Purgatory Beer Company's Fiero Coconut Rum Porter: Grain Investigation

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Abstract

This project, completed at Worcester Polytechnic Institute in collaboration with Purgatory Beer Company, investigates the effect of grain size distribution on the flavor of Fiero Coconut Rum Porter. Purgatory Beer Company has been having problems creating a consistently good-tasting version of their porter; this project team chose to research how grains influenced this inconsistency. The team analyzed the different grain sizes offered by the grain supplier and conducted home brew experiments to determine which grain size was optimal for creating the desired beer. The team also tested two variations of coconut in the flavor process, and offered recommendations on grain size and type of coconut to Purgatory Beer Company.

Executive Summary

In the past decade, over 4000 microbreweries have materialized all over the United States.[1] The increasing popularity of these breweries is due to their local charm and innovative products. Craft brewers typically experiment with their recipes and processes to achieve unique flavors of different beers. Purgatory Beer Company is a "nano brewery" that opened in 2017 in Northbridge, MA. The owners, Brian Distephano and Kevin Mulvehill, started as home brewers who eventually turned their shared passion into a business and now create beers that their customers love.[2] One specific crowd favorite is a twist on a classic American porter called the Fiero Coconut Rum Porter. It has "the traditional smoothness of [a] porter with hints of chocolate and coffee and a nice hit of coconut on the back end." Purgatory Beer Company has been having problems achieving a consistent desired flavor in their Fiero Coconut Rum Porter. The project team decided to investigate how grains could play a role in this problem.

Methods The purpose of this project was to research the effect that grain size distribution had on the flavor of this porter. To accomplish this goal, the team recognized four main objectives:

1. Identify the inconsistencies in grains used over time.
2. Determine how size distribution of grains affects wort.
3. Determine how wort and flavorings affect beer.
4. Develop recommendations on grain usage and the process for Fiero Coconut Rum Porter.

In order to fulfill these objectives, the team:

1. Interviewed co-owner, Brian Distefano, about any changes in the source, dosing, or size distribution of the grains over time.
2. Completed sieve tray analysis to quantify size distributions of the grains, ran controlled home brew experiments to create wort samples, and tested the worts for different properties in order to create trends with respect to varying grain size.
3. Fermented the home-brewed wort samples, flavored the samples by using unsulfured or untreated coconut, and tested the beers for different properties as well as taste in order to draw conclusions about a preferred grain size and coconut type.
4. Analyzed the results and created this report outlining which grain size and type of coconut gave the best flavored beer, as well as additional process improvements.

Findings The team determined relationships between the three grain size distributions offered by BSG and the carbohydrate content, alcohol content, acidity, composition, color, and taste of their home-brewed products.

No Correlation Between Grain Size and Flavor

According to the four taste testers, there was no difference in flavor between the beers made with coarse, medium, and fine grains. However, the taste testers did notice a difference in thickness and strength of the beers, and their thoughts directly aligned with the trends in data gathered on the carbohydrate and alcohol contents.

Similarities in Medium and Coarse Grains

The grain size distributions of the pale malts, which make up the majority of the porter's recipe, were very similar between the medium and coarse crushed grains. In addition, the medium and coarse beers had similar values (within 3% of each other) for carbohydrate content, alcohol content, and color (SRM). It was concluded that the medium and coarse grains resulted in a very similar beer.

Unsulfured Coconut Preferred

It was found from the hedonistic taste testing that the beers flavored with unsulfured coconut were liked the most. One of the four testers did not like any of the beers flavored with untreated coconut.

Recommendations The team believes that Purgatory Beer Company has the freedom to use either the medium or coarse grain size offered by BSG for their Fiero Coconut Rum Porter, as there were no significant differences in flavor or other tested properties between the beers made from these two grain sizes. To improve the overall brewing process, the team recommends using the coarse grain because it will not be as susceptible to clogging and will create ease of filtration. Based on the limited taste testing in regards to coconut flavor, the team recommends using unsulfured coconut flakes in the Fiero Coconut Rum Porter.

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1. Introduction

It is important for craft brewers and other commercial beer producers to create a beer that appeals to a wide audience, since over forty percent of Americans consider beer their alcoholic drink of choice.[3] This project will focus on porter, which is a dark beer that has flavors and aromas of chocolate and coffee.[4] Porters are thought to have been derived from a mixture of old, new, and mild beers,[5] and the key characteristic that defines a porter is its roasted maltiness.[6] This project works with Purgatory Beer Company's Fiero Coconut Rum Porter, which is described by the sponsor, Brian Distephano, as a beer "with the traditional smoothness of [a] porter with hints of chocolate and coffee and a nice hit of coconut on the back end." This porter is an American porter made with different malts, including chocolate, crystal, and caramel, to add a deep flavor profile to the porter. Due to popular demand, Purgatory Beer Company loves making this porter, but they have been having difficulties with achieving a consistently flavored beer and do not know the cause.

The project team recognized many variables within the brewing process that could affect the flavor. The major factors identified were the process conditions (temperature and time), the grains, the yeast, and the flavorings (coconut, rum, and cacao) along with possible side reactions. The team chose to investigate the source, dosing, and size distribution of the grains. It was found that the size distribution was the only factor inconsistent with regards to grain usage in this beer.

The goal of this project was to determine how grain size distribution affected the flavor of Purgatory Beer Company's Fiero Coconut Rum Porter. This project was split into four main objectives that were used in order to accomplish the goal. The team: (1) identified the inconsistencies in grains used over time, (2) determined how size distribution of grains affected wort, (3) determined how wort and flavorings affected beer, and (4) developed recommendations on grain usage and the process for Fiero Coconut Rum Porter.

The project was completed by running controlled home brew experiments with various grain sizes and testing different chemical and physical properties to determine which beer had the optimal flavor. The team used the results from their testing, along with research, to make a list of recommendations to give to Purgatory Beer Company. These recommendations outlined what effect grain size had on the flavor of the porter as well as possible improvements that Purgatory could make to their brewing process.

2. Background

Beer is considered the alcohol drink of choice by over forty percent of Americans, and of all Americans, sixty-two percent of males consider themselves beer drinkers.[3] With this many Americans drinking beer, it is important to create a beer that appeals to a wide audience. This project will focus on porter, which is a beer with a roasted malt character that can be accentuated by the addition of roasted barley.[6] As with many beers, porters are made with different types of malt grains that can be milled to different sizes. Purgatory Beer Company makes Fiero Coconut Rum Porter with malts from Brewers Supply Group. This porter tastes different every time that it is made, so the project group investigated how size distribution of the different grains affected the flavor of the final beer.

2.1 Porter Beer

Porter is a dark beer that originated in London. There are many different theories about how porter came to be, but the one common fact is that it was created in the 1700s.[7] Some believe that it started as a mixture of old, new, and mild beers, and others believe that it was derived from the brown ales of the period.[5,7] Porter used to be popularly made by Guinness until alterations in his recipe lead to him developing stout; the stout is now thought of as the classic dark beer made by Guinness today.[5] The cornerstone of a porter is its roasted malt character which can be accentuated by the addition of roasted barley.[6] Due to this, porter is considered a type of malty ale.[8] A porter can be an opaque deep brown to mahogany color with flavors and aromas of chocolate and coffee with a touch of smokiness.[4] It gets its dark color because the malt goes through different heat treatments, which in turn, makes the resulting beer darker.[8] It can be acidic and/or dry with a standard reference method (SRM) of 20 to 50, which signifies the dark color of porter.[4] Porters usually have a low to medium hop flavor and are brewed with a full bodied mash to give it a “fuller” taste.[7]

There are many different types of porters; the most popular include English, Baltic, and American. English porters can either be brown or robust. A brown English porter is a heftier malty ale with flavors of chocolate, caramel, and toffee to add sweetness. This type excludes roasted barley, which typically adds coffee flavor to most porters. A robust English porter is known to be very hoppy and has an intense flavor due to the addition of roasted or black patent malt.[5] Robust porter is made with darker grains to add an edge to its roast character and is known to have a higher specific gravity than brown porter.[6] Baltic porters are a porter that drink like a stout; they are an English porter with a higher alcohol content. Baltic porters typically contain molasses, toffee, chocolate, and licorice flavors. American porters are usually a dark brown to black color with a malty complexity since they use smoking malts. There is a possibility that these beers could have a lot of hops, but most importantly, American porters allow a lot of freedom to experiment with flavors.[5]

2.1.1 Fiero Coconut Rum Porter by Purgatory Beer Company

In this project, the team worked with Fiero Coconut Rum Porter made by Purgatory Beer Company. Brian Distephano, co-owner of Purgatory Beer Company and sponsor for this project, describes the Fiero Coconut Rum Porter as a beer "with the traditional smoothness of [a] porter with hints of chocolate and coffee and a nice hit of coconut on the back end." Based on the descriptions of different types of porters, along with the statement from Distephano, the project team concluded that they were working with an American porter. As seen in the recipe [Appendix A], the Fiero Coconut Rum Porter is made with different malts, including chocolate, crystal, and caramel malts, to add a deep flavor profile to the porter. Additionally, the Fiero Coconut Rum Porter uses hops (East Kent Goldings and Fuggles), which could categorize it as an American Porter.

2.2 Grains

Grains are vital in the first step of the beer-brewing process; they contain enzymes, starches, and sugars which are needed to allow for fermentation to occur. The common grains used for beer are wheat, barley, and rye. The seeds of these plants are harvested. Their seeds have a dry exterior layer called the hull and an interior waxy layer called the seed coat; inside of the seed coat is the endosperm which is a deposit of starch and sugar. The grains are milled or crushed to finer particles called grist. They are mashed, steeped, or treated with hot water to create a starchy liquid substance called wort, that is then boiled, chilled, and fermented to make beer.[8] Typical porters begin with a pale base malt along with variations of crystal, chocolate, brown, black, caramel, and roasted malts.[7] Malt is a grain, usually barely, that has undergone a process called modification, where the seeds are steeped in water and then dried in a kiln.[8] Malts can provide the sweet, warm, roasty, toasty, and rich full flavor that porters have.[9] The grains used in the Fiero Coconut Rum Porter are described in sections 2.2.1 through 2.2.7.

2.2.1 Crisp Maris Otter Malt

Maris Otter is a base malt that is used in the Fiero Coconut Rum Porter and can be used in all English style beers to provide a nutty, deep malt flavor.[9] Maris Otter is a reliable malt that has been consistently used in industry for over 45 years. It has a standard reference method range of 2.6 to 4.7 SRM.[10]

2.2.2 Rahr Standard 2 Row Malt

Rahr Standard 2 Row malt is a light, straw colored base malt used in the Fiero Coconut Rum Porter and is made from a blend of different American 2 Row barley types.[11] 2 Row malt got its name based on the formation of the corn on the barley stalk; in 2 Row malt, there are two rows of corn growing on the barley stalk.[9] 2 Row malt is a pale, all-purpose malt (1.5 to 1.9 SRM) that can be used to make any style ale since it is easy to break down with a single step infusion mash. It has a light, clean, and smooth flavor.[12]

2.2.3 Crisp Chocolate Malt

Chocolate malt is a dark brown roasted malt typically used in porters; roasting this malt to a very high degree gives it its dark and deep color and bready consistency.[9] It is interesting to note that the name "chocolate malt" is a reference to the color of the grain and not actually the flavor that it brings to the beer. Chocolate malt brings a roasted and nutty flavor to the beer, and it gives it a dark amberish red color[13] with an SRM range of 473 to 541.[6] Chocolate malt, along with other roasted malts, can add a lot of color and complexity in very small quantities.[9]

2.2.4 Weyermann® CARAFA® Type 3

Weyermann® CARAFA® Type 3 is a specialty type of roasted malt which offers a smooth and slight roastyness to a beer. It is made from spring barley and is dark-roasted to give off both coffee and chocolate flavors with a roasted aftertaste. Carafa III is similar to a chocolate or black malt, having a color rating of 664 to 766 SRM.[14]

2.2.5 Crisp Crystal 77L Malt

Crisp Crystal 77L is a darker style crystal malt, which means it was kilned longer to give a roasted effect. It has an SRM rating of 94 to 108. It provides a deep golden or dark red color to the beer and brings a flavor with sweet, malty, and caramel notes. Crystal 77L also assists in head retention, mouthfeel, and body of the beer.[15]

2.2.6 Weyermann® Carafoam®

In the Fiero Coconut Rum Porter, Weyermann® Carafoam® is used to aid in creating foam, improve head retention, and give the beer a fuller body. Carafoam is a roasted caramel malt made from 2 row German barley, with an SRM rating of 1.1 to 3.2.[16] It is desirable for beers to have a head of foam on the top after it has been poured; the addition of Carafoam in the production process of beer aids in creating the foam. It is usually recommended that Carafoam make up 5-10% of the initial grain mixture in order to get the intended effect in the final beer product.[17] In Purgatory Beer Company's Fiero Coconut Rum Porter, Carafoam makes up about 5% of the grist.

2.2.7 Grain Millers Flaked Oats

Grain Millers Flaked Oats are used in the Fiero Coconut Rum Porter in order to add a creamy texture, increase body, and provide more grainy notes to the beer.[18] Flaked oats are considered a mashable adjunct; an adjunct is defined as a starch that is added to the beer but is not malted or fermented. Adjuncts typically add different flavors and smoothness to beer while improving the head retention and clarity of the beer.[19]

2.3 Grain Size Distribution

Grains need to be crushed to a smaller size before brewing to allow for more efficiency of sugars being released during the mashing process. Finely crushed grains result in a higher efficiency but can sometimes be too fine and powdery which results in a mash that becomes “stuck” and halts the brewing process. More coarsely crushed grains allow for a freer flow of water but result in a lower efficiency. The ideal crush of the grain has a split interior with an intact husk.[20]

Grains are crushed or milled, by using a mill with different settings, to create desired sizes of grains for the mash. There are many different types of mills that can be used to mill the grains, including, a Corona Mill, a Single Roller Mill, and a Dual Roller Mill. A Corona Mill is very similar to a grinder; it forces the grains between two rotating plates. Corona Mills are usually designed to mill flour because they are very hard to adjust and therefore, mill the grain to a fine powder. Single Roller Mills push the grain between a single roller and an immobile plate; this gives the grain a coarser crush but still produces some powder. A Dual Roller Mill is the best for malts and home brewers because it crushes the interior of the grain while leaving the husk intact.[20]

Since grains can be milled to all different sizes based on the setting of the mill crush, the sizes of the grains can be quantified based on their size distribution. Size distribution is a list of values that defines the relative amount, by mass, of particles in the grain according to their size. Sieve analysis is used in order to determine the size distributions of grain samples. The grains are shaken through a stack of sieve trays which are put in descending order of hole size to separate them based on particle size. The mass of the grains retained on each tray are made into percentages of the total mass. Usually, a grain size distribution curve is plotted with the average grain size per sieve tray, in millimeters, along the x-axis versus the percentage of that size in the entire sample along the y-axis.[21]

For this project, the team investigated how the size distribution of all grains used to make Fiero Coconut Rum Porter affected the flavor of the final porter. Although not many tests have been done in literature to show if size distribution affects a beer’s flavor, there have been tests showing how grains can create a haze in the beer and how to minimize that. Beer clarity has come to be expected from many beer drinkers but during the production process many beers develop a chill haze. The chill haze is developed from the proteins and tannins in malt which form complex chains that are too small to settle out of the beer product and create a sort of hazy appearance and texture to the beer. The only way to reduce the chill haze is to remove the proteins and tannins. This is done most commonly by reducing the total amount of malt in the recipe, adding adjuncts, or filtering the beer.[22] Although there is not much literature to support that grain size distribution affects the flavor of beer, the purpose of this project is to explore this relationship.

2.4 BSG CraftBrewing

The primary supplier of grains for Purgatory Beer Company is the CraftBrewing sector of Brewers Supply Group (BSG). BSG originated in 2004 as a small scale distributor for brewers, but they have now grown into a supplier across North America for beer, wine, distilling, cider, and home brewing needs. They offer extensive varieties of malts, hops, yeasts, and other fermentation essentials.[23]

BSG offers three different mill settings: coarse, medium, and fine. Currently, Purgatory Beer Company is ordering their malts at the default setting of medium. Our team investigated which setting resulted in the best flavor of the Fiero Coconut Rum Porter.

2.5 Wort

Wort is a sugary liquid that is formed as a result from mashing grist in water. Milled grains are soaked in hot water to hydrolyze the starches into a sugary liquid that yeast can convert into ethanol and carbon dioxide. Before the yeast is added for fermentation, the wort must go through separation, boiling, and chilling processes.[8]

There are three types of wort separation. The traditional separation technique is called mash tun separation, where the grains are filtered out of the wort in the bottom of the mash tun vessel. There is a suspended plate, called the false bottom, with holes that collect the particles of spent grains as the wort is drained. The pile of grains (grain bed) serve as the actual filter for this mechanism instead of the false bottom. For this process, the size of particles affect the speed of filtration, and hulls are always necessary to lighten the grain bed. The most commercialized separation system occurs in a vessel called the lauter tun. In this process the mash is pumped from the mash tun to the wider lauter tun where a shallow grain bed is formed. The lauter tun has a set of knives that cut the grain bed in circular motion to facilitate filtration. This process is finished with hot water sprayers, sparging the grain bed. The newest system of separation is called the mash filter. This method has a series of chambers which all have a porous plastic filter covering an exit channel for the wort. The mash can be pressed through the filter using an inflated membrane.[8]

Purgatory Beer Company uses mash tun separation, followed by sparging, for their process. Once filtered, the clear, sweet wort is boiled in a kettle heated by electric probes. Boiling the wort kills off any bacteria and wild yeasts, deactivates the enzymes, removes volatile compounds with bad flavors, allows hop resins to dissolve, and clumps together excess grain protein for removal. Hops are added at various times within the boil depending on the desired outcome; the hops added to the Fiero Coconut Rum Porter are meant to counteract the bitterness of the darker malts without adding a strong flavor of their own. Next, the wort is cooled to approximately 65ºF by pumping it through a heat exchanger using a continuous glycol stream. Chilling wort prepares it for fermentation, where yeast and flavorings are added.

Worts can vary through sugar and carbohydrate content, acidity, color, clarity, and density; the beers created also vary in these characteristics along with their taste.

2.6 Sugar and Carbohydrate Content

As previously mentioned, the process of brewing converts the starches from the mashed grains into dissolved carbohydrates which are then converted into alcohol by the yeast. The carbohydrate content is measured in units of mass percent. In wort, it indicates the efficiency of the mashing process and therefore, indicates how many sugars and starches were extracted from the grains during the mash. The carbohydrate content of the wort is also a way for brewers to monitor the fermentation process. Knowing the carbohydrate content gives the brewer an idea of how many carbohydrates are in the wort and that translates into how long fermentation will take to complete.[8]

Carbohydrate content is measured by the specific gravity, the mass of a volume of a sample divided by the mass of the same volume of water, which gives the amount of dissolved starches in the sample. Specific gravity is measured with a device called a hydrometer. Hydrometers are usually temperature dependant. To measure the specific gravity of wort or beer, the user floats the hydrometer in the liquid and reads off the value at the meniscus. For beer, the specific gravity is usually reported in points, which are the thousandths of the specific gravity in excess of one; to put this in perspective, the specific gravity of water increases by 0.004, or 4 points, for each 1% of carbohydrate dissolved in it. The specific gravities of the unfermented wort and the beer product are called the original gravity (OG) and final gravity (FG), respectively. The original gravity of the wort is a way to determine the beer style. For example, a beer made from a wort with a high original gravity is called a high gravity, or a heavy beer. The final gravity is used when determining the final carbohydrate content of a beer. A way to understand the different carbohydrates and flavor compounds present in beer or wort is to use gas chromatography mass spectroscopy (GCMS), which is the most versatile way to analyze substances that can be vaporized.[8]

2.7 Alcohol Content

The alcohol content of a beer is measured by determining the alcohol by volume (ABV), which represents the volume percent of alcohol in a total volume of beer. ABV varies between types of beers due to the amount of sugars in the wort and dosing of yeast during fermentation. The overall alcohol content affects the flavor, body, and mouthfeel of beers, as well as the recommended serving.[24] ABV is determined using Table 1, in Appendix B, that relates point values of the original and final gravities of a beer. The process followed for this project is described in section 3.3.2. The exact types of alcohol present can be measured using GCMS, where specific compounds in the beer are analyzed.[8]

2.7 Acidity

Acidity in a beer, measured in units of pH, is important for understanding the flavor. The pH represents the negative logarithm of the hydrogen ions in solution. The scale goes from 0 to 14, where 7 is neutral, below 7 is acidic, and above 7 is basic.[25] The acidity affects enzyme activity in the mash, and ultimately the fermentability and flavor. The most fermentable wort has a pH between 5.3 to 5.4; too high of pH will extract bitter flavors from any hops. It is observed that the pH drops during fermentation due to yeast eating basic compounds and excreting acids. The pH of beers range from sour ales at 3.0 to lagers at 4.6.[26]

2.8 Color

The color of beer is determined based upon which wavelengths of light it absorbs versus which light it reflects. In the past, beer color was quantified based on comparisons to standard color samples, given in values of degrees Lovibond (ºL). Lighter beers range from 2 to 4 ºL, whereas darker beers, such as porter, range from 70 to 100 ºL. Modern methods of quantifying the color of beer take into account the absorption of light at 430 nm wavelength, which is a wavelength where blue and green light is absorbed. Darker beers absorb more of this light than lighter beers. Using a spectrophotometer to measure the absorption values at 430 nm, the color of beer can be calculated and reported in units of the Standard Reference Method (SRM). SRM is a simplified method of determining the color of beer, which signifies how dark the beer is but not anything about the red or yellow tones in it.[8]

Malt grains are given ºL or SRM values based on the color that it brings to a wort produced from solely itself; the color value is not a measure of the physical grain.[8] In this project, the team reports all values of color using the SRM method.

2.9 Sensory Analysis

Sensory analysis is a tactic that most commercial brewers use in order to evaluate the flavor of their beer. This procedure involves having a panel of taste testers to taste the beer and give their honest opinions on the flavor. Hedonistic testing is one type of sensory analysis that involves a group of untrained testers who answer basic questions about the beer such as, “Do you like it? Do you like the flavor? Would you drink it again?” Typically, groups of hedonistic testers are used to develop new products in a way that will appeal to a general audience if put on the market. The key thing in sensory analysis and hedonistic taste testing is to ensure that there are no distractions to the testers and that the only information available is the name; the testers are to determine the flavor of the beer on their own. The goal of hedonistic testing is to get an unbiased, honest opinion of the beer’s flavor to determine its success.[8]

3. Methodology

Purgatory Beer Company has been having problems achieving a consistent flavor in their Fiero Coconut Rum Porter. Some batches taste exactly how the brewers desire, while other batches have unexpected flavors. To investigate this problem, the project team focused on one process variable - grains. The purpose of this project was to research the effect that grain size distribution had on the flavor of this porter. The team outlined four major objectives to accomplish their goal:

1. Identify the inconsistencies in grains used over time.
2. Determine how size distribution of grains affects wort.
3. Determine how wort and flavorings affect beer.
4. Develop recommendations on grain usage and the process for Fiero Coconut Rum Porter.

Once the team determined the potential inconsistencies in grains, they ran controlled experiments. They then tested the worts and beers in the laboratory to better understand what the chemical, physical, and optical differences were.

3.1 Identify the Inconsistencies in Grains Used Over Time

In order to pinpoint the inconsistencies of the grains used over time, the group contacted Brian Distephano. The purpose of the conversation was to determine if the source, dosing, or size distribution of the grains were altered between batches.

3.2 Determine How Size Distribution of Grains Affects Wort

The three grain sizes that BSG offers, coarse, medium, and fine, were used in controlled experiments to see their effect on wort. The size distributions of the coarse, medium, and fine crush of each grain was determined and then used to create three different worts; one made from only coarse grains, one from medium, and one from fine. The worts were then analyzed using different laboratory methods to determine the specific gravity, composition, acidity, and color.

3.2.1 Sieve Analysis

To determine the size distribution of the coarse, medium, and fine grains from BSG, the team used sieve tray analysis. The trays separated the particles into the following size ranges in units of mm: 0 to 0.15, 0.15 to 0.177, 0.177 to 0.25, 0.25 to 0.425, 0.425 to 1.19, 1.19 to 1.68, 1.68 to 2.00, 2.00 to 3.36, and 3.36 to 4.76. Samples taken from the coarse, medium, and fine crush of each grain were separated, based on particle size, using the sieve trays. The contents left on each tray were weighed. Mass percentages were created and plotted versus the average size in each range.

3.2.2 Controlled Home Brew Experiments

In order to create worts for comparison, the group brewed three different batches using the coarse, medium, and fine grains. Using a scale-down of the Fiero Coconut Rum Porter recipe, 0.7 gallon batches were made. The appropriate amount of each grain was placed into a cloth bag used for the mashing process; the bag was submerged into ~155ºF water and steeped for one hour. Then the grains were sparged with warm water and the bag was removed. The starchy liquid was boiled for one hour, and hops were added twice during the boil. After cooling, samples of the three worts were collected for testing; the rest was split into fermenting jars. The detailed brewing procedure can be found in Appendix C.

3.2.3 Determining Specific Gravity Using a Hydrometer

The team used hydrometers to measure the specific gravity of the wort in order to determine its carbohydrate content. As described in section 2.6, the team floated the hydrometer in a graduated cylinder filled with wort. The original gravity value was read off of the side of the hydrometer and was converted into points by using equation 1.

$$Points = (Specific\ Gravity - 1) * 1000 \qquad (1)$$

Table 2 [Appendix B] was used to find the carbohydrate percent that corresponds to each point value.

3.2.4 Determining Composition Using Gas Chromatography Mass Spectroscopy

In order to further understand the different components present in the wort samples, the team used gas chromatography mass spectroscopy. For GCMS, the samples were extracted so that they were properly prepared for use in the instrument. To extract the organic compounds for analysis, the team began by mixing samples of the wort, deionized water, dichloromethane, and table salt. The samples were shaken and then separated using a centrifuge. The bottom-most clear layer was filtered using a syringe and PTFE filter; this filtered extract was inserted into the GCMS machine. The full procedure the team used for GCMS is outlined in Appendix D.

In gas chromatography, a sample is injected and instantly vaporized. The vapor travels with a carrier stream throughout a column, where different components of the sample stick to the column at different points and to greater or lesser extents. The exit time of each component indicates what the component is and the response of the detector indicates how much of that component is present.[8]

The team used this method to determine exactly what organic components were in each wort sample. The components in each extract were compared to the components in other extracts to analyze any differences present, which may have an effect on flavor.

3.2.5 Determining Acidity Using a pH Meter

The team used a pH meter with a probe to determine the pH, or acidity, of the worts. To measure the pH, the team submerged the pH probe in the wort until a constant pH value was read and recorded. This pH value gave the team a measure of the acidity of the wort.

3.2.6 Determining SRM Using Spectrophotometry

The team used spectrophotometry to quantify the color of the worts by finding their SRM values. This method involved putting the wort, diluted with water if necessary, into the spectrophotometer and reading the absorbance value at 430 nm wavelength light. The SRM value is a function of absorbance and dilution, as seen in equation 2, where A_{430} is absorbance at 430 nm and D is the dilution coefficient.

$$SRM = 12.7 * A_{430} * D \tag{2}$$

$D = 1$ for undilute systems, $D = 2$ for 1:1 dilution, $D = 3$ for 2:1 dilution, etc. The protocol for the laboratory procedure is outlined in Appendix E.

3.3 Determine How Wort and Flavorings Affect Beer Flavor

The methods for determining how wort and flavorings affect beer flavor are similar to the methods for determining how wort was affected by the grains. The team ran controlled experiments and tested the finished beers using hydrometry, GCMS, pH meters, spectrophotometry, and taste. The procedure for using GCMS, pH meters, and spectrophotometry are exactly the same for beer as they were for wort. The procedures that differ between wort and beer, hydrometry and hedonistic testing, as well as finishing the controlled experiments, are explained below.

3.3.1 Controlled Home Brew Experiments

In order to create beers for comparison, the group brewed three different batches using the coarse, medium, and fine grains. The same procedure was used from section 3.2.2. The wort was split up into nine fermenting jars, three for each grain size, and liquid yeast was added to each jar. The yeast was left to ferment for several days, and once the fermentation was complete, flavorings were added to each jar and were allowed to steep for a few more days. One jar was unflavored, one jar was flavored using unsulfured coconut, and the last jar was flavored using untreated coconut. As previously mentioned, the detailed brewing and flavoring procedure can be found in Appendix C.

3.3.2 Determining Specific Gravity Using a Hydrometer

The team used hydrometers to measure the specific gravity of beer in order to determine its carbohydrate and alcohol contents. The team found the final gravity of the beer samples and converted them to points values by using equation 1. The final gravity and the original gravity points were used in conjunction with Table 1 in Appendix B to determine the ABV. The ABV was used to to find a corrected-final gravity point value in order to find an accurate carbohydrate content in the beer. Hydrometers are accurate in measuring the specific gravity of wort, but they are not as accurate for beer due to the alcohol and carbonation present. For each percent of alcohol in beer, the number of points is lowered by 1.35. To account for this loss, equation 3 was used.

$$Corrected\ Points = Initial\ FG\ Points + (1.35 * ABV) \tag{3}$$

The corrected point value was then used along with Table 2 in Appendix B to quantify the carbohydrate content of the beer samples.

3.3.3 Determining Flavor With Hedonistic Testing

In order to evaluate the flavor of the different beer samples created in the team's controlled home brew experiments, the team used a panel of hedonistic testers. The team had four untrained taste testers, comprised of themselves and their peers, taste each of the nine samples of beer. The testers tasted an unidentified sample of beer and described the taste using words such as "bitter, thin, heavy, robust, etc." They then determined if they liked a certain sample more than others and if they would want to drink it again. Water was used as a palette cleanser between samples. The team ensured that the testers were unaware of the differences of each sample; the only thing they told the testers was the name of the beer, "Fiero Coconut Rum Porter."

Hedonistic testing was a key step in testing for the team because the goal of this project was to determine how the grain size distribution affected the flavor of the beer and to determine which produced the best flavor. Since the team also decided to flavor the beer three different ways (unflavored versus unsulfured coconut versus untreated coconut), it was important to determine if unsulfured or untreated coconut was preferred by the tasters. This information was used in developing recommendations for Purgatory Beer Company.

3.4 Develop Recommendations on Grain Usage and Process for Fiero Coconut Rum Porter

After completing all the testing associated with accomplishing the other objectives, the team gained a better understanding at how the size distribution of grains affected wort, and ultimately, how they affected beer flavor. To help Purgatory Beer Company, the project team created this final report outlining the recommended grain size distribution to use to create the best flavored Fiero Coconut Rum Porter based on their results from controlled home brew experiments. In this report, the team also included additional recommendations, not directly related to the grains, on improvements that Purgatory Beer Company can make to their process.

4. Results and Discussion

To address this project's goal of determining how size distribution of grains affect the flavor of Fiero Coconut Rum Porter, the team completed background research as well as scientific tests on samples of the porter from Purgatory Beer Company and from the team's controlled home brew experiments. The major results are outlined by objective below.

4.1 The Inconsistencies in Grains Used Over Time

The team asked Brian about inconsistencies with source, dosing, and preparation of the grains between the different flavored batches of porter. The only inconsistency that he stated was the size distribution; for some of the batches, BSG would mill the grains on their default setting, for other batches, Brian would mill the grains himself on a setting of "4," and for the rest of the batches, he would use a mixture of both. It was notable that Brian preferred brewing with the grains that he milled because they were slightly bigger and caused less problems with clogging and filtration than the ones from BSG. For ease of manufacturing, Brian would additionally like the team to investigate which grain size that BSG offers would be the best alternative to milling his own. This information was used to design the set of controlled experiments done on the grains, worts, and beers.

4.2 How Size Distribution of Grains Affects Wort

Since the milling was inconsistent in Purgatory's process, our team wanted to quantify the actual size distribution of each grain used and at each BSG offered mill setting. With the various crushed grains, the team created worts using each size and ran tests to compare how grain size affected wort's carbohydrate content, acidity, and color.

4.2.1 Grain Size Distribution Values Using Sieve Analysis

The six grains used in the Fiero Coconut Rum Porter were milled into the coarse, medium, and fine sizes that BSG offered. The size distribution of all eighteen grains (three sizes for each of the six grains) was determined using sieve tray analysis.

After analyzing the size distributions, it was found that the pale malts showed similar trends to each other, while the caramel and roasted malts displayed a different trend. The pale malts in this beer are Crisp Maris Otter and Rahr Standard 2 Row. A graph of the weight percent versus average particle size for Maris Otter in coarse, medium, and fine crush is shown in Figure 1; the graph for 2 Row (Figure 10) and the corresponding data tables (Table 3-8) are in Appendix F.

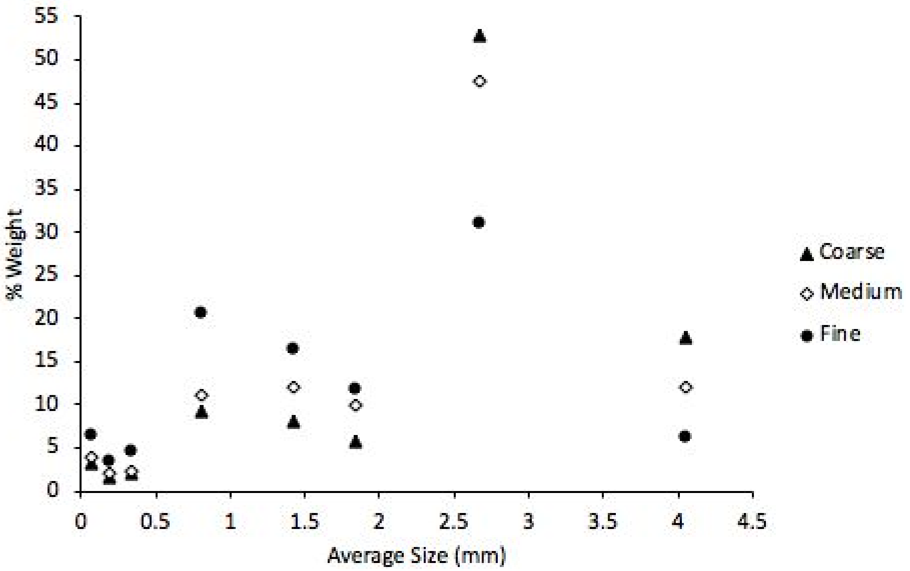

Figure 1. Grain size distribution data for the coarse, medium, and fine crush of Crisp Maris Otter Malt. The x-axis displays the average sized particle between each tray [mm], and the y-axis displays weight percent [g grain per tray/g total grain]. The raw data is found in Table 3 of Appendix F.

From this graph, it was determined that the pale malts, in any of the three crush sizes, had the maximum amount of particles at a size of 2.68 mm, where the coarse and medium were within 6 weight % of each other. The coarse grains had its next highest weight percent at a particle size of 4.06 mm, while the fine grains' was at 0.81 mm. The medium crush had a more even distribution with 1.44 and 4.06 mm being almost tied for the next highest point, showing that the medium crush was a balance between the fine and coarse. This trend is also indicated by the medium data points consistently being between the fine and coarse points. For the average particle sizes below 0.5 mm, the coarse and medium crushes are within 0.6 weight % of each other. As expected, the fine grains had greater weight percents than medium and coarse at smaller particle sizes but had lower weight percents at larger particle sizes. This transition point, where fine crush went from the maximum weight % to the minimum weight %, was between 1.84 and 2.68 mm average sizes.

The darker malts, Crisp Chocolate Malt, Weyermann® CARAFA® Type 3, Crisp Crystal 77L, and Weyermann® Carafoam®, displayed a different trend in distribution than the pale malts. For reference, the chocolate malt graph is shown in Figure 2, while the rest are shown in Figures 11-13 in Appendix F.

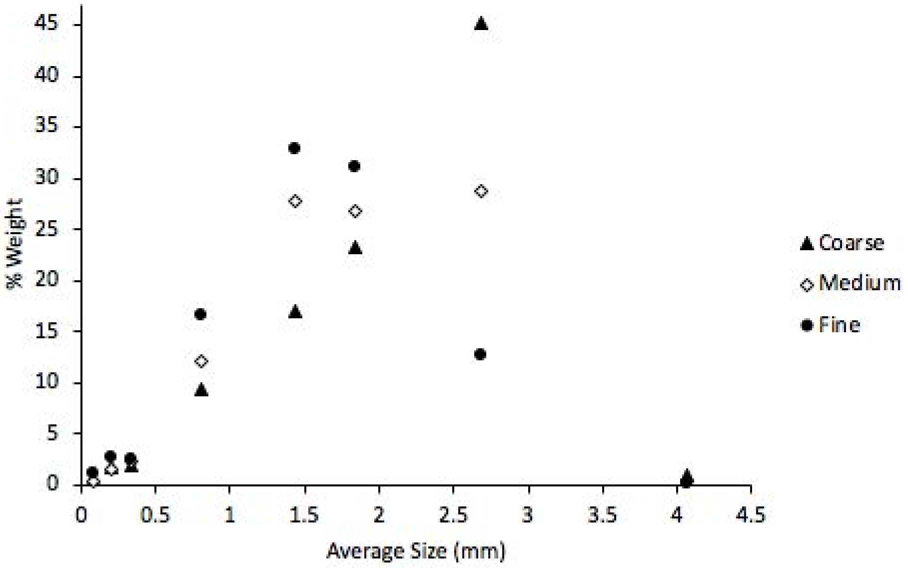

Figure 2. Grain size distribution data for the coarse, medium, and fine crush of Crisp Chocolate Malt. The x-axis displays the average sized particle between each tray [mm], and the y-axis displays weight percent [g grain per tray/g total grain]. The raw data is found in Table 5 of Appendix F.

The data for the roasted grains showed a more spread out distribution between the three crushes. The coarse crush had a maximum weight percent at 2.68 mm. The medium crush had three particle sizes which almost tied for the maximum weight percent: 1.44, 1.84, and 2.68 mm, with 2.68 mm as the true maximum by a <1 weight % difference. For the fine crush, 1.44 and 1.84 mm were almost tied for the maximum, but 1.44 mm was the true maximum by a <1 weight % difference. For the coarse, medium, and fine grains, the particle sizes below 0.5 mm are all within 1 to 2 weight %. The transition point from fine have the highest weight percents to coarse having the highest was between 1.84 and 2.68 mm. It was also found that the roasted grains all together had little to no particles at 4.06 mm. While sifting, the team noticed that the particles were overall smaller than those of the paler malts and very little grains were left on the top sieve. It was observed that there were less husks intact for these grains, possibly because they were heat treated and shriveled up once they were roasted.

In comparing the pale and darker malts, it was found that the pale malts had a more consistent trend between fine, medium, and coarse crushes, since they all had the same maximum point. The darker malts showed different variations of maximums having either one maximum or multiple. In both types of malts, it was found that medium crush was always between the coarse and the fine, and the transition point where fine transitioned from the highest weight percents to the lowest was between 1.84 and 2.68 mm. The darker grains were overall more finely crushed, no matter which setting was used. In the wort recipe, the majority (67.5%) of the grains are pale, so it is expected that the size distribution of Maris Otter and 2 Row have the greatest effect on the process. For these pale malts, the medium and coarse grains were never >7 weight % apart. From this similarity in size and dominance in the recipe, the team hypothesized that the medium and coarse worts may have more similarities to each other than with the fine wort.

4.2.2 Specific Gravity and Carbohydrate Content Values of Wort Using a Hydrometer

Once coarse, medium, and fine worts were created from the different sized grains, they were tested, along with a sample of Purgatory's wort, to determine their carbohydrate contents. The data displaying the different carbohydrate contents are shown in Figure 3.

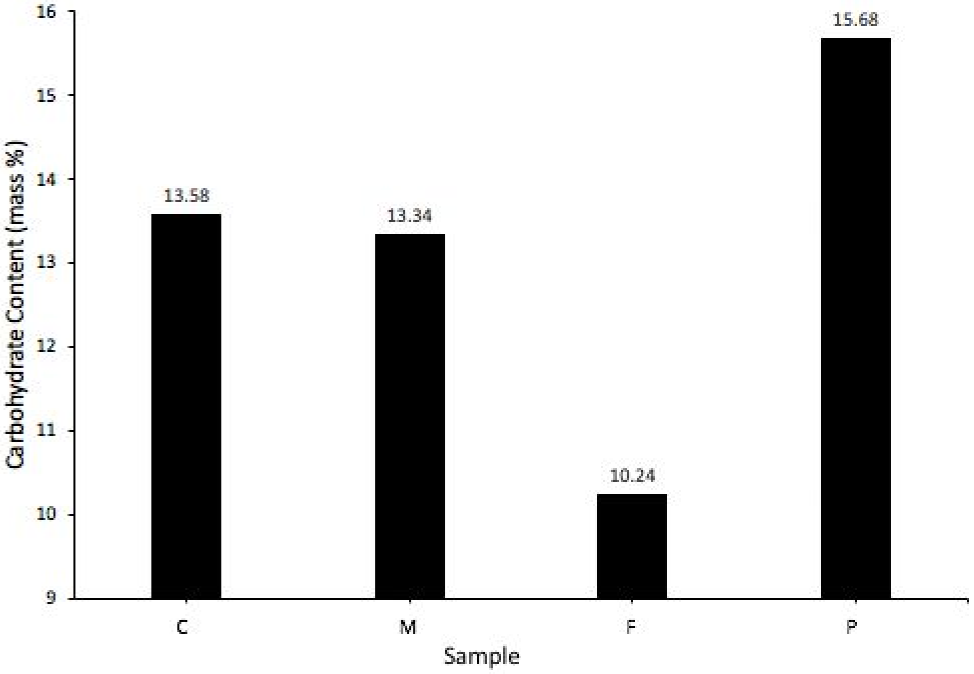

Figure 3. Carbohydrate content in mass % of the coarse (C), medium (M), fine (F), and Purgatory's (P) worts. The data is found in Table 9 of Appendix G.

These data show that Purgatory's wort had a higher carbohydrate content than the worts made from the team's controlled experiments. A possible explanation as to why the team did not achieve the same carbohydrate content as Purgatory was that the team used a steeping bag during the mash process, whereas Purgatory did not have a barrier between the grains and water. The team found that the coarse and medium worts had very similar carbohydrate contents to each other of ~13.5%, while the fine wort had ~3% less carbohydrates in it. Since the medium and coarse had higher carbohydrate contents, the team predicted that those beers would have higher alcohol contents since more carbohydrates would be converted into more alcohol. It was unexpected that the coarse wort had the highest carbohydrate content and the fine wort had the least. Literature suggests that wort made from fine grains should have the largest carbohydrate content since finer particles yield a higher efficiency in the mash. Finer particles have more surface area that allows for more mass transfer of the sugars from the grains into the wort.[20]

4.2.3 Components of Wort Using Gas Chromatography Mass Spectroscopy

GCMS testing was completed to determine the chemical composition of the wort samples. The results did not aid the team in determining how the size distribution of the grains affected the wort. Therefore, this testing was deemed inconclusive. The data can be referenced in Appendix H.

4.2.4 Acidity Values of Wort Using a pH meter

The coarse, medium, and fine worts, along with a sample of Purgatory's wort, were tested to determine their acidity, in the form of a pH value. The data displaying these results is shown in Figure 4.

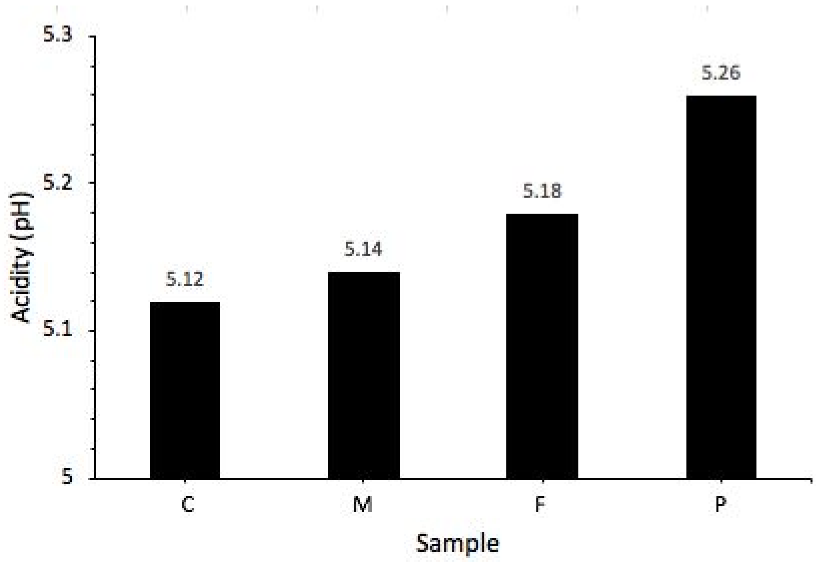

Figure 4. pH values of the coarse (C), medium (M), fine (F), and Purgatory's (P) worts.

It was found that the pH values slightly increased and became more basic as the grain size decreased. Purgatory's wort had the highest pH value and was closest in value to the fine wort. As previously mentioned, the acidity of wort ultimately affects its fermentability and flavor, and too high of a pH could extract bitter flavors from the hops. Since the pH from the controlled experiments did not exceed 5.4, the team concluded that the slight difference from Purgatory's pH did not have any effect on the flavor of the resulting beers.

4.2.5 SRM Values of Wort Using a Spectrophotometer

Standard Reference Method values were determined in order to quantify the colors of the different worts. The graph displaying these values is shown in Figure 5.

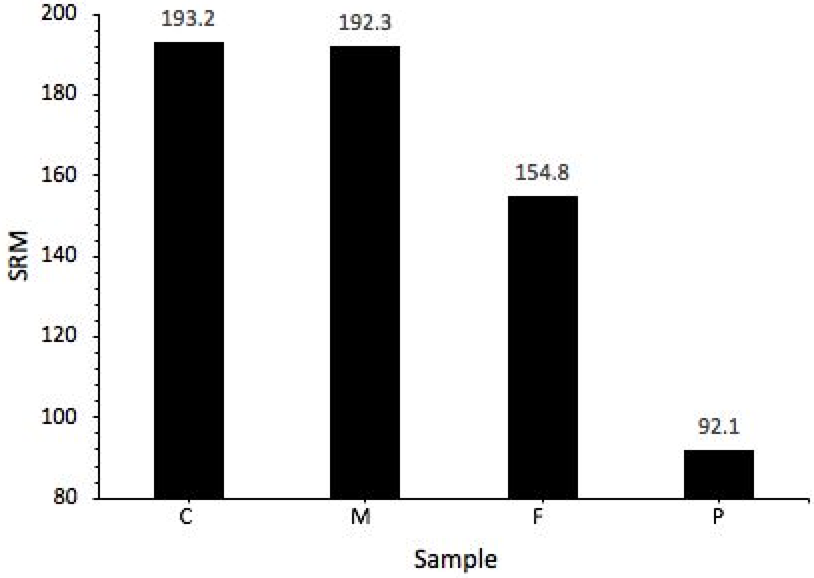

Figure 5. SRM values of the coarse (C), medium (M), fine (F), and Purgatory's (P) worts. The data is found in Table 25 of Appendix I.

From these data, it is clear that the worts made from the controlled experiments had significantly higher SRM values than the Purgatory wort. The coarse and medium worts had very similar SRM values whereas the fine wort had a slightly lower value. Typically a higher SRM value indicates a much darker color, however, to the naked eye, all of the worts looked very similar. It was noticed that the fine wort had a more red tint to it. Since SRM does not quantify red tones, the fine wort may have looked the same to the naked eye despite having a lower SRM value.

4.3 How Wort and Flavorings Affect Beer Flavor

The team turned the coarse, medium, and fine worts into nine different beers. The beers were made in order to determine how the size distribution, as well as the type of coconut flavoring, affected the beer's carbohydrate content, alcohol content, acidity, color, and ultimately, flavor. The team invented their own naming system to distinguish the nine beer samples from each other. Coarse, medium, and fine beers were labeled C, M, and F, respectively. To further discern the type of flavoring that was in each beer, 1, 2, and 3 were added after the C, M, or F. 1 signified unflavored beer, 2 signified unsulfured coconut, and 3 signified untreated coconut. For example, a beer labeled M3 meant that it was a beer made from medium sized grains and flavored with untreated coconut. This naming system will be used throughout the following results section and in data tables.

4.3.1 Specific Gravity, Alcohol Content, and Carbohydrate Content Values of Beer Using a Hydrometer

The different flavored coarse, medium, and fine beers, as well as a sample of Purgatory's Fiero Coconut Rum Porter, were tested to determine their alcohol contents and carbohydrate contents. Figure 6 displays the alcohol by volume (ABV) values for the different beers.

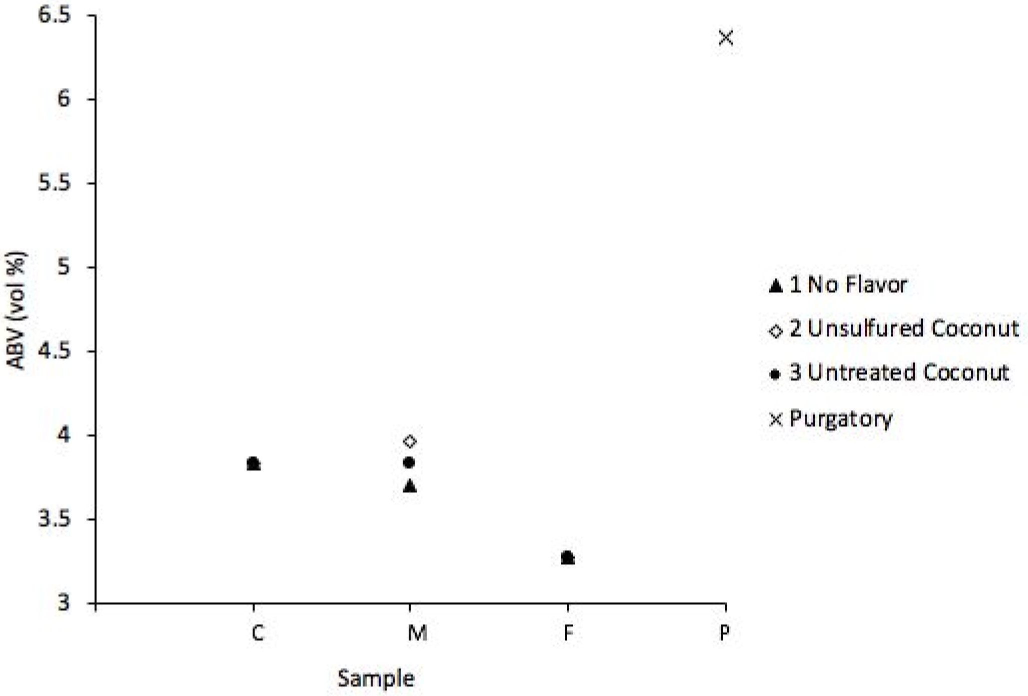

Figure 6. Alcohol content in volume % of the coarse (C), medium (M), fine (F), and Purgatory's (P) beers. The data is found in Table 10 of Appendix G.

From these data, there is an overall decreasing trend in ABV from coarse to medium to fine, with the exception of the medium beer flavored with unsulfured coconut which had the highest alcohol content of all the home brewed samples. Although this beer had the highest alcohol content, it had ~2.4% less ABV than Purgatory's porter. The specific gravities of the coarse and fine beers were consistent between all three of their different flavored samples, and in turn resulted in consistent ABV values for all coarse and fine samples. Purgatory's beer had the same specific gravity as the fine beers, 1.016, but due to the difference in the original gravities, these beers had different alcohol contents.

Once the ABV values were found for each beer sample, linear interpolation was used to find the carbohydrate contents of the samples. The carbohydrate content values are shown in Figure 7.

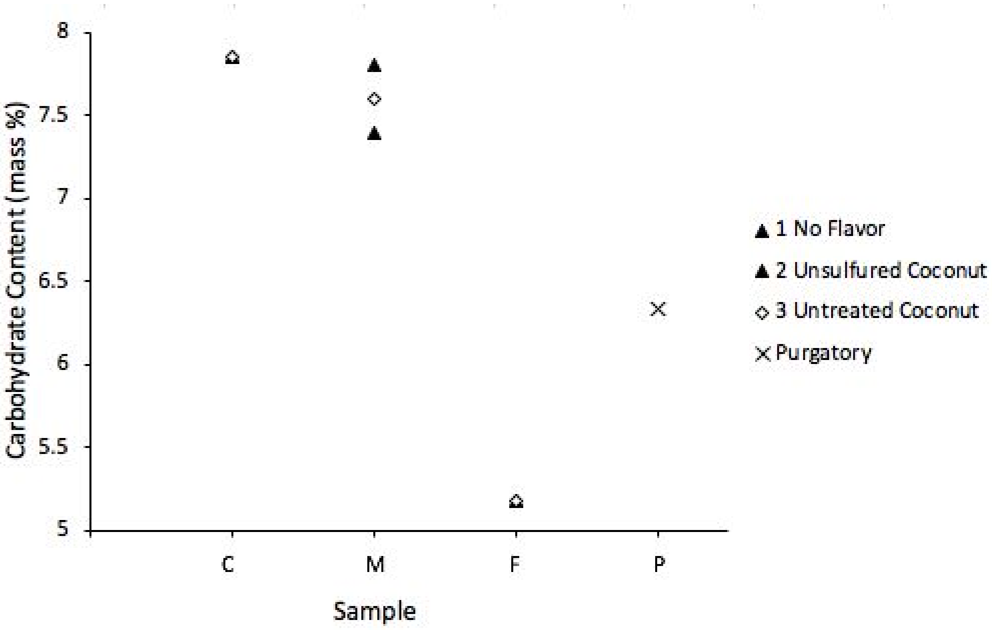

Figure 7. Carbohydrate content in mass % of the coarse (C), medium (M), fine (F), and Purgatory's (P) beers. The data is found in Table 10 of Appendix G.

Since there is a linear relationship between alcohol content and carbohydrate content in beer, the results for the carbohydrate content are very similar to the results for the alcohol content that were previously discussed. There was still a decreasing trend from coarse to medium to fine, with the exception of M2 which had the same carbohydrate content as the coarse beers. Similar to ABV, the coarse and fine beers had consistent carbohydrate contents.

As mentioned in section 4.2.2, the decreasing trend of alcohol and carbohydrate content with decreasing grain size was the opposite of what was expected according to literature. Wort made from finer grains should have the largest alcohol and carbohydrate contents because of mass transfer principle.[20] A possible limitation and reason the team saw unexpected trends could have been because they only had a thermometer to monitor the temperature throughout the mash and boil process, where a preferred system would have a temperature controller. The team noticed large inconsistencies in the temperature at different parts and depths of the pot they were using to mash, and it was difficult to regulate the temperature on a gas stove. If the mash temperature was too high, there was a possibility that the grains were not able to gelatinize properly, and therefore, they could not transfer into the wort. Less transfer of sugar from grains to water would cause smaller alcohol and carbohydrate contents than expected.[27]

4.3.2 Components of Beer Using Gas Chromatography Mass Spectroscopy

As previously mentioned in section 4.2.3, GCMS testing was completed to determine the chemical composition of the beer samples. The results did not aid the team in determining how the size distribution of the grains, as well as the different types of coconut used, affected the flavor of the beer. Therefore, this testing was deemed inconclusive. The data can be referenced in Appendix H.

4.3.3 Acidity Values of Beer Using a pH meter

To further quantify the differences between the nine beer samples in order to determine the one with the optimal flavor, the acidity values of each beer were tested. The pH values of each beer are shown in Figure 8.

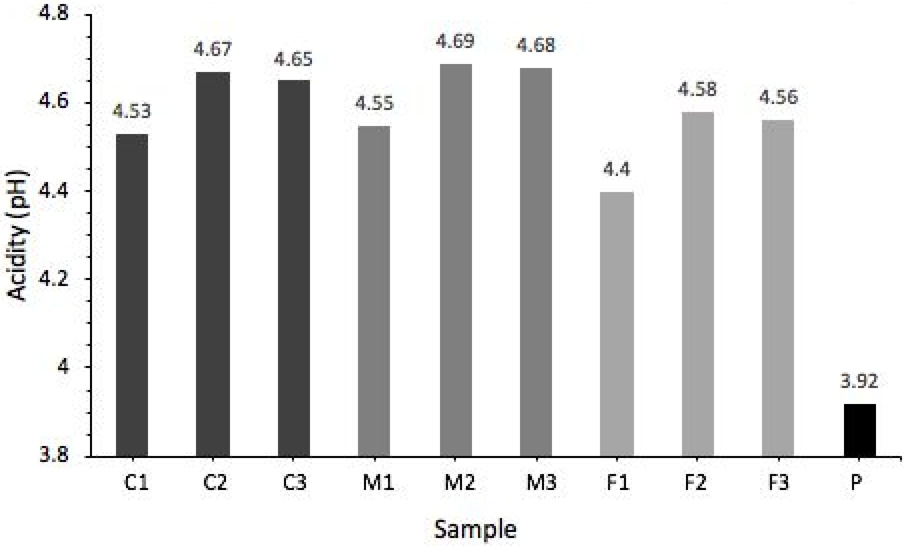

Figure 8. pH values of the coarse (C), medium (M), fine (F), and Purgatory's (P) beers.

The pH values show no real trend with grain size since the pH value increases from fine to coarse to medium. All of the pH values from the team's controlled experiments were ≥4.4 whereas Purgatory's porter had a lower pH value of 3.92. A reason why Purgatory's beer had a lower pH could be because of its higher alcohol content. Although there was no trend in acidity with grain size, the pH values increased from unflavored beer to untreated coconut beer to unsulfured coconut beer.

4.3.4 SRM Values of Beer Using a Spectrophotometer

The team did SRM testing in order to quantify the color of their beers compared to Purgatory's. The SRM values from each sample can be seen in Figure 9.

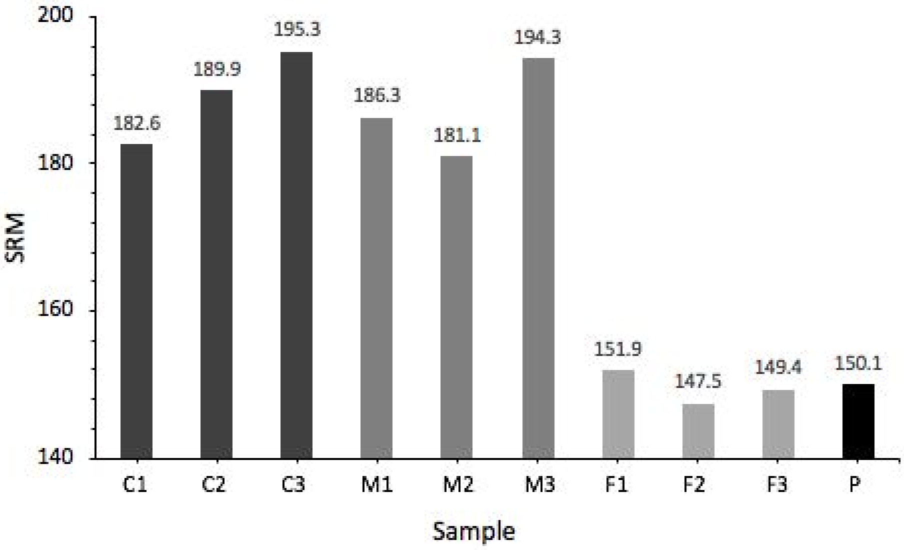

Figure 9. SRM values of the coarse (C), medium (M), fine (F), and Purgatory's (P) beers. The data is found in Table 26 of Appendix I.

The coarse and medium beers from the controlled experiments had higher SRM values than Purgatory's beer, despite looking very similar in color to the naked eye. Purgatory's beer had an SRM value of ~150 whereas the coarse and medium beers had SRM values as high as 180 to 195. As previously mentioned, Purgatory's beer could have had more different colored tints in it, giving it a darker appearance in person but a lower SRM value. In contrast, the fine beers had almost exactly the same SRM values to the Purgatory beer, with F3 being within 0.65. Overall, the average SRM values for C, M, and F decrease as grain size decreases.

4.3.5 Sensory Analysis of Beer Samples

Finally, the team had four anonymous untrained testers taste their beers in order to describe the flavor. The team decided that having humans taste the beer was the most effective way at actually determining which beer had the optimal flavor. The words that the taste testers used to describe each of the beers can be seen in Appendix J.

Overall, the taste testers' thoughts aligned with the trends in data gathered in the laboratory on the thickness (carbohydrate content) and strength (ABV) of the beers. The testers noticed that C1 had the strongest alcohol flavor and thickest mouthfeel, M1 had a "medium" rating for mouthfeel, and F1 had the least alcohol flavor and thinnest mouthfeel. With regards to the flavored beers, the testers did not recognize the coconut flavor as much in the coarse beers as they did in the medium and fine. The coconut flavor came through the most in the M3, F2, and F3 samples. Although no one beer was preferred by all four taste testers, the beers flavored with unsulfured coconut were liked the most. Two of the testers preferred C2, while tester 3 preferred M2 and F2. Upon debriefing, the team found out that tester 4 prefers lighter beers to robust porters; therefore, tester 4 preferred F1, a thinner, unflavored porter. It is also notable that tester 4 did not like any of the beers flavored with untreated coconut, which is in agreement with the other testers.

5. Conclusions and Recommendations

It was determined that the grain size distribution did not have an affect on the flavor of the Fiero Coconut Rum Porter. However, there were trends found from the limited testing between the grain size distributions and the alcohol content, carbohydrate content, and color values of the beers. All of these trends were decreasing from coarse to medium to fine grains, although the values found for coarse and medium beers were consistently within ~3% of each other; therefore, the team concluded that the differences were insignificant. The similarities between these beers were expected since the coarse and medium grain size distributions for the pale malts (majority of the recipe) were within 7 weight % of each other. The team concluded that the coarse grains from BSG may be closer in style to what Brian was milling himself, since the grains that he milled were slightly coarser than the medium and did not cause clogging.

From the hedonistic testing completed by four taste testers, the team found that the unsulfured coconut was preferred to the untreated coconut. The testers did not notice any flavors directly related to the grain size used to make the beer. They did not unanimously prefer one type of beer made from one particular grain size.

In order to make a consistently good-tasting beer, the team first recommends that Purgatory Beer Company be consistent in all ingredients and procedures used while brewing. With respect to grains, the team concludes that Purgatory Beer Company has the freedom to use the medium or coarse grain size offered by BSG for their Fiero Coconut Rum Porter, as the flavor and other tested properties showed no significant differences. As an improvement to the overall brewing process, the team recommends using the coarse grain because they believe that it will not be as susceptible to clogging and will create ease of filtration. To receive the grains from BSG in a timely manner, it is important to contact them at least 2 weeks in advance of the scheduled brewing date. Based on the limited taste testing in regards to coconut flavor, the team recommends using unsulfured coconut flakes in the Fiero Coconut Rum Porter.

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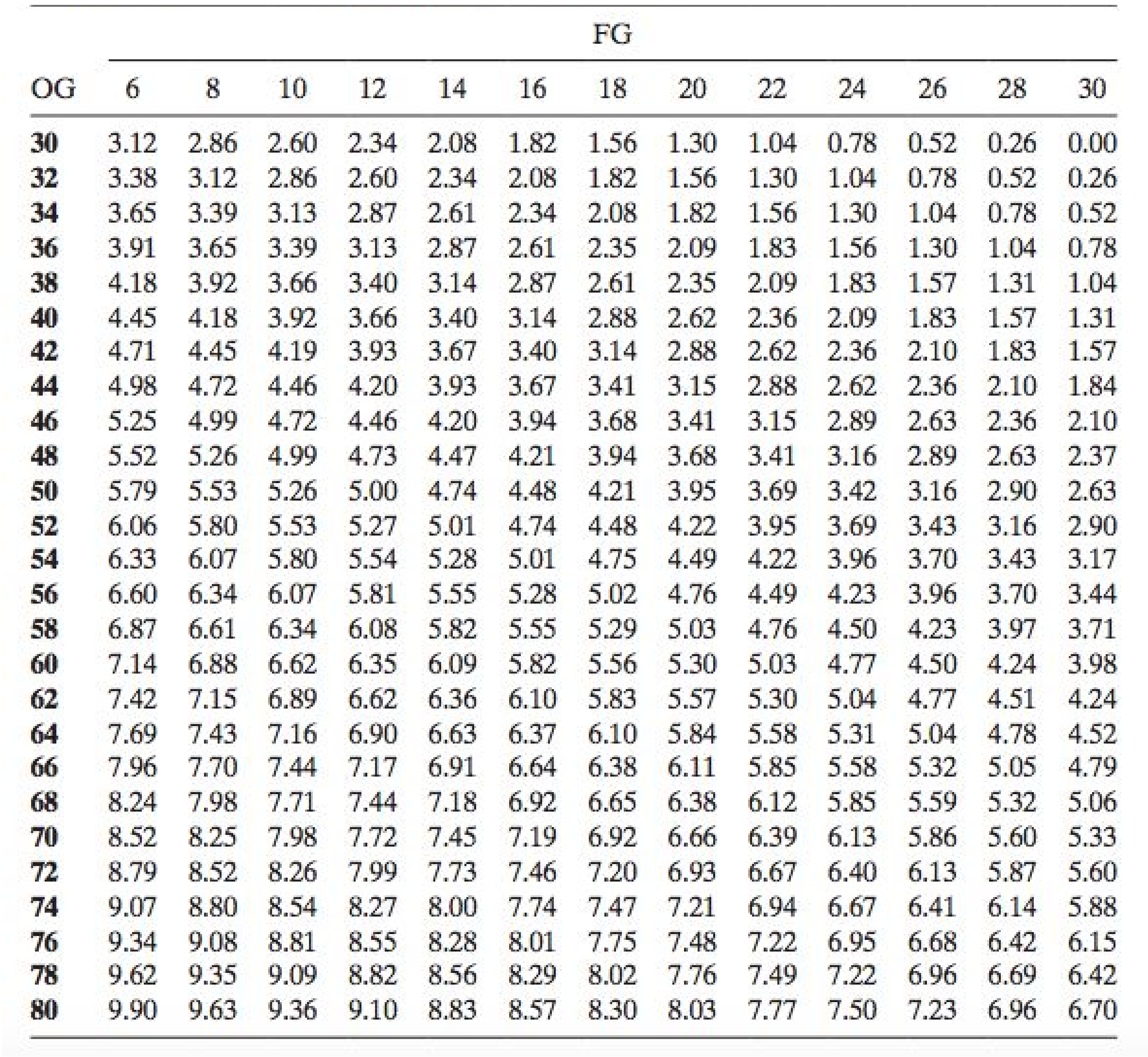
Appendices

Appendix A: Fiero Coconut Rum Porter Recipe

[Redacted due to proprietary information]

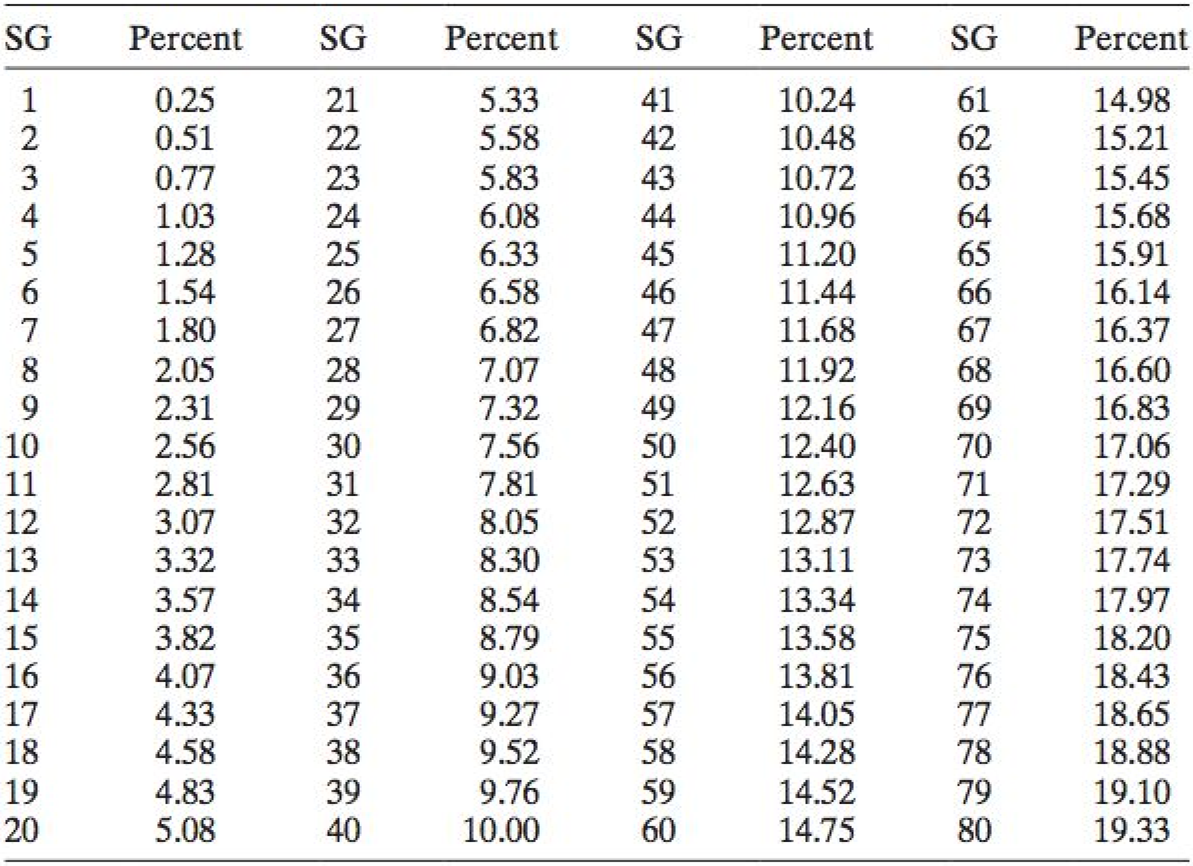
Appendix B: Alcohol and Carbohydrate Content Tables

Table 1. Alcohol by Volume Estimation, Table 10.3 in The Chemistry of Beer: The Science in the Suds.



	FG												
OG	6	8	10	12	14	16	18	20	22	24	26	28	30
30	3.12	2.86	2.60	2.34	2.08	1.82	1.56	1.30	1.04	0.78	0.52	0.26	0.00
32	3.38	3.12	2.86	2.60	2.34	2.08	1.82	1.56	1.30	1.04	0.78	0.52	0.26
34	3.65	3.39	3.13	2.87	2.61	2.34	2.08	1.82	1.56	1.30	1.04	0.78	0.52
36	3.91	3.65	3.39	3.13	2.87	2.61	2.35	2.09	1.83	1.56	1.30	1.04	0.78
38	4.18	3.92	3.66	3.40	3.14	2.87	2.61	2.35	2.09	1.83	1.57	1.31	1.04
40	4.45	4.18	3.92	3.66	3.40	3.14	2.88	2.62	2.36	2.09	1.83	1.57	1.31
42	4.71	4.45	4.19	3.93	3.67	3.40	3.14	2.88	2.62	2.36	2.10	1.83	1.57
44	4.98	4.72	4.46	4.20	3.93	3.67	3.41	3.15	2.88	2.62	2.36	2.10	1.84
46	5.25	4.99	4.72	4.46	4.20	3.94	3.68	3.41	3.15	2.89	2.63	2.36	2.10
48	5.52	5.26	4.99	4.73	4.47	4.21	3.94	3.68	3.41	3.16	2.89	2.63	2.37
50	5.79	5.53	5.26	5.00	4.74	4.48	4.21	3.95	3.69	3.42	3.16	2.90	2.63
52	6.06	5.80	5.53	5.27	5.01	4.74	4.48	4.22	3.95	3.69	3.43	3.16	2.90
54	6.33	6.07	5.80	5.54	5.28	5.01	4.75	4.49	4.22	3.96	3.70	3.43	3.17
56	6.60	6.34	6.07	5.81	5.55	5.28	5.02	4.76	4.49	4.23	3.96	3.70	3.44
58	6.87	6.61	6.34	6.08	5.82	5.55	5.29	5.03	4.76	4.50	4.23	3.97	3.71
60	7.14	6.88	6.62	6.35	6.09	5.82	5.56	5.30	5.03	4.77	4.50	4.24	3.98
62	7.42	7.15	6.89	6.62	6.36	6.10	5.83	5.57	5.30	5.04	4.77	4.51	4.24
64	7.69	7.43	7.16	6.90	6.63	6.37	6.10	5.84	5.58	5.31	5.04	4.78	4.52
66	7.96	7.70	7.44	7.17	6.91	6.64	6.38	6.11	5.85	5.58	5.32	5.05	4.79
68	8.24	7.98	7.71	7.44	7.18	6.92	6.65	6.38	6.12	5.85	5.59	5.32	5.06
70	8.52	8.25	7.98	7.72	7.45	7.19	6.92	6.66	6.39	6.13	5.86	5.60	5.33
72	8.79	8.52	8.26	7.99	7.73	7.46	7.20	6.93	6.67	6.40	6.13	5.87	5.60
74	9.07	8.80	8.54	8.27	8.00	7.74	7.47	7.21	6.94	6.67	6.41	6.14	5.88
76	9.34	9.08	8.81	8.55	8.28	8.01	7.75	7.48	7.22	6.95	6.68	6.42	6.15
78	9.62	9.35	9.09	8.82	8.56	8.29	8.02	7.76	7.49	7.22	6.96	6.69	6.42
80	9.90	9.63	9.36	9.10	8.83	8.57	8.30	8.03	7.77	7.50	7.23	6.96	6.70

Table 2. Carbohydrate Percent, Table 10.2 in The Chemistry of Beer: The Science in the Suds.



SG	Percent	SG	Percent	SG	Percent	SG	Percent
1	0.25	21	5.33	41	10.24	61	14.98
2	0.51	22	5.58	42	10.48	62	15.21
3	0.77	23	5.83	43	10.72	63	15.45
4	1.03	24	6.08	44	10.96	64	15.68
5	1.28	25	6.33	45	11.20	65	15.91
6	1.54	26	6.58	46	11.44	66	16.14
7	1.80	27	6.82	47	11.68	67	16.37
8	2.05	28	7.07	48	11.92	68	16.60
9	2.31	29	7.32	49	12.16	69	16.83
10	2.56	30	7.56	50	12.40	70	17.06
11	2.81	31	7.81	51	12.63	71	17.29
12	3.07	32	8.05	52	12.87	72	17.51
13	3.32	33	8.30	53	13.11	73	17.74
14	3.57	34	8.54	54	13.34	74	17.97
15	3.82	35	8.79	55	13.58	75	18.20
16	4.07	36	9.03	56	13.81	76	18.43
17	4.33	37	9.27	57	14.05	77	18.65
18	4.58	38	9.52	58	14.28	78	18.88
19	4.83	39	9.76	59	14.52	79	19.10
20	5.08	40	10.00	60	14.75	80	19.33

Appendix C: Controlled Home Brew Experiment Protocol

Home Brew Process (to make 0.6936 gallons final)

1. Fill the pot with filtered water for mash.
    a. [Redacted due to proprietary information] Bring to 165ºF
2. Measure grains and place in the cheesecloth bag
    a. [Redacted due to proprietary information]
3. Place the cheese cloth bag into the hot water for 1 hour. Maintain temperature at 155+/-5ºF. DO NOT LET BOIL.
4. Move the bag around. Sparge (pour over grain bag) with [Redacted due to proprietary information] hot (155 ºF) filtered water.
5. Remove grain bag. Allow to drip until most wort is drained.
6. Bring the temperature of wort to 210ºF. Boil for 1 hour.
    a. [Redacted due to proprietary information]
7. Place pot into ice bath in sink and stir the wort until it reaches 70ºF.
8. Ladle the chilled wort into 4 mason jars.
9. Prepare the fermenting. Add yeast and fill the CO2 trap with water.
10. Add flavoring after 7-10 days of fermenting.
    a. [Redacted due to proprietary information]

Appendix D: Gas Chromatography Mass Spectroscopy Protocol

1. Combine 5 mL wort or beer, 5 mL DI water, 5 mL dichloromethane, and 2.25 g of table salt into a centrifuge tube.
2. Cover and swirl tube until mixed (about 1 minute).
3. Place the tubes into the centrifuge and centrifuge at 3000-3500 rpm for 10 minutes.
4. Using a pipette, collect the bottom lighter colored layer of liquid. Filter the layer using a PTFE or PVDF filter tip attached to a syringe into a GCMS vial. Do not force through the syringe to avoid particles getting through the filter.
5. Run vial through the GCMS instrument.

Appendix E: Spectrophotometry Protocol

1. Turn on machine and set wavelength to 430 nm.
2. Ensure the filter is set to correct range, which contains 430 nm.
3. Ensure there is nothing in the machine and adjust T dial to 0% transmittance.
4. Place a blank sample (1 cm cuvette with water ensuring its been wiped clean of all particles on the outside) into the machine and adjust the transmittance to 100% for calibration.
5. Remove blank.
6. Place a clean 1 cm cuvette with filtered and de-gassed wort or beer sample into the machine.
7. Switch reading to absorbance mode and record the absorbance of the sample.

Appendix F: Grain Size Distribution Graphs and Data Tables

Table 3. Grain size distribution data for Crisp Maris Otter Malt

Average Size (mm)	Coarse Weight Percent	Medium Weight Percent	Fine Weight Percent
4.06	17.66	11.93	6.05
2.68	52.83	47.44	30.98
1.84	5.798	9.94	11.73
1.44	8.11	11.85	16.31
0.81	9.13	11.13	20.57
0.34	1.93	2.12	4.52
0.20	1.41	1.86	3.37
0.08	3.14	3.72	6.47

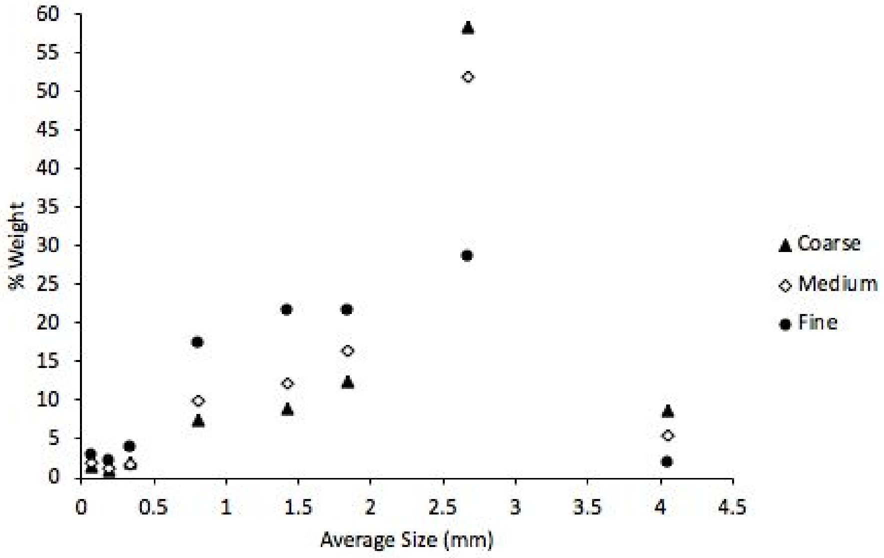


Figure 10. Grain size distribution data for the coarse, medium, and fine crush of Rahr Standard 2 Row Malt. The x-axis displays the average sized particle between each tray [mm], and the y-axis displays weight percent [g grain per tray/g total grain]. The raw data is found in Table 4.

Table 4. Grain size distribution data for Rahr Standard 2 Row Malt

Average Size (mm)	Coarse Weight Percent	Medium Weight Percent	Fine Weight Percent
4.06	8.67	5.33	1.75
2.68	58.39	51.85	28.66
1.84	12.43	16.40	21.73
1.44	8.88	12.08	21.64
0.81	7.44	9.75	17.37
0.34	1.77	1.70	3.81
0.20	0.92	1.09	2.05
0.08	1.50	1.80	2.99

Table 5. Grain size distribution data for Crisp Chocolate Malt

Average Size (mm)	Coarse Weight Percent	Medium Weight Percent	Fine Weight Percent
4.06	1.04	0.27	0.20
2.68	45.11	28.70	12.61
1.84	23.31	26.82	31.09
1.44	16.96	27.85	32.94
0.81	9.42	12.02	16.70
0.34	1.87	2.33	2.57
0.20	1.77	1.61	2.77
0.08	0.52	0.40	1.12

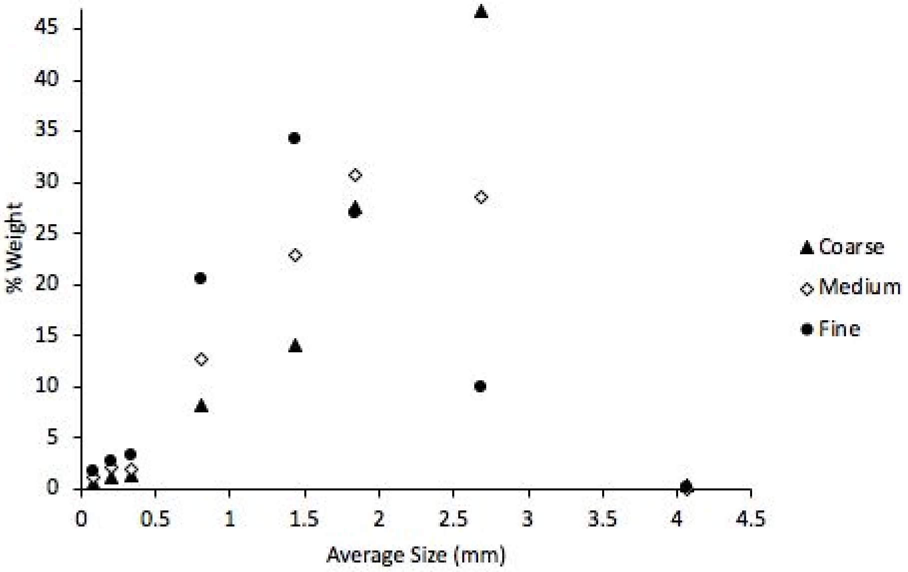


Figure 11. Grain size distribution data for the coarse, medium, and fine crush of Weyermann® CARAFA® Type 3. The x-axis displays the average sized particle between each tray [mm], and the y-axis displays weight percent [g grain per tray/g total grain]. The raw data is found in Table 6.

Table 6. Grain size distribution data for Weyermann® CARAFA® Type 3

Average Size (mm)	Coarse Weight Percent	Medium Weight Percent	Fine Weight Percent
4.06	0.41	0.06	0.20
2.68	46.81	28.64	10.00
1.84	27.58	30.64	27.07
1.44	14.14	22.79	34.33
0.81	8.11	12.71	20.57
0.34	1.33	1.95	3.30
0.20	1.16	2.06	2.79
0.08	0.46	1.15	1.73

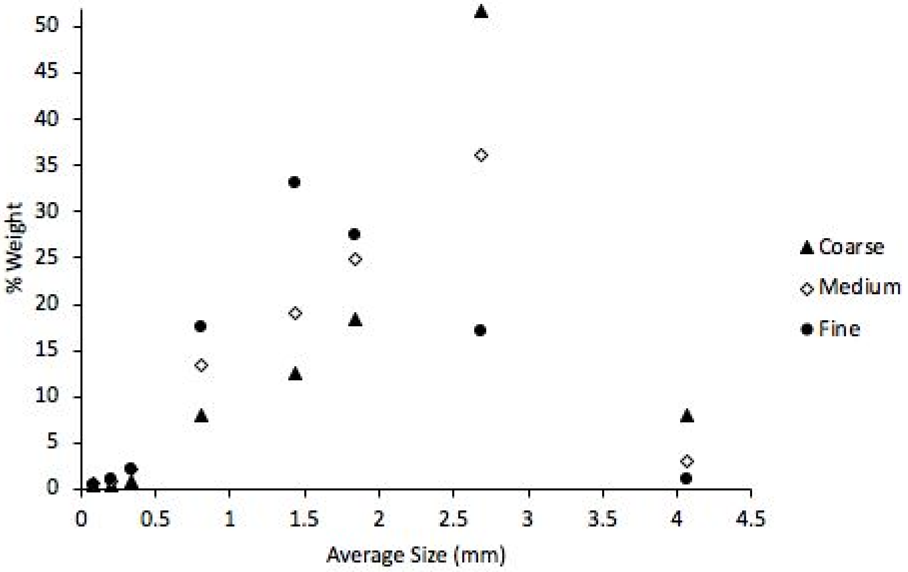


Figure 12. Grain size distribution data for the coarse, medium, and fine crush of Crisp Crystal 77L Malt. The x-axis displays the average sized particle between each tray [mm], and the y-axis displays weight percent [g grain per tray/g total grain]. The raw data is found in Table 7.

Table 7. Grain size distribution data for Crisp Crystal 77L Malt

Average Size (mm)	Coarse Weight Percent	Medium Weight Percent	Fine Weight Percent
4.06	7.90	2.97	0.96
2.68	51.68	36.06	17.19
1.84	18.44	24.86	27.54
1.44	12.49	19.09	33.16
0.81	7.90	13.49	17.57
0.34	0.88	2.13	2.17
0.20	0.41	0.84	0.96
0.08	0.29	0.56	0.45

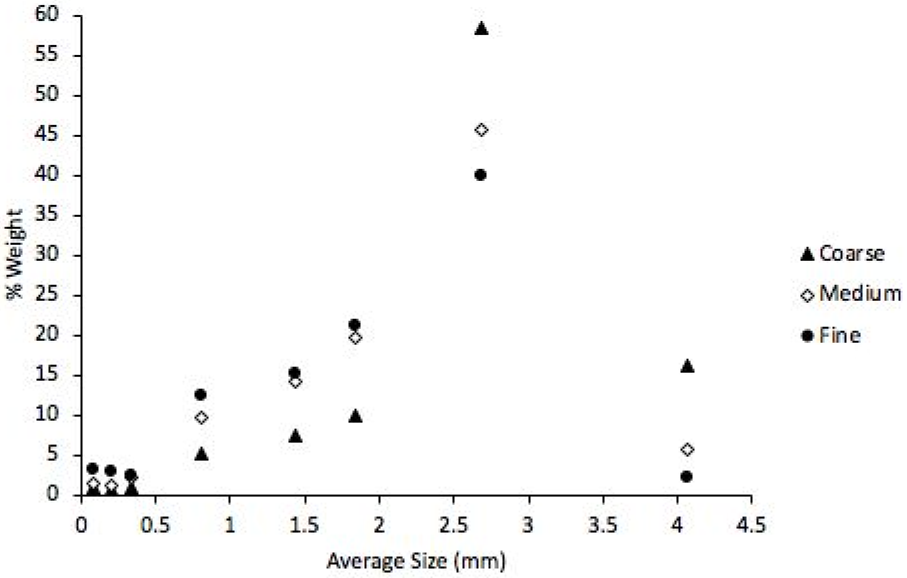


Figure 13. Grain size distribution data for the coarse, medium, and fine crush of Weyermann® Carafoam®. The x-axis displays the average sized particle between each tray [mm], and the y-axis displays weight percent [g grain per tray/g total grain]. The raw data is found in Table 8.

Table 8. Grain size distribution data for Weyermann® Carafoam®

Average Size (mm)	Coarse Weight Percent	Medium Weight Percent	Fine Weight Percent
4.06	16.24	5.69	2.27
2.68	58.50	45.63	39.97
1.84	9.91	19.68	21.27
1.44	7.57	14.33	15.25
0.81	5.25	9.77	12.56
0.34	0.98	2.11	2.53
0.20	0.63	1.28	3.03
0.08	0.92	1.51	3.11

Appendix G: Carbohydrate and Alcohol Content Data for Worts and Beers

Table 9. Specific gravity, points, and carbohydrate content data for wort samples

Sample	Specific Gravity	Points	Carbohydrate Percent (%)
Purgatory Wort	1.064	64	15.68
Coarse Wort	1.055	55	13.58
Medium Wort	1.054	54	13.34
Fine Wort	1.041	41	10.24

Table 10. Specific gravity, points, and carbohydrate and alcohol content data for beer samples

Sample	Specific Gravity	Points	Alcohol Content (ABV, %)	Corrected Points	Carbohydrate Percent (%)
Purgatory Porter	1.016	16	6.37	24.6	6.33
C1	1.026	26	3.83	31.17	7.81
C2	1.026	26	3.83	31.17	7.81
C3	1.026	26	3.83	31.17	7.81
M1	1.026	26	3.7	30.99	7.81
M2	1.024	24	3.96	29.35	7.32
M3	1.025	25	3.83	30.17	7.56
F1	1.016	16	3.27	20.41	5.08
F2	1.016	16	3.27	20.41	5.08
F3	1.016	16	3.27	20.41	5.08

Appendix H: GCMS Data for Worts and Beers

Table 11. Components in Purgatory's wort

Retention Time (min)	Area	Area %	Name of Component
2.53	378206	2.04	1-(3,4-Diethocybenzoyl)-6,7-diiso propxy-isoquinoline
2.67	3513092	18.95	Paromomycin
2.755	4863106	26.23	Ethylene, 1,2-dichloro-, (E)-
2.97	391135	2.11	1-Pentene, 3-methyl-
3.311	723322	3.9	Ethyl Acetate
3.416	30224	0.16	Propane, 2-ethoxy-2-methyl-
3.473	50314	0.27	Trichloromethane
3.559	315552	1.7	1-Propanol, 2-methyl-
3.821	40530	0.22	Amylene hydrate
6.665	2930213	15.81	1-Butanol, 3-methyl-
6.832	649989	3.51	1-Butanol, 2-methyl-
7.996	199769	1.08	Heptane, 4-methyl-
9.463	398273	2.15	2,3-Butanediol
12.304	509026	2.75	2,4-Dimethyl-1-heptene
14.968	202755	1.09	1-Butanol, 3-methyl-, acetate
25.04	201828	1.09	Heptane, 2,5,5-trimethyl-
25.378	223671	1.21	Heptane, 2,5,5-trimethyl-
30.491	140170	0.76	2-Undecene, 4,5-dimethyl-, [R*,S*-(Z)]-
30.829	97759	0.53	Ethanol, 2-(dodecyloxy)-
32.961	1999894	10.79	Phenylethyl Alcohol
43.431	342713	1.85	Benzene, 1,3-bis(1,1-dimethylethyl)-

48.003	199379	1.08	2-Hexyldecyl acetate
48.58	133543	0.72	2-Isopropyl-5-methyl-1-heptanol

Table 12. Components in coarse wort

Retention Time (min)	Area	Area %	Name of Component
2.57	489410	5.68	Thiazolo[4,5-d]pyrimidine-5,7(4H, 6H)-dione, 2-amino-4-butyl-
2.7	3325710	38.61	Hexaborane
2.789	4711790	54.71	Ethylene, 1,2-dichloro-, (E)-
3.12	52988	0.62	2,2-Dimethyl-3-hydroxypropionaldehyde
3.504	32590	0.38	Trichloromethane

Table 13. Components in medium wort

Retention Time (min)	Area	Area %	Name of Component
2.54	409637	4.79	Silane, diethyldi(4-chlorophenoxy)-
2.696	2929162	34.24	Methylene Chloride
2.769	4428952	51.78	Ethylene, 1,2-dichloro-, (E)-
2.985	741797	8.67	(Z)-2-Heptene
3.462	44649	0.52	Trichloromethane

Table 14. Components in fine wort

Retention Time (min)	Area	Area %	Name of Component
2.53	438558	4.5	O,O-Diethyl O-(6-methyl-5-(3-(triflouromethyl)phenoxy)-2-(4-(triflouromethyl)phenyl)-4-pyrimidinyl) thiophosphate
2.67	3305826	33.88	Pentaborane(11)
2.752	5660948	58.03	Ethene, 1,1-dichloro-

3.09	292132	2.99	1,3,2-Dioxaborolan-4-one, 2-ethyl-5-methyl-
3.451	58662	0.6	Trichloromethane

Table 15. Components in Purgatory's beer

Retention Time (min)	Area	Area %	Name of Component
2.54	433794	2.64	Propanedioic acid, (phenylmethylene)-
2.67	2541541	15.46	trans-2,3-Epoxyoctane
2.738	3333954	20.26	1,2-Dichloroethylene
2.845	867328	5.28	Methane-d, trichloro-
2.945	930090	5.66	1-Pentene, 2-methyl-
3.01	141776	0.86	Methane-d, trichloro-
3.055	146181	0.89	1,3-Butanediol
3.277	513862	3.13	Ethyl Acetate
3.378	24983	0.15	Propane, 2-ethoxy-2-methyl-
3.429	45639	0.28	Trichloromethane
3.513	793387	4.83	1-Propanol, 2-methyl-
6.596	2231105	13.57	1-Butanol, 3-methyl-
6.761	691348	4.21	1-Butanol, 2-methyl-
7.93	177818	1.08	Heptane, 4-methyl-
10.459	985759	6	Propanoic acid, 2-hydroxy-, ethyl ester, (S)-
12.253	322135	1.96	2,4-Dimethyl-1-heptene
32.945	2083692	12.68	Phenylethyl Alcohol
43.449	174204	1.06	Benzene, 1,3-bis(1,1-dimethylethyl)-

Table 16. Components in coarse beer with no flavorings (C1)

Retention Time (min)	Area	Area %	Name of Component
2.535	421564	0.92	Acetamide, N-(4-chlorobenzyl)-2-(3-cyano-4,6-dimethylpyridin-2-ylsulfanyl)-
2.686	3090764	6.78	Methylene Chloride
2.758	6119013	13.42	Ethylene, 1,2-dichloro-, (E)-
3.08	225782	0.5	n-Hexane
3.301	170431	0.37	Ethyl Acetate
3.535	664894	1.46	1-Propanol, 2-methyl-
6.632	1401166	3.07	1-Butanol, 3-methyl-
6.801	417881	0.92	1-Butanol, 2-methyl-
9.792	159566	0.35	Octane
33.031	1497793	3.28	Phenylethyl Alcohol
67.198	31428750	68.93	Nonadecane

Table 17. Components in coarse beer with unsulfured coconut (C2)

Retention Time (min)	Area	Area %	Name of Component
2.545	407250	2.55	Eseroline, 3a-desmethyl-5-O-methyl-
2.686	3518947	22.07	Methylene Chloride
2.758	4699009	29.47	Ethylene, 1,2-dichloro-, (E)-
2.965	895815	5.62	Cyclobutane, ethyl-
3.035	420132	2.63	Butanal
3.306	194003	1.22	Ethyl Acetate
3.542	685249	4.3	1-Propanol, 2-methyl-
5.19	145392	0.91	Pentanal
6.647	1470505	9.22	1-Butanol, 3-methyl-

6.816	458450	2.87	1-Butanol, 2-methyl-
9.805	209120	1.31	Octane
33.02	1811765	11.36	Phenylethyl Alcohol
63.209	364107	2.28	D-Alanine, N-neopentylocycarbonyl-, octadecyl ester
63.418	377862	2.37	5-Decanone
64.924	289704	1.81	Isovaleric acid, 3-methylbutyl-2 ester

Table 18. Components in coarse beer with untreated coconut (C3)

Retention Time (min)	Area	Area %	Name of Component
2.53	460331	2.92	3-Pyridinecarboxylic acid, 1-(2,4-dimethylphenyl)-1,6-dihydro-4-hydroxy-2-methyl-6-oxo-, ethyl ester
2.67	3210970	20.38	5,6-Dicarbadecaborane(12), 5,6-dimethyl-
2.75	5432905	34.46	Ethylene, 1,2-dichloro-, (E)-
2.96	1198842	7.61	1-Pentene, 2-methyl-
3.08	282012	1.79	Pentane, 2,2,4-trimethyl-
3.11	106973	0.68	Thiophene, 2,5-dihydro-
3.165	55125	0.35	1,10-Diaminodecane
3.295	185792	1.18	Ethyl Acetate
3.53	611879	3.88	1-Propanol, 2-methyl-
6.626	1400188	8.89	1-Butanol, 3-methyl-
6.794	437336	2.78	1-Butanol, 2-methyl-
9.784	187421	1.19	Octane
12.29	101673	0.65	2,4-Dimethyl-1-heptene
33.004	1719856	10.92	Phenylethyl Alcohol

Table 19. Components in medium beer with no flavorings (M1)

Retention Time (min)	Area	Area %	Name of Component
2.545	417090	2.95	Podocarpa-6,8,11,13-tetraen-12-ol, 13-isopropyl-, acetate
2.67	2956781	20.89	Oxirane, 2,2'-(1,4-butanediyl)bis-
2.747	5071861	35.84	Ethylene, 1,2-dichloro-, (E)-
2.95	643103	4.54	2-Methyl-2-pentyl methylphosphonofluoridate
3.08	139380	0.98	Piperidine
3.293	240921	1.7	Ethyl Acetate
3.528	548002	3.87	1-Propanol, 2-methyl-
6.624	1329652	9.4	1-Butanol, 3-methyl-
6.793	406634	2.87	1-Butanol, 2-methyl-
9.781	276242	1.95	Octane
12.285	88749	0.63	2,4-Dimethyl-1-heptene
24.524	108379	0.77	Undecane
32.982	1787253	12.63	Phenylethyl Alcohol
40.174	138357	0.98	Dodecane

Table 20. Components in medium beer with unsulfured coconut (M2)

Retention Time (min)	Area	Area %	Name of Component
2.535	419508	3.14	3-Bromo-7,7'-dimethyl-4,4'-dihydroxy-1, 1'-binaphthalene-5,5',8,8'-tetrone
2.684	2628483	19.67	Methylene chloride
2.746	5202676	38.93	Ethylene, 1,2-dichloro-, (E)-
2.955	999624	7.48	Cyclohexane
3.07	53448	0.4	2-Butenal, 2-methyl-
3.291	255660	1.91	Ethyl Acetate

3.528	513157	3.84	1-Propanol, 2-methyl-
6.623	1199387	8.98	1-Butanol, 3-methyl-
6.791	391681	2.93	1-Butanol, 2-methyl-
9.78	120304	0.9	Octane
32.972	1579313	11.82	Phenylethyl Alcohol

Table 21. Components in medium beer with untreated coconut (M3)

Retention Time (min)	Area	Area %	Name of Component
2.54	348176	2.92	6-Nitropiperonal
2.67	2627844	22.06	Decaborane(14)
2.74	4859689	40.78	Ethylene, 1,2-dichloro-, (E)-
3.281	236486	1.99	Ethyl Acetate
3.516	559527	4.7	1-Propanol, 2-methyl-
6.6	1313003	11.02	1-Butanol, 3-methyl-
6.767	379647	3.19	1-Butanol, 2-methyl-
32.952	1589085	13.34	Phenylethyl Alcohol

Table 22. Components in fine beer with no flavorings (F1)

Retention Time (min)	Area	Area %	Name of Component
2.535	387478	2	4H-1,2,4-Triazole-3-thiol, 4-(2-fluorophenyl)-5-(1-methylethyl)-
2.67	2413886	12.47	2-(3-Methylphenoxy)octahydro-1H-1,3,2-benzodiazaphosphole 2-oxide
2.738	4944204	25.54	Ethylene, 1,2-dichloro-, (E)-
2.94	776306	4.01	Cyclohexane
3.01	388511	2.01	Butanal
3.28	137127	0.71	Ethyl Acetate
3.515	606302	3.13	1-Propanol, 2-methyl-

5.154	117507	0.61	Pentanal
6.6	1447453	7.48	1-Butanol, 3-methyl-
6.766	425897	2.2	1-Butanol, 2-methyl-
9.748	243958	1.26	Octane
32.948	1398865	7.23	Phenylethyl Alcohol
63.145	2767155	14.29	D-Alanine, N-neopentyloxycarbonyl-, hexyl ester
63.355	2273153	11.74	4-Methyl-3,5-decandione
64.851	644534	3.33	2,3-Dimethyl-undec-1-en-3-ol
79.966	385625	1.99	Bicyclo[3.2.0]heptan-2-one, 5-(ethoxycarbonylmethyl)-6-hydroxy-3,3-dimethyl-6-vinyl-

Table 23. Components in fine beer with unsulfured coconut (F2)

Retention Time (min)	Area	Area %	Name of Component
2.54	458452	3.19	Molybdenum tetracarbonyl-[N-butylL-N,N-bis(2-phosphinoethyl)amino]-
2.684	2346009	16.33	Methylene chloride
2.735	6080092	42.34	Ethylene, 1,2-dichloro-, (E)-
3.055	510591	3.55	n-Hexane
3.273	159278	1.11	Ethyl Acetate
3.505	628848	4.38	1-Propanol, 2-methyl-
6.583	1453176	10.12	1-Butanol, 3-methyl-
6.753	395421	2.75	1-Butanol, 2-methyl-
7.918	83457	0.58	Heptane, 4-methyl-
9.736	216036	1.5	Octane
12.245	104718	0.73	2,4-Dimethyl-1-heptene

24.481	121199	0.84	Undecane
32.946	1354870	9.43	Phenylethyl Alcohol
40.135	164598	1.15	Dodecane
67.06	287474	2	Heneicosane

Table 24. Components in fine beer with untreated coconut (F3)

Retention Time (min)	Area	Area %	Name of Component
2.535	433817	3.1	Propanedioic acid, (1-ethylbutyl)-, dimethyl ester, (R)-
2.67	2648777	18.95	1,5-Hexadiene, 3-chloro-
2.748	5199106	37.21	Ethylene, 1,2-dichloro-, (E)-
2.955	883469	6.32	1-Pentene, 2-methyl-
3.055	311664	2.23	n-Hexane
3.293	158959	1.14	Ethyl Acetate
3.529	621683	4.45	1-Propanol, 2-methyl-
6.624	1501185	10.74	1-Butanol, 3-methyl-
6.792	425345	3.04	1-Butanol, 2-methyl-
7.956	87617	0.63	Heptane, 4-methyl-
9.779	167033	1.2	Octane
12.274	149554	1.07	2,4-Dimethyl-1-heptene
24.504	81547	0.58	Undecane
32.955	1305993	9.34	Phenylethyl Alcohol

Appendix I: SRM Data for Worts and Beers

Table 25. Standard Reference Method values for wort samples

Sample	Absorbance	Dilution Factor	SRM Value
Purgatory Wort	2.418	3	92.13
Coarse Wort	2.173	7	193.18
Medium Wort	2.163	7	192.29
Fine Wort	1.741	7	154.77

Table 26. Standard Reference Method values for beer samples

Sample	Absorbance	Dilution Factor	SRM Value
Purgatory Porter	1.688	7	150.06
C1	2.396	6	182.58
C2	2.448	6	189.59
C3	2.197	7	195.31
M1	2.445	6	186.31
M2	2.377	6	181.13
M3	2.186	7	194.34
F1	1.993	6	151.87
F2	1.936	6	147.52
F3	1.960	6	149.35

Appendix J: Hedonistic Taste Testing Data

Sample	Tester 1	Tester 2	Tester 3	Tester 4
C1	Alcohol flavor is pronounced	Bitter, strong	Coffee notes, would drink it, simple flavor	Sweet, not thick or watery, tastes porter but tastes like a lighter beer, bland flavor
C2	Bitter, deep, rich, liked this the most	Bitter, robust, deep, uncarbonated, liked this the most	Slightly bitter, stronger one flavor than C1, robust, thin	Richer chocolatiness, thicker than C1, bitter aftertaste, more like a porter
C3	More bitter than C2, different mouthfeel, thinner	More bitter, thin/watery	Light, watery, slightly bitter but not as much, faint flavor, lightest of the coarse	Not as rich with flavor or as bitter as C2, dull flavor and a little watery
M1	Strong, thinner mouthfeel than C1, sour	Strong, bitter, smells roasted	Sweeter, do not like, thin, no flavor, bitter aftertaste	No taste, mostly watery with hint of chocolate, lighter beer
M2	Coconut/nutty rum flavor, medium thickness	Rum flavor, watery, not very bitter, fine aftertaste, pretty good	Flavor hits in beginning, chocolatey, not light or heavy (medium), less bitter, likes this one	Stronger porter flavor, chocolatey, thick, bitter aftertaste, robust, alcohol flavor
M3	Mild bitterness, smoother	Coconut!, mild bitterness, rum, strong/robust flavors, thin	Coconut!, bitter but sweeter because of more coconut flavor, robust, likes this one	Very bitter, overpowering bitterness, watery, hint of chocolate, like a black coffee
F1	Malty, grain flavor, less alcohol, not as much CO2	Not bitter, tastes like coffee, not as much alcohol flavor	Bitter!, cannot describe flavor well because there is not much	Watery with more chocolate flavor, not too bitter, likes this the best but no overpowering flavor
F2	Coconut!, malty, earthy, cacao	Coconut!, sweet, robust,	Slight coffee and chocolate, strong	Bitter, a little chocolate with no other powerful

	flavor	a lot of flavors more than beer flavor	flavor of something unidentifiable, tastes like typical porter, likes it	flavor, average mouthfeel, watery
F3	Weird stinky coconut flavor, thin consistency, not rich	Weird coconut flavor, not bad, watery	Light coconut flavor with another unidentifiable, bitter aftertaste	Do not like, very bitter, not chocolatey, average mouthfeel