Fermenter Design for (Batch and Continuous Operation) Production of Ethanol from Corn

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Abstract: The liquid portion of the slurry has 8-12% ethanol by weight. The whole process requires 48-72 hours. The batch fermentation systems can be used and out of is more popular. For continuous operation we need 4 numbers of fermenter according to the fermentation time.The Batch and Continuous fermentation systems can be used and out of both batch process is more popular. By using material balance, we get the volume of fermenter for 1 KL ethanol production. With help of volume and design equations we can calculate Length, Height, Thickness, I.D., O.D., Weight of Vessel, Head thickness & cost of Fermenter. The sizes of bioreactor vary from microbial cell to shake flask (100-1000 ml) to laboratory scale vessel (1 – 50 L) to pilot level (0.3 – 10 m^3) to industrial scale (2 -500 m^3) for large volume industrial applications. Lab scale fermenter are typically constructed with the glass and the pilot scale and the industrial scale vessel are normally fabricated with stainless steel.1000 ml of 0.1M sodium acetate buffer solution poured into 1000 ml (Erlenmeyer) conical flask, 20 g of Aspergillums Niger (crude enzyme), 5 g of brewer's yeast, 20 g of treated corn added and 1 g of MgSO4, 2 g of (NH_4) H2PO4 added as nutrient. The flask corked properly, sealed with aluminium foil paper and incubated at 30 ^{O}C for 48-72 hrs. in an incubator. We can increase the fermentation time 4-6 days for analysis of yield of ethanol from biomass. As per literature study optimum time of fermentation is 48-72 hrs. i. e. 2-3 days. As per analysis 1000 ml (1 L) of ferment yield of 98.7 ml of ethanol. That shows the 9.87 % of yield of ethanol from corn with substrate concentration 140-160 gm/L. With help of yield we design fermenter (Reaction Vessel) for both continuous and batch operation. With help of design book and design equation we calculating the L, Di, t, h and Do of fermenter.

Keywords: *Corn, Ethanol, Batch and continuous operation, Fermenter Design.*

Introduction

Ethanol as most important alcohol can be produced by converting the sugar content of any starchy material into alcohol with the evolution of carbon dioxide (CO_2) under controlled environmental conditions. Production of ethanol from lignocellulose materials such as corncob, cornstalk, cornhusk, sugarcane bagasse and sugarcane bark though faces challenges but can substitute bio-ethanol production from edible food substances. In this process yeast and heat are used to break down complex sugars into more simple sugars, producing ethanol. Starchy materials are first hydrolysed to fermentable sugars and subsequently fermented with the required yeast species to produce ethanol. Ethanol is best alternative over non-renewable petroleum products while corn stalk is suitable agricultural waste for ethanol production. Corn stalks are initially pre-treated to make it more and productive for saccharification and fermentation to yield of ethanol.

1. Wet Milling

Wet milling is used to produce many products besides fuel ethanol. Large-scale, capital-intensive, corn processing wet mills produce such varied products as high fructose corn syrup (HFCS), biodegradable plastics, food additives such as citric acid and xanthan gum, corn oil (cooking oil)and livestock feed.

2. Dry-Grind

In dry mill process, the entire grain kernel is ground into flour. The starch in the flour is converted to ethanol during the fermentation process, creating carbon dioxide and distillers' grain. Fermentation is one of the oldest process known to man. Ethanol is mainly produced by dry-grinding process (approximately 67%) and its percentage is increasing rapidly.Dry-grind ethanol process whole grain is processed and the residual components are separated at the end of the process. There are five major steps in the dry-grind method of ethanol production.

Raw Materials and Chemicals

1. Biomass (Corn)

2. Enzymes

3. Yeast (Microorganism)

4. NaOH

5. Water

6. Nutrients for Microorganism

Unit Operation for Material Balance

1. Pre-treatment

2. Scarification and Fermentation

3. Filtration

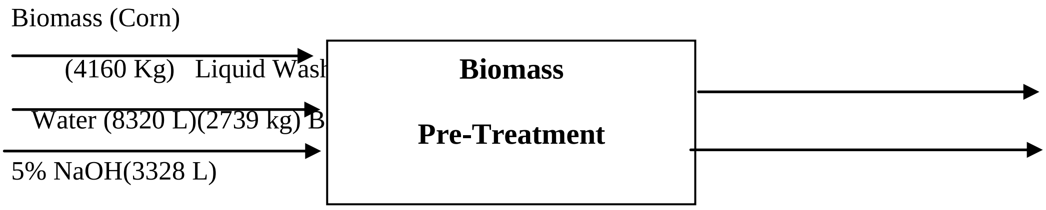
4. Distillation and Recovery

Material Balance

Material Balance for Pre-treatment

Basis – 1000 L/Day Ethanol Production.

For production of ethanol from cornneeds pre-treatment. Here, alkali treatment (5% of NaOH) are used for treatment of lignocellulose biomass for increase fermentation of biomass and increase yield of ethanol. Conditions for pre-treatment of biomass is 50 ^{O}C temperature and 2 hrs. Contact time. Biomass contains 53% cellulose, 19% hemicellulose, 15.5% lignin and 12.5% other materials. After biomass pre-treatment recoverable biomass feed to Simultaneous Saccharification and Fermentation (SSF) unit. According to composition 4160 kg of biomass contains 2204 kg cellulose, 790 kg hemicellulose, 649 kg lignin and 515 kg other components.



Material Balance for SSF

After pre-treatment of biomass is send in fermenter for SSF process where Saccharification and Fermentation. In scarification glucoamylase completes the breakdown of the starch into simple sugar. This process occurs at 30-35 ^{O}C. In the fermentation step yeast grown in seed tanks are added to the corn mash to begin the process of converting the simple sugars to ethanol. For fermentation requires 72 hrs. time and optimum temperature 35-40 ^{O}C.

Biomass Recovery (2739)

Water (5480 L)Fermented Biomass

Enzyme (16.44 Kg) (822 Kg)

(Yeast) Microorganisms

(4.11 Kg) (7417 Kg)

Saccharification and Fermentation (SSF)

Non-fermented Biomass

According to above material balance, we get amount of ferment requires for production of 1000 L/Day ethanol. By using this volume we can calculate fermenter thickness, head thickness, inside and outside diameter, Length of fermenter by using design equations. The liquid portion of the slurry has 8-12% ethanol by weight. The whole process requires 48-72 hours. The Batch and Continuous fermentation systems can be used and out of both batch process is more popular.

Material Balance for Filter

Filtration process carried out for separation of filtrate (Liquid) from the solid- liquid mixture. Total biomass feed to the filter unit where liquid to be separated from the solid. Overall Material Balance for Filter,

Total Biomass (8239 Kg)

Wet Solid (1542 Kg)

Filtration

6697 Kg)

Total Biomass feed (8239 kg) = Filtrate (6697 kg) + Wet Solids (1542 kg

Material Balance for Filtrate,

Filtrate (6697 kg) = 822 kg Fermented Biomass + 5480 kg Water + 395 kg non-fermented biomass

Wet solid 1542 kg = Total Biomass Feed 8239 kg – Filtrate 6697 kg

Material Balance for Distillation Column

After fermentation, the liquid portion of the slurry has 8-12% ethanol by weight. Because ethanol boils at a lower temperature than water does the ethanol can be separated by a process called distillation. Conventional distillation/rectification systems can produce ethanol at 92-95% purity. Maximum recovery of ethanol is 98 % of fermented biomass.

Overall Material Balance for Ethanol,

Feed 6697 kg = Distillate 805 + Bottom Product 5892 kg

Here, fermented biomass in filtrate is 822 kg but maximum recovery of ethanol will be 98%. Hence, the distillate will be 0.98 * 822 = 805 kg

Distillate (805 Kg)

Filtrate (6697 Kg) (Fermented E

Wet So

Distillation

(5892 Kg)

Volume of ethanol produce can be calculate by using density of ethanol (0.8 kg/L). As density is the ratio of mass / volume.

Volume = mass /density

Volume of Ethanol (in L) = 805/0.8 = 1006 L.

Rate of Bottom Product = Feed – Distillate = 6697 – 805 = 5892 kg

Fermenter Design

Introduction

Fermenter is a vessel that maintains optimum environment for the development of significant microorganism used in large scale fermentation process and the commercial production of products like Alcoholic beverages, Enzymes, Antibiotics, Organic acids etc. The fermenter aims to produce biological product like vaccines and hormones.

Laboratory Scale Bioreactor/Fermenter

In fermentation with strict aseptic requirements it is important to select materials that can withstand repeated sterilization cycles. For small scale operation glass and/or stainless steel.Glass is useful because it gives smooth surfaces is non-toxic, corrosion proof and it is usually easy to examine the interior of vessel. The glass should be 100% borosilicate. The laboratory bioreactor can be made from,

1. Glass bioreactor (without the jacket) with an upper stainless steel lid.

2. Glass bioreactor (with the jacket) with an upper stainless steel lid.

3. Glass bioreactor (without the jacket) with the upper and lower stainless steel lids.

4. Two part bioreactor - glass/stainless steel

5. Stainless steel bioreactor with peepholes.

Fermenter Design

Stepwise Procedure for Fermenter Design

1. Calculate the volume of ethanol produce from 1 or 2 L of ferment by lab based experimental analysis.

2. Ferment means the medium and molasses mixture which produce the citric acid.

3. Convert that volume for 1 T/Day citric acid production i.e. by calculation we get volume of ferment requires to produce 1 T/day ethanol.

4. By considering volume we can calculate internal diameter and length of fermenter.

5. Then using design equation we can calculate outer diameter & thickness of vessel.

6. With help of outer diameter and thickness next we can calculate the weight of heads and vessel.

7. Finally we can calculate the cost of vessel requires. (Total cost for vessel = Material cost and Fabrication Cost)

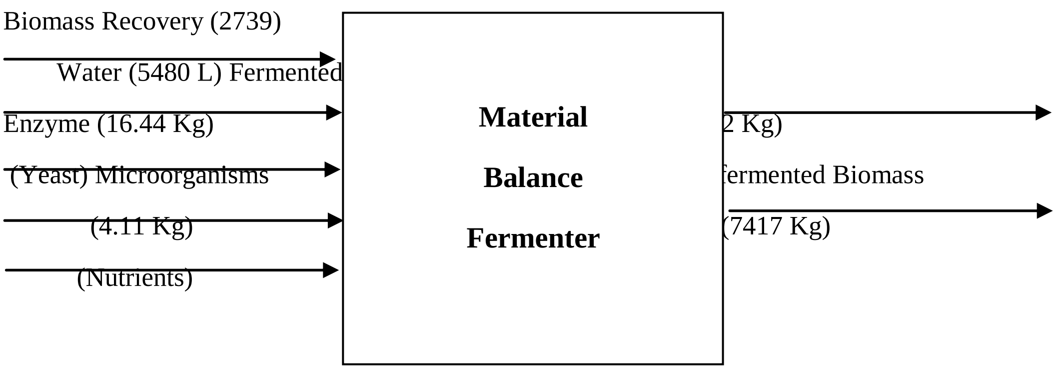
8. Then add cost of agitator, motor, supports, gas Spurger etc.

Feed Conditions

Temperature – 35 - 40 ^{O}C and Pressure – 101.325 KPa (1 atm)

Fermentation Time – 48-72 hrs.

Fermentation Balance



Here, fermented biomass in filtrate is 822 kg but maximum recovery of ethanol will be 98%. Hence, the distillate will be 0.98 * 822 = 805 kg

Here, fermented biomass in filtrate is 99 kg but maximum recovery of ethanol will be 98%.

Hence, the distillate will be 0.98 * 99 = 98 gm. Volume of ethanol produce can be calculate by using density of ethanol (0.875 gm/ml). As density is the ratio of mass / volume. Volume of Ethanol (ml) = 97/0.875 = 110 ml/L of Ferment.

Fermentation Kinetics

In the anaerobic pathway, glucose is converted to ethanol and carbon dioxide via glycolysis. The overall reaction produces two moles of ethanol and carbon dioxide for every mole of glucose consumed, with the reaction energy as two moles of ATP for use in biosynthesis or maintenance.

$$C_6H_{12}O_6 = 2C_2H_5OH + 2CO_2 + \text{heat}$$

As per various literature the conversion of glucose or fructose to ethanol will be up to 75 % and our ferment contains the 19.15 % of fructose that can be converted in to the ethanol. Total ferment feed to fermenter will be 8239 kg/day. Ferment contains distilled water, corn, nutrients, yeast etc.

According to material balance contains the 19.15 % of fructose that will be 1577.75 kg/day of fructose. Mass flow rate of glucose will be 65.75 kg/hr.

Molar Flow rate of Fructose = Mass Flow Rate/ Molecular Weight of Fructose

Molecular Wt. Fructose ($C_6H_{12}O_6$) = 12*6 + 12*1 + 16*6 = 180 kg /Kmol

(F_Ao) Molar Flow Rate for Glucose = 65.75/180 = 0.365 Kmol/hrs.

Density of Fructose = 1694 kg/m^3

Density = Mass/Volume

Hence, Volume = Mass / Density

Volume = 1577.75 kg/1694 kg/m^3= 0.9313 m^3= 931.2 L Fructose in the ferment feed.

Volumetric Flow = Discharge / Time

= 931.2 L/ 24*3600 Sec

Volumetric Flow = 0.01077 L/sec

Moles of Fructose in feed(N_Ao) = Mass of fructose/ Molecular Weight

= 1577.75/180

Total Moles of Fructose feed (N_Ao) = 8.65 kmol

Final Moles (N_A) = (N_Ao) (1-X_A)

Final Moles (N_A) = 2.16 kmol.

Initial Concentration of Fructose (C_Ao) = n/V = 8.65*1000/931.2 L

C_Ao = 9.28mole/lor kmol/m^3

C_A = 9.28 (1-X_A) = 9.28 (1-0.75) = 2.32mole/lit

Where, C_Ao and C_A be the initial and final concentrations for fructose.

For first order kinetics,

$$C_6H_{12}O_6 = 2C_2H_5OH + 2CO_2 + \text{heat}$$

Rate of Reaction – (r_A) = K $C_{A\,=}$ dC_A /dt = (C_Ao- $C_{A)}$ / t

– **$(r_A) = K\ C_{C6H12O6} = dC_A/dt = (C_Ao - C_A)/t$**

K* 2.32 (mole/l) = 9.28-2.32(mole/l)/24 hrs.

Hence, K (Rate Constant) = 0.1242 hr^{-1}

Enthalpy and Gibbs Energy Data

SR.NO	COMPOUNDS	H (KJ/kmol)	G (KJ/kmol)
1	$C_6H_{12}O_6$	-1274.45	-910.52
2	C_2H_5OH	-276.98	-174.138
3	CO_2	-393.51	-394.38
4	$C_{12}H_{22}O_{11}$	-2222.12	-1544.65
5	H_2O	-285.840	-228.61

Reactions involved in the manufacture of ethanol are as,

$C_{12}H_{22}O_{11} + H2 \longrightarrow 2C_6H_{12}O_6$

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

Total Moles of Fructose feed (N_Ao) = 8.65 kmol

Moles of Fructose Reacted = 8.65 * Conversion = 8.65 * 0.75 =6.487 kmol.

Moles of Fructose Reacted = 6.487 kmol.

For First Reaction,

$C_{12}H_{22}O_{11} + H2 \longrightarrow 2C_6H_{12}O_6$

As per stoichiometry requirement,

1 Moles Reacted of $C_{12}H_{22}O_{11}$ = 2kmol of $C_6H_{12}O_6$ Produce

X Moles Reacted of $C_{12}H_{22}O_{11}$ = 6.487 moles of $C_6H_{12}O_6$ Produce

Moles of $C_{12}H_{22}O_{11}$ required= 3.24kmol

Moles of H_2 required= 3.24 kmol

For Reaction 1,

$\Delta H°_R = \Delta H°_{PRODUCTS} - \Delta H°_{REACTANTS}$

= (6.48 X (-1274.45))-((-2222.12 * 3.24) + (-285.84 * 3.24))

$\Delta H°_R$= -135.36 KJ/kmol

Heat of reaction is negative so reaction is exothermic.

$\Delta G° = \Delta G°_{PRODUCTS} - \Delta G°_{REACTANTS}$

= (6.48 X (-910.65))-((-1544.50 * 3.24) + (-228.54 * 3.24))

$\Delta G°$= -156.36 KJ/kmol

For Reaction – 2,

$C_6H_{12}0 \rightarrow 2C_2H_5OH + 2CO_2$

As per Reaction,

1 kmol Reacted of $C_6H_{12}O_6$ = 2 kmol of C_2H_5OH Produce

6.48 kmol Reacted of $C_6H_{12}O_6$ = X kmol of $C_6H_{12}O_6$ Produce

Kmol of $C_6H_{12}O_6$ Produce = 12.96 kmol.

Similarly,

Kmol of CO_2 Produce = 12.96 kmol.

$\Delta H°_R = \Delta H^{\circ}_{PRODUCTS} - \Delta H^{\circ}_{REACTANTS}$

= (12.96 X (-276.98) + 12.96 X (-393.51)) – 6.48 (-1274.45))

$\Delta H°_R$ = -431.11 KJ/kmol

Heat of reaction is negative so reaction is exothermic.

$\Delta G° = \Delta G^{\circ}_{PRODUCTS} - \Delta G^{\circ}_{REACTANTS}$

= (12.96 X (-174.38) +12.96 X (-394.38)) - (-910.52 * 4.48)

ΔG° = -1470.96 KJ/kmol

Fermenter Design for Batch and Continuous Operation

Design of Fermenter for Batch Operation

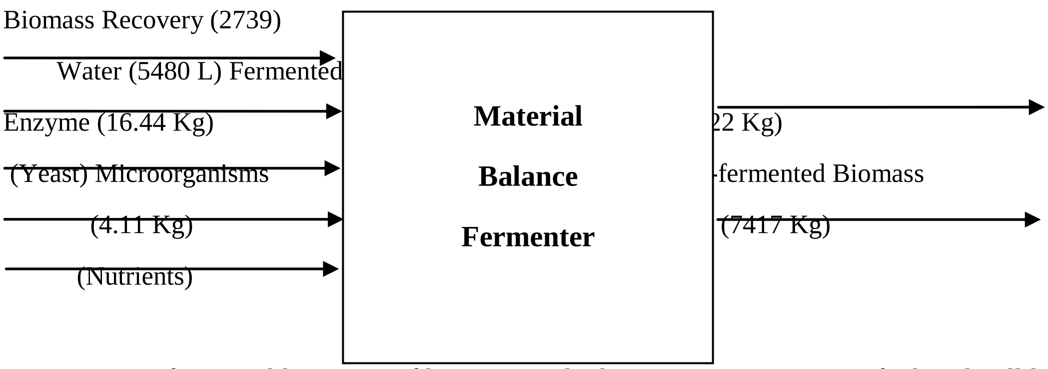
Feed Conditions

Temperature – 35 - 40 ^{O}C (For both Temp.)

Pressure – 101.325 KPa (1 atm)

Fermentation Time – 48 hrs.

Fermentation Balance



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Here, fermented biomass in filtrate is 99 kg but maximum recovery of ethanol will be 98%. Hence, the distillate will be 0.98 * 99 = 98 gm. Volume of ethanol produce can be calculate by using density of ethanol (0.875 gm/ml). As density is the ratio of mass / volume. Volume of Ethanol (ml) = 97/0.875 = 110 ml/L of Ferment.

Volume of Fermenter

As per material balance,

Total Feed (Composition) for Fermenter or Reactor = 8239.65 kg/Day

Total mass of Ethanol produce = 805.87 kg

8239.65 kg Feed ferment = 805.87 kg Ethanol output

Ethanol contains in slurry or ferment = (805.87/8239.65) * 100 = 9.78 %

Design based on 1 Tonnes per day Production.

Density of Ethanol = 785 kg/m^3 at room temperature.

Using, Density = Mass/ Volume

Volume of Ethanol for 1T (1000 kg) production = 1000/785 = 1.27 m^3

= 1.27*1000 = 1270 L

Volume of Ethanol per produce batch = 1.27 m^3 (1270 L)

Volume of ferment can be calculated,

100L Ferment = 9.78 lit Ethanol (Fermentation Medium Produce 9.78 % of Ethanol)

X litre ferment = 1270 litre

X = 12985.86 L

For production of 1 T/Day requires 12985.86 L (12.99 $m^{3)}$ ferment medium of corn.

For batch operation we need to 48 hrs. Time fermentation.

So, Volume will be twice = 1270* 2 = 2570 L of Ethanol.

For production of 2 T requires 12986*2 L = 25976 L of ferment medium.

Volume of Fermenter (Reactor) (20% Extra) =31171 liters (31.18 $m^{3)}$

Diameter and Length of Reactor (Fermenter)

Fermenter/Reactor cylindrical vessel can be design from process & mechanical design, Volume = 31.78 m^3

V = Area * Length = $\pi/4$ * Di* L

L = 1.5 Di

V = $\pi/4$ * Di* 1.5 * Di

31 = $\pi/4$ * Di^2 * 1.5

By solving we get,

Di = 5 m (take 5 m)

L = 5 * 1.5 = 7.5 m

Di = 5 m and L = 7m

Thickness and Outer Diameter of Fermenter

Shell Thickness ($t_{s)}$)

t_s =P Di / (2 f j – P) + C

$= 101325 * 5 / (2* 138 *10^6 * 0.85 – 101325) + 1$ mm

= 0.001727 m + 1 mm

= 0.002160*1000 + 1 mm = 2.160mm + 1 mm = 3.160

t_s = 4 mm (Take)

Outer Diameter (Do)

Do = Di + t_s = 5 + 2 * 4 * 10^{-3} = 5.08 m

Here,

f = Permissible stress for SS-316 = 138 MPa = 138 * 10^6 Pa (20000 psi)

J = Joint Efficiency = 0.85 (85%)

C = Corrosion Allowance

t_s= 4 mm and Do = 5.06 m

Weight of Cylindrical Shell and Tori Spherical Head

Weight of Cylindrical Shell= $\pi/4 * (Do^2- Di^2) * L * \rho$ (Density)

ρ = 7950 kg/ m3 (Density of Stainless Steel-316)

Weight of cylindrical shell = $\pi/4 * (5.06^2 - 5^{2)} * 7.5 * 7950$

= 28266 kg

Weight of Tori Spherical Head = $\pi/4 * (Do^2- Di^2) * \rho$

= $\pi/4 * (4.06^2 - 4^{2)} * 7950$

Weight of tori spherical head = 3769 kg

Weight of Top and Bottom head = 2 * 3019.5 = 7538 kg

Total Weight of Vessel = Weight of Vessel + Weight of Head

= 28266 + 7538 = 35804 kg

Total Weight of Vessel = 35804 kg

Fermenter Costing

As per design total weight of material = 35804 kg.

Material cost = 250 Rs / kg

Total Material cost = 35804*250 = 89, 51,000 Rs.

Fabrication Cost (45-60 Rs / kg) = 60 * 35804 = 2848240 Rs

Agitator with motor and assembly cost = 2 Lac (Apr.)

Spurger cost = 0.5 Lac

Support cost is 15% of total material cost = 0.15 * 89, 51,000 Rs.

= 1342650 Rs

Jacket cost is 15% of Total Material Cost = = 1342650 Rs

Total Fermenter Cost of fermenter = Rs. 1, 40, 34,540

For complete fermentation of corn required time is 48 hrs. i.e. is 2 days so, in case of batch operation we need to install 2 No. of fermenter. 2 fermenter for 4 days operation including one day cleaning and feeding. According to fermentation time we feed material in 1^{st} and 2^{nd} feed 1^{st} and 2^{nd} day will get output as 3^{rd}, and 4^{th} with twice volume as continuous operation.

Total Fermenter Cost of fermenter = 1, 40, 34,540* 2 = 2, 80, 89,080 Rs.

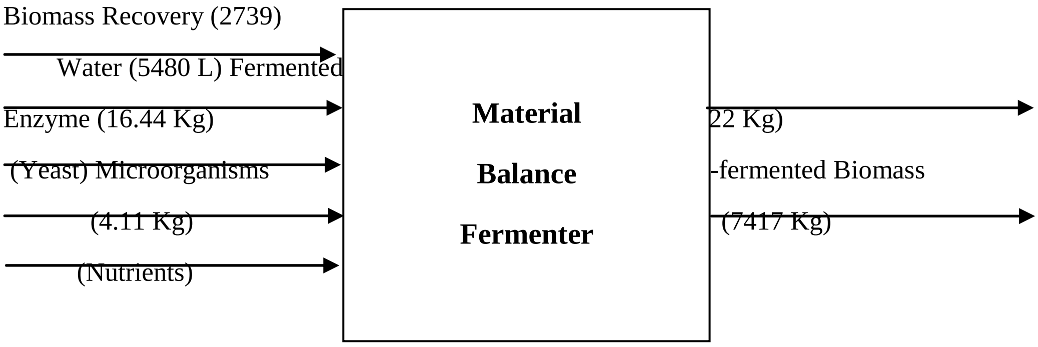
Feed Conditions

Temperature – 35 - 40 ^{O}C

Pressure – 101.325 KPa (1 atm)

Fermentation Time – 48-72 hrs.

Fermentation Balance



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For production of 1 T/Day requires 12985.86 L (12.99 $m^{3)}$ ferment medium of corn.

Volume of Fermenter (Reactor) (20% Extra) =15580 liters (15.58 m^3)

Diameter and Length of Reactor (Fermenter)

Fermenter cylindrical vessel can be design from process & mechanical design, Volume =15.58 m^3

V = Area * Length = $\pi/4$ * Di* L

L = 1.5 Di

V = $\pi/4$ * Di* 1.5 * Di

15.58 = $\pi/4$ * Di^2 * 1.5

By solving we get,

Di = 3.38 m = 4 m

L = 4 * 1.5 = 6 m

Di = 4 m and L = 6 m

Thickness and Outer Diameter of Fermenter

Shell Thickness ($t_{s)}$

t_s =P Di / (2 f j – P) + C

= 101325 * 4 / (2* 138 *10^6 * 0.85 – 101325) + 1 mm

= 0.001727 m + 1 mm

= 0.001727*1000 + 1 mm = 1.727 mm + 1 mm

t_s = 3 mm

Outer Diameter (Do)

Do = Di + t_s = 4 + 2 * 3 * $10^{-3\,=}$4.06 m

Here,

f = Permissible stress for SS-316 = 138 MPa = 138 * 10^6 Pa (20000 psi)

J = Joint Efficiency = 0.85 (85%)

C = Corrosion Allowance

t_s= 3 mm and Do = 4.06 m

Weight o **ead**

Weight of Cylindrical Shell= $\pi/4$ * (Do^2- Di^2) * L * ρ (Density)

ρ = 7950 kg/ m3 (Density of Stainless Steel-316)

Weight of cylindrical shell = $\pi/4$ * (4.06^2 - $4^{2)}$ * 6 * 7950

= 18117 kg

Weight of Tori Spherical Head = $\pi/4$ * (Do^2- Di^2) * ρ

= $\pi/4$ * (4.06^2 - $4^{2)}$ * 7950

Weight of tori spherical head = 3019 kg

Weight of Top and Bottom head = 2 * 3019.5 = 6039 kg

Total Weight of Vessel = Weight of Vessel + Weight of Head

= 18117 + 6039 = 24156 kg

Total Weight of Vessel = 24156 kg

Fermenter Costing

As per design total weight of material = 24156 kg.

Material cost = 250 Rs / kg

Total Material cost = 24156*250 = 60, 39,000 Rs

Fabrication Cost (45-60 Rs / kg) = 60 * 24156 = 1449360 Rs

Agitator with motor and assembly cost = 2 Lac (Appr.)

Spurger cost = 0.5 Lac

Support cost is 15% of total material cost = 0.15 * 6039000 Rs. = 9, 05,850 Rs

Jacket cost is 15% of Total Material Cost = = 9, 05,850 Rs

Total Fermenter Cost with Design Structure = 9550060 Rs

For complete fermentation of corn required time is 48-72 hrs. i.e. is 3 days So, for this operation in case of continuous operation we need to install 4 No. of fermenter. 3 fermenter for 3 days operation and one as standby. According to fermentation time we feed material in 1st, 2nd and 3rd as randomly 1st, 2nd and 3rd day will get output as 4th, 5th and 6th day. After it will continuous in manner. Actually process is batch but operation can operate at continuous in manner.

Hence as per operation requirement,

Hence,

Total cost of fermenter 4 no. of fermenter equal to 4* 9550060 = 3, 82, 00240 Rs

Conclusion

The Batch and Continuous fermentation systems can be used and out of both batch process is more popular. By using material balance, we get the volume of fermenter for 1 KL ethanol production. With help of volume and design equations we can calculate Length, Height, Thickness, I.D., O.D., Weight of Vessel, Head thickness & cost of Fermenter. The sizes of bioreactor vary from microbial cell to shake flask (100-1000 ml) to laboratory scale vessel (1 – 50 L) to pilot level (0.3 – 10 m^3) to industrial scale (2 -500 m^3) for large volume industrial applications. Lab scale fermenter are typically constructed with the glass and the pilot scale and the industrial scale vessel are normally fabricated with stainless steel.

For continuous operation, for complete fermentation of corn required time is 48-72 hrs. I.e. is 3 days so, in case of continuous operation we need to install 4 No. of fermenter. 3 fermenter for 3 days operation and one as standby. According to fermentation time we feed material in 1st, 2nd and 3rd as randomly 1st, 2nd and 3rd day will get output as 4th, 5th and 6th day. After it will continuous in manner. Actually process is batch but operation can operate at continuous in manner. For this system we design fermenter for 13.85 m^3 volume get internal and outer diameter as 4 and 4.06 m resp., Thickness and length 3mm and 6 m resp. We need four fermenter of volume 15.58 cubic meter each and need of total cost for both fermenter will be Rs. 3, 82, 00240.

For batch operationfor complete fermentation of corn required time is 48-72 hrs. i.e. is 2-3 days so, in case of batch operation we need to install 2 No. of fermenter. 2 fermenter for 4 days operation including one day cleaning and feeding. According to fermentation time we feed material in 1st and 2nd feed 1st and 2nd day will get output as 3rd, and 4th with twice volume as continuous operation. For this system we design fermenter for 31.17 m^3 volume get internal and outer diameter as 5 and 5.06 m resp., Thickness and length 4 mm and 7.5 m resp. We need two fermenter of volume 31.17 each cubic meter each and need of total cost for both fermenter will be Rs 2, 80, 89,080.According to the cost view the batch operation is economical and requires low maintenance, labour cost and less time consuming and needs two fermenter. For continuous operation need high cost than the batch need four fermenter. In view of continuous is suitable operation than the batch in which regular feeding of fermenter and regular output. Also one fermenter is in standby operation

References

[1] A. E. Farrell, R. J. Plevin, B. T. Turner and A. D Jones, Ethanol Can Contribute to Energy and Environmental Goals, Science 311(5760): 506 – 508, (2006) and National Corn Growers Association (NCGA) Annual Report (2005).

[2] Adeleye S.A., Braide W., Kanu I.A. and Oranusi U.S., Production Of Bioethanol From Agricultural Waste, Department of Microbiology, Federal University of Technology, P.M.B 1526, Owerri, Imo State, Nigeria, Journal of Fundamental and Applied Sciences, W. Braide et al. J Fundam Appl Sci. 2016, 8(2), 372-386, ISSN 1112-9867.

[3] Anil Kumar, Navpreet Kaur Walia, Kamaljeet Kaur Sekhon , Dharam Paul Chaudhary, Swaranjit Singh Cameotra and Pallavi Srivastava, Optimization of Fermentation Parameters for Bioconversion of Corn to Ethanol Using Response Surface Methodology, Thapar University, Patiala 147001, Punjab, Department of Plant and Environmental Sciences, University of Copenhagen, Frederiksberg, Denmark 3Directorate of Maize Research, IARI campus, Pusa, New Delhi and Institute of Microbial Technology, Sec. 39A, Chandigarh-160036, India, Journal of Petroleum & J Environmental Biotechnology, ISSN: 2157-7463 JPEB, an open access journal, Volume 5, Issue 3 1000178.

[4] Andrew McAloon, Frank Taylor and Winnie Yee, Determining the Cost of Producing Ethanol from Corn Starch and Lignocellulosic Feedstocks, U.S. Department of Agriculture, Eastern Regional Research Centre, Agricultural Research Service and U.S. Department of Energy, National Renewable Energy Laboratory Biotechnology Centre for Fuels and Chemicals, 1617 Cole Boulevard Golden, Colorado 80401-3393, October 2000, NREL/TP-580-28893.

[5] Andy Aden, Biochemical Production of Ethanol from Corn Stover: 2007 State of Technology Model, A national laboratory of the U.S. Department of Energy Office of Energy Efficiency & Renewable Energy, Technical Report NREL/TP-510-43205 May 2008, Prepared under Task No. BB07. 2410.

[6] Anil Panghal, Shubham Jadhav, Poorva Sharma, Akshay Bagal and Akshay Jadhav, Designing of Fermenter and its utilization in food industries, Department of Food Technology and Nutrition, Lovely Professional University, Punjab, Preprints, 24 August 2018.

[7] Agrawal Rohit and Mukesh Kumar, Design of a System for Lab-scale Production of Ethanol from Artificial Syngas, Submitted as part of the course ABEN487: Senior Design Project, Agricultural and Biosystems Engineering North Dakota State University Fargo, ND May, 2010.

[8] Carlos Cardona, Felipe Scott, Julián Quintero, Marjorie Morales and Raúl Conejeros, Process design and sustainability in the production of bioethanol from lignocellulosic materials, Universidad Nacional de Colombia Sede Manizales, Instituto de Biotechnology y Agroindustry, Manizales, Caldas, Colombia and Pontificia Universidad Cattolica de Valparaíso, Facultad de Ingeniería, Escuela de Ingeniería Bioquímica, Valparaíso, Chile, Electronic Journal of Biotechnology ISSN: 0717-3458.

[9] Craig Young and Anthony Aldi, Continuous Production of Ethanol via a Magnetically Stabilized Bioreactor, Department of Chemistry and Biochemistry, W. Grant McGimpsey Christopher R. Lambert 3 May 2011.

[10] Dimas Sultan Syawala, Tatik Wardiyati and Moch. Dawam Maghfoer, Production Of Bioethanol From Corncob and Sugarcane Bagasse With Hydrolysis Process Using Aspergillus Niger and Trichoderma viride, Graduate School of Plant Science and Faculties of Agriculture, Brawijaya University, Jl. Veteran Malang 65145, East Java, Indonesia, IOSR Journal Of Environmental Science, Toxicology And Food Technology (IOSR-JESTFT) e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 5, Issue 4 (Jul. - Aug. 2013), PP 49-56.

[11] Dr. Ashok Sharma, Dr. Sarita Sharma, Dr. Sanjay Verma and Mr. Rahul Bhargava, Production of Biofuel (Ethanol) from Corn and co product evolution A Review, Professor and M. Tech. Student , Department of Chemical Engineering, Ujjain Engineering College Ujjain, International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056, Volume: 03 Issue: 12 | Dec-2016.

[12] Deepak Kumar, Kent D. Rausch, Mike E. Tumbleson and Vijay Singh, Ethanol Production from Corn fibre Separated after Liquefaction in the Dry Grind Process, Agricultural and Biological Engineering and DOE Centre for Advanced Bioenergy and Bioproducts Innovation, University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA, Energies 2018, 11, 2921.

[13] D.P. Chaudhary, S. Mandhania, Pallavi Srivastava, Ashwani Kumar, Ramesh Kumar and R. S. Kumar, Corn to Ethanol: Retrospect's and Prospects Maize: Leading to a new Paradigm, Directorate of Maize Research, Pusa Campus, New Delhi 110 012, IGFRI, Jhansi, U.P., (India).

[14] M. Tutt, T. Kikas and J. Olt, Influence of different pre-treatment methods on bioethanol production from wheat straw, Institute of Technology, Estonian University of Life Sciences, Kreutzwaldi 56, EE51014, Tartu, Estonia, Agronomy Research Biosystem Engineering Special Issue 1, 269-276, 2012.

[15] Mohammad Emal Qazizada, Design of a batch stirred fermenter for ethanol production, Technical University in Zvolen, Faculty of Environmental and Manufacturing Technology, Department of Machinery Control and Automation Technology, Masarykova 24, 960 53 Zvolen, Slovakia, International Conference on Manufacturing Engineering and Materials, ICMEM 2016, 6-10 June 2016, Nový Smokovec, Slovakia, Elsevier, Procedia Engineering 149 (2016) 389 – 403.

[16] Meenakshi A. and Kumaresan R., Ethanol Production from Corn, Potato Peel Waste and its Process Development, School of Chemical and Biotechnology, SASTRA University, Thanjavur,613402, Tamilnadu, India, International Journal of Chemtech Research CODEN (USA): IJCRGG ISSN : 0974-4290 Vol.6, No.5, pp 2843-2853, Aug-Sept 2014.

Books

1. Eminem, Barrater, Bergamottin cacao and ulu Mehmet, Mathematical modelling of packed bed Bioreactor vol-15, No-4,1999,279-292.
2. M.V. Joshi, Process Equipment Design, Vol 4.
3. Dr. Shrikant Dawande, Process Equipment Design, Vol 2.
4. Microbiology Course Material Semester - V by Dr. Priyadarshini Mallick.

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