Fermentation Essay, Research Paper

It is impossible to set a date as to the first time fermentation was performed. It is possible, however, to guess, and this guess is roughly 8,000 years ago. Wine has been written about for centuries, in the Greek and Roman myths and scriptures. The Greek god of wine, Dionysius, was in charge of the fermentation atop Mount Olympus. The people of this time may not have known exactly what they were doing, but it was a somewhat complicated procedure. The crushing of grapes, and the storing of their juices led to an amazing beverage that is still used in current society. This process of fermentation was used throughout the time of early Christianity, and other religions, for purposes within sermons. Throughout the Renaissance, fermentation was used in the making of wine as well as bread, not to mention new medical applications. Fermented products were brought to America along with the new settlers. With new government, though, America was put into a prohibition, which did not last long. Today, fermentation processes are carried out nearly perfectly, without too large of variations among the products.

Although fermentation has been known of for at least 8,000 years, in 1865 Louis Pasteur was the scientist who really discovered the process of fermentation. At this time, Pastuer was the Dean and professor of chemistry at the Faculty of Sciences in Lille, France. He was originally asked by a friend to investigate difficulties he was having manufacturing alcohol by the fermentation of beetroot. Often, instead of alcohol, the fermentations were resulting in lactic acid. At that time, fermentation leading to the production of wine, beer, and vinegar was believed to be a simple and straightforward breakdown of sugar to the desired molecules. It was believed that the chemical breakdown of sugar into alcohol during the fermentation of wine and beer was due to the presence of inherent unstabilizing vibrations. Yeast cells were found in the fermenting vats of wine and were known as living organisms, yet they were only believed to be either a product of fermentation or catalytic ingredients that provided useful ingredients for fermentation to proceed.

The brewers of wine, beer, and vinegar were having horrible times with quality control. Yields of alcohol might suddenly fall off; wine might unexpectedly grow ropy or sour or turn to vinegar; vinegar, when desired, might not be formed and lactic acid might appear in its place; or the quality and taste of beer might unexpectedly change. Pasteur went through with several experiments and immediately came up with clues to help him unravel the fermentation mystery. The first clue that he noticed was that when alcohol was fermented normally, the yeast cells were plump and budding. But when lactic acid would form instead of alcohol, small rod like microbes were always mixed with the yeast cells. The second clue uncovered during the analysis of the batches of alcohol showed that amyl alcohol and other complex organic compounds were being formed during fermentation. This could not be explained by the simple catalytic breakdown of sugar shown by Lavoisier. Some additional processes must have been involved. The third clue was that some of these compounds were able to rotate light, meaning they were asymmetric. Pasteur had previously shown that only living organisms are able to create asymmetrical compounds. He concluded and was able to prove that living cells, the yeast, were responsible for forming alcohol from sugar, and that contaminating microorganisms turned the fermentations sour.

Over the next several years Pasteur identified and isolated the specific microorganisms responsible for normal and abnormal fermentations in production of wine, beer, and vinegar. He showed that if wine, beer, and milk were heated to moderately high temperatures for a few minutes, microorganisms would be killed and thereby sterilize (pasteurize), the batches and prevent their degradation. If pure cultures of microbes and yeasts were added to sterile mashes uniform, predictable fermentations would follow.

It has taken many years to evolve the fermentation process to its current state. It is now available in mass production, with the same products as individual projects. Fermentation is used commercially to produce a wide variety of products that are consumed by people of all ages. This fermentation is specifically called ethanol fermentation or ethyl alcohol fermentation. This is carried out, in basic terms, by a reaction that converts a disaccharide into CO2 and ethyl alcohol. In some cases both of these end products are wanted, in some only one or the other is preferred. Ethanol, CH3CH2OH, is an alcohol, a group of chemical compounds whose molecules contain a hydroxyl group, OH, bonded to a carbon atom. Lactic fermentation also exists but is carried out inside the body and is not used for external use. Ethanol fermentation is used to make a lot more things then the average person would think. Most people know it for its contributions to the creation of all alcoholic drinks, such as wine, beer, hard liquors, and Champagne or sparkling wine. While it is true that fermentation is used for these things it is also used in baking foods, like bread, and in medicine in the form of rubbing alcohol.

Alcoholic fermentation has a commercial name, but a chemical existence. The chemistry associated with it seems much harder than the simple fermentation process. It also reaches humans on a more personal level when introduced to the body. The stages between and including fermentation and digestion are important to the world as a whole as well as the past and the future.

Before the process of fermentation is spoken of, its most essential ingredient must be understood. Yeast is what makes grape juice different than wine and what gives us fluffy bread rather than dense hardtack. Yeast is a fungus that has the ability to carry out aerobic respiration, but more importantly, has the ability to carry out anaerobic respiration, which fermentation is the second step in. Yeast is made up of many components that are shown on the table below.

Components % Of which %

Dry Materials (D.M.) 30.0-33.0 ——- ——-

Nitrogen/D.M. 6.5-9.3 ——- ——-

Proteins/D.M.(Nitrogen x 6.25) 40.6-58.0 Glutathion 0.5-1.5

Carbohydrates/D.M. 35.0-45.0 glycogentrehalose 5-108-20

Cellular lipids/D.M. 4.0-6.0 phospho-lipids 1-2

Minerals/M.S. 5.0-7.5 potassiumsodiumcalciummagnesiumphosphorus 0.8-2.00.01-0.20.02-0.150.04-0.180.8-1.3

Vitamins ——- Thiamin (B1)Riboflavin (B2)Pyridoxine (B6)Niacin (PP) 0.002-0.0150.002-0.0080.002-0.0060.010-0.050

The majority of all yeasts reproduce through budding, but some have been observed to use spores as their way to produce more yeast. Yeast cannot be held fully responsible for the products that it helps produce. Enzymes contained within it have made the process of fermentation more complex than previously thought. An enzyme called apozymase is essential for the fermentation, but it cannot act alone. A coenzyme, conveniently called co-zymase, works along with apozymase to bring about the alcoholic fermentation of sugar. The co-enzyme is able to withstand very high temperatures and avoid being denatured, which allows the enzyme to work efficiently in many environments. In addition to these two components, phosphorus is needed. There are still many other steps in the production of ethyl alcohol from sugar, in terms of enzymes, co-enzymes, and essential cycle steps that show drastic changes in the chemical composition of the sugar.

The process of fermentation occurs after the process of glycolysis. When there is no oxygen present after glycolysis, the pyruvate from glycolysis undergoes fermentation. The process of alcoholic fermentation includes reactions which reduce pyruvate to alcohol using the donated e- and H+ from NADH + H+ (NADH is oxidized) thus recycling NAD+ for use in glycolysis. There is no additional energy gain during these reactions and the whole purpose of the fermentation process is to regenerate NAD+. This process occurs in the cell cytoplasm.

NADH + H+ ——–> NAD+ + 2e- + 2H+

Alcoholic fermentation occurs because of the fermentation of ethanol and occurs in two steps. The first reaction is a nonhydrolytic cleavage step in which Pyruvate (3C) is decarboxylated to 2 x Acetaldehyde (2C) + 2CO2. This is mediated by the enzyme Pyruvate decarboxylase that also contains thiamine pyrophosphate (vitamin B1) as a coenzyme. The second reaction is the reduction of the carbonyl acetaldehyde and results in the formation of ethanol. In this step 2 x Acetaldehyde (2C) is reduced to 2 x Ethanol (2C) by the enzyme Alcohol Dehydrogenase. Oxidation of NADH + H+ provides the e- and H+ required for this reaction and results in the regeneration of NAD+. Acetaldehyde serves as the final electron acceptor in ethanol. This is the equation:

2 x Pyruvate + 2NADH + H+ ——–> 2 x Ethanol + 2NAD+ + 2CO2

Which can also be shown as:

CH3CCOO- CH3CH CH3CH2

Therefore for the incomplete breakdown of glucose under anaerobic conditions the equation is:

Glucose + 2ADP + 2P ——-> 2 ethanol + 2 ATP + 2H2O + 2CO2

The world s first encounters with fermentation were in the form of wine. Grapes were crushed and then stored in barrels for a period of time. If the barrel were full of the grape juice and in an oxygen-deprived environment, wine would be produced. How could this be possible though, for yeast was not added to these early wines. To this day, yeast is, for the most part, neglected to be added in the production of red wine. The grapes needed for red wine are crushed as are grapes for white wine, but rather then filtering out the skins like in white wine, red wine includes them in the fermentation process. Within the skin lies the essential color dye needed to give the wine the color that it is known for, but it also, more importantly, contains yeast. The yeast within the skins can be used for the breakdown of the sugars within the juice into alcohol. The concentration of ethanol produced by this fermentation varies, but under normal circumstances it will never exceed 14%. An amount greater than 14% will result in the killing of the enzymes that allow, like apozymase, the sugars to be broken down

White wine on the other hand needs yeast, because its lack of skins leaves it yeast-deprived, and therefore alcohol deprived. Rose wine is a combination of the two. The skins of the grapes are allowed to sit in the vats for a recorded amount of time, two or three days, and then taken out. The wine results in a rose color, but after the extraction of the skins it needs to be replenished with fresh yeast that will allow it to ferment longer.

Champagne is another commonly used alcoholic beverage that has its roots with the wines. It is known for its bubbles and exploding corks. These are both results of what is called the second fermentation. The first steps are identical to that of white wine. The first place that it differs is in the bottling. Rather than putting the white wine in a normal bottle and having it shipped out, it is put in an extra thick bottle with added yeast. These bottles are then set up on a rack where they undergo their second fermentation. The bottles are slowly rotated so that the top is nearly facing the floor. This turning is to extract the sediment that remained in the bottle. The contents are then frozen, and when the cap is taken off, the debris in the neck will fall to the floor, and the empty space will be filled with nitrogen. A durable cap is then placed on top, and the Champagne is done. The bubbly nature of the liquid is due to the carbon dioxide given off in the second fermentation that takes place within the bottle. The carbon dioxide is trapped inside the bottle rather than being allowed to escape like in traditional wine making. With the carbon dioxide trapped inside, extra pressure is built up. This extra pressure results in the manufacturing of thicker bottles and stronger corks held down with wire for Champagne.

The effects of these ethyl alcohol rich solutions on the body will be described a little later. Another very important product of fermentation is bread. Many people know that yeast is put into bread and that without it the bread would be solid as concrete. What they don t know, though, is that the bread goes through fermentation with the help of the yeast. The exact same process occurs – starches and sugars are converted into carbon dioxide and ethyl alcohol. The only difference between wine and bread other than one being a liquid and one being a solid is that bread bakes in high temperatures. When wine is stored, it is stored in somewhat low cellar temperatures not coming near the boiling point of ethanol, 78.5 degrees Celsius. In the oven this temperature is far exceeded. The increased temperature results in the evaporation of all of the ethanol produced during the fermentation of the bread. The only product of fermentation that is left is the carbon dioxide, which is observed through the small air gaps in the bread that give it its light and airy characteristics.

Alcoholic fermentation does more than produce food products for consumption; it supplies us with important medical uses. The most well known medical use for this process is found in what we call rubbing alcohol, pure ethanol. This is a clear substance that cannot be consumed without death resulting. It is used externally for sores on the body, and has a relaxing effect. How though can a substance be pure ethanol? After all, in all of the other fermentation examples that we saw, a sugar, yeast, and some other reactant (whether it was bread dough or grape juice) were used. It was also said that an alcoholic percentage of over 14% would kill the fermenting enzymes. It takes a little more effort to make this pure substance than it does for the others. The first step could be the same as that in making wine. Fermentation simply has to take place somewhere; a grape yeast solution would be a good environment for the ethanol to be made but corn or soybeans could also be used. After the fermentation is done a distilling apparatus is set up. This apparatus consists of two beakers, one rubber stopper, a Bunsen burner, and a long tube in the shape of a U. The fermented product is put into the beaker that lies over the Bunsen burner. A rubber stopper is then placed over the beaker. One end of the long U-shaped tube is placed into that beaker, the other end is put into another beaker. The Bunsen burner is now turned on; since the boiling point of ethanol is much lower than that of water, it is easy to separate the two by heating them to a temperature in-between. The ethanol will boil and evaporate at 78.5 degrees Celsius, while the water in the solution will not boil until it reaches 100 degrees Celsius. Hence, the Bunsen burner will be set for a temperature around 85 or 90 degrees Celsius. This will allow only the ethanol and not the water to evaporate.

The ethanol, now in gas form, passes out of the beaker and into the U-shaped tube. This tube is surrounded by ice or ice water. This cold environment that the tube supplies allows the ethanol gas to condense into its liquid form again. The liquid is collected in the second beaker. This solution will not be pure alcohol but it will range from 94-96% alcohol and 6-4% water. It can be further purified with the use of various dehydrating agents.

The making of ethanol over the years, especially during the prohibition, has been looked at with scrutiny by the government. Moon-shiners could have easily taken this commercially sold medical product, pure ethanol, and used it to make the liquor used for consumption. This was seen as a problem by the government before it even happened. The labs that the ethanol was produced in were forced to add a denaturing agent into the ethanol. These agents supply the ethanol with a poisonous characteristic that cannot be consumed no matter how diluted it is. In order to rid the ethanol of these characteristics, mob labs during the prohibition had scientists working hard to find a series of reactions that would counteract the denaturing. By the time the mob scientists could figure out how to make the ethanol pure again, the government would change the denaturing agent. This was all done to ensure that the government was getting its money from alcohol tax, and during prohibition, that illegal alcohol was not being produced to easily.

The fermentation of these products is just one aspect of the science behind the commercial use of alcohol. The bottle in itself is very important. Wine bottles along with most beer bottles have a tint to them. Whether it be green or brown, the bottles to these fluids are not usually clear. This is very important to the survival of the liquor inside. Due to the long period that it takes to make wine, bacteria can be present; this is also applicable to beer because its alcohol content is also too low to fully kill the bacteria within. The bacteria number is small and does not affect the taste or the nature of the wine or beer. This is only true, however, when the bottle is colored. If the bottle were clear then an unlimited amount of light would be able to pass through. This light would be very bad for the overall nature of the liquor. The bacteria inside would feed of this light and go through the process of photosynthesis. The bacteria would grow and multiply, as well as produce extra oxygen within the bottle that can lead to oxidation. This increase in bacteria number will dramatically alter the taste of the liquid and make it undrinkable.

The effects of ethanol on the body offer yet another scientific aspect that is derived from the fermentation process. Alcohol enters the body just like any other liquid or food. It is put into the mouth then passed down the esophagus, and then enters the stomach. The stomach then sends it to the small intestine that distributes it throughout the body via blood. The ethanol is diluted and enters the blood stream in correlation with the concentration of water. The liver has a major role in the processing of the ethanol that is toxic to the body. An enzyme within the liver called dehydrogenase enzyme assists in the transformation of ethanol into another toxic liquid acetaldehyde plus two hydrogen atoms. The reaction is shown below.

The acetaldehyde, like the ethanol, needs to be destroyed in order for the body to digest it. Aldehyde dehydrogenase enzyme is the enzyme that, along with water, is responsible for converting the acetaldehyde molecules into acetate ions. The reaction is shown below.

The resulting hydrogen atoms are not put to waste. They are used to convert NAD to NADH. This is a vital processing of hydrogen atoms that occurs in many processes within the body. The reaction is shown below.

NAD + H NADH

The process shown above can only work so fast. The disposal rate of ethanol in a 150-pound human is about 0.5 ounces of ethanol per hour. When more than 0.5 ounces of ethanol are consumed within an hour, the liver falls behind in the disposal of the toxins.

Ethanol has made its mark on society from the first people of Mesopotamia to the city living people of today. It has put itself into the lives of everyone, from consumers, to sellers, to manufacturers, to all the people between. Its chemical process has been used for thousands of years while remaining unknown. Now that it has been mapped, ethanol applications have become more consistent and have been able to grow to great production levels. The breakdown of sugars through glycolysis and fermentation that leads to the production of ethanol and carbon dioxide could not happen without yeast. This fungus, along with the enzymes that it contains, is vital to the anaerobic process. Products such as liquors, baked goods, and medicines rely on this process to keep the public happy. The effects of the ethanol produced through fermentation on the body can be handled to a certain degree. Diseases, though, can be gained from excessive use of ethanol due to the liver s lack of ability to break down the ethanol in large quantities. Fermentation, in its general form, is known by almost everybody, but its many aspects, relating to subjects from chemistry to society, are only known by few. There is no way to guess what our present world would be like without the important contributions that fermentation has made. Many think that the world would be better, and others think it would be worse. One thing that cannot be questioned, though, is that the fermentation leading to the creation of ethanol has made billions and billions of dollars in profit, along with giving millions of people jobs. It is amazing that something that has had such a large impact on the world (as the fermentation of ethanol has) begins on the molecular level.

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