Non-Alcoholic Beer Synthesis: Alcohol Extraction and Repurposing

(Technical Paper)

Non-Alcoholic Beverages: Rehab or Relapse

(STS Paper)

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Christopher Griffis

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Technical Project Team Members

Sara Reisz

Patrick Salvanera

Gloria Zhao

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Signature _____ _____ Date _10/28/22___
Christopher Griffis

Approved _____ Date _____

Technical Advisor: Eric W. Anderson, M.S., Department Chemical Engineering

Approved _____ Date _____

STS Advisor: Richard D. Jacques, Ph.D., Department of Engineering & Society

Introduction

Non-alcoholic (NA) and alcohol-free beverage sales have consistently increased in the past couple of years. Currently, these beverages have around a 7% Compound Annual Growth Rate (CAGR) (Dingwall, 2022). This comes as the new generation seeks healthier alternatives to alcoholic products. These beverages have less calories than their alcoholic alternatives. Still, other consumers still want the alcoholic taste/effects but are seeking out less unhealthy alternatives. For example, hard seltzers are lower in sugars and calories than alternatives such as beer (Taylor, 2022). This market has a CAGR of 18.6 %, but may start to experiences slower growth with time ("Hard seltzer," 2022). Another healthier alternative to beer is hard kombucha. These beverages still possess the probiotic benefits of kombucha while containing around the same alcohol content as beer. This is an incredibly new market with a large potential for growth. Estimates indicate the market could increase sevenfold from 2021 to 2030 ("Hard kombucha," 2022). Undeniably, both non-alcoholic beverages and healthier beer alternatives represent a market which has seen and expects to continue seeing a surge in growth.

The Technical Capstone project revolves around designing and optimizing a system which incorporates two relatively untapped markets: non-alcoholic beverages (NA beer) and healthier beer alternatives (hard kombucha). This system will create beer, extract the alcohol from beer, and inject the alcohol into kombucha, creating non-alcoholic beer and hard kombucha in one process. The crux of this process design experiment is the method of alcohol extraction. In the case of this Capstone project, reverse osmosis (RO) will be utilized for the effective extraction of alcohol without losing the flavor of the beer. The end goal is to determine economic and logistical viability for the incorporation of such a process into a mid-sized brewing company.

For the STS research project, a broader topic of alcoholism will be studied. More specifically, non-alcoholic beer carries around an association of being useful for alcoholism recovery. This comes from the beer allowing an alcohol abuser to avoid the negative effects of alcohol on their day-to-day lives. However, there is almost a 50/50 split line with another group claiming that NA beer can trigger relapse. Relapse may occur due to the aroma and taste of this beverage which could cause the consumer to seek alcoholic beverages. The correct "answer" may be either one of these sides (or a combination of both). This project hopes to investigate and clear up the confusion surrounding this debate. Simply stated, if this technical project seeks to create a non-alcoholic beer product with an overall beneficial purpose, then it is vital to investigate the implications surrounding the consumption of said product.

Technical Topic

The non-alcoholic beer and hard kombucha industries are two rapidly growing markets. Non-alcoholic beer sales have "climbed ninety percent over the last decade" (Smith, 2022). Additionally, over the next seven years, hard kombucha sales are expected to have a compound annual growth rate of 23.76% (Maximize Market Research, 2023). Focusing on non-alcoholic beverages, many people are leaning towards them as a healthier alternative to alcoholic ones: non-alcoholic beer contains fewer calories and sugars than alcoholic beer (Maximize Market Research, 2022) and has been shown to help "maintain blood electrolyte homeostasis during exercise" (Castro-Sepulveda et al., 2016). Current target demographics for non-alcoholic beer include those who want to reduce alcohol intake, those who abstain from alcohol for religious or health reasons, and those who enjoy the ritual of drinking but do not want to experience the effects of alcohol. Despite the market growth and demonstrated interest, however, non-alcoholic drinks are currently not prevalent or available mainstream due to it being an expensive process to

make (Salanta et al., 2020). While the process technology has been researched, it has not been implemented yet on a widespread, commercial scale because the process is not profitable.

To address the potentially lucrative non-alcoholic beverage market, a number of dealcoholization methods have been developed in recent years. Two such methods include thermal and membrane separation. Thermal separation involves vacuum distillation to separate the alcohol from the beverage based on differences in their volatilities, whereas membrane separation, most notably reverse osmosis (RO) membrane filtration, involves pushing a beverage across a semipermeable membrane and separating water and ethanol from the rest of the beverage based on particle size selectivity (Jackowski & Trusek, 2018). However, there is a fundamental problem with these methods concerning their large-scale implementation feasibility. These dealcoholization methods, while valid processes, are too expensive by themselves to be implemented on a commercial scale. Companies currently trying to produce non-alcoholic drinks view the process as a standalone entity by making them exclusively, therefore failing to consider the profitability of catering to two separate audiences: people who want alcoholic drinks and people who want non-alcoholic drinks. If the current approach by these companies continues to be taken, beverage companies will continue to fail at making profitable non-alcoholic beverages and will continue to ignore the demographics of people interested in novel non-alcoholic and alcoholic beverages, leading to wasted potential areas for profit.

The aim of this technical project is to avoid this scale-up feasibility obstacle by designing an industrial-scale manufacturing process that produces two beverages — a non-alcoholic beer and an alcoholic kombucha — to make this process commercially profitable. The first part of the process will involve brewing beer and converting it to non-alcoholic beer via reverse osmosis. The creation of beer will follow standard brewing procedures, in which malt kernels are milled,

water is added, enzymes are activated via heat, and yeast is added to convert sugars to ethanol during fermentation (Grover et al., 2022). Then, reverse osmosis membrane filtration will separate the ethanol from the beverage. The second part of the process will involve fermenting kombucha and injecting it with the removed ethanol from the beer. The fermentation of kombucha involves steeping tea, adding sugar and symbiotic culture of bacteria and yeast (SCOBY), removing SCOBY after fermentation, and carbonation (Wang et al., 2022); after which ethanol will be infused in the final beverage.

Initial design data for the manufacturing process will be obtained from research articles pertaining to the non-alcoholic beer and kombucha processes. We will use computational tools, such as Aspen Plus and Matlab, to generate, test, and monitor unit operation for process optimization. We will be reaching out to Geoffrey Geise, associate professor at the University of Virginia who specializes in membrane research, to inform our membrane selection, assist in design specifications, and operate modeling software to design and perform analysis on the filtration membrane system. Lastly, we will be using hand calculations and Microsoft Excel to solve material balances and compare results with simulation software. Additionally, we will reach out to and visit Three Notch'd, a specialty local brewing company, and conduct an interview to gain insights into commercial brewing design.

An iterative process will be used to optimize our process: each iteration of the system design will provide design data for the next. To demonstrate the value of the system, we will perform an extensive economic analysis on our end design to determine if our process is commercially viable.

STS Discussion

Alcoholism or Alcohol use disorder (AUD) is a condition described as "an impaired ability to stop or control alcohol use despite adverse social, occupational, or health consequences" ("Understanding," 2020). This can come in a variety of forms with some signs (alcohol craving) being more obvious than others (increased alcohol tolerance). Surprisingly, a large chunk of the population has some form of AUD. One research paper found that 11.8% of people meet the requirements for having AUD with 13.8% of those people experiencing severe AUD (Nehring et al., 2023). Those recovering from AUD struggle with their greatest obstacles known as triggers. Triggers are negative reactions brought upon by reminders (odors, people, places) of previous negative experiences ("How," n.d.). These triggers can cause someone to unhealthily cope or relapse. NA beer may meet the criteria for being a trigger in both odor and taste. Thus, it is important to analyze the potential for NA beer being a trigger and compare that to the potential for NA beer being a positive coping method for recovery.

There is no doubt that NA beer can function as a relapse trigger. However, anything can be a trigger, so it is necessary to determine the magnitude of effect NA beer has. One literature review collated 10 studies on alcoholism and NA beer and produced a few conclusions. The first conclusion was that drinking NA beer increased alcohol craving; the craving was strongly correlated to alcohol dependency, where people with more severe AUD were more likely to crave alcohol after drinking NA beer (Caballeria et al., 2022). This result demonstrates how the severity of AUD helps determine the potential for relapse. Part of this correlation may come from another conclusion of the study which was that "heavy drinkers tended to use NoLo [no-alcohol or low-alcohol] drinks on top of the existing consumption of alcoholic drinks" (Caballeria et al., 2022). Heavy drinkers who consume these NA beverages when already drunk

may have an increased chance of associating these beverages with alcohol consumption. This may then increase the chance for someone to relapse. Such messaging can be found in many addiction center websites (Nichols, 2023). Aside from the odor and taste, these centers claim that non-alcoholic beverages still have alcohol (0.5%) which may "pave the way to rationalize having a stronger drink" ("The Dangers," 2021). One small mistake can cause weeks', months', or years' worth of setback on the path to recovery. As such, many addiction centers do not see value in the advocacy for NA beverages as a path to recovery. Regardless, the relationship between NA beer consumption and increased potential for relapse unmistakably exists.

Though the research and advocacy against non-alcoholic beer consumption for alcoholics has footing, there are still other research papers and personal testimonials that seem to defy the anti-consumption messaging. One research paper investigated the effect non-alcoholic beverages had on total alcohol consumption. In it, they found that providing NA beverages caused participants to consume less total alcohol, an effect which lasted even 8 weeks after testing (Yoshimoto et al., 2023). This provides the promising conclusion that NA beer may help heavy drinkers reduce their alcohol consumption. The method of easing off of alcohol is best because the alternative, "Cold Turkey" (completely cutting off all alcohol), can bring about harmful and potentially fatal side effects ("Dangers," 2023). The potential for NA beer to be a recovery aid can be seen in a plethora of testimonials. On the social news website Reddit, many users have shared their experiences with NA beer as a recovery method. On one such post, a user described how NA beer has been helping them stay sober with over a hundred comments each with a user describing their own positive experience with consuming NA beer for recovery (Budget-Coffee2895, 2021). These users, all with varying ranges of AUD, found a path toward recovery. Yet, a major issue with NA beer consumption is the stigma surrounding it. One person suffering

from AUD described their experience trying to cut back on alcohol by drinking NA beer at a concert. Their friends found out this person was not drinking actual alcohol, so they decided to drink alcohol to "avoid the scrutiny of being sober" (Browne, 2021). A potential recovery method such as drinking NA beer should not bring about negative societal reactions. One of the greatest aspects in recovery is having a supportive network. Though the stigma of this beverage is disappearing with time, it still exists and hinders the potential recovery process that NA beer has been demonstrated to provide to some people.

Both sides of the argument have research-based and experience-based justifications. As such, the "answer" to the question of NA beer being a useful AUD recovery method seems to be much more complicated than the black and white arguments that are typically displayed surrounding the matter. More investigation is required into the matter. The plan is to compile additional research data surrounding the topic in order to draw upon a more specific conclusion. This includes the gathering of additional sociological and psychological research papers as well as testimonials and experiences. In the end, it is crucial to gain a better understanding of the effect NA beer has on relapse in order to view the technical project through a more societal lens.

Conclusion

As the culture surrounding alcohol consumption morphs with time, the popularity of non-alcoholic and alternative alcohol beverages seems to only be on the rise. A process which capitalizes on both markets appears to be a fruitful response to the trends currently seen. More specifically, an optimized process which extracts the alcohol from beer and transfers it into kombucha initially appears to be a prospective project that may have economical viability. This viability only continues to improve as technological advances in membrane separation are quickly occurring. Of course, money is not the only important factor. A company needs to

produce a product which has positive societal outcomes. As such, the effect of NA beverages on alcoholism is an extremely important topic to research. In total, this project should provide both positive societal and economic benefits.

Still, alcohol separation is an incredibly novel aspect of brewing. Many of the available processes are proprietary and kept secret by these brewing companies. Additionally, alternative methods may be cheaper. For example, some companies use experimental yeasts that inhibit alcohol production. Other companies use vacuum distillation to remove the alcohol from the beer. Both of these processes have their own advantages and disadvantages. In the same context, consumption of NA beer has its own advantages and disadvantages. It may help or hurt depending on the person, which may make an alternative such as a prescribed drug a seemingly better option. In the end, success can only be determined through further research.

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