Anaerobic Cellular Respiration Lab (Beer Lab)

The History of Beer

Beer is as old as civilization itself. One of the most common and popular of beverages, it is made in very corner of the world and was even outlawed by the U.S. Constitution for a period of time. The simple combination of **barley, water, hops, and yeast** produces many different styles of beer. "Modern" beer is one of the oldest products of civilization, and may even have been a stepping stone to the invention of leavened bread and pizza dough. Historians believe that the ancient **Mesopotamians and Sumerians** were brewing beer as early as **10,000 BC**. Although the product would have been somewhat different from today's bottled varieties, it would be recognizable.

A Strange Beginning

Some ancient records suggest the earliest and most primitive forms of beer were produced by tribal aboriginals, using methods quite different than would be "acceptable" today. Women of the tribe would chew mixtures of grain and corn, mixing it with their saliva. They would then spit the chewed grains into a large communal "spittoon". This spittoon be filled with water and chewed up grain/corn. We now know that saliva contains the enzyme **amylase**, which is needed to convert the starch (in the grain) into sugar. This sugar-water and saliva mixture would then be turned into beer using yeast, obtained by gently scraping the white film from the **feces of un-weaned infants**. Within a day, the entire mixture was bubbling, and after a week, the 'beer' was ready to drink. As legend has it, after a night of drinking the primitive beer, the aboriginals were able to communicate with their Gods.

Malting

Malting is essentially the process of germinating (sprouting) the gains/seeds. During malting the embryo produces the **enzymes** that later are used to break down proteins and starches into smaller nutrients. After malting, the grain (now called malt) is often roasted and kiln dried to add different colors and flavors to the beer. Before the malt is ready for brewing, it must be crushed by a mill.

Mashing

In this step, warm water is added to the crushed malt in a large vessel called a mashtun. The brewers job is to maintain the mash (water and crushed malt mixture) at a specific temperature for a period of time to allow the enzymes to break the large protein and starch molecules down into their subunits.

Lautering

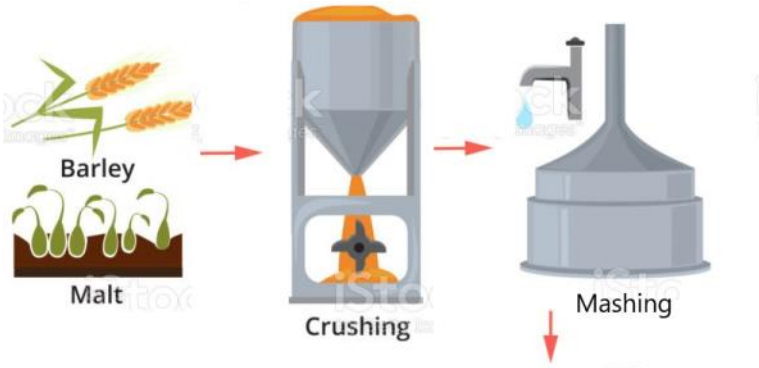
In this step the sweet liquid is separated from the spent grains. This is accomplished using a device similar to a strainer.

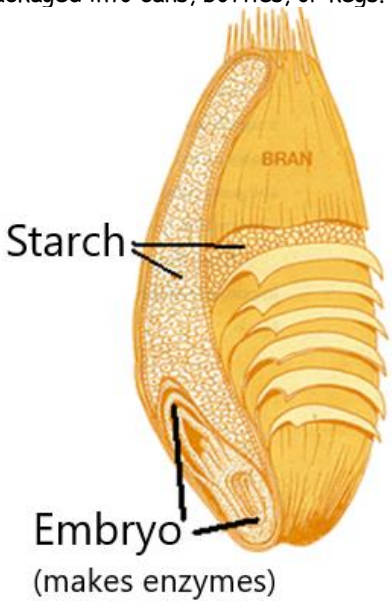
Boiling

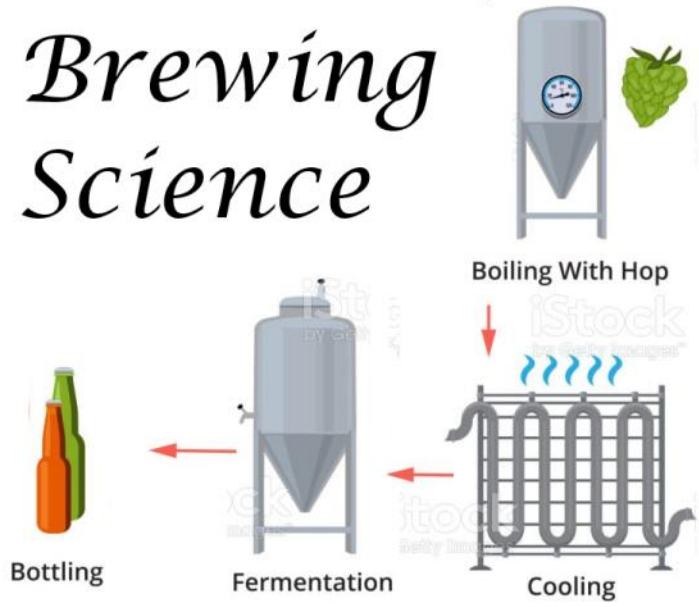
The liquid collected from the mash (called wort), is boiled and hops are added for **flavor, aroma and to help preserve the beer**.

Fermentation

After boiling, the wort is cooled, then yeast is added. When the yeast run oxygen they switch to anaerobic respiration. When they run out of sugar, they settle to the bottom of the fermenter and become dormant. Finally, the beer carbonated, and packaged into cans, bottles, or kegs.







Day One – The Mash

Note: Never leave your water/barley mixture (called the mash) on a hot plate without constantly stirring with the glass stirring rod right to the bottom of the beaker. This will cause scorching, will destroy your enzymes, and ruin your lab.

Step One: The Mash

1. Send 1 person to the front with your 600 ml beaker to weigh out 100 g of barley.
2. Send 1 person to the front with your 400 ml beaker and hot paws and Mr. W will fill your beaker with 90°C water.
3. Add the hot water to the barley in the 600 ml beaker and stir well. This 600 ml beaker is your "mashtun".
4. To **keep your enzymes happy** maintain your mash temperature between 60-70 °C. You may need to heat your mash on a hot plate if the temperature drops below 60 °C.
5. Hold your mash between 60-70 °C for minimum 20-25 minutes.

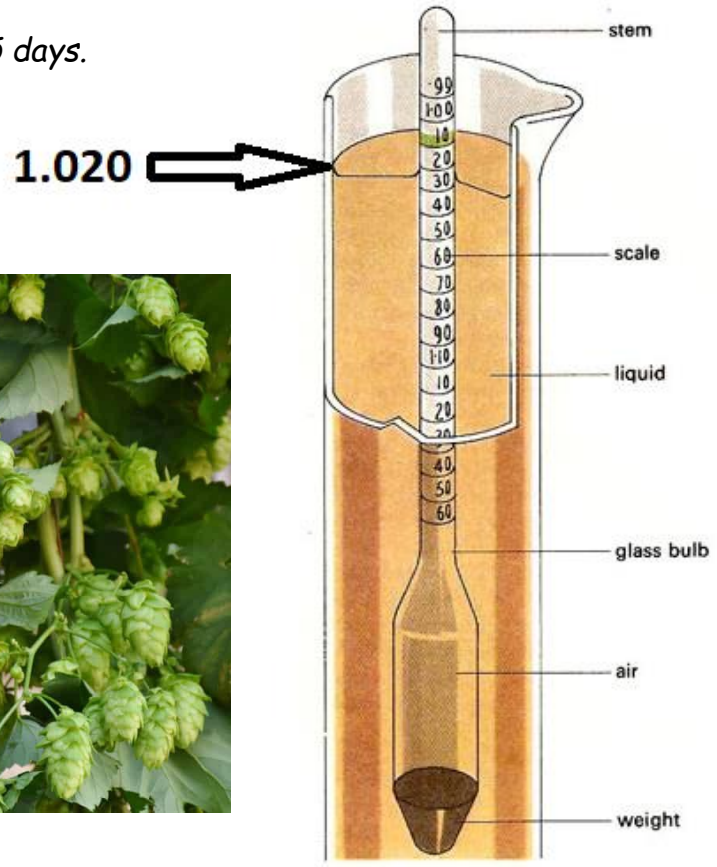
Step Two: Lautering and Sparging (The process of separating the liquid from the grain)

1. Get approximately 350 ml of hot tap water in your 400 ml beaker.
2. Follow the verbal instructions given to you by Mr. Wick for separating the liquid from the grain.
3. Pour the unfermented beer (now called wort, pronounced "wert") into a CLEAN 1000 ml beaker and cover with tin foil (don't tape).
4. Write your period number and an appropriate name for your beer on the foil.
5. CLEAN UP but **leave everything at your station**!!!!

Day Two – The Boil

Boiling your Wort

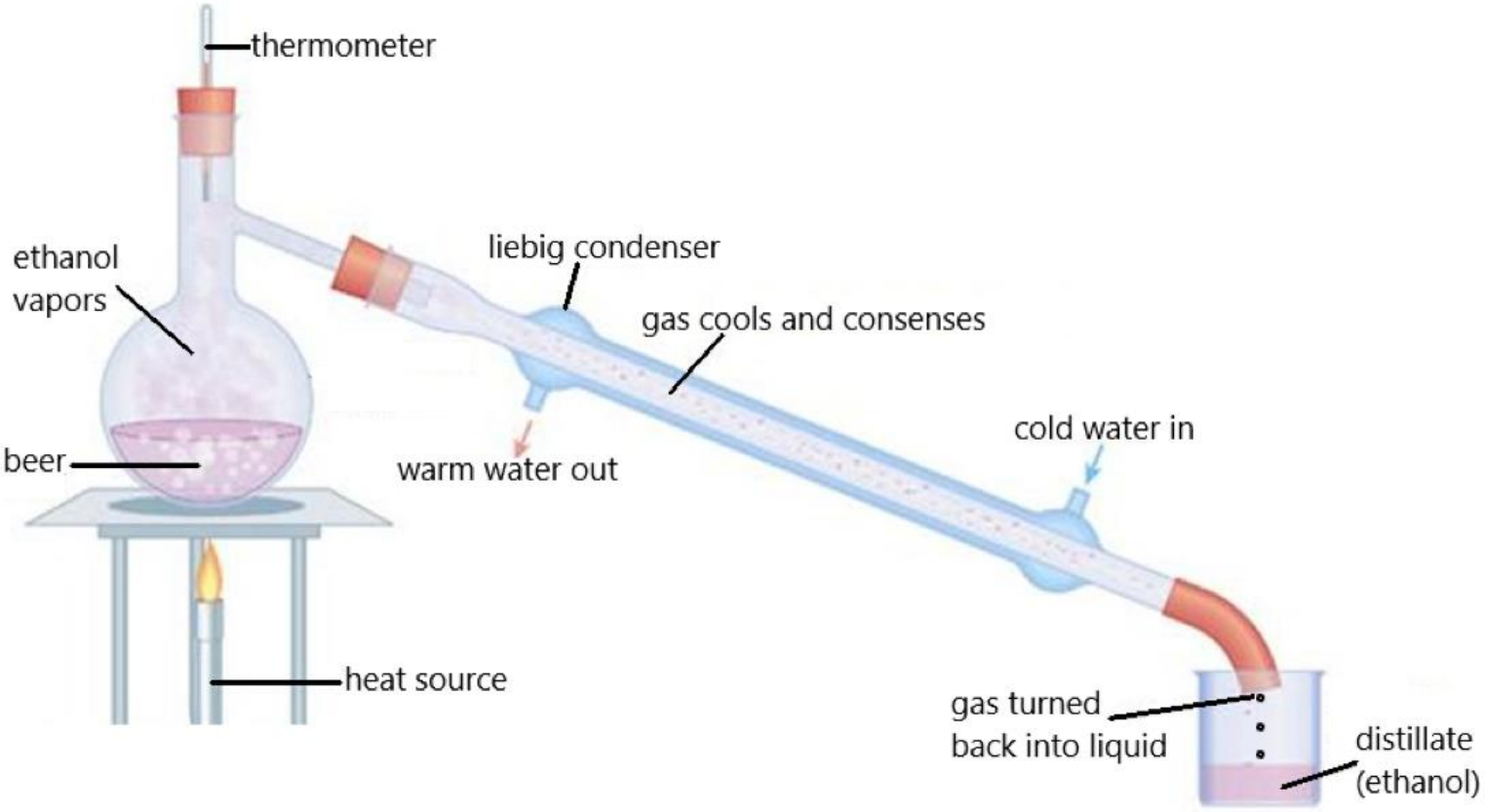
1. Clean a new 1 L beaker with soap and water. Carefully pour the top clear portion of your wort into your clean 1 L beaker. Be careful to disturb as little sediment as possible. Discard the sediment and wash the old beaker.
2. Get Mr. W to add some yeast nutrient to you wort. This provides extra amino acids for yeast health and a nice rapid fermentation.
3. Top your wort up to 800 ml with tap water.
4. Before you boil your wort you must find its initial specific gravity (specific gravity is the ratio of the density of any liquid to that of water). This is measured by pouring a sample of your wort into the cylinder and floating a hydrometer in it.
   SEE DIAGRAM BELOW TO LEARN HOW TO READ HYDROMETER
   Record the value on a sheet of loose leaf as you will need it later for a calculation which yo***u will be marked on!*** It's usually between 1.010 and 1.030
5. Add 1 boiling chip and several hop pellets of your choice to your wort.
6. Place your beaker on your hot plate and bring it to a boil.
   DO NOT LET THE WORT BOIL OVER OR YOU WILL BE CLEANING A SMELLY BURNT MESS!!!
7. Boil the wort for 5-10 minutes.
8. Remove from the heat, immediately cover with foil and leave to cool.
9. Once it cools to 35°C Mr. W will aerate your wort by bubbling oxygen through it for 15 seconds.
10. Mr. W will then add brewers yeast.
11. It is now technically "beer" ☺
12. *Your beer will now ferment for 3-5 days.*



Day Three – Distillation

Distillation

1. Although we will not be bottling or kegging our beer, that is what would happen next.
2. Your beer is too flat and cloudy to taste but you may smell it if you wish. If it does not smell like beer you likely ran into contamination issues sometime during the process.
3. Next you must find the *final* specific gravity of your beer. Record this value next to where you recorded the initial specific gravity on day 2 of the lab.
4. As a final step, we will perform a group distillation using a **liebig condenser** (pictured below).
5. Bring your beer to the front to add to the 'group brew' that will be distilled.
6. A flame test will be performed on the distillate. ***This is worth a portion of your lab mark!***



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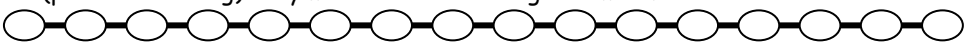
Note: Hand in only one copy per group when the lab is complete.

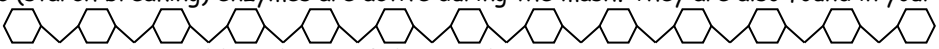
1. Beer is the combination of what four simple ingredients?
2. According to historians, by whom and when was beer first made?
3. What enzyme (found in saliva and produced by barley embryos) converts starch into fermentable sugar?
4. Where did tribal aboriginals obtain their brewer's yeast?
5. List the 5 stages of the brewing process beginning with crushing the grain (see the Brewing Science diagram).
6. What is malting?
7. Why do we have to malt the barley? (Why not just grind up un-malted barley straight from the farmer?)
8. How do brewers make different colored beer?
9. The mash is a mixture of crushed malt and water. What is the role of the brewer during the mash?
10. Proteolytic (protein breaking) enzymes are active during the mash.



    a. What are the "building blocks" of protein?
    b. Why do yeast need these building blocks?

    (Hint: think back to a major biochemical process from unit 2…need another hint….think ribosomes ☺)

11. Diastatic (starch breaking) enzymes are active during the mash. They are also found in your saliva.



    a. What are the "building blocks" of the starch?
    b. Why do yeast need these building blocks?

12. Why was it crucial **NOT** to let the temperature of the mash go much above 70°C?
13. The pH of the mash should be around 5.5 (slightly acidic). Professional brewers monitor the pH and add phosphoric acid if necessary. Why are brewers so concerned with the pH of their mash?
14. What is lautering?
15. List three reasons why hops are added during the boil?
16. After your wort cools, Mr. Wick will aerate the wort by bubbling oxygen through it. Keeping this in mind, what type of respiration will the yeast perform in the early stages of fermentation when this gas is still present in the wort?
17. What causes the yeast to switch to **anaerobic** respiration?
18. Keeping in mind the previous answer, explain how you might be able to produce non-alcoholic beer.
19. a. Write the word equation for **Anaerobic Respiration** (alcohol fermentation).
    b. Write the word equation for **Aerobic Respiration**.
20. Why would it be dangerous to place an airtight lid on the fermentation vessel during fermentation?
21. Why, after many days of vigorous activity, does the fermentation begin to slow and yeast begin to settle to the bottom?
22. Use the formula provided below to calculate the percentage alcohol (ethanol) of your beer.

    % Alcohol (Ethanol) = [Initial Gravity – Final (post distillation) Gravity] ÷ 0.0075

    Initial specific gravity (unfermented beer) = _____

    Final specific gravity (fermented beer) = _____

    % Alcohol (Ethanol) in Your Beer = _____

23. After distillation, we will use a flame test to determine if anaerobic fermentation took place.
    Write the chemical equation for the Combustion of Ethanol.