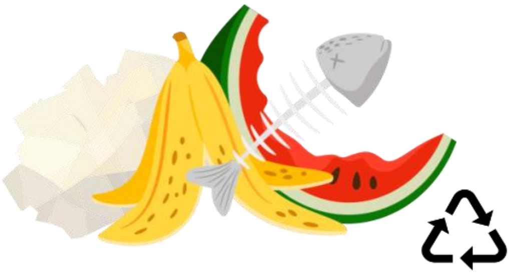
PERFUME FROM WASTE

Dani Sara



« Je déclare sur honneur avoir développé et rédigé ce mémoire sans l'aide abusive d'autrui. »

"I declare on my honor that I have developed and written this mémoire without abusive assistance from others."

Dani Sara

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1. INTRODUCTION

The use of kitchen waste has grown in popularity in recent years from a lot of fields due to environmental impacts that throwing it away brings .Food depletion and greenhouse gas emissions that are linked to food waste have been the main reasons for international organisations, NGOs and policymakers to take interest in the re-use and processing of kitchen waste in more efficient ways instead of letting it go to waste.

Altogether, one third of the food produced for human consumption is wasted, this is approximately about 1,3 billion tons of food per year. Not only is food production highly resource intensive but it is also accompanied by other disadvantageous factors. These include environmental impacts, for example, deforestation, soil erosion, air and water pollution and greenhouse gas emission that happen during food production, storage, transport and waste management. The food waste or kitchen waste is collected via waste collection and is brought to a landfill where numerous greenhouse gases are formed and harm the environment.

KITCHEN WASTE AS A RESSOURCE

However, food or kitchen waste are actually renewable raw materials that have the potential to be used for bioethanol production. This type of bioethanol production using renewable raw materials such as kitchen waste and food waste has significantly increased in the last 10 years. In the United States for example, there are 209 ethanol plants that are operated, producing 59.05242 liters of ethanol per year.

Bioethanol is currently mostly produced from sugar- and starch containing feedstocks, nonetheless there is also a use of lignocellulosic biomass, which includes agricultural and forestry residues. For the enzymes to be able to have access and create fermentable sugars, pre-treatment is required. Lignocellulosic feedstocks are classified as low cost feedstocks even though their processing involves technical as well as economic difficulties. The reason why they are preferred over sugar and starch feedstocks, is that their use does not compete with food production.

In a lot of developed countries, the governments are encouraging the use of renewable energies and renewable resources for various reasons, to secure access to energy, to develop and also maintain agricultural activities all while maintaining the guarantee of food safety[1]. Due to the current situation with global warming and the fossil fuel problematic, renewable resources are highly researched and tested in order to replace fossil fuel. Renewable resources are known for causing less environmental and societal concerns, in addition to this it could be a long-term solution.

OVERVIEWOF THE PERFUME INDUSTRY

Traditional perfumes can be pricy and can range from 100 euros to 1000 euros. Luxury brands like Dior and Louis Vuitton are making a lot of profit with these highly priced perfumes. The perfume industry is

[1] Food safety is a scientific discipline that consists of methods of food handling, preparation and storage, preventing food-born illnesses. Cited from: https://en.wikipedia.org/wiki/Food_safety

a big and growing business[2]. Nonetheless, there is an ongoing discussion about excessive margins[3], the products

For starters the perfume bottle is a big contributor to the overall price of the perfume, some bottles are sculpture-like and designed by artists. In the past perfume bottles have been considered very noble, they are considered “objets d’art” and some of the most prestigious bottles are exhibited in museums. The perfume bottle’s production costs about 6 dollars to make. Then, there’s packaging, which costs approximately 4 dollars. This includes bottle packaging as well as materials that are needed for the department store counters, for example perfume testers and displays. Marketing which costs about 8 dollars per bottle is a big part of the campaign, generally there are advertisement videos made and aired out as well as advertising panels. Oftentimes, these advertisements are backed with celebrities to make the perfume even more desirable. The marketing strategy uses department store marketing which is done at the point of sale as well as media marketing, in magazines, outdoor ads on bus shelters and as previously mentioned tv ads. Still, seeing the advertisement does not equal buying the product for a lot of customers, hence the importance of customers encountering the scent first. This is the reason why testers, which are promotional ploys, exist and are so important for selling perfumes.

Manufacturing of the perfume costs about 15 dollars per bottle, this includes everything from the salary of the brands CEO to corporate office expenses as well as the chemists’ pay check, who are the ones who produce the fragrance. The actual ingredients only cost about 2 dollars, being mainly composed of water, alcohol and fragrant components. Although some of the fragrance materials can be expensive on their own, the amounts used in perfume composition are extremely small.

[2] According to a market research report, in 2018, the market was worth 31.4 billion dollars in the USA alone: Perfume Market Size, Share & Trends Analysis Report By Product (Mass, Premium), By End User (Men, Women), By Distribution Channel (Offline, Online), By Region, And Segment Forecasts, 2019 – 2025: https://www.grandviewresearch.com/industry-analysis/perfume-market.

[3] One perfume can cost 100 dollars for the customers but can be made for a little over 20 dollars.

2. OBJECTIVES

The goal of this mémoire is to create a perfume from different types of kitchen waste preferably potato peels. One of the goals is to gain ethanol using the potato peels, meaning the starch and cellulose have to be broken down into simple sugars in order for the yeast to ferment it. This yeast and potato peel mixture is then distilled in order to separate the ethanol from the mixture and only have ethanol in the distillate. The second type of feedstock that has been used to attempt ethanol production was with fruit peels, banana peels, orange peels, kiwi peels and apple peels. These are sugar containing peels, meaning there is no need to convert something in order to obtain simple sugars. These are simply treated with a hydrothermal pre-treatment. Then they are fermented by the yeast which turns the simple sugars into ethanol just like with the potato peels. Then the mixture is distilled just like the one containing potato peels. In addition to making my own ethanol from waste, the objective was also extracting essential oils from different types of fruit peels. To obtain essential oils from fruit peels distillation of these is required and then the distillate is placed into freezer so that the oil can set and is easier to recognize and extract. This freezer method is not necessarily ideal for larger quantities. Finally, the last step is to compose a fragrance, which is a challenge because most perfumers use 40 to 80 materials to be in a perfectly balanced fragrance. The initial idea is to make a natural perfume meaning limiting the use of synthetic materials and basing the perfume on naturally sourced materials. Using only ethanol and different essential oils was the first step to creating an all-natural perfume from waste.

3. ETHANOL PRODUCTION

It is relatively hard to determine when bioethanol production from solid feedstock started exactly, however there are some clues as to when and how bioethanol was produced through history. Approximately 9000 years ago, it is believed that China started bioethanol production, they used a distillation technique in order to increase their ethanol yield. It is also believed that the Egyptians used vegetable waste to produce ethanol by letting the waste ferment naturally.

In the 12th century, Ireland was the first country to utilize starchy feedstocks for ethanol production, later on during the 18th century ethanol made from corn was used in lamp oil to replace whale oil. Its first "big" use was in 1826 in a combustion engine by Samuel Morey in the United States of America. Then in the 1880s, it went on to be used in automobiles in the form of grain alcohol, bioethanol that was produced from grain. In the year 1906, the Ford Model-T car was capable of using a mixture of ethanol and gasoline as fuel. In the year 1933, the first ethanol-gasoline fuelling station called "Corn alcohol gasoline" was opened in Nebraska, USA. It was at that time, where bioethanol intended to be used with gasoline and made from corn gained popularity. This popularity and rise in ethanol production due to the low prices of the feedstock, which was corn.

During the year 1940 however, cheap oil fields were discovered, ethanol production was decreased, since there was no need to have an alternative to gasoline. The prices of the petroleum oil increased because of the oil crisis, thus the ethanol production increased again in the year 1970. This increase in ethanol production was especially led by the United States, which almost produced 90 billion gallons of ethanol per year. Brazil also invested in ethanol production, the Brazilian government established a plan called "National Alcohol Program" or "ProAlcohol" in 1975, which intended to make ethanol from sugar cane at a large-scale production. This plan was so successful, that Brazil used 95% anhydrous[4] ethanol to operate more than half the cars in the country. Bioethanol production at a commercial level has become highly popular, and widely used due to its safety and environmental benefits.

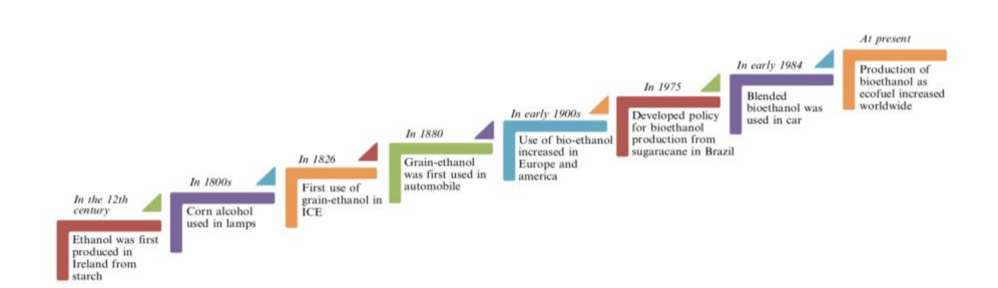


Fig. 8.1 Historical background of bioethanol production.

Image 1: https://www.researchgate.net/publication/329512149_Prospects_and_technological_advancement_of_cellulosic_bioethanol_ecofuel_production 11/04/20

[4] With all the water removed.

ECONOMICAL AND POLITICAL ASPECTS

A lot of countries have invested in bioethanol production due to its many advantages over Oil based fuels as well as environmental advantages. The leading countries that have invested the most in ethanol production are the United States, Brazil, the European Union and China. As the diagram shows, the United States and Brazil are the countries that produce the largest amount of bioethanol, accounting for almost 90% of global production.

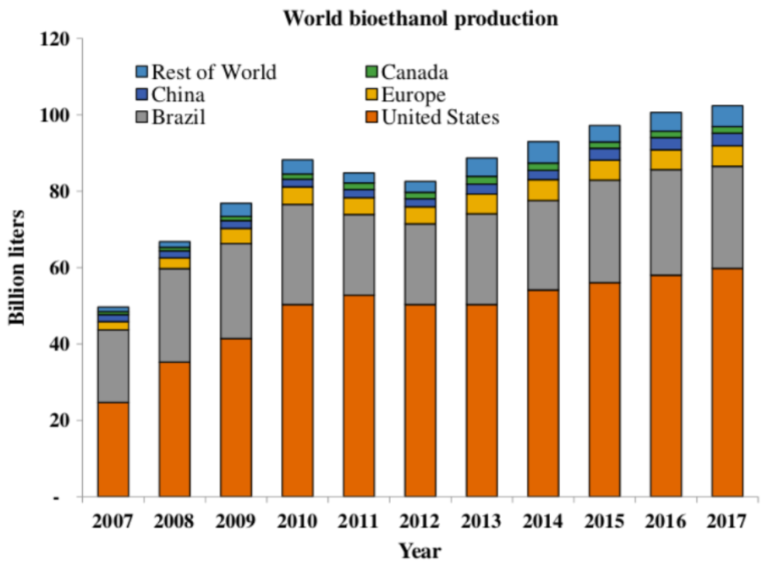


Fig. 16.1 Ethanol production in the major biofuel producing countries: 2007–15. Data from: Renewable Fuels Association. http:/www.ethanolrfa.org/resources/industry/statistics/#1454098996479-8715d404-e546.

Image 2 : https://www.sciencedirect.com/science/article/pii/B9780081027288000164 12/04/20

A lot of countries are investing in bioethanol production due to high oil prices, global warming concerns and because this could be an alternative energy source. Currently, the majority of big oil reserves are concentrated in the Middle East, Russia and the United States and the prices of crude oil are on the rise, thus there is a need to find another alternative. The world demand for crude oil is also growing, approximately by 2.5% per year and the crude oil demand is said to increase by 37% by 2030. The oil demand would grow up to 115 million barrels per day by 2030. These are factors that urge us to find an alternative and bioethanol has the potential to be a new alternative energy source and also an alternative fuel. This would be highly critical, and we could be heading into an energy crisis in the future.

Bioethanol could be used as an alternative fuel, more precisely to replace fossil fuel, hence why bioethanol production popularity has grown in recent years. This is especially helpful, because the production of bioethanol relies on feedstocks that are highly abundant, mainly from plants, and is thus carbon-neutral. Carbon neutrality is a big selling point for bioethanol production, as it means that the carbon released during the use of the fuel is balanced since the plants needed as feedstocks reabsorb the carbon. Thus, bioethanol fuel, called biofuel emits less greenhouse gases (GHG) during combustion than traditional petrol and diesel during combustion.

The environmental benefits of bioethanol use are a large selling point for countries, especially the reduction of GHG emission. This said the amount of GHG emission is dependent on the technology/ method that is used during bioethanol production. For example, the methods that are used for feedstocks like sugarcane and corn are well established, with an estimated saving of 65% of greenhouse gases whereas production methods for agave are not.

ENVIRONMENTAL IMPACTS

However, there are studies that have been led to investigate the negative environmental impacts that bioethanol production can have. A study that has been led by Zeh et al[5] informed that the cultivation of bioethanol crops might be a cause for the release of large quantities of carbon dioxide, which increases the amount of carbon dioxide in the air and also water pollution.

Another problem, that arises with bioethanol production is he feedstock that is used. The majority of feedstocks for bioethanol production that is used are directly or indirectly a part of human consumption, thus competing with the agriculture. This would include requiring land for the production of bioethanol, a study led by Searchinger et al.[6] estimated that 12.8 million hectares of land would be necessary to meet the global target of bioethanol production, which is 57 billion liters of bioethanol. This food vs bioethanol production issue has is one of the main reasons there is a need for a new technology/method or feedstock use. The low-agricultural by-products such as sugarcane bagasse, grass, straw and wood are dealt to avoid this food and bioethanol conflict. Also, new feedstocks that grow naturally in water limited environments such as the Agave Tequilana could be highly benefitting the bioethanol industry as it does not compete with food production and it does not need a lot of water.

This is a cause for concern for a lot of experts, who are concerned about overdeforestation and the conversion of croplands to replace them with "biofuel crops" and advise against creating biofuel crops. In Indonesia, Malaysia and Thailand, for example, there has been a destruction of the rainforest due to bioethanol production.

Nonetheless, bioethanol is still a great energy source, with the rising demand for energy and the uncertainty of the petroleum resources. It is a better energy source alternative since the dependence on crude oil is less high. That said, fossil fuel production is still cheaper[7], so that the industries tend to

[5] Life cycle assessment of energy products: environmental assessment of biofuels. http://www.globalbioenergy.org/uploads/media/0705_EMPA_-_Life_cycle_assessment_of_energy_products_environmental_of_biofuels.pdf

[6] Use of US cropland for biofuels increases greenhouse gases through emissions from land-use change.

[7] According to the International Energy Agency, in the first half of the year 2017 (January to June) and second half of the year 2017 (July-december) the cost of bioethanol production has been higher than the cost of gasoline production in Brazil. In the USA, bioethanol production cost was higher in the first half of the year 2017 but not in the second half of the year 2017: https://www.iea.org/data-and-statistics/charts/biofuel-and-fossil-based-transport-fuel-production-cost-comparison-2017

gravitate towards it. The problem is, that the resources are not infinite, thus we cannot rely on fossil fuels and have to search for alternative energy sources.

INDUSTRIAL BIOETHANOL PRODUCTION

Types of Feedstock

Bioethanol or ethyl alcohol is a clear liquid with the following molecular formula: CH_3-CH_2-OH and is the same organic compound used in alcoholic beverages. It is produced by microbial fermentation of sugar using various feed stocks such as sugarcane, corn, maize, wheat, agricultural waste, etc. However, bioethanol can also be obtained by a chemical process using ethylene. The available feedstocks for bioethanol production can be split into four categories:

First – generation: starchy crops biomass, kernels[8]

Second – generation: lignocellulosic biomass (plant dry matter)

Third – generation: algal biomass (microalgae, microbes)

Fourth – generation: Capturing carbon dioxide

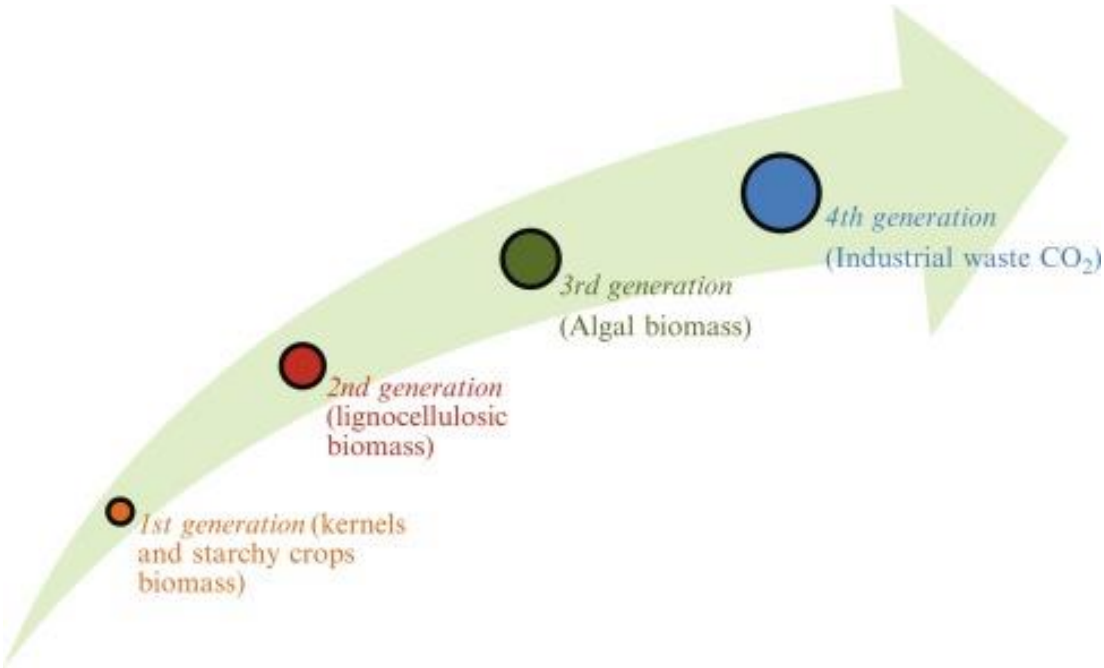


Image 3: https://www.researchgate.net/publication/329512149_Prospects_and_technological_advancement_of_cellulosic_bioethanol_ecofuel_production 11/04/20

[8] Edible part of nuts.

Table 16.1 Types of biofuel and bioethanol by production technology

First-generation biofuels		**Second-generation biofuels**	**Third-generation biofuels**
Biodiesel (directly extracted from seeds)	Bioethanol (fermentation process)	Bioethanol (fermentation of lignocellulosic parts)	Bioethanol, biodiesel, etc.
• Palm seed	• Corn	• Straw	• Algae
• Rape seed	• Sugarcane	• Wood	
• Sunflower	• Sugar beets	• Grass	
• Soybeans	• Barley	• Plant waste	
• Canola	• Wheat	• Agave	
• Mustard	• Sorghum		

Image 4: https://www.sciencedirect.com/science/article/pii/B9780081027288000164 12/04/20

Bioethanol is mainly used as an alternative to petroleum or it is used to create a blend of bioethanol and petroleum in order to reduces petroleum consumption thus fossil dependency. Compared to fossil fuels, oil and natural gas, biofuel is an alternative that is much more attractive because of its many advantages such as environmental friendliness, renewability, biodegradability, etc. However, the sustainability of bioethanol is still a debated topic. The production of bioethanol mainly requires food crops, especially for the first-generation feedstock which has the highest fermentable sugar content. As a result, bioethanol production is competing with food supply and also with land utilization. To stay out of this food-fuel conflict, the second-generation biofuel production that uses lignocellulosic biomass[9] is an alternative that has been sought out. The advantages of the second-generation feedstock are that they can grow on almost every soil, need less water, less fertilizer and most importantly they are not competing with food supply. However, there is a disadvantage in using second-generation feedstock, compared to the first-generation feedstock, second-generation feedstock has a lower concentration in sugar and the production of bioethanol requires more advanced processing equipment.

With the goal of avoiding the first-generation and second-generation issues, another alternative for bioethanol production has been explored, the third-generation feedstock. This bioethanol production involves algal biomass like microalgae and this type of feedstock seems to be a promising alternative because of its advantages over first- and second- generation feedstocks. Microalgae cultivation involves a low-cost cultivation as well as a high conversion of energy. Although, the bioethanol that has been produced from microalgae is less stable than the one from first- and second-generation feedstocks. The fourth-generation feedstock is the newest approach to producing bioethanol, it uses carbon dioxide capturing method which requires advanced technologies[10]. This method of production is said to be

[9] i.e.: woody biomass, forest residue, …

[10] i.e.: electrochemical synthesis, oxide electrolysis and petroleum hydroprocessing.

carbon negative, meaning there is less carbon produced from this method than is being captured, which is very promising.

The various feedstocks require different technologies for the conversion of glucose, starch or lignocellulose into ethanol. This means, that the methods used for ethanol production vary based on the feedstock that has been used. For the production of ethanol from sugary feedstocks[11], the sugar juice is extracted from the feedstock, then it is purified by adding lime to it, to neutralize organic acids. When the sugar is purified, it is then fermented using microorganisms such as yeast, the mixture is distilled then ethanol is obtained. For starchy feedstocks, the first step is wet milling or dry milling the feedstock, a step which is needed to increase ethanol yield. The wet milling method is used to separate the corn kernel into its components, this separation process is called steeping. Then an enzymatic hydrolysis is required, which converts the starch that has just been steeped into sugar, the sugar is later converted to ethanol the same way as in sugary feedstocks. During the dry milling, the steeping is skipped, but the entire corn kernel is ground and then ethanol is produced similarly to the wet milling method. As the wet milling method requires extensive equipment, a lot of industries use the dry milling method. While wet milling is more appropriate for large-scale ethanol production, dry milling is fitting for small-scale production because it requires less equipment.

For lignocellulosic feedstocks that contain lignin, cellulose and hemicellulose, these components form a rigid structure, which makes it harder for enzymes to work during enzymatic hydrolysis. Thus, different pre-treatment methods have to be adopted to deconstruct the structure, this includes chemical and physiochemical methods. The structure that has to be deconstructed is crystalline cellulose in which hydrogen bonds hold the long cellulose chains tightly together in a crystalline structure. During pre-treatment, not only is the crystal structure broken down, but lignocellulosic and hemicellulosic structures are removed. As a result, the porous surface area is increased, and this facilitates the access for the enzyme, cellulase, which increases the conversion of cellulose into glucose. Compared to other feedstocks, the conversion of cellulose into glucose requires a step more, pre-treatment.

[11] i.e. sugarcane, sweet sorghum…

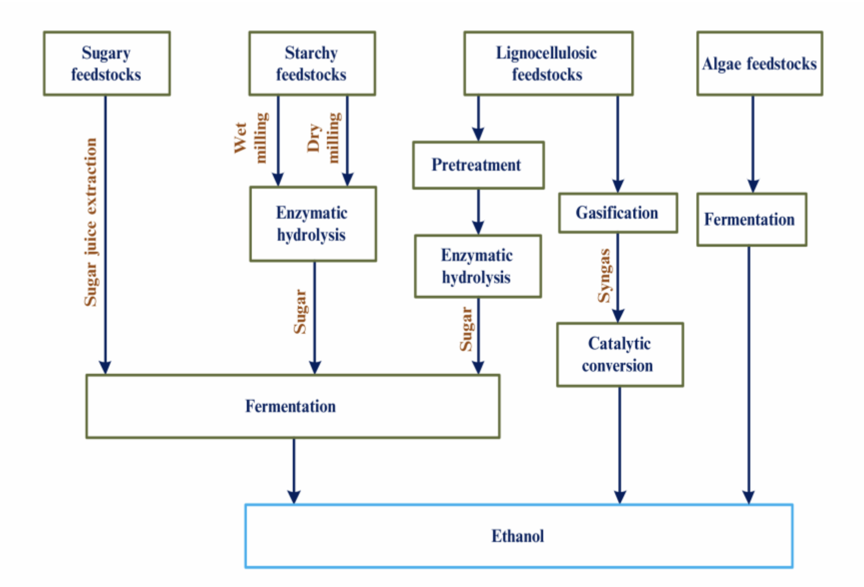


Fig. 8.4 Possible routes of bioethanol production.

Image 5 : https://www.researchgate.net/publication/329512149_Prospects_and_technological_advancement_of_cellulosic_bioethanol_ecofuel_production 12/04/20

Processes

Bioethanol that is derived from agricultural waste has received a lot of attention. The main type of feedstock that has been used to produce bioethanol has been sugar feedstock. However, the fact that bioethanol production and food production compete with one another is not optimal. Therefore, another type of feedstock has been exploited, namely the second-generation feedstock containing lignin, cellulose and hemicellulose. There are different steps that have to be followed in order to obtain bioethanol from this type of feedstock. Firstly, a pretreatment is required which is used to make the next step of hydrolysis a lot more efficient and manageable. During hydrolysis, simple sugar is formed, which can then be fermented into ethanol by the yeast and the mixture can be distilled in order to separate the ethanol from the rest. This step can also be referred to as purification.

Yeast

For the fermentation process to take place, microorganisms, in this case yeast, play an important role in bioethanol production. The yeast (Saccharomyces cerevisiae) that is used during the fermentation process is particularly appropriate because of the high ethanol yield, its high ethanol tolerance and the capacity to use a wide range of sugars. Yeasts are able to turn simple sugars into ethanol via fermentation, however if another type of feedstock is used that does not have a lot of fermentable sugars, for example starchy corps, the feedstock must first be converted into fermentable sugars and those can then be fermented by yeasts.

Potato peels contain enough starch, cellulose, hemicellulose, lignin and fermentable sugars to use as ethanol feedstock.

Process

In order to obtain bioethanol from lignocellulosic biomass there are different steps that have to be followed:

1. Pre-treatments
2. Hydrolysis
3. Fermentation
4. Purification/ distillation

1. Pre-treatments

As the term already says it pre-treatment is a type of treatment that is done before actually handling the feedstock. It is used in order to enhance components exposure, like cellulose, hemicellulose and starch. This is done to maximize yield before going onto the hydrolysis, as this makes the access for the enzymes easier. Subsequently, the conversion of carbohydrate into fermentable sugars is higher. Here are a few examples of pre-treatment methods that can be used.

Steam explosion pre-treatment

The steam explosion pre-treatment (SEP) is a method used to fractionate biomass components. During this type of pre-treatment, high pressure saturated steam is applied, then the pressure is reduced so that the materials decompress explosively. This sudden decompression causes the fibers in the biomass to separate. The steam penetrates the plant cell wall, this causes hemicellulose degradation and lignin transformation or conversion due to the high temperatures. In addition to this SEP also influences cellulose crystallinity, making it even more beneficial for the yield. SEP is typically done at a temperature between 160-260 degrees Celsius and with pressure between 0,69- 4,83 MPa. This is done for a few seconds or a few minutes. Then, during hydrolysis an acid, for example sulfuric acid is added to increase the hemicellulose sugar yield. The higher the temperature, the higher the hemicellulose removal, thus this creates an enhanced cellulose digestibility and higher sugar degradation. The fact that it does not require a high of energy input makes this method especially attractive however due to the high temperatures used, there is a probability that the formation of fermentation inhibitors takes place.

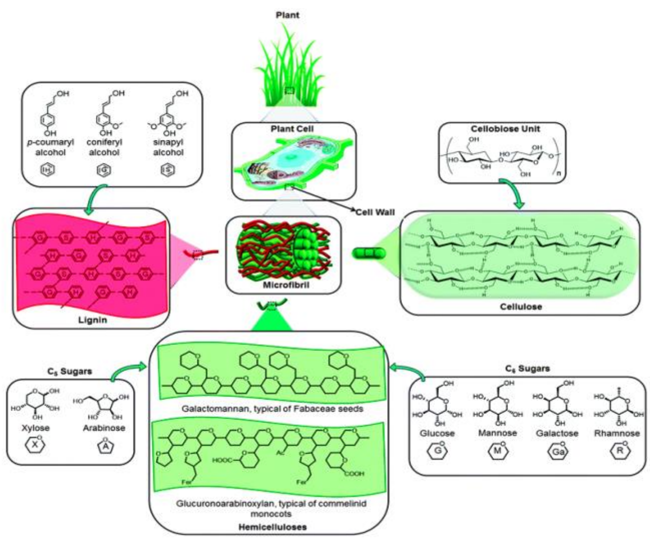
Mechanical pre-treatment

The mechanical pre-treatment is done to mill (or to cut) the lignocellulosic biomass into smaller components. The objective of milling is to decrease the particle size as well as to decompose the cellulose crystalline structure. If the particle size is smaller, the surface area becomes bigger. This leads to an increase in hydrolysis yield, which is the next step. The difference that the mechanical pre-

treatment makes in hydrolysis yield varies from 5% to 25%, depending on the feedstock, the milling method used and the duration of the milling. Nonetheless, mechanical pre-treatment does require a lot of energy and thus, it has been deemed not as beneficial as a pre-treatment. The high-energy requirement makes this method economically not practicable.

Liquid hot water pre-treatment

Another type of pre-treatment is the liquid hot water pre-treatment. During this process, the lignocellulosic biomass is heated to a temperature that varies between 160 and 180-degrees Celsius. This high heat causes the hemicelluloses and subsequently the lignin to solubilize. This type of pre-treatment is also called autohydrolysis and the length of this hydrothermal pre-treatment can range from a few minutes up to several hours. The advantage of this type of pre-treatment is that no additives are required such as, for example, acid catalyst that are supposed to minimize the production of inhibitory byproducts. Nonetheless, this is still a high-energy demanding method because it requires high pressure as well as large amounts of water. During this process, the water acts as a weak acid, meaning it causes the depolymerization of the hemicellulose and forms acetic and uronic acids . This makes the cellulose more accessible and as a result the hydrolysis is facilitated. An important factor during this method, however, is to keep the pH level between 4 and 7, otherwise there will be a formation of inhibitors.



Components of lignocellulose

Image 6 : https://pubs.rsc.org/en/content/articlehtml/2015/py/c5py00263j 20/04/20

clude:

- Low cost chemicals for pre-treatment
- Minimal emission of waste
- Low energy input methods
- By products minimization or by-products that do not pose additional inhibition/problems

2. Hydrolysis

Hydrolysis is useful because the access to the sugars is hindered, therefore physical or chemical methods are needed to derive the sugar. The most common acids used for hydrolysis is sulfuric acid (H_2SO_4) and hydrochloric acid (HCl). There is an alternative to acid hydrolysis, which uses cellulose

solvents, ionic liquids[12] (ILs) since they are also able to dissolve cellulose. The most popular hydrolysis methods are acid hydrolysis and enzymatic hydrolysis.

Acid hydrolysis

During acid hydrolysis, the acid is used to disrupt the hydrogen bonds between cellulose chains, as a result the cellulose is decrystallized and it forms a homogenous gelatin with the acid. Afterwards, water is added at a medium temperature and glucose hydrolysis takes place. The concentrated acid breaks down the cellulose as well as the hemicellulose in the lignocellulosic biomass. The advantage of acid hydrolysis as opposed to enzymatic hydrolysis for example, is a faster rate of hydrolysis however the glucose also degrades quicker in acidic conditions. Another downside to acid hydrolysis compared to enzymatic hydrolysis, is that there are more side products that are formed whereas enzymatic hydrolysis is more precise. Sulphuric acid and hydrochloric acid are the two most commonly used acids at a moderate temperature that ranges from 100-150 degrees Celsius. When temperatures and acid concentrations are too high, the formation of inhibitors, acetyl groups form and inhibit the fermentation and later on the ethanol yield.

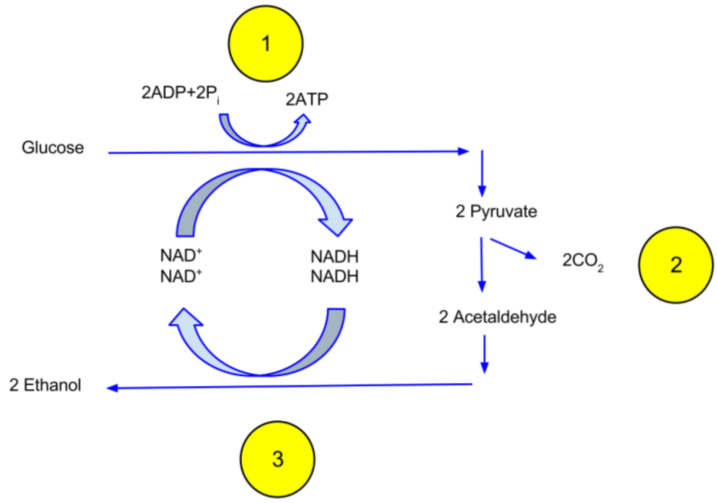
Enzymatic hydrolysis

As the names states it, enzymatic hydrolysis uses enzymes to break down lignocellulose into simple sugars. The enzyme used in this case is called cellulase. Enzymatic hydrolysis is favorable because it requires less energy and creates fewer inhibiting factors for the fermentation. Nonetheless, the enzymes are very expensive and are hard to work with since there are numerous structures of cellulose, hemicellulose and lignin that have to be broken down first. If this is not done, some enzymes can actually be absorbed by condensed lignin, which inhibits hydrolysis. For the hydrolysis of hemicellulose, hemicellulase is required, which hydrolyses xylan, a big polymer that can be found in hemicellulose. This mixture of the both enzymes, cellulase and hemicellulose has proven to be very effective, since removing the hemicellulose increases substrate accessibility.

3. Fermentation

Fermentation is a very important part in ethanol obtention. During this process, the sugar, such as glucose or fructose that is present in the different feedstocks such as fruit peels are converted into sugar and finally into ethanol.

[12] "An ionic liquid is a salt in the liquid state" Cited from https://en.wikipedia.org/wiki/Ionic_liquid

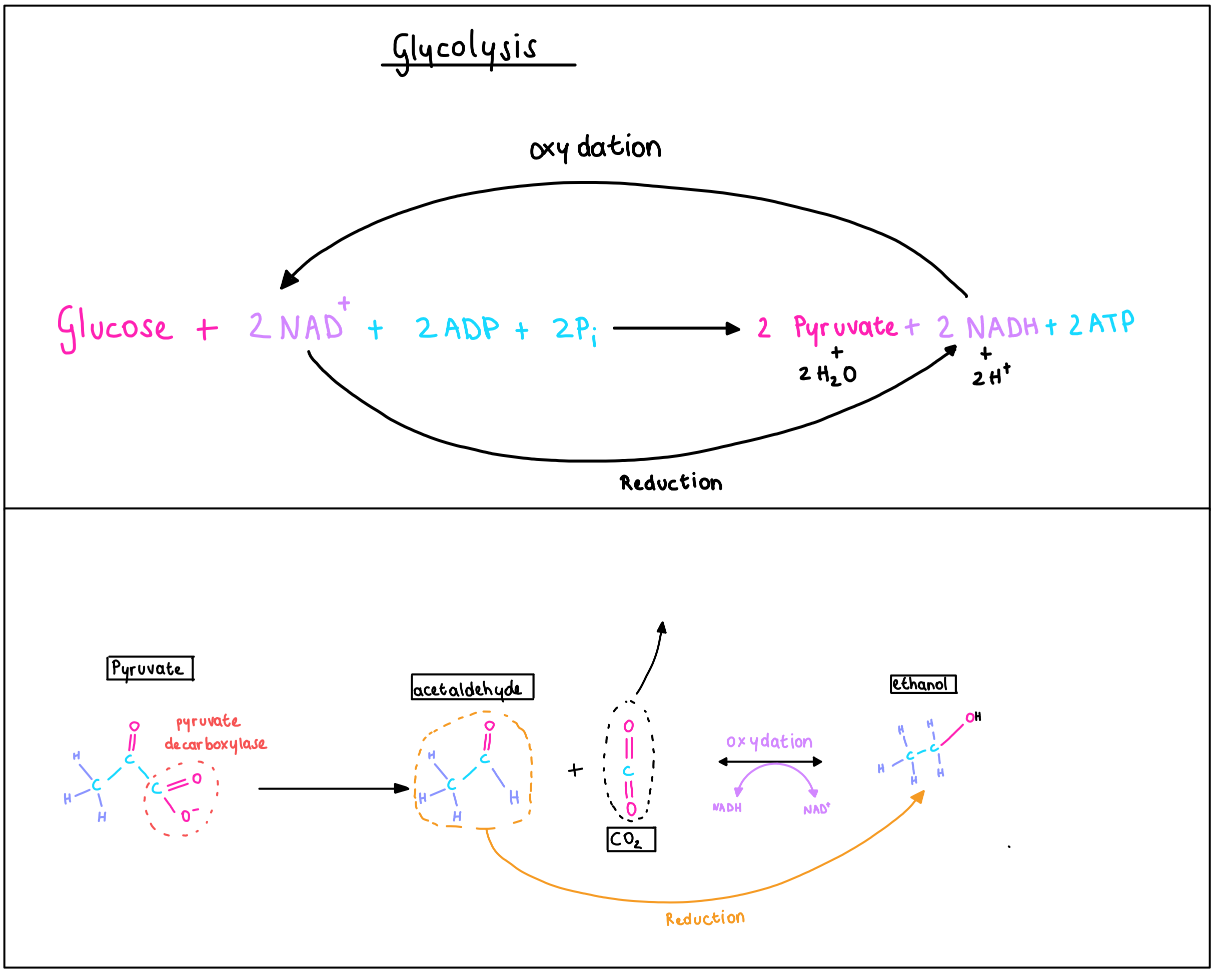


1) One glucose molecule is broken down into two pyruvate molecules. This process releases energy, meaning this process is exothermic. The energy is necessary in order to bind the phosphate molecules to ADP Then NAD^+ is reduced into NADH, since it is a redox reaction. NAD is a coenzyme.
2) The two pyruvate molecules are broken down into two acetaldehydes and CO_2.
3) The two acetaldehydes are converted into two ethanol molecules

Image 7 : https://en.wikipedia.org/wiki/Ethanol_fermentation (o4/o4/20)

So, let's take a closer look at glycolysis. As previously shown, one glucose molecule is broken down into 2 pyruvate molecules. And in the process of breaking down the glucose molecules 2 ATP molecules and NAD+ is reduced to NADH. The process where NAD+ NADH is called reduction. Furthermore, during this reaction where the glucose molecule is broken down, there are 2 H2O molecules and 2 H+ ions that are produced. Since we have established that this is an anaerobic process, meaning there is no oxygen involved, cellular respiration cannot happen.

Once the glycolysis is finished, the two molecules of pyruvate lose their carboxyl group. This process of the carboxyl group loss is facilitated by the enzyme pyruvate decarboxylase. Once the carboxyl group is removed, it forms a CO2 molecule. As previously mentioned, this is a by-product of the yeast fermentation. What is then left over are 2 acetaldehyde molecules. These acetaldehyde molecules can then undergo a reduction process, where they are reduced by NADH to form ethanol. While the acetaldehyde is being reduced to ethanol, the NADH is oxidized to NAD+. So that glycolysis can occur again, and the process can be repeated and doesn't stop immediately.

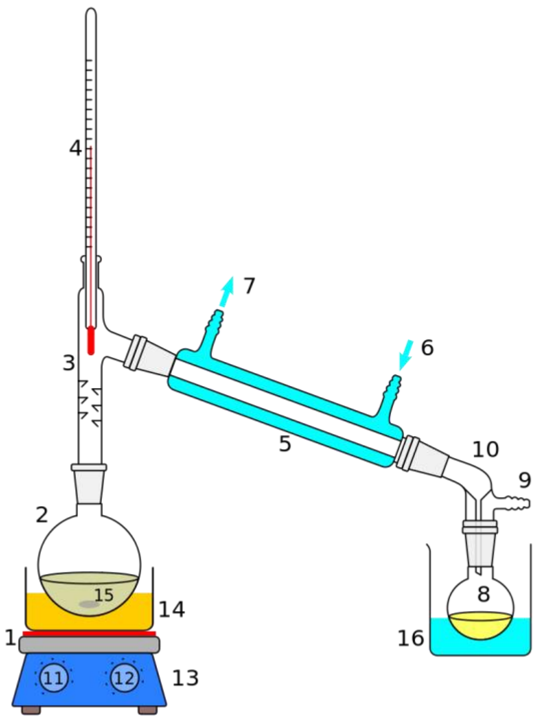


In addition to this, ethanol production is highly dependent on the yeast cell growth and it must be a helping factor. This cell growth must be assured because otherwise there would not be a consumption of ATP molecules which leads to an accumulation of ATP molecules in the cell. This accumulation then leads to the inhibition of the phosphofructokinase, an enzyme that is responsible for the glycolysis of fructose-6-phosphate, which means the glycolysis cannot happen. The phosphofructokinase is one of the most important enzymes in the glycolysis process. There are also other by products besides ethanol and CO_2 that are created during fermentation, for example glycerol and acids. The optimal working conditions for the cellulase is between 40 and 50 degrees Celsius at a pH of 4 or 5.

However, during the fermentation process, the yeast cells can suffer some sort of “stress”. This includes nutrient deficiency, a temperature that is too high, contamination and ethanol accumulation. These “stresses” can consequently affect the fermentation process, thus the ethanol yield.

4. Distillation

Distillation is a process that is used to separate components or substances from a mixture based on their different boiling points, in this case the goal being to isolate the ethanol. The process consists in boiling and condensation and uses the volatility of the mixture’s components. The way distillation works is that the mixture is heated up to about 80 degrees Celsius since the ethanol’s boiling point is about 79 degrees Celsius, the ethanol will evaporate and then condense and can then be collected.



1. Source of heat
2. Round bottomed flask
3. Still head
4. Thermometer
5. Condenser
6. Cooling water comes in
7. Cooling water goes out
8. Distillate + receiving flask
9. Vacuum/ Gas inlet
10. Still receiver
11. Heat knob
12. Stirring speed knob
13. Stirring and heat plate
14. not used
15. Mixture
16. Not used

Cited from: https://en.wikipedia.org/wiki/Distillation

Image 8

LABARATORY EXPERIMENTS

Experiment 1

Objective: Determine how much ethanol yield can be obtained from one banana peel.

Materials:

- Peel of one banana
- Knife
- Cutting board
- Autoclave
- Brix refractometer
- Heat-safe Erlenmeyer flask
- Fermentation lock
- Scale
- Beakers
- Yeast

- Distilled Water
- Orbital Shaker
- Small Beaker
- Heat resistant gloves

Methods:

Firstly, it is preferable to take a well-ripened banana since it appears that it has more soluble sugars, which increases ethanol yield. The first step is to cut the banana peel into more manageable, smaller pieces so that they fit into the Erlenmeyer flask. 150 mL of distilled water is added to the Erlenmeyer flask to cover up the banana peel. Then the container is placed into the autoclave as a method of hydrothermal pre-treatment to maximize sugar yield, thus ethanol yield. During this step the sugars are made more accessible for the yeast during fermentation. The container should not be sealed shut entirely otherwise there is a risk that the pressure could be too high so that the container explodes. Afterwards, the container is taken out of the autoclave using the heat resistant gloves. Then, proceed to measure 0,5g of yeast and add it to 10 mL of distilled water. Then, this yeast and water mixture is added to the Erlenmeyer flask containing the autoclaved banana peel. The whole content in the Erlenmeyer flask is transferred to another Erlenmeyer flask so that a fermentation lock can be inserted. The flask is then put onto the shaker and left to ferment for 3 days. After that, the mixture was taken off the shaker and the banana peel pieces were taken out of the flask. The mixture is distilled to separate the ethanol from the mixture. During distillation, it is very important to observe the thermometer closely, because the boiling point of the ethanol is at 78,4 degrees Celsius.

Results

The concentration (mass/mass percentage or degrees Brix [°Br]) of soluble sugars is measured using a refractometer with automatic temperature compensation (ATC). It is assumed that the refractive index change during fermentation is solely due to the change in sugar concentration.

Directly after the pre-treatment the sugar content measured by the refractometer was 2,8%.

The sugar content was then measured every day for three more consecutive days:

Fermentation day	Sugar (brix) content (%)
Day 1	2,2
Day 2	1,2
Day 3	1

After distillation, it was evident that the amount of ethanol that could be produced from a single banana peel was so small that it was insignificant. It was unclear if the distillate only contained ethanol or a mixture of ethanol with different types of esters.

Experiment 2

Objective: Test different fruit peels to determine which one has the highest sugar concentration and determine their ethanol yield.

Materials:

- Scale
- Knife
- Cutting board
- Autoclave
- Brix refractometer
- Heat safe Erlenmeyer flask
- Fermentation locks
- Recipients (Beakers)
- Yeast
- Distilled water
- Orbital shaker
- Heat resistant gloves
- Peels of 1 apple
- Peels of 2 kiwis
- Peels of 1orange

Methods:

Firstly, the different peels of the different fruits were cut into small manageable pieces, weighed and placed in a conical-bottom flask. The peels were then covered with distilled water and autoclaved for 20 minutes (121°C ; 1 atm). The sugar content of each sample was determined using a refractometer. Yeast was added to each sample and the cultures were incubated on an orbital shaker for 3-4 days at room temperature. After fermentation the samples were distilled separately.

Substrate	Substrate mass (g)	H_2O added (g)	Total mass (g)
Apple peel	108.6	321.8	430,4
Kiwi peel	58.6	199.2	257,8
Orange peel	115.0	276.4	391,4

Results:

After pre-treatment:

Fruit peels	Sugar (brix) content (%)
Apple	3,9
Orange	4,2
Kiwi	3,2

First day of fermentation for Apple and orange peels:

Fruit peels	Sugar (brix) content (%)
Apple	2,0
Orange	2,5
Kiwi	/

Third day of fermentation for apple and orange peels. Second day of fermentation for kiwi peels:

Fruit peels	Sugar (brix) content (%)
Apple	1,1
Orange	2
Kiwi	1,2

Fourth day of fermentation for apple and orange peels. Third day of fermentation for kiwi peels:

Fruit peels	Sugar (brix) content (%)
Apple	1,1
Orange	2
Kiwi	2

Calculation of potential ethanol yield

[$x_{(e)}$ = ethanol
$x_{(s)}$ = sugar]

Apple peels:

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$$

- inital brix − final brix = Δ brix → theoretical amount of sugar that has been fermented.

A.N
$\Leftrightarrow$ 3,9 % − 1,1 % = 2,8 %

- 2,8% of 321,8g = 9,01g → sugar mass
  (H_2O added ↗)

- $n = \frac{m}{M}$

A.N
$\Leftrightarrow$ $n = \frac{9{,}01\,g}{180\,g/mol}$

$\cong$ 0,05 mol

- $\frac{n}{2}$ = 0,025

- $m_e = M \cdot n$

$\Leftrightarrow m_e = M_e \cdot n_s$

$\Leftrightarrow m_e$ = 46 g/mol · 0,025 mol

= 1,15g → theorethical ethanol yield in grams

Orange peels:

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$$

- inital brix - final brix = Δ brix → theoretical amount of sugar that has been fermented.

A.N ⇔ 4,2 % − 2 % = 2,2 %

- 2,2 % of 276,4 g = 6,08 g → sugar mass
  (H_2O added ↗)

- $n = \frac{m}{M}$

A.N ⇔ $n = \frac{6{,}08\,g}{180\,g/mol} \simeq 0{,}034\ mol$

- $\frac{n}{2} = 0{,}017\ mol$

- $m_e = M \cdot n$

⇔ $m_e = M_e \cdot n_s$

⇔ $m_e = 46\,g/mol \cdot 0{,}017\,mol$

$\simeq 0{,}77\,g$ → theorethical ethanol yield in grams

For the kiwi peels, I did not calculate the potential ethanol yield, since there was a problem with the last brix measurement, it went up instead of down. The brix content goes down and is typically at its lowest on the third day of fermentation, indicating that the fermentation is happening and that the yeasts are converting sugar into ethanol. The last measurement (highlighted in yellow) went up by 0,8% which would indicate that the sugar content went up, which little to not plausible.

After distillation the alcohol/ethanol content still seemed very low and it was unclear if the distillate only contained ethanol or a mixture of ethanol with different types of esters.

Experiment 3

Objective: Compare the use of brewing malt and purified amylase as a catalyst for starch hydrolysis. Can malt be used instead of amylase to hydrolyze sugar?

Materials:

- Potato peels of numerous potatoes (P.P)
- Malt
- Maxilase (as a source of alpha amylase)
- Autoclave
- Incubator
- Orbital shaker
- Cutting board
- Knife
- Distilled water
- Yeast
- Malt grinder
- Scale
- Brix refractometer
- Heat safe Erlenmeyer flasks
- Recipients (Becher)
- Fermentation locks
- Heat resistant gloves

Methods:

First, the potatoes are peeled. Then the total potato peels are weighed and divided into 3 different heat safe Erlenmeyer flasks since three samples contain potato peels. Approximately 68g of potato peels per sample were used. The samples are then subjected to different treatments, outlined in the table below:

Types of samples	Ingredients
Sample 1	Malt + H_2o + Yeast (-)
Sample 2	Amylase + H_2o + Yeast (-)
Sample 3	P.P + Malt + Yeast + H_2o
Sample 4	P.P + Amylase + Yeast + H_2o

Sample 5	P.P + H_2o + Yeast

As a type of pre-treatment this time, the potato peels, were not cut into pieces, but instead they were blended using a stick blender in order to increase surface area and increase ethanol yield, In addition, the amount of water added to cover up the potato peels could be reduced. As little as possible of water was added to keep the concentration as high as possible. Then the potato peels and the water are put into the autoclave. The malt is then ground with the malt grind machine. Then the samples that contain malt and potato peels are incubated at 65 degrees Celsius for about 2 hours. Then all the samples are prepared, so the amylase samples are prepared, and yeast is added to all the samples and left to ferment.

Results:

There are no results, because the experiment could not be completed due to the CoV-2019 pandemic.

Experiment 4 (planned)

Objective: Use cellulase in addition to amylase for the enzymatic hydrolysis of lignocellulosic raw materials in order to obtain simple sugars.

Materials:

- Yeast
- Amylase
- Cellulase
- Potato peels
- Autoclave
- Incubator
- Orbital shaker
- Cutting board
- Knife
- Distilled water
- Scale
- Brix refractometer
- Heat safe Erlenmeyer flasks
- Recipients (Beakers)
- Fermentation locks
- Heat resistant gloves

Methods:

As with the previous experiments, the potato peels are blended and mixed with an arbitrary but minimal amount of water. The different samples that are planned are:

Types of samples	Sterile	Yeast	Amylase	Cellulase

Sample 1				
Sample 2	✓	✓	✓	
Sample 3	✓	✓		✓
Sample 4	✓	✓		
Sample 5	✓	✓	✓	✓

The first sample is supposed to be a spontaneous fermentation, meaning the sample is not sterilized by autoclaving and no yeast is added. The other 4 samples are all sterilized, and yeast is added to all of them. The sample 2 only contains amylase meaning the starch from the potato peels is converted into simple sugars by the amylase. The third sample uses cellulase instead of amylase meaning, the enzyme breaks down cellulose into monosaccharides (simple sugars). For sample 5, both amylase and cellulase are used for hydrolysis, meaning both the starch and cellulose are broken down into monosaccharides.

4. ESSENTIAL OIL PRODUCTION

Fruit peels are often discarded after the edible part of the fruit has been eaten. Instead of disposing of them and simply throwing them in the trash, there might be a better solution. A lot of fruit peels like citrus peels or orange peels contain a lot of essential oils which could be used for the production of essential oils. These essential oils can be extracted and purified using different methods, such as steam- or hydrodistillation. A very important factor in essential oil production is the composition of the extracted essential oil, since the quality varies depending on the essential oil characteristics. The next step is to make perfume out of the extracted essential oils.

HISTORY

Essential oils are one of the oldest form of medicine. They are subtle aromatic compounds that are extracted from flowers, seeds, leaves, stems, roots, fruits and herbs. According to ancient Egyptian hieroglyphs and Chinese manuscripts, these essential oils were used by priests and alchemists to heal sick people. In many ancient cultures, essential oils were oftentimes more valuable than precious stones like gold and had a spiritual meaning attached to them.

In the year 1910, Rene Maurice Gattefosse a French chemist and perfumer, suffered a severe burn while working in his laboratory, the first thing that he could grab was lavender oil. He was astonished because the pain diminished, and the burn healed without infection or scarring. As a result of Gattefosse's discovery, during World War II essential oils were used to treat infections and wounds of soldiers by Dr. Jean Valet[13].

To this day essential oils are broadly used, since many people are increasingly interested in using toxic free and alternative methods of healing.

CHEMISTRY

Essential oils are a mixture of volatile components of terpenoid[14] nature. These terpenoid components are primarily monoterpenes and sesquiterpenes, these have been identified as hydrocarbons and oxygenated derivatives[15] in the shape of alcohols, aldehydes, ketones, esters, ethers, peroxydes and phenols. However, there are also non-terpenoid components that constitute essential oils, phenylpropanoids, fatty acids, as well as nitrogen- and sulfur-containing compounds although these last two are less common.

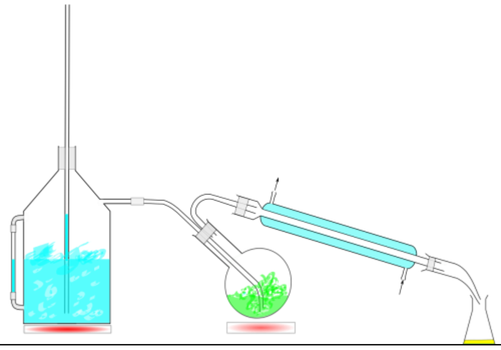
[13] http://www.essanteorganics.com/Portals/0/History_of_Essential_Oils.pdf

[14] " built up from units of the simple five-carbon molecule isoprene ". Cited from : https://www.britannica.com/topic/essential-oil 02/05/20

[15] Responsible for odours.

EXTRACTION OF ESSENTIAL OILS

Steam distillation is the method that is used in order to obtain essential oils. During steam distillation, the steam that is created from the boiling water in the round bottom flask carries the volatile components into the condenser. These components are cooled and brought back to their liquid state. The non-volatile components stay behind in the round bottom flask.



Steam distillation

Image 9: https://upload.wikimedia.org/wikipedia/commons/thumb/5/52/Steam_dist.svg/1280px-

LABARATORY EXPERIMENTS

Experiment 1

Objective: Obtain essential oils from the peels of 3 clementines.

Materials:

- Clementine peels
- Traditional distillation apparatus
- Distilled water
- Cutting board
- Knife
- Freezer
- Essential oil recipient

Methods:

First the clementines are peeled, then the peels are cut into really small pieces and put in the round bottom flask. Distilled water is added to cover up the peels. The mixture is distilled for about 1 hour. The distillate is collected and placed in the freezer to make the oil extraction easier since the oil is clearly visible at the top and can be scrapped of, in liquid form it is difficult to extract it from the distilate.

Results:

A thin oil layer was visible after the distillation.

Experiment 2

Objective: Produce orange essential oil using a large amount of orange peels.

Materials:

- Orange peels
- Distillation apparatus (in brass)

- Distilled water
- Cutting board
- Knife
- Freezer
- Essential oil recipient
- Heating plaque

Methods:

The base of the distillation apparatus is filled with water to a level of ±2cm. The orange peels are chopped up and put into the distillation apparatus. The distillation apparatus is placed on a hot plate and heat is applied at the maximum setting for two hours. The distillate is collected and put into the freezer overnight. Once the hydrosol is frozen, the oil fraction can be collected from the surface.

Image 10 : https://shop.premium-coppers.com/wp-content/uploads/2018/08/alquitarra-10-L.jpg

Results:

A thin oil layer was visible after the distillation.

5. PERFUMES

Perfumes are used to give the body and living spaces a pleasant scent. A lot of people have the urge to use perfume in order to feel good, to feel clean. This urge or need to use perfume can be explained with the relation between scent, emotion and memory that we create. Perfumes are usually liquid based product consisting of a mixture of aromatic components such as essential oils, fixatives and solvents.

HISTORY

The use of perfumes is not a new practice but has existed for thousands of years. Perfumes have been used to enhance one's own body scent as well as to emulate nature's smells. The word perfume comes from the Latin "per" which means through and "fumum" which means smoke. In ancient perfume making processes, the oil was burnt to scent the air, hence why the latin words "per" and "fumum" describe this process perfectly.

The first ones to use it were the Egyptians, however they used it for ritual rites purposes. They burned incense, which was called "Kyphi" and was made out of henna, myrrh, cinnamon and juniper. They also used soaked aromatic wood, gum, resins in water and oils as a body lotion. Also, the dead bodies would be perfumed in order to assign specific deities[16] to them. As a result, the word perfume became another meaning, perfume was referred to as "the fragrance of the gods".

The Egyptian perfumery went on to serve as an inspiration and influence for the Greek and Roman empires. At first perfume was something that was primarily practised in the Orient, but after the defeat of the western Roman empire, it started to spread in Europe. In the 13th century perfume samples were brought to England, France and Italy from Palestine by the Crusaders. Perfume went on to be a healing medicine in the 17th century, because Europeans discovered that some fragrances had healing properties. During the plagues, doctors thought that preventive treatments, such as pouches containing cloves, cinnamon and spices would help prevent people from getting the diseases.

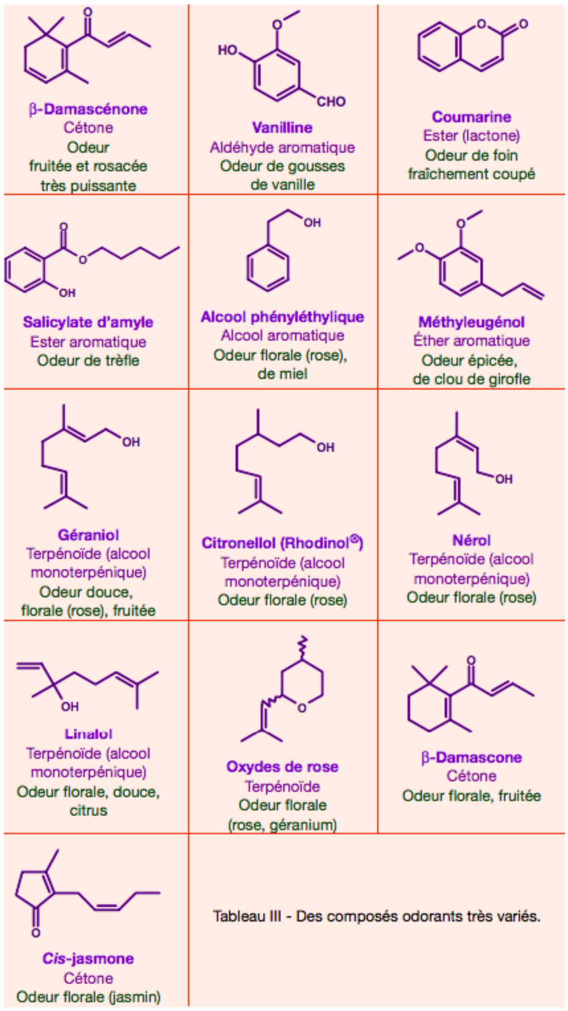
Image 11 : https://cour-de-france.fr/vie-quotidienne/corps-costume-et-parure/etudes-modernes/article/les-parfums-a-versailles-aux-xviie-et-xviiie-siecles?lang=fr 08/04/20

[16] deity refers to a divinity, a god or goddess.

Moreover, the perfumery became highly popular among the monarchy of the French King Louis XIV. He even used perfume so much that his court was called “la cour parfumée[17]” and he was referred to as “le roi le plus doux fleurant[18]”. He was known to be the most perfumed king to ever exist and his court had a floral pavilion containing fragrances as well as dried flowers in bowls to “freshen the air”. He even hired his perfumer to develop a new scent for each day of the week. At this time, Grasse a region in France became the centre of perfumery and a leading producer of perfume because a large variety of flowers grew in that region.

In England, in the late 18th century, synthetic chemicals became popular for the purpose of perfumes that could be mass marketed. The first ever synthetic perfume was “made from nitric acid and benzene, nitrobenzene. It was often used to give a scent to soaps and gave off an almond like smell. Later on, other synthetic chemicals for perfume making were made, for example coumarin from the south American Tonka bean by William Perkin and synthetized violet and vanilla by Ferdinand Tiemann of the university of Berlin. Simultaneously, in the United States, Francis Despard Dodge synthetized citronellol from citronella oil[19], which had a lemon like scent.

Not only did the perfumery progress through the centuries but so did the perfume bottles. In Egypt, glass bottles were crafted to hold perfumes. This custom spread to Europe in the 18th century in Venice, as glass bottles in the shape of animals were used to store perfume.



Various types of fragrance compounds.

Image 12: file:///Users/dansa/Downloads/2008-323-324-oct-nov-p.42-Fernandez.pdf 30/04/20

CHEMISTRY

Terms of chemistry, perfumes are made from two categories of products, the natural materials and the synthetic materials. Perfume is a blend of alcohol and various fragrance materials. The natural materials used are different extracts from flowers, plant leaves, plant roots and plant grains. However, they can also be won from different animals. These different extracts can also be categorized into two groups,

[17] “the perfumed court”.

[18] This can be translated to “the sweetest smelling king of all”.

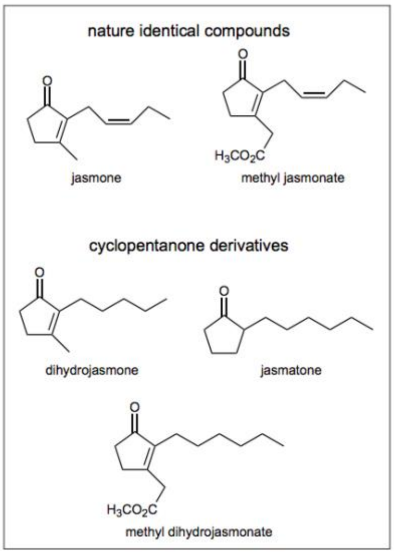
[19] It is an oil that is obtained from the leaves and steams of cymbopogon, more commonly called lemongrass.

those obtained by hydrodistillation and those that are obtained with different types of solvents.

Essential oils used in perfume composition are complex mixes of 10 to 100 volatile components that are easily soluble in ethanol. In addition to these natural fragrance extracts, there are a number of synthetic materials used. These synthetic materials have either been spotted in nature or can be chemically synthetized from another component. This way, there is an opportunity to constantly synthetized and evaluated so that new components can be used in perfume making. Nonetheless there are only a few that can be used for perfume making, since different factors have to be taken into account, like toxicity, carcinogenic compounds as well as skin irritating compounds. Not only are these newly found synthetic materials analyzed so that they do not hurt humans, they also have to pay attention to the effect that they can have on the environment, more precisely ecotoxicity. Another factor to count in for perfume making usage is that these components have to be soluble in ethanol and can remain stable in ethanol, otherwise they cannot be used.

There is an economic aspect that most perfume companies and perfume makers take into account, while natural extracts are often harder to work with, synthetic materials are often a lot more expensive. For example, orange, cedar wood and lavender essential oils retail at a price of 3 to 20 euros for one kilogram which is very advantageous. Other synthetic products, that have been made by the company Firmeniche, β-damascénone ((E)-1-(2,6,6-triméthyl-1,3-cyclohexadién-1-yl)-2-butén-1-one), can be bought for 11oo euros per kilograms.

COMPOSING A PERFUME



Here are different natural compounds that give off the jasmine scent.

Image 13: https://www.researchgate.net/publication/231266608_Chemistry_Perfu

Perfumes are often created by perfumers following their moods the atmosphere, which they want to express through the perfume in the making. This is achieved by using natural materials or synthetic compounds which then create a harmonious fragrance that translates the atmosphere that the perfumer or perfume company wanted to give across. Perfume composing can actually be compared to what music composition looks like, it needs to be a balanced and harmonious mix. A perfume mi is said to be in an accord if the blend is balanced in terms of odor intensity and the pleasing effect that this blend brings. For one perfume there are between 40 and 80 materials used.

In perfume composing there re chords and discords, meaning there are certain cents that go well together and other that are not in harmony. In perfume terminology, the shelf of materials used for perfume making is referred to as the organ and the individual ingredients used are described as notes that contribute to the overall perfume. These different notes are split into head notes, heart notes and base notes. Head notes[20] or op notes are the most volatile and only last a few minutes on the skin, they are immediately perceived once the perfume is applied and form the initial

[20] i.e mint, lavender coriander.

impression of a perfume. Heart notes[21] or middle notes, however, are as the name states the heart of the perfume, they constitute the main part of the perfume a last for a few hours on the skin. Heart notes appear immediately after the head notes disappear.

Base notes or end notes are a very important part of the perfume and detain the less volatile parts of the fragrance composition. Base notes[22] are perceived after the heart notes and bring a certain depth to the perfume.

During perfume making, the head notes give the initial impact, then the heart notes form the essence or the bulk of the perfume and finally the base notes are added. The balance of head-, heart- and base notes is up most important otherwise the balance of the perfume will be offset. The base notes are meant to hold the head notes back, so that the volatile components do not immediately disappear, instead they persist as long as the entire perfume does. The head notes from natural perfumes for example consist of citrus oil, various herbs, like rosemary and lavender and green notes, which are crushed foliage of plants. For the more commercial perfume, synthetic materials that can be used as head notes are aliphatic aldehydes and monoterpene esters[23].

[21] i.e seawater, sandalwood, jasmine.

[22] i.e tobacco, amber, musk.

[23] Found in essential oils of fruits and plants.

6. DISCUSSION

The purpose of this mémoire was to find a sustainable way to create ethanol and essential oils and using those two components to create a fragrance / a perfume. A lot of times fragrances a very expensive and are not very sustainable. The idea was to make a kind of environment-friendly and sustainable perfume. These days, more and more people tend to gravitate towards more sustainable and environment conscious products and are ready to invest into these products. By creating bioethanol from different fruit peels and vegetable peels like potatoes, the goal is to reuse the waste that would otherwise be discarded. Another reusable thing are fruit peels or different plants that can actually be used for essential oil production. The fragrance, which is then created, if these two ingredients are used is 100% recycled. This is in my opinion a really big selling point, eco-friendly and eco-conscious are becoming more and more attractive to the customers.

However, there was one big factor that troubled our effectiveness while working in the laboratory, organization. To work effectively and quickly which is of the essence with the limited time at my disposal, organization is very important. In my opinion, planning experiments ahead of time and planning a few experiments simultaneously is essential for succeeding and getting to do everything that was planned. Another big problem was that the pH was never measured for the samples, which is a disadvantage since it's very important in some cases, for example, for the cellulase enzymes to perform at their maximum rate. In addition to this, the lab book that we were assigned could have been used more frequently and more details could have been written down. This lack of planning and organization, led to us missing a lot of results of different experiments as well as not being able to do what we had planned, which is really unfortunate, since it hinders me from drawing a clear conclusion on my work.

In terms of the interpretation of the experiments made, I can say that a lot of it didn't turn out right. The first experiment that was done was the one where the objective was to determine the ethanol yield from one banana peel. Which was also problematic since the soluble sugar amount in the banana peel was so small that there was barely any ethanol yield. Which brings this to another factor that affected this mémoire, which is that not enough calculations were made to at least predict the amount of ethanol yield we could have gotten. This first experiment made us think about how we would be able to separate the esters that are also present in the mixture. After this first attempt, the goal was to test different peels and see how much ethanol yield can be generated off of them. This led to the second experiment in which apple peels, kiwi peels and orange peels were used. The first brix content measurement showed that the orange peels had the most sugar content after the pre-treatment was done, meaning after the peels were autoclaved. However, there was the same problem as in the first experiment, the amount of peels that we used was not enough in order to generate a proper amount of ethanol after distillation and the ester problem was still ongoing. Then came the idea to make the third experiment, which relied on using malt and alpha amylase and comparing both of them. The malt breaks down the starch present in the potato peels and converts it into monosaccharides. These sugars can then be fermented by the yeast and the mixture can be distilled to obtain ethanol. The alpha amylase works the same, however the enzyme that we used was from a drug called Maxilase which contains alpha amylase as well as sugar, which can offset the results that we were hoping for. So, the next step was to use purified alpha amylase instead. The next experiment that was planned but was never made is the fourth experiment. The objective was to break down the cellulose in the potato peels but also the starch by using purified alpha amylase. Then both cellulase and amylase were meant to be used to hopefully maximize ethanol yield.

While preparing samples, we noticed that it would be smarter if the potato peels were mixed instead of cutting them into small pieces. Meaning it would reduce the surface of the potato peel and actually make it easier for the amylase, cellulase and malt to hydrolyze starch and cellulose into fermentable sugars. The water that was added to the peels was also kept at a minimum in order to keep the sugar and starch concentration as high as possible.

I think, the essential oils production, would have actually worked f there was enough time to complete the experiments.

In general, this mémoire is a great project in my opinion since it focusses on sustainability and of the methods and measurements were optimized, I think that this would actually be possible. In addition to this the cost of making such a perfume would significantly be lower than traditional perfume making, since kitchen waste was used to produce it. I think that this perfume would also have a big selling point which is sustainability, environement-frieniness but also, I think that it is fascinating that something that makes us smell goo is made from kitchen waste which oftentimes doesn't. A lot of customers would actually find this intriguing in my opinion and buy for this sole reason. I would actually enjoy continuing this project in the science enterprise as I think it has a lot of potential.

7. ACKNOWLEDGEMENTS

I would like to give a special thanks to my mémoire director, Nicolas Aschman for guiding me through this entire project. As well as to Louis Feiereisen, which was my lab partner and helped me during experiment planning and experimenting.

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