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 delectable 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 powdering alcohol were designed based on what was 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 packing machine. The mixer utilized a horizontal stirring process to homogeneously mix maltodextrin and water. Once thoroughly mixed, a drum dryer was used to fix the mixture into a crystalline-amorphous solid. A hammer mill was then used to ensure that 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 zinc, preventing the alcohol from dissolving in the capsule. Finally, the mixture is placed within a 0.01” sized capsule and blister packaged. Once the necessary unit operations and their functions were determined, the team began designing the site and operational parameters, as well as economic analysis, based on power requirements needed to meet the 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 throughput, 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 $1,903,600 to begin operation, and then $8,634.16 per batch (Appendix B, Table 2). The throughput is roughly 23,000 capsules a batch, and are expected to sell for around $1 a piece.

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 flow will run through the necessary unit operations to produce our final product of encapsulated alcohol. The first mixing phase is significant to the project as 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.

Market Analysis

Marketing information was gathered from the database Mintel, which revealed both quantitative and qualitative data. From surveys, it was concluded that there is a high demand for alcohol, both in drinks and in novel drinks. The trend in the market is steady growth; alcohol is a consistent marketplace and is an easy target for consumers to fall back on. 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 run 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 labor costs. To determine the economic success of our project, we incorporated all 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 during its third 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 | $1.35 million |
| Return on Investment | $1.35 million |
| 1st year: $2 million | Discounted Cash Flow | For interest rate of 15% |
| 2nd year: $1.5 million | $108.3 million |
| 3rd and after: $8.8 million | |

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.

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 be used in the chemical desorption properties of alcohol. I 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 time 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 wrung 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 tabbing.

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

Acknowledgements

- Dr. Olsen ², Professor
- Troy Tanner ¹, Masters Candidate
- Dr. Carajal ¹, Researcher
- Dr. Mosher ², Professor

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