus on converting the alcohol to a powder and ultimately decided to eliminate the production of alcohol from the process. The next iteration gave us the ability to put more emphasis on how to obtain a powdered alcohol. Finding a few patents, the design changed to mix alcohol and maltodextrin. Next, the mixture was sent to a spray dryer in order to create the alcohol powder desired. There were a lot of issues when trying to design the spray dryer using alcohol. There arose many safety concerns with the volatility of alcohol, as well as there being limited literature reviews. After the conclusion that the spray dryer wasn't the optimal choice for the design, a reference back to the General Foods patent occurred and the design was modified to utilizing a drum dryer. This proved to be much more efficient for the process. As experimentation began, it was learned that pressing the powder into a tablet would lose alcohol as it would be wringed out like a towel under compression. This led to changing the product from a tablet to a capsule. Because of the product being in a capsule, the addition of a spin coater was implemented in order to defend against the alcohol powder eating away at our capsules and avoiding alcohol loss due to tableting.







Alternatives and Impact

Society is impacted by a new fun, convenient, and creative choice on how to enjoy an alcoholic beverage. The product introduces a new level on consumer convenience that is unmatched compared to hauling around heavy bottles, and also greatly reduces the potential of introducing waste. The ethical impact of this product is that it could have the potential to be abused, as all alcohol does. There are currently laws in place that prevent the large scale manufacturing of powdered alcohol, implying the severity of ethical, global, and societal considerations.

Another alternative solution that deserves mentioning was discovered in the 1974 General Foods patent. Here they stated that spray drying the maltodextrin-water mixture would be possible. With this, the particle properties could be more easily controlled by changing the conditions of the spray dryer. Moving forward with our possible alternatives, we would need to make sure that our process is meeting cGMP standards. We would also have to prepare our facilities and processes to meet all FDA regulations, as our product is considered to be a part of the food and beverage industry.

A further manufacturing option that could be explored is compressing the powdered alcohol into an effervescent tablet. This would require the addition of effervescent excipients, as well as the use of a tablet compressor.

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