Conversion of Vegetable Waste in To Ethanol

Deshpande D.P
Faculty of Chemical Engineering Department, DYPIEMR,Akurdi

Adwant A.V
Head,Department of Mechanical Engg,DYPIEMR,Akurdi

Hakke V.S
Faculty of Chemical Engineering Department, DYPIEMR,Akurdi

Abstract - Rapid industrialization and urbanizations has increased the pollution and causes concern to environmentalists. The pollution load on environment is unmanageable and dangerous to human being the vegetable waste dumped in open areas alarming nearby residential areas. Alcoholic Fermentation of sugar syrup from VW was observed to be associated with physical and chemical changes besides yeast growth only during the past century has wider application of this procedure been recognized. Now scientists are directing the life processes of yeasts, bacteria, and moulds to produce chemicals. Alcoholic fermentation is the conversion of sugar into carbon dioxide gas (CO2) and ethyl alcohol. In this experiment, fermentation from vegetable waste (vw) by using yeast (saccharomices servisiae) is carried out for 72 hr at 30-35oC in the fermentor. Thermodynamics feasibility and chemical kinetics of fermentation reaction was studied. The rate of fermentation is found to be 1.515x10-4 mole/lit/hr. The conversion of sugar by stiometrically is found to be 55%.

Keywords: vegetable waste, fermentation, kinetic, thermodynamic

I. INTRODUCTION

In brewing, alcoholic fermentation is the conversion of sugar into carbon dioxide gas (CO_2) and ethyl alcohol. This process is carried out by yeast enzymes. This is fact a complex series of conversion that bring about the conversion of sugar to CO_2 and alcohol. Yeast is a member of the plant family and in brewing we use the sugar fungi form of yeast. These cell gains energy from the break down of the sugar. The by-product, CO_2, bubbles through the liquid and dissipates into the air. The other by-product alcohol, remains in the liquid which is great for us but no for the yeast, as the yeast dies when the alcohol exceeds its tolerance level.

Brewer's yeast tolerate up to about 5% alcohol. Beyond this alcohol level the yeast cannot continue formation. Wine yeast on the other hand tolerate up to about 12% alcohol. The level of alcohol tolerance by yeast varies from 5% to about 21% depending on yeast strain. The formation process for the other limits such as temperature. Grater than 27^0C kills the yeast less and than 15^0C results in yeast activity which is too slow. The amount of sugar in the solution can be too much and can prevent fermentation. Some recipes suggest adding the sugar in parts throughout fermentation rather than all at the beginning. This is especially true if the brew is aimed at producing a high level of alcohol. Some yeast strains have evolved to handle higher sugar levels. Yeast such as Tokay and Sauterne.

Fermentations occur when microorganisms consume susceptible organic substrate as part of their own metabolic processes. Such interactions are fundamental to the decomposition of natural materials, and to the ultimate return of chemical elements to the soil and air without which life could not be sustained. Natural fermentations have played a vital role in human development and are probably the oldest form of food preservation. Although the growth of microorganisms, in many foods is undesirable and considered spoilage, some fermentation are highly desirable. Fruit and fruit juices left to the elements acquired an alcoholic flavour; milk on standing became mildly acidic and eventually became cheese; cabbage turned to sauerkraut. These changes tasted good and so early civilizations encouraged the conditions that permitted them to occur. Sometimes the desired results were obtained repeat repeatedly, but this was not always so. It soon was also discovered that certain alcoholic fruit juices and sour milks would keep well, and so part of the food supply was converted into these forms as a means of preservation. Today, other methods of food preservation are superior to fermentation as means of preserving many foods. In technically

advanced societies the major importance of fermented foods has come to be the variety they add to diets. In many less developed areas of the world, however, fermentation and natural drying are still the major food preservation methods, and, as such, are vital to survival of much of the world's population. The various preservation methods discussed thus far, based on the applications of heat, cold, removal of water, application of radiation, and other principles, all have the common objective of decreasing the numbers of living organisms in foods, or at least holding them in check against further multiplication. In contrast, fermentation, whether for preservation purposes or not, encourages the multiplication of microorganisms and their metabolic activities in foods. But only selected organisms are encouraged, and their metabolic activities and end products are highly desirable. A partial list of fermented foods from various parts of the world is given in Table 12.1. The increasing application of biotechnology and genetic engineering techniques to food production is bringing added importance to food fermentations.

II. MATERIALS AND METHODS

FERMENTOR

Capacity: - 5 litters

Fermentor is vertical cylindrical shell. It is provided with parts of six fittings.

1) Spurger
2) Exhaust
3) Thermo well
4) Inoculation
5) pH sensor
6) water circulation

AUTOCLAVE

Autoclave is used for the sterilization of fermentor and raw material. It help to kill harmful germs, bacteria's. The autoclaving temperature is 118^0 C at 15 lb pressure.

Material preparation

1) Vegetable waste (VW)

Vegetable waste is the waste generated in community and agricultural waste hence VW includes residential waste (E.g. Household) vegetable market waste etc.

2) Yeast:

Selected strains of saccharomyies cerevisiae (Baker yeast) are commonly employed fermentation. It produces a large amount of alcohol. Yeast is a source different enzyme. Yeast are the complex organic compounds with catalyze specific chemical reaction in living organism. Invertase and zymases secreted by yeast.

II] Preparation of medium

The half Kg of VW is diluted with water to make up solution up to 3Kg. add 10ml of HCl and boil for 45 minutes under reflex condition. Due to this hydrolysis of reaction takes place. the solution is then sterilized in autoclave. This kills harmful bacteria (germs). The pH value of medium is adjusted to 5. Adding sodium hydroxide (NaOH). pH below 5 inhabits lactic acid. Bacteria other possible microbial contaminants are inhabit by high sugar and alcohol content reaction and anaerobic condition of fermentation as result of this consideration VW is sterilized.

III] Fermentation

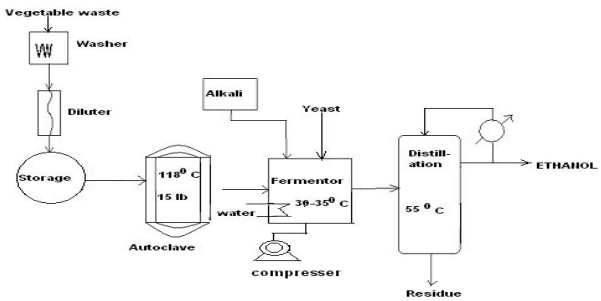
Alcoholic fermentation is an example of anaerobic fermentation. Fermentation has therefore to be carried out in the absence of oxygen. In alcoholic fermentation carbon dioxide is produces. Pushes out air and automatically exert an anaerobic atmosphere. The fermentation reaction is being exothermic; the fermentor gets heated and temperature control is needed. water is use as coolant for this purpose. The fermentation is carried out for 72 hours at 30 to 35^{0}C in a fermentor. After mixing yeast process being started and agitation speed is maintained at 480 rpm.

Chemical reaction

$$C_6H_{12}0_6 \xrightarrow{Zymase} 2C_2H_5OH + 2CO_2$$

IV] Recovery

The fermented mass is distilled to obtain ethyl alcohol. The fractions containing 60% alcohol are known as high wine. These fractions are then distilled to get 95% alcohol (Raw spirit). Because of the ability of the alcohol to from azeotropic mixture containing 5% water even after successive distillation only 95% alcohol is obtain. To prepare absolute ethanol. The 5% water is remove by forming an azeotropic mixture of benzene, water and ethanol which is then distilled with increase in temperature.



Flow sheet for the production of Ethanol

III. RESULTS AND DISCUSSIONS

Important operating parameters

The rate at which the micro-organisms grow is of paramount importance in AD process. The operating parameters of the digester must be controlled so as to enhance the microbial activity and this increase the anaerobic degradation efficiency of the system. Some of this parameters are discussed in the following section.

1) pH level

Anaerobic bacteria, especially mathanogens, are sensitive to the acid concentration within the digester and their grow can be inhabited by acidic conditions. The acid concentration in aqueous system is expressed by the pH value, i.e. the concentration of hydrogen ions. At neutral conditions, water contains a concentration of 107 hydrogen ions and has a pH of 7. Acid solution have pH less than 7 while alkaline are at a pH higher than 7. It has been determined that optimum pH value for AD lies between 5.5 and 8.5. During digestion, the two processes of acidification and methanogenes is require different pH level for optimum process control. The retention time of digestive affects the ph value and in a batch reactor acetogenesis occur at a rapid pace. Acetogenesis can lead to accumulation of large amounts of organic acids resulting in pH below 5. Excessive generation of acid can inhabits methanogens, due to their sensitivity to acid conditions. Reduction pH can be controlled by addition of sodium hydroxide.

2) Temperature

There are mainly two temperature ranges that provide optimum digestion condition for the production of methane and mesophilic ranges. The mesophilic range is between 20^0C to 40^0C and optimum temperature is considered to be 30^0C to 35^0C.

3) Retention (Residence) time

The required retention time for completion of the AD retention varies with differing technologies, process temperature and composition. The retention time for waste treated in fermentor is 3 days (72 hours).

4) Mixing

The purpose of mixing in fermentor is to blend the fresh material with digestive containing microbes. Furthermore, mixing prevents some formation and avoid temperature gradients within the fermentor. However excessive mixing can disrupt the mixing varies with the type racier

And solids contents in the fermentor.

IV. CHEMICAL KINETICS

The reaction taking place during the alcoholic fermentation of VW is,

$$C_6H_{12}0_6 \xrightarrow{Zymase} 2C_2H_5OH + CO_2$$

Consider the first order reaction we have; $\mathbf{t} = \frac{1}{k} \ln [C_{A0}/ C_A]$

Where,

C_{A0}- Initial concentration of A.

3Kg of solution gives 0.03266Kg of ethanol

$$C_A = \frac{0.03266}{3} \times 100$$

C_A = 1.09 %

C_A- Desired concentration of A

Now,

$C_{A0} = 0$

C_A = 1.09%

t = 72 hours

$$72 = \frac{1}{k} \ln \left[\frac{0}{0.0109} \right]$$

k = 1/72

k = 0.0139 hr^{-1}

Now, we have

$$C_M \ln \frac{CAo}{CA} + (CAo - CA) = k \times C_{E0}.\ t$$

$$C_M \ln\left[\frac{0}{0.0109}\right] + [0 - 0.0109] = 0.0139 \times 0.0588 \times 72$$

$C_M - 0.0109 = 0.0588$

$C_M = 0.0697$

The rate of reaction is given as,

$$-r_A = k \frac{C_{Eo} \times C_A}{C_A + C_M}.$$

$$= k \times 0.0139 \frac{0.0588 \times 0.0109}{0.0697 + 0.0109}$$

$-r_A = 1.1053 \times 10^{-4}$ mol/lit hr

As $C_A > C_M$ most of the enzyme is free form.

Where,

$C_M \rightarrow$ Michaelis- Menten constant

k $\rightarrow$ rate constant

V. THERMODYNAMIC FEASIBILITY

Thermodynamics deals with energy changes accompanied with all types of physical and chemical changes. It helps us to lay down criteria for feasibility or spontaneity of process including of chemical reaction under the given set of condition of temperature, pressure and concentration.

The free energy of reaction (ΔG) is parameter to judge the driving force of reaction process.

$$C_6H_{12}0_6 \xrightarrow{Zymase} 2C_2H_5OH + CO_2$$

Heat of formation and combustion of reactant and product are:-

Component	**ΔH_f (KJ/Kmole)**
C_2H_5OH	-277.2 $x10^{-3}$
CO_2	-393.513 $x10^{-3}$
H_2O	-285.840 $x10^{-3}$

Table 3 : Heat Of Formation

H_C of $C_6H_{12}O_6$ = -2816 $x10^{-3}$ KJ/Kmole

Corresponding reactions are:-

$C + O_2 \longrightarrow CO_2$ ------- (1)

$H_2 + ½\ O_2 \longrightarrow H_2O$ ---(2)

$C_6H_{12}O_6 + 6\ O_2 \longrightarrow 6\ CO_2 + 6\ H_2O$ -----(3)

$6C + 6\ H_2 + 3O_2 \longrightarrow C_6H_{12}O_6$ ----- (4)

Heat of formation of Glucose:

$\Delta H_f\ C_6H_{12}O_6 = 6\ \Delta H_{f\,1} + 6\ \Delta H_{f\,2} - \Delta Hc$

$= 6 \times (-393.513 \times 10^{-3}) + 6 \times (-285.840 \times 10^{-3}) - (-2816 \times 10^{-3}$

$\Delta H_f\ C_6H_{12}O_6 = -1260.118 \times 10^{-3}$ KJ/Kmole

$\Delta H_f = -81.308 \times 10^{-3}$ KJ/kmole

Now, We know that

$\Delta G_f = \Delta H_f - T\Delta S$

As the reaction is in the liquid phase, $\Delta S = 0$

$\Delta G_f = \Delta H_f$

$\Delta G_f = -81.308 \times 10^{-3}$ KJ/kmole

Now,

$\Delta G_f = -RT \ln K_P$

$-81.308 \times 10^{-3} = -8.314 \times 300 \times \ln k_p$

$\therefore\ k_p = 1.00003$

As for reaction,

$\Delta G_f < 0$ and $k>1$.

Reaction is feasible.

From the above discussion, it is proved that the batch process is thermodynamically feasible.

II] Material balance for Mixing:-

Basis: - 3Kg

As there is no chemical reaction taking place and taking into account a steady state condition, material balance is-

Input = Output

I/P = 3Kg $\xrightarrow[\text{Mixing}]{\text{O/P = 3Kg}}$

III] Across the reactor:-

Basis reaction:-

$C_6H_{12}0_6 \xrightarrow{Zymase} 2C_2H_5OH + CO_2$

Composition of inlet stream:-

Component	Quantity	Wt%
VW	0.5Kg	16.67%
H_2O	2.5Kg	83.3%
Total	**3Kg**	**100%**

Table 4 : Composition Of Inlet Stream

Sugar content in raw material = 0.00466 Kg/lit

Sugar externally added = 0.05 Kg

Total sugar content = (0.00466 X 3) + 0.05 = 0.06398 Kg

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

180 2 X 46

0.6398 ?

By Stichiometry Ethanol produced = 0.03266 Kg

After processing conversion= 55%

$$\frac{55}{100} \times 0.03266 = 0.017962 \text{ Kg}$$

∴ Actually ethanol produced = 0.017962 Kg

VI. CONCLUSION

Alcoholic Fermentation of sugar syrup from VW was observed to be associated with physical and chemical changes besides yeast growth. The process results in increase pH reducing in total and volatile acidity. Alcohol content and biomass over the fermentation period. This is due to metabolism of carbohydrates by yeast and other chemical reactions. The increase in acidity and the stabilization of pH was partly due to buffering action caused by unionized weak acids during 3 day of the fermentation period. Alcoholic fermentation from vegetable waste (vw) by using yeast (saccharomices servisiae) is carried out for 72 hr at 30-35°C in the fermentor. Thermodynamics feasibility and chemical kinetics of fermentation reaction was studied. We performed the alcoholic fermentation and the rate of fermentation is found to be **1.515X 10^{-4} mole/lit.hr**. By doing the material balance of mixing the conversion of sugar by stichiometry is found to be **55%.**

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