

You Too Can Brew: The Impacts, Ingredients, and Techniques of Homebrewing

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Abstract—The following document is an analysis of homebrewing. Specifically, this paper focuses on the impacts of homebrewing on the craft beer industry; the four main ingredients used by homebrewers to brew beer; and the process of homebrewing.



1 INTRODUCTION

IF you are legally old enough, there is a very good chance that you have tried a beer at some point in your life. Maybe you tried your first sip and never touched the stuff again. Maybe you have a beer every now and again while socializing with friends. Or maybe you spend your free-time traveling to the top rated breweries in your state and waiting in hour-long lines, just to receive a limited released, highly coveted, \$60.00 bottle of beer. I will be the first to admit that I am a part of that third group. As a 29 year old, I have spent the last 8 years of my life closely following the growth of the beer industry in the United States. My passion for drinking and collecting beer eventually led to my latest hobby, brewing it myself. The knowledge I have gained while learning to brew my own beer has undoubtedly transformed my beer preferences, appreciation, and frankly, snobbery.

This paper will begin by analysing the business of beer in The United States, specifically focusing on the impact of craft beer and it's reliance on homebrewing to educate and influence consumers' preferences in their beer selection. Next, this paper will dive deeper into what goes into beer, showcasing its four main ingredients, water, malt, hops, and yeast. Lastly, this paper will describe the process of homebrewing, highlighting specific techniques used by homebrewers to brew some of the most

popular styles of beer consumed today. The United States' beer industry is currently undergoing a period of shifting market share, shifting preference, and an increase in consumer's beer-knowledge. Homebrewing is one of the most influential hobbies currently helping influence this shift by educating the market about the ingredients and processes used to make beer.

2 US CRAFT BEER & HOMEBREWING'S INFLUENCE

TEN years ago, if someone in The United States was asked to name their favorite brewery, chances are they would name a macro brewery. These macro breweries, often referred to as Big Beer, consist of companies such as Anheuser-Busch Inbev and MillerCoors. Today, if someone in The United States was asked to name their favorite brewery, there is a very good chance the response would be a local craft brewery. The history of beer in The United States dates back to its founding; however, the beer industry really started to take shape in the decades following World War II. The battle between Big Beer and craft breweries has expanded considerably over the last decade as consumers throughout the US have become more educated about the taste, production, and community associated with local craft beer. In Kenneth Elzinga's article, *The U.S. Beer Industry: Concentration, Fragmentation, and a Nexus with Wine*, the recent history of Big Beer is examined

with an emphasis on it's battle to dominate and monopolise the beer market. One reason that Big Beer companies are having trouble growing at the same rate as their smaller craft brewery competitors is their inability to produce a beer that knowledgeable beer consumers prefer. This can be seen in an experiment conducted and detailed by Jarrett Hart in his article, *Drink Beer for Science: An Experiment on Consumer Preferences for Local Craft Beer*. In their article, *Craft Beer in the United States: History, Numbers, and Geography*, authors, Kenneth Elzinga, Carol Tremblay, and Victor Tremblay, argue that the growing trend of craft beer preferring consumers and producers is attributed to the rise, adoption, and promotion of homebrewing.

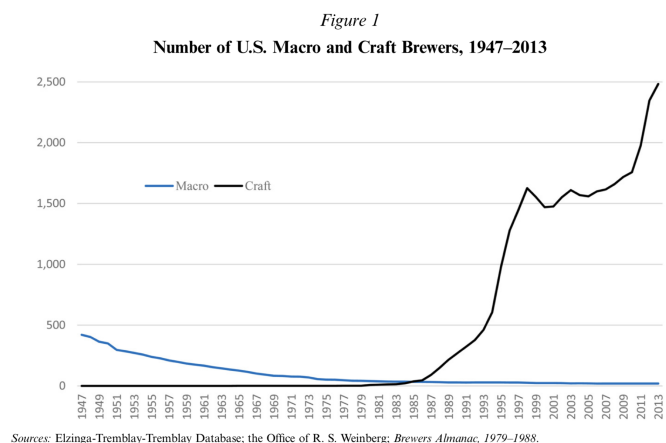
2.1 Make Room For Craft Beer

Post World War II, the beer industry began a period of consolidation. As the total number of traditional brewers in the United States declined, the volume of beer being produced increased [1]. As the beer industry grew in sales, Big Beer began its early formation and started to put smaller competitors out of business. In his article, Elzinga uses the state of Michigan as a case study of Big Beer's formation. According to Elzinga, in 1957, the leading brands of beer in Michigan were Goebel, Stroh's, Pfeiffer and Drewrys [1]. If you are scratching your head wondering who these breweries are, it's because none of them are in business anymore. Their demise was due in part to exits and mergers, paving the way for the entrance of the Big Beer companies we know today. In the 1950's the Big Beer companies of today barely even made the list of top breweries in Michigan, with Budweiser coming in at #10, Miller at #13, and Coors not even making the list [1]. By 1970 the beer scene had changed. Pabst was the leading seller in Michigan and Anheuser-Busch was #3. During this time, imported beer made up less than 1% of total beer sales [1].

By 2010, 75% of total US beer shipments were made by Anheuser-Busch Inbev and MillerCoors [1]. Elzinga attributes their rise and success to their exploitations of economies of scale and their massively funded advertising

campaigns. Between 2009 and 2010, \$232 million dollars was spent on advertising for Coors Light. During that same period, \$382 million was spent on advertising for Bud Light [1]. It is no wonder how Big Beer became the monopolies they are today. With their massive budgets for advertising and ever increasing monopolistic mergers, Big Beer has positioned itself well to control the beer industry. While these corporations have focussed on strategically placing themselves within the beer market, they have failed to focus on one of the most important things, brewing beer people actually want to drink.

While Elzinga mentions Big Beer's dominance in 2010, Jarrett Hart points out in his article that beginning in the early 2000's, craft breweries experienced consistent growth while large breweries saw a steady decline in sales. In 2017, craft breweries sold \$26 billion dollars worth of beer, making up 12.7% of total U.S. beer sales [2]. This is a major gain in market share compared to local craft breweries from a decade prior. One of the main reasons the craft brewing industry has managed to capture a significant market share in a relatively short period of time is due to the increasing numbers of craft breweries in The United States. The graph below shows a decline in the number of macro breweries over the last 65 years and a surge in the number of craft breweries over the last 30 years [1].



Witnessing their market share decline, Big Beer attempted to combat this by purchasing stakes in some of the U.S.'s largest craft brew-

eries. In 2015, Constellation acquired Ballast Point Brewing Company for \$1 billion. During that same year, Heineken acquired 50% of Petaluma-based Lagunitas Brewing for an undisclosed amount [2]. Why did major beer corporations begin acquiring their craft beer competitors? In the 2010's, Big Beer recognized a shift in the consumer's preference for a different style of beer brewed by companies they considered to be local.

2.2 Do Consumers Really Care?

In Jarrett Hart's article, the average college-town beer-drinker is examined with the implementation of an experiment designed to measure the consumer's desire for local, craft beer, rather than the beer of major corporations. Using a 60-tap pub in Davis, California, Jarrett Hart examined 301 unique participants. During the experiment Hart asked participants to write the price they would be willing to pay for 10 different beers on tap. At the end of the experiment participants received a \$2.00 coupon towards a beer of their choice. The results of the experiment helped shed light as to why big beer, who traditionally brew lagers, were failing to capture the attention of craft beer drinkers. Of the 301 participants, 104 selected an India Pale Ale as the beer they wanted to drink [2]. Currently, IPA's make up 3.1% of the total U.S. beer market; however, they make up 33% of the craft beer market [2]. Hart's experiment clearly showed consumer's preference for the hoppy beer style IPA. The experiment gave another reason Big Beer may be failing to capture the craft beer market. Of the 301 participants, 188 selected beer they considered to be local, from California, and 215 participants selected beer they considered to be craft beer [2]. According to Hart, "Average consumers do not value craft beer differently from non-craft, but those with more knowledge of craft beer increasingly value the attribute." The issue for Big Beer is that the average consumer is becoming more knowledgeable. Hart admits that the majority of people who selected local, craft-brewed IPA's, consider themselves to be knowledgeable about craft beer. This is

important because it suggests that part of the reason consumers are becoming more prone to drinking locally brewed craft beer is due to their increase in knowledge about it. Kenneth Elzinga, Carol Tremblay, and Victor Tremblay make a very similar argument in their article.

Elzinga and the Tremblays also mention Big Beer's decrease in the beer industry. According to them, between 2003 and 2013, Anheuser-Busch InBev went from a market share of 49% to 45.6%, declining by 250,000 barrels. Similarly, with a decrease of 2 million barrels, MillerCoors fell from a market share of 29.1% to 27%. Meanwhile, during this period, craft brewery, Boston Beer Company, increased from 1.2 million to 2.9 million barrels of beer produced [3]. It is clear by this data that by 2013, "Big Beer" began its decline in popularity and craft beer began securing its place in the beer industry. Elzinga and the Tremblays argue that the rise in craft beer's popularity is due in part to a budding beer education developed by consumers. To prove this, the authors profile a few key members of the craft beer industry.

2.3 Homebrew Heroes

One of the most important people in craft beer history is Fritz Maytag. In 1965, Maytag purchased a failing San Francisco brewery named Anchor Brewing. As the new owner of this brewery, Maytag successfully turned the troubled business around and introduced one of the most important beers in the craft beer industry. Maytag was the first person to brew an India Pale Ale, also known as an IPA [3]. To this day, Anchor Brewing is a staple in the craft beer scene. The success of the brewery and its owner inspired a wave of new craft brewers [3].

After visiting Anchor Brewing, Jack McAuliffe began brewing beer himself out of his home. As an avid homebrewer, McAuliffe dedicated his life to beer and decided to open his own craft brewery in Sonoma County in 1976 called, Albion Brewing Company. McAuliffe was one of the first homebrewer turned craft-brewmaster to pair food with beer. Unfortunately, for McAuliffe, his success as a brewer did not last long and Albion

brewery closed its doors in 1982. Perhaps McAuliffe would have found greater success had he opened his brewery a few decades later. Fortunately for the craft beer industry, McAuliffe was not the only homebrewer inspired by Anchor Brewing [3].

Avid homebrewer Ken Grossman's passion for beer helped him become one of the craft beer industry's most successful businessmen. Grossman taught homebrewing in Colorado until he visited Anchor Brewing. After his visit to the successful San Francisco brewery, Grossman decided to open his own craft brewery. In 1981, Grossman founded Sierra Nevada Brewing Company in Chico, CA [3]. According to Elzinga and the Tremblays, in 2013, Sierra Nevada became the second largest craft brewer with sales of close to 1 million barrels. Ken Grossman utilized his early education in homebrewing to educate his patrons, employees, and fans about beer. Sierra Nevada's own website currently lists the recipe and instructions for homebrewing one of their most popular beers, their Pale Ale. Additionally, Sierra Nevada also hosts a yearly summer camp for homebrewers, allowing the lucky participants to learn, brew, and analyse their own beer using the equipment and expertise of the Sierra Nevada brewery. This shows that one of craft beer's most successful breweries, recognizes the importance of educating the market about homebrewing.

Elzinga and the Tremblays argue that these homebrewers were vitally important to the modern-day beer enthusiast's interest in locally brewed craft beer. The authors go on to say that homebrewing is an important introduction to the purchase of commercially produced craft beer. "The stimulation of demand for craft brewing was achieved through the dissemination of information about (1) home brewing, which weaned many beer consumers away from the lager products of Big Beer; (2) craft beer production; and (3) beer as a serious consumption good to be paired with food, rather than as a liquid that quenched thirst on a hot day or offered an inexpensive buzz" [3].

2.4 Craft Beer's Reliance On The Homebrewer

The Craft Beer Association, who represent all craft brewers, also promote the American Homebrewers Association [3]. This is very special because it is not often that an industry would promote and encourage the knowledge of how to make the very product they are selling. This exemplifies the craft beer industry's realization regarding the significance of its consumers learning to brew their own beer and the favorable impact this knowledge has on the consumer's beer preferences and future purchases. Craft brewers welcome education, competition and collaboration among their peers and patrons.

Big Beer is in trouble. A loss in market share and total sales to their comparatively underfunded competitors has led macro breweries to purchase stakes in other beer companies. For a segment of the industry who has traditionally dominated the market over the last 60 years by merging, consolidating and driving competitors out of business, Big Beer is trying a new approach by purchasing stakes in other breweries with no intention of merging them with their own companies. Companies like Anheuser-Busch Inbev, Constellation and MillerCoors recognize the consumer's growing preference for beer made by what they believe is a local business. By acquiring stakes in these breweries and allowing them to continue their operations as usual, Big Beer has begun to capture its own portion of the craft beer market in a stealth fashion. As craft breweries begin to sell portions of their companies to macro breweries, it is increasingly important for consumers to educate themselves on the beer they are drinking. One of the best ways to do this is by learning to brew your own beer and learning to appreciate the subtle and often not-so-subtle characteristics of a locally brewed, craft beer. By appreciating the ingredients and understanding the brewing process, consumers will be able to continue to reshape and influence the evolving beer industry in The United States.

3 THE 4 MAIN INGREDIENTS OF BEER

BEER is thought to have first been brewed around 5,000 years ago in ancient Mesopotamia. The earliest recipe for beer currently dates back to 1800 B.C.E. in the "Hymn to Ninkasi", a composition dedicated to the Sumerian goddess of beer. Ancient Egyptians used beer as a form of payment and consumed it as part of their daily diet. These ancient beers used many different ingredients including mandrake, dates, bark of fir trees, olive oil, and fresh eggs [4] [6]. Beginning in the 9th century, hops were introduced into beer as a means of preservation [7]. In 1516, the Duke of Bavaria introduced "Reinheitsgebot", also known as the German Beer Purity Law. This strict set of rules mandated that beer only be made with three ingredients; water, barley, and hops. Unbeknownst to them at the time, beer also contained a fourth ingredient that was added, quite literally, out of thin air during the fermentation process. This mysterious fourth ingredient was yeast [5]. These four ingredients are the main ingredients that make up the beer consumed today.

3.1 Water

Water is one of the most often overlooked ingredients in beer, making up 90 to 95% of beer's overall content [14]. It is important to know the mineral content and pH balance of your water before brewing, since both components lend to specific tastes. Various styles of beer will call for various ratios of these components in order to perfect the overall tasting profile [14]. Luckily, homebrewers are not confined to brewing specific styles based on the contents of the water from their tap. There are various solutions to manipulate the content of your water in order to best fit the style of beer being brewed.

The first step to perfecting your water is to find out what is in it. This can be done by calling your local water utility company and asking for the most recent water quality report for your area.

3.1.1 pH

The measurement of pH is used to determine the relative acidity or basicity in a liquid. This

is determined based on the measuring of dissociated salts, undissociated salts, and organic compounds. Neutral, or distilled water has an identical concentration of hydrogen and hydroxide ions. Water containing higher levels of hydrogen is considered acidic and water containing higher levels of hydroxide is considered basic. Mathematically, pH is depicted using the the negative logarithm of hydrogen ion concentration in solution. This is usually given as a number between 1 (acidic) and 14 (basic) [15].

Homebrewers can measure the pH of their water using an electronic pH meter or pH strips. Water softeners can be used to adjust the pH of the water [15]. Various steps throughout the brewing process (discussed in later sections) will require different pH ranges. The following data, provided by homebrew supply store, MoreBeer!, shows the ideal pH ranges throughout the brewing process.

Stage	pH Level	Effect
Pre-Mash	6-7	
Mash	5.2-5.5 (follow recipe instructions)	(optimal enzymatic action)
Wort	(follow recipe instructions)	(coagulation of proteins)
Fermentaion	(follow recipe instructions)	(optimal yeast environment)
Finished Beer	4-5	

3.1.2 Minerals

A report from your local water utility company should include information about the minerals in your water. There are three main techniques for reducing the mineral content in your brewing water [15].

The first technique is to boil your water. Boiling helps to reduce carbonate levels by getting calcium and magnesium to precipitate out of solution. Additionally, boiling will help remove dissolved oxygen which can negatively effect the chemistry of your mash. Lastly, it helps eliminate chlorine and kills microbes from the water. The second technique is to use a filtration system. Carbon filtration, reverse osmosis, and deionization are all techniques used by brewers to filter their water [15]. The final technique is to dilute the water with distilled

water. This technique allows for an overall reduction of minerals, chlorine and carbonate levels.

3.2 Grain

Throughout history, brewers have used various grains to make their beer. The most common grain used is barley due to its high starch content [14]. Other grains such as rice, wheat, oats, corn, rye, and sorghum are also used today. Most of the beers brewed by the macro breweries discussed earlier use rice and corn as an addition to their barley grain bill [14].

3.2.1 Malting

Most of the grain used to brew beer has gone through a process known as malting. Grain is transformed into malt by first soaking in warm water. This stage of the malting process causes the grain to create enzymes which are responsible for turning the grain's protein into fermentable sugar. This sugar is later used by the yeast to produce alcohol [16].

3.2.2 The Grain Bill

Every beer recipe call for a specific bill of grains. As suggested earlier, most beers will use a majority of malted barley for their grain bill. This malted barley is often referred to as a Base Malt. Base Malts are lighter in color and provide the majority of the fermentable sugar to the beer. Specialty Malts are used to add color, aroma, and flavors, such as chocolate, coffee, and caramel

3.3 Yeast

Yeast is the living organism that transforms the sugar, provided by the malted grain, into ethanol and CO₂. Early brewers did not realize yeast was an ingredient in beer. As they let their sugar water sit and ferment in open tubs, bacteria in the air latched onto the sugars and produced ethanol. Today, brewers understand the use of yeast in their beer and rather than let nature add it by itself, brewers directly add yeast to their beer before fermentation.

There are two types of yeast used in brewing today. The first type, ale yeast, is used to brew ales such as pale ales, IPAs, stouts, and porters. This style of yeast is known as a top fermenting yeast since it rests on the top of the sugar water as it transforms into beer. Ale yeast usually requires a fermentation at a warmer temperature. The second type of yeast is lager yeast. This is a bottom fermenting yeast that requires a colder temperature when fermenting. Lager yeast is used to brew such styles as pilsners, helleses, and bocks [14].

3.4 Hops

The use of hops in beer originated as a means to preserve beer for long periods of time. Since its introduction into the beer ingredients list, hops have become a staple, providing aroma, flavor and bitterness to beer. Hops are traditionally grown between the 30th and 50th northern latitude in places like Oregon, Washington, Germany, and England. Recently, scientists have created new strains of hops that are growing quite well in different climates such as, Australia, New Zealand, Japan, and Florida [14]. There are currently hundreds of different strains of hops./par Concentrated, pellet, and whole hops are all used throughout the brewing industry. Depending on when they are added to the brewing process, hops can add flavor, aroma, or bitterness. Hops added at the beginning of the boil lend bitterness to the beer. Hops added during the middle of the boil tend to add flavors that include pine, citrus, and many others. Hops added at the last moments of the boil will add aroma to the final beer. These aromas may again include pine, citrus, etc. In hoppy beers, such as pale ales and IPAs, hops are additionally added during the fermentation process, a technique known as dry-hopping [14].

3.5 Experimental Additions

While traditional beer is usually made from just four ingredients, many craft breweries are trying to innovate and reimagine beer styles by incorporating new ingredients into their beer. For example, one of the latest "beer crazes"

is pastry stouts. These highly collectable beers have all the traditional characteristics of a stout; however, they incorporate additional ingredients often used in deserts such as, cocoa nibs, vanilla, peanut butter, and children's cereal. Additionally, other styles of beer, like sours, incorporate a variety of fruits into their beer recipes. Craft brewers have even begun to add different ingredients to styles of beer that have traditionally only been brewed with the four main ingredients. For example, brewers have begun incorporating ingredients such as lactose, and tea into their Milkshake IPAs.

4 THE PROCESS OF HOMEBREWING

Now that the ingredients have been covered, it is finally time to discuss the actual art of making beer. Up until 2013, homebrewing was not legal in all 50 states, however the federal government declared the hobby legal in 1978 when President Jimmy Carter signed it into law [13]. It was only recently that United States citizens were legally allowed to brew beer themselves. Because this paper is intended for average beer consumers and or enthusiasts, the brewing process discussed will focus on home brewing techniques, rather than the techniques used by commercial brewers.

4.1 Equipment

Everything needed to brew beer can be found in any homebrew shop or online. When brewing a beer for the first time, it is often recommended to purchase a beer "clone" kit. Clone kits contain all the necessary ingredients needed to brew a clone of a beer. Alternatively, each ingredient can be purchased separately if you want to follow a particular recipe or invent your own. The following is a list of everything needed to brew beer.

Brewing Equipment

(1) Required Ingredients	(6) Wort Chiller
(2) Hot Liquor Tank	(7) Glass Carboy
(3) Mash Tun	(8) Airlock for Carboy
(4) Boil Kettle	(9) Keg
(5) Propane Burner w/ fuel	(10) CO2 Tank w/ hookups

4.2 Mashing

Mashing is a very important step in homebrewing. This is the point in the beer making process where enzymes convert malt's starches into sugars. Two key enzymes responsible for this breakdown of starches are beta-amylase and alpha-amylase. The purpose of mashing is to create wort. Wort is the protein, carbohydrate, and dextrin filled liquid that will ultimately be turned into beer [12].

Mashing begins with the first step known as *dough-in*. The step has the homebrewer add the dry, ground, malted grain into the mash tun along with water at a specific temperature (depending on the recipe and grain used). This step begins the dissolution and hydrolysis of the malt [12]. It is very important to stir the grain during this step, making sure that each piece of grain becomes soaked in water. Once every grain is soaked, the temperature of the mash should be reduced to 112-140 degrees Fahrenheit. This is known as a *protein-rest*. The purpose of this rest is to reduce large proteins into smaller ones and takes about 10 to 45 minutes depending on the recipe [12]. The next stage of mashing is known as *saccharification*. This step has the homebrewer raise the temperature of the mash to 140 to 158 degrees Fahrenheit. At this point, the majority of carbohydrates are transformed into both fermentable sugar and unfermentable sugar [12]. The final stage of mashing is known as the *mash-off*. This step raises the temperature of the mash to 165 degrees Fahrenheit, terminating the enzymatic activity and halting sugar production [12].

4.2.1 Malt Extract

Inexperienced homebrewers may choose to forgo mashing using grain and may instead use malt extract, which can be purchased from any homebrew shop. Malt extract is mixed with water to produce the same wort that is created during mashing. While using this technique saves time and is considerably easier, most homebrewers agree that it provides an inferior product to an all-grain brewed beer.

4.3 The Boil

Now that the wort has been created by mashing, it is time to transfer the wort from the mash tun into the boil kettle. This can be done using brewing hoses found in any homebrew shop. Before the boil can begin, water should be added to the wort in order to raise the overall volume above the end target volume for the beer. How much water should be added depends on the size of the boil kettle and recipe. A typical boil loses 1 - 1.5 gallons of water per hour, so it is important to do a little bit of math in order to determine your optimal starting volume [11]. Once you have the optimal volume of wort, it is time to begin the boil.

Each style and recipe of beer will require various boiling instructions. It is important to follow the recipe's instructions in order to produce ideal flavor, alcohol content, color, and aroma. A recipe for an IPA will be used in this section in order to depict a typical boiling session. A typical boil for an IPA lasts for 60 minutes. Once the wort is boiling the recipe's bittering hops are added. Allowing these hops to boil for 60 minutes will see 90% of the hop acid isomerization occur. This is what provides the bitterness to the beer [11]. After 30 minutes have passed, flavoring hops are added to the boil. With only 30 minutes left in the boil, these hops do not have a opportunity to release their bitterness and instead release a flavor profile specific to their strain of hop. Lastly, aroma hops are added during the final 15 minutes of the boil. This limited amount of boiling time only allows these hops to release their specific aroma and not much flavor.

After 60 minutes, the burner may be turned off. As the wort begins to cool down, a technique referred to as *whirlpooling* is applied. The goal here is to create a whirlpool in the wort by stirring the wort in a circular fashion very quickly. The purpose of this step is to gather all of the solid, hop and grain chunks into the center of the beer. The whirlpool then forces these solids to the bottom of the boil kettle, clearing the beer in color and removing these unwanted chunks from the suspended liquid mixture.

The next step is to cool the wort down as quickly as possible. This will keep any unwanted off-flavors from developing in the wort. To cool it quickly, a wort chiller is used. A wort chiller is a long copper tube used to transfer the wort from the boil kettle into its fermentation vessel. As the beer passes through the copper piping, its temperature is greatly reduced [11].

4.4 Fermentation

As the wort is transferred from the boil kettle, it is important to allow the wort to vigorously splash into the carboy. This splashing will introduce oxygen into the wort which will improve the yeast's ability to feed on the wort's sugars. Before adding the yeast, an original gravity of the wort should be taken. This can be done using a hydrometer or a refractometer. A hydrometer is less expensive however it requires the brewer to waste about a cup of wort to measure. Refractometers on the other hand are significantly more expensive, but allow the brewer to measure the specific gravity of the wort using a single droplet.

Once the wort is in the carboy and the original gravity has been measured and recorded, it is time to add the yeast. Depending on the style of beer being brewed, a lager or ale yeast will be used. One of the byproducts of the yeast breakdown of sugar is CO₂. As the wort begins to ferment, this CO₂ is released. If fermentation occurs in a sealed container, there is a high chance of the carboy exploding. To combat this issue, an airlock is used to keep the pressure inside the carboy at a tolerable level. An airlock is designed to allow CO₂ to escape from the carboy, while keeping air from entering.

4.4.1 Primary Fermentation

Now that the wort and yeast have been mixed, and an airlock has been securely attached to the carboy, the wort can be left to ferment. Fermentation typically begins in about a day or two. As the yeast breaks down the sugar and converts it into ethanol and CO₂, a cap of thick, tan-colored foam called krausen will begin to form on top of the wort [10].

The temperature at which the carboy should be kept at depends on the style of beer being

made. Most homebrewers store their beer in a cool dark area, such as their closet. Other homebrewers build fermentation chambers out of mini-fridges and chest freezers and regulate precise fermentation temperatures using a thermometer-controlled on/off switch. A typical fermentation temperature for an ale is between 68 and 72 degrees Fahrenheit. For a lager, typical fermentation temperatures range from 45 to 55 degrees Fahrenheit [11]. Fermenting at too high of a temperature may produce unwanted fruity flavors into the beer. Fermenting at too low of a temperature may keep the yeast from fully developing, making your beer less alcoholic and overly sweet [11]. If storing the wort in a cool dark place, rather than a temperature controlled fermentation chamber, it is important to note that the act of fermentation alone typically heats the wort by 10 to 15 degrees Fahrenheit [11].

4.4.2 Secondary Fermentation

After 1 to 2 weeks of fermenting, the beer should be finished with its primary fermentation process. At this point, bubbles released by the airlock should have stopped and the yeast should have been knocked out of suspension, forming a cake at the bottom of the carboy. The next step is to separate the wort from the yeast cake, also known as the *trub*. This is important because the trub can produce off flavors in the finished beer. To transfer the wort, a tool called a *racking cane* can be used. During this transfer, it is important to leave behind as much trub as possible.

After a few days in the secondary fermenter, the beer has finished its fermentation process. Additional trub may have formed at the bottom of the secondary carboy. This is normal. Some beers like IPAs or stouts can require an additional step at this stage known as dry-hopping or flavoring. For IPAs, additional hops can be added to the secondary fermenter to give the beer a more hop forward flavor profile. Similarly, stouts may add additional flavoring ingredients like cocoa nibs at this stage.

4.4.3 Alcohol Content

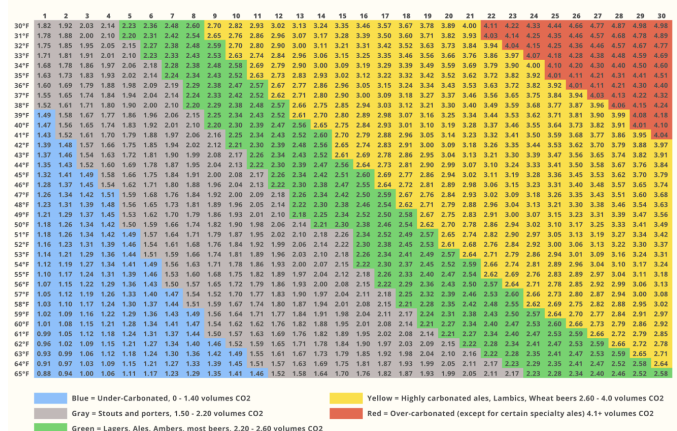
After fermentation has completed, a final gravity reading should be taken. Using the following formula, the alcohol content of the beer can be calculated [9]:

$$ABV = 132.715(OriginalGravity - FinalGravity) \quad (1)$$

4.5 Carbonation

The final stage of brewing beer is carbonation. To carbonate the beer, it is important to first transfer the beer from the secondary fermentor into a keg. Once the beer is in the keg a CO2 canister can be hooked up to the pressure valve on the keg. This technique is known as *force carbonation*. Rather than relying on the beers formation of its own CO2, force carbonating speed up the carbonation process significantly. The whole point of force carbonation is to get the CO2 absorbed into the beer as quickly as possible. To do this, it is best to store both the CO2 canister and the keg in a cold fridge. It is recommended to carbonate at the same temperature you plan to serve the beer at [8]. Depending on the style of beer, different PSIs should be set on the CO2 canister. The following chart shows the various PSIs required for different styles of beer.

FORCE CARBONATION CHART



[8]

After a few days of having the beer set to a PSI determined by the chart above, the beer should be fully carbonated. At this point it is important to pull the pressure release valve on the keg in order to bleed off some of the pressure from the CO2. The beer is finally finished.

5 CONCLUSION

The purpose of this paper was to provide an in-depth education of homebrewing to interested beer drinkers. The art of homebrewing has evolved over the past 5 centuries, yet some things about the art have remained consistent. A standard beer is made up of four simple ingredients that have stood the test of time. As beer consumers continue to educate, share, and brew beer, the craft beer industry will continue to grow. While the techniques for brewing beer may seem overwhelming, the craft beer community is incredibly supportive and willing to help each other learn and discover the necessary techniques for brewing beer. As long as consumers continue to be interested in the brewing process, big beer companies will continue to lose market share as communities come together to share their passion for locally brewed craft beer.

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