Making a Better Brew:

The Clarification of Beer

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ChemE 152, Term Paper

May 10th, 1999

Introduction:

The study of beer appears to be one of the most highly investigated topics on any college campus. From the fraternity houses to the dorms to the basement of LeConte Hall, beer appears to be everywhere you go on this campus. More importantly, it is being consumed at a rapid rate. A recent study has shown that more then two out of every five college students is a binge drinker.[1] In order to promote this type of activity, it is in the interest of the brewer to produce a beer with a high degree of clarity. There has been a gradual trend towards a beer lighter in both gravity and color. This is due to the fact that lighter beers tend to be easier to consume in large quantities. The public is also becoming more discrimination and demanding with respect to the clarity of beer, so that a high level of sales can be maintained only where the product is of a consistent high quality.[2] In this paper, the techniques which can be applied at varying stages in the brewing processes to give such a product will be examined.

The Brewing Process:

In order to understand the applications of clarification techniques, a brief overview of the brewing process is necessary. Please see the attached diagram at the end of this paper for a schematic of the brewing process. The first step of brewing is mailing, in which raw barley is converted to malted barley (also known as just plain "malt"). This process involves converting the starch inside the kernel into soluble sugars, called maltose, by stimulating the natural germination process with moisture. The malted barley is also sometimes roasted in a kiln to bring out various colors and flavors for the beer. Most often, professional maltsters handle this process and sell the malt to breweries,

[1] Kang, Peter. "Study: Binge Drinking Prevalent." Daily Californian 5 May 1999: 3.
[2] Peaty, Ian. You Brew Good Ale: A History of Small Scale Brewing. Phoenix Mill: Sutton, 1997.

though megabrewers often do their own malting. The malted barley is then milled, where the intent is to just crack open the husk of the barley kernel. The cracked grain, now called grist, is then added to the mash tun where it is infused with hot water. Together, the grist and water create a thick substance called the mash. The mash is heated and cooks, allowing the grain's starches to continue to convert to fermentable sugars. The mash is then sent to a lauter tun to separate the grain from the liquid. The lauter tun drains the liquid through a false bottom that keeps the grain in the tun while allowing the liquid to drain through.[3] Basically they function like giant kitchen colanders. The separated liquid from the lauter tun, called the wort, is then boiled in a brew kettle. In the brew kettle, the wort is brought to a boil, sterilizing the liquid and any ingredients added to it. The brew kettle is also where the brewer goes about balancing the sweet flavor of the wort with the bittering effects of the hops. During this time, the brewer adds the hops to the wart at various intervals, depending upon the type of flavor he wishes to impart to the brew.[4] When the bitter wort is finished in the brew kettle, it is then taken to a process for clarification, and the various processes for clarification will be discussed below. The bitter wort is then pumped through a wort chiller, where it is cooled down quickly. This is necessary because the wort needs to be made ready for yeast, which is killed at temperatures of 100°F or higher (even temperatures above 80°F can cause yeast cell mutation and foul flavors).[5] Next, the wort is pumped into the primary fermentation tank where a slurry of fresh, aerated yeast is added to the tank. Within 24 hours of the addition of the yeast, vigorous fermentation usually begins. The wort is allowed to sit in the primary fermentation tank for approximately a week. After this time, the yeast is strained

[3] Jeffery, E.J. Brewing: Theory and Practice. London: Nicholas Kaye, 1956.
[4] Nachel, Marty. Brewing For Dummies. Chicago: IDG, 1997.

out and the beer is transferred to a secondary fermenter, sometimes called an aging tank. The beer spends from a couple weeks (for ales) to a couple months (for lagers) in the secondary fermentation tank before finally being sent on to packaging.[6]

Why Clarification is Needed:

The area of greatest interest lies in the process that happens after the bitter wort leaves the boiling kettle and before it reaches fermentation. After an hour or two of boiling time, the heat in the brew kettle is shut off, and the beer, now called bitter wort, is prepared for transfer to the fermentation tank. The hops can be removed by a hop extractor, which uses a homogenous membrane for ultrafiltration. Also the hops can be removed in a whirlpool, in which all solid matter is forced to the center of the vessel by centrifugal force and the now clarified wort is drawn off from the side.[7] It should be noted that a centrifuge use to be used to remove solid material from the wart, but the lower capital cost of the whirlpool has caused it to replace the older method.

The wort clarification is generally carried out to remove suspended resins and protein matter that arise during the boiling process. The particle size is about 25 to 75 microns. Protein matter in the wort is generally from tannins (tannic acid) from the hops along with mineral salts and hop bittering materials that are also added while the beer is in the brew kettle. Wort going to the fermenter free of these substances gives a cleaner fermentation and the beer an the end of the fermentation has less suspended solid material. It also minimizes the blinding of yeast-cell walls due to protein tannin adsorption.[8] In excess, this could give rise to a reduction in fermentative power. A

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[5] See [4] above.
[6] Miller Brewing Company Homepage. http://www.millerbrewing.com. 1999.
[7] See [4] above.
[8] Priest, F.G., Campbell, I. (1996). Brewing Microbiology. New York: Chapman & Hall.

possible adverse effect of the removal of too much of this material by wort filtration is that the beer will posses a rather thin taste.

Processes for Clarification:

The two main processes for beer clarification is the use of ultrafiltration or the use of a whirlpool. Both processes have the same purpose of removing tannins and other large molecules from the beer.

The single largest application of ultrafiltration has been in the processing of cheese whey, but it is also very effective when used in the recovery of proteins in wort, where this process is called the hop extractor. Ultrafiltration is a process where a semi-permeable membrane separates the components of the beer/protein mixture according to their molecular size. The wort solution is pumped into the ultrafiltration chamber, tangential to the membrane. A hydrostatic pressure is applied to the upstream side of the supported membrane, and the bulk of the wort is of small enough molecular weight to diffuse through the membrane, while the larger tannins and proteins are rejected by the membrane. The retained material always concentrates at the membrane-solution interface, but is swept away by fluid dynamic forces as it is pumped out in the retentate stream.[9]

The membrane used in this process consists of a highly asymmetric polyethersulfone membrane. This membrane is porous throughout, with the pore size varying randomly both across the membrane and through the membrane. That is to say, the pore diameter varies as it passes from one side of the membrane to the other. On the retentate side of the membrane is a skin face having relatively large diameter pores while the opposite face of the membrane has relatively small diameter pores. The difference in

porosity is approximately 200:1. In addition, the membranes have a gradual slope of the pore size from the skin face to the permeate side. Thus, during filtration, larger proteins and tannins can enter the membrane through larger pores, but do not exit through the smaller pores. This design prevents the clogging of the pores with large particles. A membrane with a mean flow pore diameter of typically 0.65 microns is most well-suited for the clarification of beer.[10] This membrane is generally supported by a macroporous layer which is necessary to support the thin polymer membrane.

The other method to clarify the wort is to use a whirlpool tank. The whirlpool tank consists of a vertical stationary tank with the feed from the brew kettle at the top and the outflow for the clarified wort at the side, while the hops and proteins are siphoned to the bottom of the tank. The whirlpool functions by having the wort leaving the brewing kettle flow into the whirlpool tank at a tangent to the tank so that the discharge into the tank causes a rotary motion of the tank's contents. The inlet is horizontal to the liquid surface and is positioned above the liquid surface so as not to interfere with the free rotary flow.

In the whirlpool, the rotation of liquid forms a forced vortex and its surface forms a paraboloid of revolution. The pressures in the liquid on a given horizontal level therefore increase with distance from the center. Therefore particles present in the inlet fall downward by gravity, and if the pressure forces acting towards the center due to the vortex are greater then the centrifugal forces (this depends on the size and density of the particle), they will tend to move towards the center. Compaction then occurs at the central areas on the bottom of the vessel, the resultant forces tending to squeeze excess

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[9] Gump, Barry. Beer and Wine Production. Washington DC: American Chemical Society, 1993.
[10] Wang, I. United States Patent. #5869174. 1998.

liquid from the spaces between the particles.[11] The clarified wort is drawn off from the side of the tank and pumped into the wort chiller before going to fermentation.

A final note is that these two methods of clarification are sometimes used in series by some brewers. Depending on the clarity of beer desired, it is possible to use the whirlpool tank to remove the larger proteins and then use the hops extractor for finer purification of the wort. Also, beer clarification does not exclusively need to be confined to the pre-fermentation step. Another method of clarifying beer is to centrifuge the beer after it comes out of the fermentation process. It is already necessary to strain the yeast out of the beer at this stage, and this process is just taken a step further to remove all solid particulate in a final centrifuge stage before pasteurization and packaging.[12]

[11] Findlay, W.P.K. Modern Brewing Technology. New York: Macmillan, 1971.
[12] Johnstone, J.T., Whitmore D.J. (1971). Clarification of Beer. New York: Macmillan.