Chapter 70

OSMOF (One Stage Molasses Fermentor): Design of Acetic Acid Fermentor with the Integration of Anaerobic Digester and Electrical Resistance Heating

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Abstract

Acetic acid is an important chemical compound that widely needed in several downstream industries over the world. Acetic acid is usually produced by chemical methods than biological methods (fermentation), because of the higher yield and also lower cost. But, the use of chemical method is not eco-friendly, so that the new technology is needed. OSMOF (One Stage Molasses Fermentor) is an acetic acid producing machine from molasses waste with the integration of anaerobic digester and electrical resistance heating technology. The process consists of sterilization of the machine, then pre-treatment of molasses by dissolving molasses with 2.5 liters of distilled water and adding 30% H_2S0_4 up to pH 3.5. Then it was pasteurized at 60°C for 2 hours and added with 0.1 N NaOH to neutralize the pH of the molasses to 6.5. Furthermore, fermentation was carried out with *Clostridium acetobutylicum* at 37°C, pH 6.5 for 20 hours and 40 hours. Fermented molasses using OSMOF for 20 hours produced optimum acetic acid with a pH of 2.86; concentration of acetic acid is 0.55 M and content of acetic acid is 3.30%. The advantage of OSMOF is produces higher acetic acid (3.30%) than two stage technology (2.5%). The other advantages offered by these new technology include the time to manufacture acetic acid is 10 times faster, lower operating costs, efficient and environmentally friendly (green technology). It can increase the productivity of acetic acid in a country, reduce waste, and environmentally friendly.

Keywords: *anaerobic digester, acetic acid, molasses, electrical resistance heating, one stage*

Introduction

Acetic acid or vinegar is an organic acid chemical compound having the molecular formula CH_3COOH. Acetic acid is a chemical product much-needed a lot of companies in the world, it can be seen by global market which reach 13 million tons, and expected to reach around 16 million tons in the year 2020 (Xu, 2015). Nowadays, acetic acid produced by chemical methods using petrochemical raw materials or by biological methods (fermentation) using acetic acid bacteria (Awad et al., 2012). Currently, chemical production is widely used for production of acetid acid because it is faster and lower operating costs compared to biological methods. Unfortunately, chemical method also has the potential to produce residues that are harmful to health and environment. The production of acetic acid by fermentation is usually done in two stages, takes a long time (9 days) and the resulting product is low (Barrao et al., 2011). Therefore, new technology is needed to increase the production of acetic cid by using fermentation method.

OSMOF (One Stage Molasses Fermentor) is an acetic acid producing machine from molasses waste with the integration of anaerobic digester and electrical resistance heating technology. Molasses (sugarcane drops) is potential to be a raw material to produce acetic acid, because it

contains sugars with levels 50 to 60%, abundant availability, and low prices (Chikhoune et al., 2014). Anaerobic digester has four stages, that are hydrolysis, acidogenesis, acetogenesis and methanogenesis (Adekunle and Jude, 2015). The electrical resistance heating does not require an intermediary for heat transfer, but it directly passes through the material itself. According to Martin *et al*. (2017) , food response to the flow of electric current is to produce internal heat in food, so it is improving process time efficiency.

Method

a. Tools and materials

The tools required in the manufacture and testing of one-stage acetic acid fermenters are iron cutters, welding machine, solder, drill tool, grinding wheel, ruler, slider, and sandpaper. Materials used are glass tubing, stainless steel, 5V 5V power supply, OVR Relay 220 V, 8 pin Socket, Terminal, TBA Isolator, rubber insulator, 2x10 Takuiki Nyz cable, 6th TL switch, Araldite iron glue, Sealant glue, thermocouple type K, thermocontroller OMRON E5CWL, box controller, DC motor DGM-0041, Cartridge heater, JP-420 bolt, nut.

b. Fermentation of Molasses

The molasses fermentation begins with a pre-treatment process that 60 g of molasses is diluted with 1 liter aquades of and adds 30% H_2S0_4 until pH is 3.5. And then pasteurized at 60°C for 2 hours. The molasses were then neutralized to a pH of 6.5 with 0.1 N NaOH. The pre-treatment molasses were fermented by adding 10% v / v inoculum at 37°C for 20 hours.

c. Acetic Acid Level Test

Testing of acetic acid concentration is done by acid acid titration that is by taking sample as much as 10 ml and diluted in 100 ml aquades.10 ml of diluted sample is added by 3 drops of PP indicator. The sample was titrated by 0.1 N NaOH solution and calculated acetic acid levels. The calculation formula of % of acetic acid are:

$$\% \text{ of acetic acid} = ml_{NaOH} \times N_{NaOH} \times Mr_{CH3COOH} / \text{ml of sample} \times 1000 \quad (1)$$

d. Temperature Sensor Accuracy Tests

The temperature control system test aims to compare the Proportional Integral Derivative (PID) Controller and On-Off Controller system on OMRON E5CWL Thermocontrol, with te set point is 60 ^{0}C for 2 hours. Accuracy of this temperature sensor is calculated by the formula:

$$\eta = 1 - \frac{correction\ factor}{tolerance} \times 100\% \quad (2)$$

e. Efficiency Test

The efficiency of the tool shows the percentage of the outgoing energy ratio (E_{out}) and the incoming energy (E_{out}).

$$E_{out} = m \cdot c \cdot \Delta T \quad (3)$$

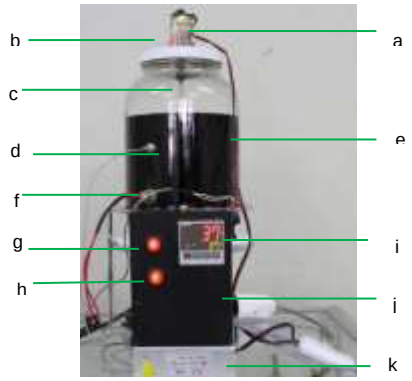
$$E_{in} = V \cdot I \cdot t \quad (4)$$

$$\text{Efficiency} = (E_{out} / E_{in}) \times 100\% \quad (5)$$

Result

a. Assembly One Stage Molasses Fermentor

The assembly of One Stage Molasses Fermentor produces several components that can be seen in Fig.1.



Information:
Keterangan:
a. DC motor
b. *One way valve*
c. Agitator
d. Sensor suhu
e. Fermentor
f. Heater
g. Power button of thermocontroller
h. Power button of agitator
i. Box controller
j. Thermocontroller
k. Power Supply

Fig. 1 *One Stage Molasses Fermentor*

b. Temperature Control System Testing

Based on Fig.2, during 2 hours observation, PID controller drop to set point value and keep stable for 2 hours, while On-Off controller shows unstable temperature as it drops to 59°C. Therefore, OSMOF uses a PID Controller system.

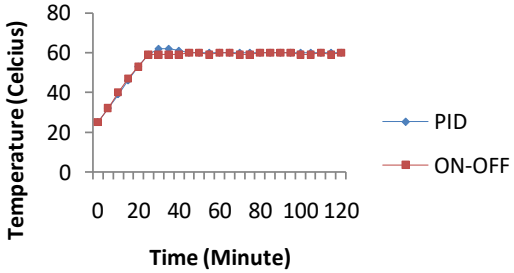


Fig. 2 PID and On-Off Controller test results

c. Temperature Accuracy Testing

Based on the data in Table 1, the correction level of thermocontrol of one acetic acid fermentor is 0.33. so thermocontrol efficiency in acetic acid fermentor is 83,33%.

Table 1. Temperature Accuracy Test Results

Master (℃)	Actual	Appoinment	Correction
30	30,3	30	0,3
40	40,2	40	0,2
50	50,5	50	0,5

d. Efficiency Testing

Temperature used in the fermentation process is 37°C with a time control of 20 hours and a voltage of 220 V. Based on equation (5), obtained the value of appliance efficiency by 88,17%.

e. Testing of pH, Concentration and Acetic Acid Content

The variables tested consisted of pH, concentration and acetic acid concentration. The results of pH, concentration and acetic acid concentration are shown in Table 2.

Table 2. Results of pH, Concentration and Acetic Acid Content

Hours	pH	Acetic Acid Concentration (M)	Acetic Acid Content (%)
10	5.40	0.445	2.67
20	4.27	0.55	3.30
30	3.56	0.545	3.27
40	3.37	0.535	3.21

Based on the data in Table 2, the fermented molasses using OSMOF is optimum in 20 hours, with the pH, concentration, and level are 4.27; 0.55 M; and 3.30%.; while for 30 and 40, the concentration and the content of acetic acid is descread. The acetic acid content produced by OSMOF (3.30%) is higher than 2 stages technology that produce acetic acid content of 2.5% (Cortes et al., 2017).

Conclusion

The optimum result was obtained at 20 hours fermentation time, with pH of 2.86; acetic acid concentration of 0.55 M and acetic acid level of 3.30% Therefore, the results of this study require further research with the use of another anaerobic bacteria, so that the resulting acetic acid content is higher.

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