CO2 EMISSION REDUCTION BY USING CORN AS A RAW MATERIAL IN REFINED ALCOHOL PRODUCTION

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Abstract: In the paper, we analyze the operation of a plant producing refined alcohol with a capacity of 25,000 kg/day, which uses corn as the primary raw material. On the site location, there are a cow farm, a plant for the combined production of heat and electricity using biogas, and a distillery production plant. The raw material for biogas is manure from a cow farm. The energy required for the production process and the operation of the supporting systems (space heating, own consumption of the CHP plant, etc.) is obtained by burning biogas and ethanol so that fossil fuels are used only in cases of plant start-up or incident situations of production process failure.

The analysis presented in this paper aims to set up a carbon dioxide balance for a production plant with accompanying systems and its comparison to the carbon dioxide consumption necessary for corn's growth.

Keywords: distillery, corn, CO_2 emissions, energy

Contents

1. INTRODUCTION

During the period of pandemic of Covid19 there were needs for production growth of technical (refined) alcohol. In order to modernize distillation process and to increase the quantity and quality of ethanol study was made. In the study several different parts of distillery were calculated and designed:

- facility for preparation of raw material;
- facility for distillation;
- facility for dehydration of ethanol.

The continuous operation in distillery is obtained by work of several heat exchangers, three distillation columns (raw material, aldehyde and rectification column), two cookers, two propagators, six fermentors, two adsorbers, several tanks and piping between mentioned apparatus. Plant is designed to produce 25000 l/day of ethanol, which is $96\%_{vol}$ pure ethanol. It is also possible to make high percent ethanol, or as it is called dehydrated ethanol ($99\%_{vol}$).

In distillery several fluid are used:

- cooked mixture of corn and water;
- water;
- steam;
- ethylene glycol.

Steam is produced in the boiler room, in which one boiler is working on pressure of $8bar_A$. In few heat exchangers ethylene glycol from gas engines is used as a cooling fluid. Distillery also has a biogas facility for biogas production, corn field near and cow farm. In figure 1 is presented a simplified scheme of distillery facilities.

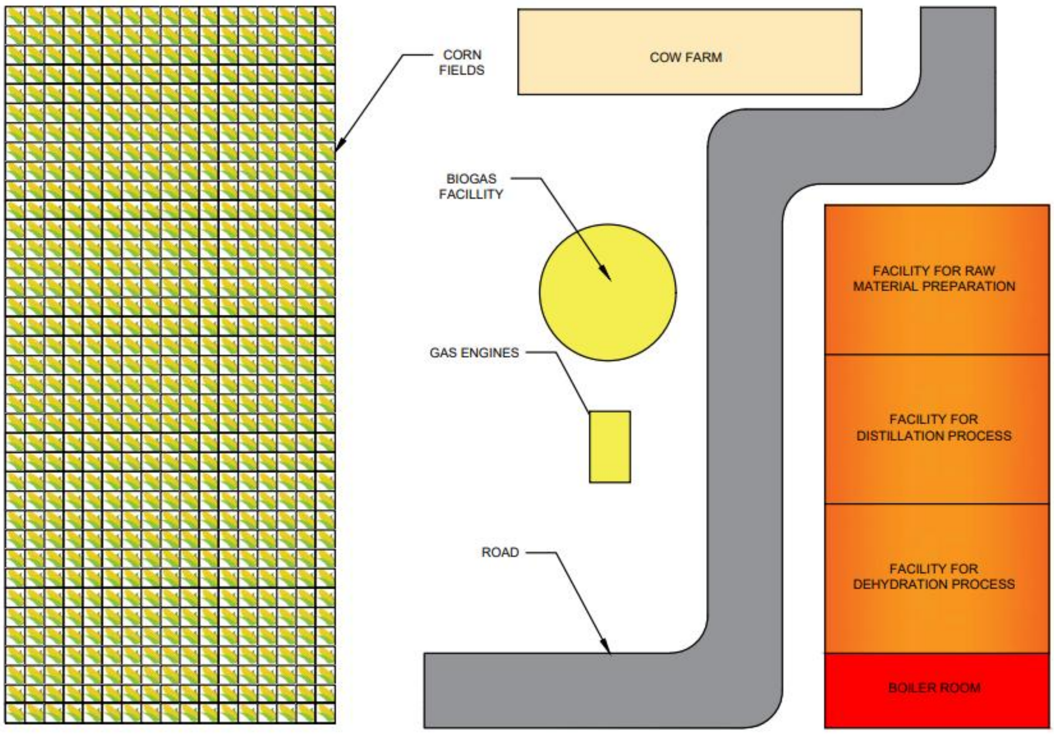

Figure 1 Scheme of distillery facilities

2. DISTILLERY FACILITIES

2.1.Raw material preparation

Before distillation happens raw material must be prepared for process. At the entrance to the raw material preparation facility raw material is milled and mixed with water and transported on to heating in heat exchangers before cooking. Mixture is being cooked in two cookers. In the first cooker alpha-amilase is added in order to break long starch chains. In the second cooker gluco-amylase is added because of easier forming of fermentable sugars.

After cooking mixture needs to cool down to the temperature that is suitable for fermentation process. Mixture is transported to propagators, where source of nitrogen is added in order to develop yeast. When mixture start fermentation process in fermentors yeast starts some complex chemical reactions and the result is forming of ethanol. During the fermentation process substancial amount of carbon dioxide is generated and it is being mixed with water. After mixing with water carbon dioxide is released to the atmosphere. Fermentation last from 50-70 hours and is being stopped when concentration of fermentable sugars in the mixture is from 0,2-0,3%.

2.2.Distillation facility

Fermented mixture is being transported to the distillation facility by pump. Before treatment in raw material column mixture is additionally heated in three heat exchangers. After heating it comes to raw material column, where absolute pressure is 0,25 bar. Vacuum is obtained by reduction valve just before entrance to raw material column.

After treatment in raw material column ethanol leave column in vapor phase. Ethanol vapor is being condensed in heat exchanger, additionally heated in another heat exchanger and transported by pump to aldehyde column. This column has function to remove aldehyde compound from ethanol, because these compounds give ethanol very bad and aggressive smell.

After treatment in aldehyde column ethanol is being transported by pumps after condensation and additional heating to the rectification column. In the rectification column heavy fraction are removed from ethanol and they are being transported to heavy fractions tank. At the top of the column rectificated ethanol is being released as a ethanol vapor. This vapor is being condensed in four heat exchangers and is being transported to tank for rectificated ethanol. This kind of ethanol is ready for use and it is being transported outside of the facility to big storage tanks.

With $96\%_{vol}$ ethanol distillation facility is on its maximum. With apparatus in distillation facility it is not possible to achieve higher purity of ethanol. In order to achieve $99\%_{vol}$ ethanol dehydration facility is being used.

2.3.Dehydration facility

From distillation facility $96\%_{vol}$ ethanol is transported to dehydration facility by pumps. Ethanol is being evaporated and heated in two heat exchangers, which use water steam as a hot fluid. Ethanol vapor is going through one of two adsorbers, which are filled with zeolite, which adsorbes water from ethanol. Other adsorber is in regeneration mode (desorption) – water is being desorbed from zeolite by using part of hot ethanol vapor that comes out of first adsorber.

Vapor of 99%$_{vol}$ ethanol needs to be condensed, which is done by water cooled heat exchanger and it is additionally cooled in another exchanger and sent to storage tank for dehydrated ethanol. Dehydrated ethanol can be exported to the countries of EU because of it quality, so by dehydration economical benefits can be achieved. Ethanol vapor that is used for regeneration process in second adsorber is being also condensed and it is being transported to rectification column, where is treated for the second time.

2.4.Boiler room

Several heat exchangers use water steam as a hot fluid. Steam is generated in boiler room at pressure of 8bar$_A$. Maximum pressure of steam in distillery is 4bar$_A$, so in front of apparatus reduction valves were installed.

2.5.Biogas facility

In biogas facility biogas is being generated, so distillery has its own source of energy, that is generated by combustion of biogas. By combusting biogas about 2,2MW of electrical energy is being generated. From the energy aspect distillery is self-sustainable.

3. ECONOMY ANALISYS ON DISTILLERY

Economy analysis has been done on profitability of distillery. In table 1 investment costs are shown, while fix and variable operational costs are shown in tables 2 and 3. Most important parameters for economy analysis of distillery (plant income, profit, payment period) are shown in table 4.

Table 1 Investment costs of distillery

Variable name	Symbol	Value
Plant investment costs	C_{ISBL}	2.161.441,3
Investment cost of infrastructure	C_{OSBL}	432.288,3
Engineering costs	C_{ENG}	103.749,2
Unforeseen costs	C_{CONT}	389.059,4
Total fix investment costs	C_{FC}	3.086.538,2
Working capital	C_{WC}	129.686,5
Plant run-in costs	C_{SU}	259.373
Total investment costs	C_{INV}	3.475.597,6

Total investment costs are obtained by adding working capital and plant run-in cost to total fix investment costs.

Table 2 Fix operational costs of disilery

Variable name	Symbol	Value
Working manpower	C_L	483.559
Supervision	C_{SL}	72.533,8
Maintenance	C_M	86457,7
Regional costs on plant location	C_{OF}	278.046,4
Regional costs on corporation level	C_{OK}	389.559,1
Quality control costs	C_{QC}	72.533,8
Taxes and fees	C_{PT}	21614,4
Insurance	C_O	21614,4
Ecological taxes	C_{ET}	25937,3
Total fix operational costs	C_{FOT}	1.451.856

Table 3 Variable operational costs of disilery

Variable name	Symbol	Value
Fuel price, €/year	C_L	1.025.280
Raw material price, €/year	C_{SL}	9.187.361,8
Water steam price, €/year	C_M	3.075,8
Cooling water price, €/year	C_{OF}	295,9
Process water price, €/year	C_{OK}	45,13
Chemically treated water price, €/year	C_{QC}	1,84
Taxes and fees	C_{PT}	21614,4
Insurance	C_O	21614,4
Ecological taxes	C_{ET}	25937,3
Total variable operational costs	C_{FOT}	10.341.054,8

For chosen price of refined alcohol in amount of 1 €/l and price for dehydrated alcohol of 1,6 €/l plant income, profit and payment period.

Table 4 Plant income, profit and payment period

Variable name	Symbol	Value
Gross profit	C_{BD}	1.148.158,2
Net profit	C_{ND}	918.526,6
Payment period	VP	3,78
Plant income, €/year	C_{PP}	16.416.666,7

4. ANALYSIS OF DISTILLERY WORKING FLUIDS TO ALCOHOL PRODUCTS AMOUNT RELATIONS

As it is said at the beginning of this paper for working process in distillery several fluid are used (cooling water, steam, ethylene-glycol). Two main product are being planned for production in distillery: refined alcohol ($96\%_{vol}$) and dehydrated alcohol ($99\%_{vol}$). Total amount of fluids, that are used in distillery is show in table 5.

Table 5 Total amount of fluids, that are used in distillery

Fluid	Amount	unit
Cooling water	536716	kg/h
Water steam	5690	kg/h
Water from wells	9805	kg/h
Ethylene-glicol	28590	kg/h
Raw material	14430	kg/h

In table 6 relations between amount of working fluid and amount of alcohol products. Also, relation between amounts of dehydrated and refined alcohol.

Table 6 Relations between amount of working fluid and amount of alcohol products

Fluid or product	Fluid or product
1kg/h of dehydrated alcohol	≈1kg/h of refined alcohol
1kg/h of cooling water	0,026kg/h of refined alcohol
1kg/h of steam	2,47kg/h of refined alcohol
1kg/h of steam in dehydration facility	1,89kg/h of dehydrated alcohol
1kg/h of cooling water	0,025kg/h of dehydrated alcohol
1kg/h of ethylene-glycol	0,49kg/h of refined alcohol

5. CARBON DIOXIDE IN DISTILLERY

Carbon dioxide is a compound that is generated in the fermentation process. System works in that way that carbon dioxide is being mixed with water after it leaves fermentors at the top. It is thrown out of the process by scruber, which is placed in raw material preparation facility.

Today emissions of CO_2 are one of the main problems that causes global warming. Reduction of emissions of greenhouse gases is nowadays mandatory for many states.

Emission of carbon-dioxide is also happening during the life cycle of corn. Quantification of this emissions is covered by coefficient CF (carbon footprint). This coefficient has different values which depends on way it is being planted (corn planting technique):

- CT-conventional tillage;
- RT-reduced tillage;
- NT-no tillage.

Carbon footprint for mentioned ways of corn planting is given in table 6.

Table 6 Carbon footprint as a function of corn planting technique [4]

Type of tillage	Carbon footprint, $CO_{2,eq}/t_{corn}$
CF_{CT}	184
CF_{RT}	189,8
CF_{NT}	178

West and Marland gave data for carbon footprint on USA territory. These data is given in the table 7.

Table 7 West's and Marland's data for carbon footprint on USA territory

Type of tillage	Carbon footprint, $CO_{2,eq}/t_{corn}$
CF_{CT}	228
CF_{RT}	246
CF_{NT}	225

On 1ha of corn field there can be between 5t to 15t. For this case lowest corn production will be taken into account.

From mass and energy balances data is obtained for CO_2, that is generated from fermentation process. The amount of CO_2 from fermentation is 1264. Estimated amount of CO_2 for whole distillery is 1500 and it also includes CO_2 from combustion process in boiler.

6. CLOSE CYCLE OF DISTILLERY

Distillery can use close cycle for functioning and in that way become totally independent from other energy sources. Because in distillery there is a production of electrical energy for plant running, one thing which is mandatory to achieve for complete close cycle is to have self-produced fuel for boilers. To achieve full close cycle there is need for use of ethanol based burner in the boiler. If that is achieved there will be no need for acquisition of gas for burning in boiler. In that case, operational cost will be substantially lower too.

7. CONCLUSION

New, modern distilleries use much better working process than older ones. Quality of alcohol is much better and there is no bad smell of alcohol, which is caused by aldehydes in alcohol. Also, new technology is much more efficient because of the lower energy consumption. Higher amount of product is produced from the same amount of raw material in modern distilleries, than in older distilleries.

Modern distilleries also have significant impact on energetics, especially if plant works in a close cycle, like distillery which is the main part of this paper. Emissions of CO_2 are lower than in older distilleries. Plant income is remarkably bigger than in older distillation process. Payment period is 3,78 years. Because of the much higher quality of alcohol it can be distributed abroad. So, in conclusion modern distillation technology is profitable for implementation.

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