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Getting fuel from maltose (malt sugar)

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Abstract

This process is preferable than sucrose in production of natural gas because maltose is hydrolyzed into two glucose molecules. While sucrose gives only one glucose molecule. This process depends on bioremediation which is defined as using of organism to degrade hazardous organic contaminants into safe environmental compound.
An anaerobic yeast is being used to convert sugar into alcohol then it is being oxidized to obtain acetic acid then some neutralization and heating reactions in the presence of catalysts the elevate the pressure to get natural gas, the resulted product from these chemical reactions are 6 liters of natural gas from just 1 liter of maltose solution.
Maltose is extracted from malt and then add maltase enzyme to get two molecules of glucose. Then glucose is being fermented in anaerobic conditions using *Saccharomysesceviseae*yeast and zymase enzyme to get ethanol. Oxidize ethanol using potassium dichromate acidified with concentrated sulfuric acid to get vinegar.
In a neutralization reaction, acetic acid is neutralized with sodium hydroxide to get sodium acetate and water. The resulted sodium acetate is reacted with soda lime (a mixture of sodium hydroxide and calcium oxide for the sake of reducing the melting point in the reaction) with heating in Bunsen flame to obtain methane and sodium carbonate.
methane gas is reacted with hot water at a temperature of 725˚C using a gravimetrical oven (the temperature can be controlled up to 900˚C) and the pressure is increased to 200 atmospheric pressure to form a mixture of hydrogen gas and carbon monoxide which are combined rapidly after the reaction to produce hydro-gas or natural gas which is an efficient fuel.

Key words: *Saccharomysesceviseae*, methane, natural gas, renewable energy, maltose, malt sugar.

INTRODUCTION

Although it is not allowed for drivers to drive their cars after drinking whisky, the cars in the future will not run without it. That dream can be come true by discovering new methods to transform by-products from malt drinks into a natural gas. These types of biofuels could be produces on a big industrial scale, by exploiting two main by-products from malt distillation: pot ale and spent grains, Scotland for example consumes and produces 1600 million liters of pot ale and approximately half a million of spent grains which call them draff (dregs or refused) during distillation business.
There are many promising approaches to produce fuel from organic and biological wastes nowadays, the scientists are looking for renewable, environment-friendly and effective types of biofuels. Producing fuel from malt is very economic and effective, it will be very welcomed in the future.

Figure 1.Eco-friendly fuels made from malt extracted from whisky-biofuels industry news

For enhancing the removal of organic matter from cereal-based distillery stillage, there are two stages consisting of fermentation using *Aspergillusawamori foll*owed by microbial fuel cell (MFC) is proposed. By reduction in total and soluble chemical oxygen demand up to 40% and 70% respectively, along with 98% suspended solids reduction which has been achieved during fungal pretreatment. The process generates chitosan, a useful fermentation by product from fungus, as 0.6 to 0.7 g/L of settled sludge with mycelium (3.8% solids).

Before treatment of waste water with fungal strain, the power generation has been enhanced by 2.9 times as an organic loading rate of 1.5 kg chemical oxygen demand per cubic meter daily, demonstrating soluble chemical oxygen demand reduction of 92% in MFC. While treating distillery wastewater, these two stages are integrated with biological process demonstrates 99% chemical oxygen demand removal and almost complete removal of settled sludge delivering ample scope of scale-up and industrial application for effective result of wastewater treatment (1).

Drying operation of malt plays a vital role in the cost of this process although there are not enough studies about malt processing and drying (2). Agricultural by-products are important components in livestock feed, distillery by-products are protein rich and traditionally cost competitive in cattle production. However, recently distilleries have started to use by-products also as a permanent and a renewable source of energy and fuel, in order to reduce carbon footprint of alcohol production. Many former studies adopted systems-based material and energy were performed to calculate the life cycle green-house gas (GHG) emissions for whisky production of 2 scenarios as by-products were used either as beef cattle feed to replace other protein sources (as soya bean and rapeseed) or as anaerobic digester feedstock in order to generate renewable energy as electricity and heat.

System expansion is used to handle quantitatively the by-products in the analysis. The results showed a great reduction in greenhouse gas by replacing feed crops with by-products or by using by-products in anaerobic digester plants to generate biofuel. The greatest reduction in greenhouse emissions was achieved when by-products was used to replace soya bean in animal food. However, the results of this technique are very sensitive according to the method followed, including the accounting method of the greenhouse emissions of soya bean production.

The availability and usability of these by-products or co-products can strongly vary according to the location of production which can give changeable results. In agricultural production in Scotland for example, malt is the most important arable crop species, in terms of area of cultivation, the total mass grain production and the amount of crop protein produced (3). The malt grown in Scotland is used either directly for animal feeding or as a row material of alcohol including whisky production. The whisky distillation process uses only carbohydrates of malt, so therefore the utility of the remaining compounds including protein is very important in exploiting this crop. As a result, the main by-products of malt whisky produced in Scotland is named draff which is defined as unprocessed by-products of the mashing process. Pot ale , liquid by-product of distillation, and distiller dark grains with soluble substances are widely used as protein source and cheap ingredients especially in cattle and beef production. In 2012, it was estimated that a total 60% of distillery by-products on a dried product basis were obtained from whisky industry in Scotland which was potentially available for animal feed (4). Therefore in this region specifically, whisky industry and procession can be considered as a national income source.

In addition to usage of distillery by-products as livestock feed, distillery in Scotland and other regions in the United Kingdom have recently used these materials as a source of renewable energy. This technology is adopted by the government due to its low cost and because this industry helps to reduce the emissions of greenhouse gas. Furthermore, the decreased use of traditional fossil fuels can participate in reducing carbon dioxide and carbon monoxide emission to replace them with clean fuels extracted biologically from malt (5). A recent trend in this area has been adopted to increase by-products utility as a feedstock to produce biogas to generate energy as heat and electricity. This strategy is expected to have multiple benefits in reducing greenhouse emissions. For example, in addition to using renewable energy generated in digestion, the digestate which known as the remaining materials after anaerobic digestion contains nutrients that can be used instead of industrial fertilizers and to reduce greenhouse emissions related to the production of fertilizers (6) (7).

The trending alternative of usage distillery by-products has been raised in Scotland and elsewhere in the United Kingdom (8). As the use of renewable energy increases, the farmers are getting worried about the future availability of crops and their by-products costs for feeding animals. However, it should be noted that also the feed use of these by-products can have beneficial effects on behalf of decreasing greenhouse gasses emissions by decreasing usage of carbon-intensive feed ingredients. For this reason, a systematic comparison of greenhouse emissions associated with alternative usage of by-products which is needed to quantify these effects.

It is a system-based which links between whisky malt and using its by-product as a fuel in a cattle production system to quantify the life cycle of greenhouse gas emissions. The analysis system approaches to make malt of whisky a major product of distillery. The by-product of the process is used to replace the emissions of greenhouse gas with environmental alternatives by quantifying emission of emission production. In order to achieve this, the whisky production system is linked with other systems as beef cattle production system, crop production system and energy production system. The energy flows is analyzed and greenhouse emissions are quantified. The goal of this approach is quantifying and calculating the greenhouse gas emissions for 2 baseline scenarios: the first scenario depends mainly on distillery by-products by using cattle feed to replace soya bean or rapeseed meal as a protein source (guarantee maintaining the nutritional quality of the feed). The second scenario depends also on distillery by-product but in presence of anaerobic digester as *Saccharomysescevisеae* feedstock in order to generate renewable energy as heat and electricity. For both of these scenarios, the functional unit was 1 liter of pure alcohol (ethanol) and the system boundary is cradle from distillation process. However, instead of the whisky chain production itself which remain the same 2 scenarios, the main focus of this experiment is producing biofuels from renewable sources or exploiting by-products of greenhouse gas emissions in other connected systems analyzed through system expansion approach.

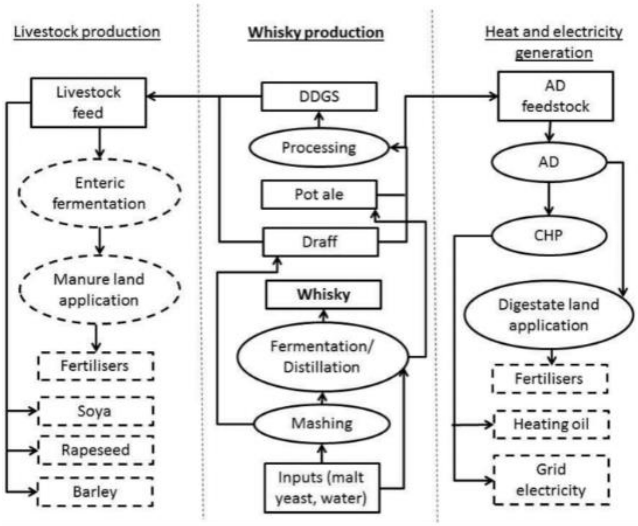

Figure 2.Simple diagram of fuel production systems affecting greenhouse gas emissions. The rectangles demonstrate inputs or outputs and ovals indicate the processes. The points with broken lines are replaced products. AD is an abbreviation for anaerobic distillation, CHP for combined heat and power and DDGS for dried distillers grains with soluble

The greenhouse gas emissions are very related to whisky production which were quantified according to data from an earlier study (9) and the changes of these emissions are affected by the alternative by-products, were included within the calculations. Following this analysis, the processing and the end use of the by-products were analyzed in different scenarios. The changes in the material and both increase and decrease in greenhouse gas emissions were included in the chain of whisky production. For this analysis, the quantities of the primary by-products from one liter of pure alcohol were obtained and were estimated to be 0.56 kg of draff and 0.36 kg of pot ale. In all the systems included within these calculations, changes in carbon dioxide emissions, methane and nitrous oxide were quantified and the overall greenhouse gas emissions were expressed in carbon dioxide terms: with a 100-year timescale, where one kilogram methane and nitrous oxide are equivalent to 25 kg and 298 kg carbon dioxide respectively.

The nutritional contents are based on the feedipedia database. Assuming digestible protein, the nutritional data were used to quantify the animal intake difference of dry matter and nutrients when by-products or alternative ingredients were used in the feed as these information were used to quantify greenhouse gas emissions arising from the livestock production system.

MATERIALS AND METHODS

It is known that maltose is extracted from malt, so to get natural gas from malt follow these steps

1-Maltose is processed with enzyme called invertase or maltase to convert maltose into two molecules of glucose according the equation below

$C_{12}H_{22}O_{11}$+ maltase → 2 $C_6H_{12}O_6$

Maltose+ maltase → 2 glucose

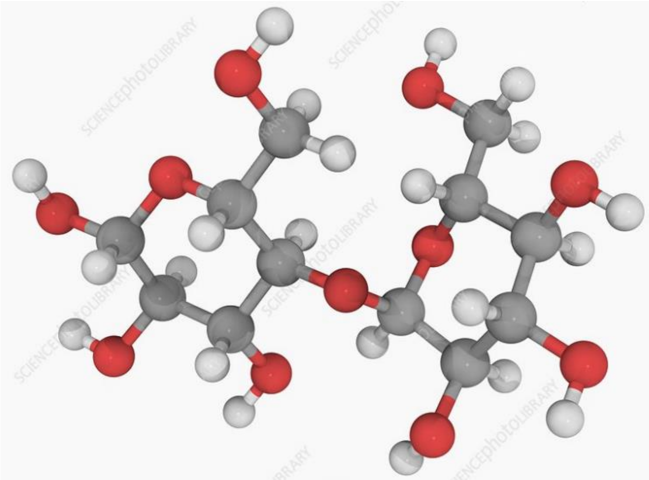

Figure 3.Structure of precursormaltose in space consists of twelve carbon atoms, twenty two hydrogen atoms and eleven oxygen atoms

2-Ferment glucose molecules in anaerobic conditions using anaerobic respiration yeast called *Saccharomyces cerevisiae* in the presence of zymase enzyme as a catalyst to obtain ethanol or ethyl alcohol according to the equation below

$2C_6H_{12}O_6 + 2H_2O \rightarrow 2C_2H_5OH + 2CO_2$

Glucose + zymase / *Saccharomyces cerevisiae*(anaerobic) → ethanol

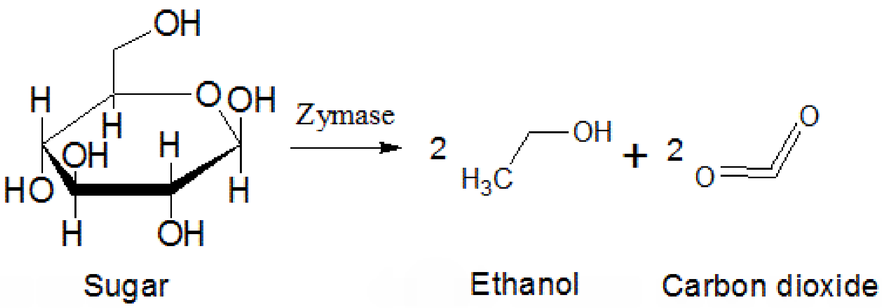

Figure 4.Zymase enzyme is used to convert sugars into ethanol and carbon dioxide

3-Oxidize ethanol using potassium dichromate acidified with concentrated sulfuric acid to get a less stable compound which is acetaldehyde or ethanal which is quickly and spontaneously oxidized to produce acetic acid or vinegar according to the equation below

$2C_2H_5OH + K_2Cr_2O_7 + H_2SO_4 \rightarrow 2CH_3CHO + (O) \rightarrow 2CH_3COOH$

Ethanol+ Potassium Dichromate+ Sulphoric acid (Conc.) → Acetaldehyde→ Acetic acid

4-In a neutralization reaction, neutralize acetic acid with sodium hydroxide to get sodium acetate and water according to the equation below

$2CH_3COOH + 2NaOH \rightarrow 2CH_3COONa + 2H_2O$

Acetic acid+ Sodium hydroxide→ Sodium Acetate + water

5-The resulted sodium acetate is reacted with soda lime (a mixture of sodium hydroxide and calcium oxide for the sake of reducing the melting point in the reaction) with heating in Bunsen flame to obtain methane and sodium carbonate. Precaution in this step; the tip of the tube must be downwards because the resulting methane gas is light and volatile according to the equation below

$2CH_3COONa + 2NaOH + CaO + Heat \rightarrow 2CH_4 + 2Na_2CO_3$

Sodium Acetate+ Soda lime→ Methane+ Sodium Bicarbonate

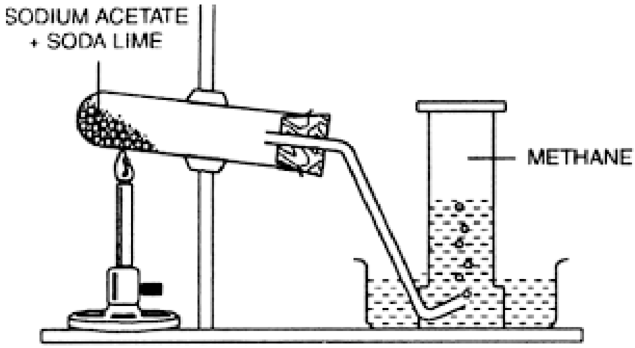

Figure 5.Reaction between soda lime and sodium acetate to form methane, the tip of the tube is downwards (on the right) to prevent evaporation and volatilization of resulted methane and put in cold water sank to decrease the reaction temperature

6-Finally, methane gas is reacted with hot water at a temperature of 725° C using a gravimetrical oven (the temperature can be control up to 900 ° C) and the pressure is increased to 200 atmospheric pressure to form a mixture of hydrogen gas and carbon monoxide which are combined rapidly after the reaction to produce hydro-gas or natural gas which is an efficient fuel according to the illustrated equation below

$2CH_4 + 2H_2O +$ Heat $\rightarrow 6H2.CO$

Methane + water + Catalyst→ Natural gas

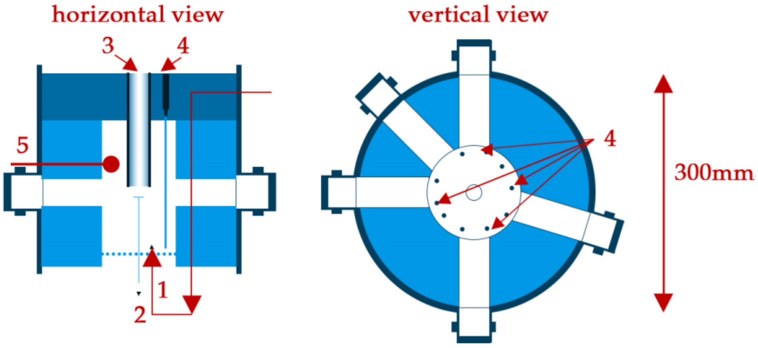

Figure 6.Vertical and horizontal view for gravimetrical oven showing its dimensions and components

RESULTS

The most important benefit from this process is getting fuel more than the amount of given malt, as the equation started with 1 mole of maltose and ends with getting 6 moles of natural gas. In practice, the net result of the process is 6 liters of natural gas for each 1 liter of maltose whisky solution. This can solve the problem of fuel proportionally.

Figure 7.Application of extracting maltose from malt wastes to be used as a biofuel or beer beverage as a recycling project

Biofuel can be more efficient than the fossil fuel. Malt engineering, which is a productive plant, produces natural gas by this method. In this study, it was found that malt is able to yield 7500 liters of biofuel per acre of land.
In simple terms, this means that a Boeing 747 plane can fly for 10 hours using biofuel produced from 18 acres of land. Comparing between many plant sources produce biofuels, malt can produce about 39 to 45 times of biofuel per unit of agricultural land.
However, even after scientific research and commercial efforts, current production volumes of biofuels are very small. Making these products need to be done on a larger scale and need more advance technology and low cost crops.
Malt is proposed to produce biofuel rather than natural gas. For instance, malt contains about 0.15% oil which can be used to produce biodiesel. Some researchers theorize that 3% of oil in the plant can be toxic to the plant itself. But computer models theorize that oil content can be increased to reach 60%.
These plants can be modified genetically to replace fossil fuels. Genetic modification can increase oil production in the plant to reach 36% in the leaves of malt. To be sustainable, biofuel must not be expensive and high yield to avoid use fossil fuel which are impure and pollutants. malt can produce 60% of oil per acre.
Malt provides also commercial benefits related to energy, for instance, the plant parts left after juice extraction, known as beer, can be burned to produce steam and electricity. According to those analyses, this can generate electricity to empower the factories, so the surplus power could be sold back to the grid, displacing electricity produced from fossil fuels (10).
Malt plant should be engineered to be cold tolerant especially in cold countries to be grown widely.
Presently, in current dollars, this fuel will cost airline about 1.71$ per gallon which is less than other biofuels extracted from algae or other crops like palm oil. Malt can be grown in tropical countries in South America, Africa and Europe. Growing of malt can reduce carbon dioxide emission by 16.8%.
Now, malt can be modified to produce biodiesel and bio-jet fuel in addition to natural oil production.

DISCUSSION

Starchy materials like malt contain complex materials as maltose that can be broken down into hexose sugar by water lysis in acid or in the presence of a process called malting. Natural gas production from sugar requires following these steps:
1-Extraction or crushing to enable yeast enzymes to ferment the sugar
2-dilution which is required for certain materials
3-fermentation
4-Distillation
Starchy components require following these steps to get the fuel materials:
1-milling to free the starchy material from grain kernels
2-dilution
3-cooking to dissolve and gelatinize the starch
4-conversion starch into sugar by malting, enzymes or acid hydrolysis by following the steps of fermentation and distillation
There are many variables in the manufacturing of natural gas from beer. Even materials from the same group can require various processes. The final alcohol concentration is about half the sugar content prior to fermentation. To determine the amount of fermentable sugar in a mash, it is best to test the material in the laboratory. If this is not possible, the sugar content can be estimated using a hydrometer. The use of hydrometers and tables for converting specific gravity to approximate sugar content. It should be noted that the hydrometer tests any solution must be filtered to remove any undissolved solids. Otherwise the readings will be inaccurate. Sugar content can be measured optically using sugar refractometer. However, these devices are very expensive.
Since the use of hydrometer to measure sugar content is an approximation at best, the amount of dilution can be fine-tuned by measuring the alcohol content of the beer after fermentation. The hydrometer is also used for measurement but the readings are much more accurate. Naturally, if the alcohol content of the beer is less the toleration level of the yeast you are using, the mash will be over diluted.

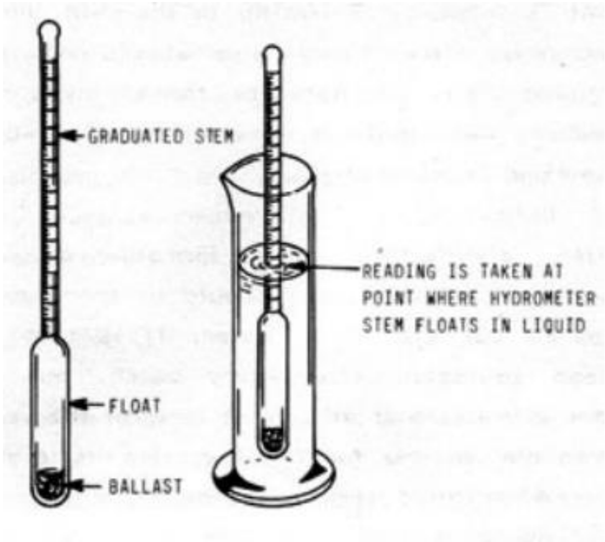

Figure 8.Illustrates hydrometer design as a small tube with calibrated points for measurement the specific gravity of liquids. The most familiar example is the device used to check battery charge or anti-freeze protection

The resulting bacteria from distillery are those that produce lactic acid. Although the production of fuel is not with the taste of the product, any lactic acid forms subtracts of the alcohol. The production of lactic acid and other contaminants should be avoided as much as you can. The development of these microorganisms is repressed with pH values under 5. Above 5 their growth is detrimental to other desirable processes taking place during mashing and fermentation. Consequently, the pH should be checked during conversion. If it is much more than 5, it should be reduced by acid.

The acid most used is sulfuric acid, although any other mineral acid can be perfectly appropriate. Hydrochloric or muriatic acid is available and can be obtained from swimming pools suppliers. The acid should be added cautiously, the mash stirred, and the pH is checked because it is very important not to add too much. If you added too much by accident, the pH can be raised with sodium hydroxide (caustic soda) solution or sodalime. But after a certain point, this is useless and the mash should be scrapped.

While adjustment during mashing is desirable, the proper pH during fermentation is absolutely important. When the pH drops to less than 4.11 the fermentation stops. If this process happened before sugar conversion completely, the yield will be low. On the other hand, yeast needs slightly acidic medium to grow. Consequently, the pH should be kept between 4.8 and 5 to obtain the optimum results.

There are 2 ways for adjusting the pH. The first, as mentioned, is acid addition. The second way which is probably the best, is addition of the naturally acid residue resulted from the previous distillation. These residues are called stillage, and adding them to the mash is called back slopping.

The buffer capacity of the mash is important. When an acid and a base are mixed together, they react violently to produce a salt and water. Buffering can be considered as a barrier of the acid and the base to prevent their direct contact and provide a safe reaction. Grain mashes pH buffer should be adjusted to be between 5 and 6, poorly buffered between 4.4 and 5.07 while well buffered between 3.5 and 4.4. The addition of stillage in buffering between 4.4 and 5. This provides stability and generally provides a high yield much more than without stillage. Different materials can tolerate different quantities of back slopping. It is possible to have too much of a good thing, and too much of back slopping can be detrimental. The cleaning of fermenting tubs, pipes and other components is very important. If mash and fermentation residues are allowed to accumulate, bacterial contamination will be rampant and will greatly reduce natural gas yield through decreasing alcohol production.

Because the density of the liquids changes with temperature, corrections must be made for hydrometer calibration. More often than not, the temperature of the solution you are testing is not the same the hydrometer calibrated. Correction values are very accurate for ethanol liquids but not accurate for sugar solutions.

As stated above, sugar materials need the least processing of all alcoholic solutions. Molasses and other sugar-containing need to be diluted and their pH should be adjusted. Other materials such as grapes and other fruits, need to be crushed or extracted to make the sugar readily accessible to the yeast enzymes.

Before fermentation, maltose materials, such as pure malt, beer and whisky.. Etc. are usually put through an extraction process. This means that the maltose-containing juice is separated from the rest of material. This done by pressing techniques like these used in crushing grapes or making cider. Extraction is not absolutely necessary. The materials can also be simply crushed to expose the juices for fermentation process. However , with most distillation equipment, the solids will have to be removed before going to the still.

Crushing material instead of extraction leaves all sugar needed for fermentation, although the material must be strained before distillation. Again some necessary liquids will remain and the residue solution will be washed with a little water. If you are using a simple put still, filtering it will not be necessary if it was cleaned thoroughly after each run. In this case, the crushing method is preferred.

Certain materials such as corn stalks, sugar cane, malt..etc. require heavy pressure to guarantee material extraction and hence perfect fermentation through enzymes. The alternate process here is shredding material and then heating it with a little amount of water to dissolve it. Note that to obtain complete recovery of the sugar, the process described must be repeated several times. Again the point is reached offsets according to the amount of sugar and some compromising must be made. Note that extraction of one gallon will help to dissolve sugar much better than two gallons of sugar.

Malt materials fall into two categories:

1-material itself like grains, in which the starch is encased by protecting hulls

2-those materials where the starch is more readily available

Milling or grinding the material to expose the starch is necessary for the former group, but not the latter. Otherwise, all starchy materials require certain amounts of materials to convert maltose into glucose before fermentation.

Large amount of malt can make the mash too viscous, thick and hard to handle. This is only objectionable if it is required to be pumped from container to another or even handled. If you are doing everything in the same pot, the viscousness can often be tolerated. Otherwise, premalting will solve this problem.

Almost any kind of grain milling equipment can be used, or the grain can be milled by your local feed plant. Unfortunately, there is no alternative process, and if you are going to use grain as your feedstock, it will have to be milled. Cooking is necessary for all starchy materials, the purpose is to dissolve all the water soluble starches and then, as much as possible, gelatinize them.

CONCLUSIONS

Because there is a lot of energy needed to boil water before cooking process, it is best to cook with a little amount of water as possible. Then, after cooking, additional water may be added to dilute the mash for optimum concentration for fermentation. If the additional water is added at a time when it is desirable to cool the mash, for example after cooking and prior to conversion, cooling time is saved. Most grains can be cooled for 15 to 20 gallons of water per bushel. Note that when cooking with little amount of water, special attention must be given during stirring of the mash. Otherwise lumping and burning may happen.

Cleaning of the mashing and other instruments is done by using steam in commercial operations. However, in a small plant, a good washing using disinfectant is enough. Any disinfecting cleaner can be used, but in the interest of economy, it is preferred to use formaldehyde solution from chemical supply house. For use it should be diluted into 20:1 or more. Be warned that formaldehyde is a horrible and bad smelling chemical which is intensively irritating to the skin, nose and eyes. The fumes also should not be inhaled. An alternative to formaldehyde is ammonia gas specifically ammonium hydroxide solution, but the same cautions should be applied.

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