Comparison of kinetic model for biogas production from corn cob

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Abstract. Energy demand increases every day, while the energy source especially fossil energy depletes increasingly. One of the solutions to overcome the energy depletion is to provide renewable energies such as biogas. Biogas can be generated by corn cob and food waste. In this study, biogas production was carried out by solid-state anaerobic digestion. The steps of biogas production were the preparation of feedstock, the solid-state anaerobic digestion, and the measurement of biogas volume. This study was conducted on TS content of 20%, 22%, and 24%. The aim of this research was to compare kinetic models of biogas production from corn cob and food waste as a co-digestion using the linear, exponential equation, and first-kinetic models. The result showed that the exponential equation had a better correlation than the linear equation on the ascending graph of biogas production. On the contrary, the linear equation had a better correlation than the exponential equation on the descending graph of biogas production. The correlation values on the first-kinetic model had the smallest value compared to the linear and exponential models.

1. Introduction

The rising impact of fossil energy consumption on global climate patterns and the environment has initiated the invention of renewable energy sources. Biomass is a type of renewable energy which has zero carbon emission [1]. Biomass can be converted into biofuel such as biogas by anaerobic digestion. Biogas is a mixture composed of methane (CH_4), carbon dioxide (CO_2), hydrogen (H_2), nitrogen (N_2) and hydrogen sulfide (H_2S) [2]. Anaerobic digestion is a process that breaks down organic matter through the action of microorganisms [3]. The steps of biomass conversion into biogas consist of three stages, i.e. hydrolysis, acid formation, and methane production [4]

Corn cob can be used as a raw material for biogas production. Corn cob is one of the agricultural wastes which is widely available in Indonesia. The total production of corn in Indonesia is 19.61.435 in 2015 [5]. Corn is also considered as an important agricultural crop for over 70 million farm families worldwide [6]. In addition to corn cob, food waste can also be used as biogas feedstock. Currently, food waste only is utilized as animal feedstock or landfilling, as a result, it causes serious health and environmental problems [7]. Food waste has high organic and moisture content [8]. Several factors which affect biogas production include temperature, pH, Carbon/Nitrogen ratio, total solid, volatile solid [9]. This study concentrated on the kinetic rate of biogas production at the variation of total solid (TS) content. Hence, the objective of this research was to compare kinetic models of biogas production from corn cob.

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2. Material and methods

2.1. Feedstock and inoculum

Corn cob was dried and chopped into 2-3 cm then stored at room temperature. Corn cob was used as feedstock. Food wastes were used as co-digestion. Cow's rumen was used as an inoculum.

2.2. Solid-state anaerobic digestion

Corn cob, food waste, and inoculum were mixed and loaded into 2 L digester. Water was added to adjust TS content of 20%, 22%, and 24%. This research was conducted at room temperature and neutral pH. Biogas volume was measured every 2 days by water displacement method.

3. Kinetic model for biogas production

The kinetic of biogas production was modeled by linear and exponential equations. On the linear equation, the rate of biogas production will increase along with the increase of time, then it attains a peak value and decreases linearly to a zero point. The linear equation is stated as follows [10] :

$$y = a + bt \tag{1}$$

where, y = the biogas production rate (ml/g/day); t = the biogas production time (day); a = the intercept (ml/g/day); b = the slope (ml/g/day). On the ascending graph of biogas production, b is positive, while on the descending graph, b is negative.

On the exponential equation, the rate of biogas production increases exponentially with the digestion time. After reaching a peak value, it will decrease exponentially to a zero point. The exponential equation is expressed as follows [11] :

$$y = a + b\,exp(ct) \tag{2}$$

where, y = the biogas production rate (ml/g/day); t = the biogas production time (day); a, b = constants (ml/g/day); c = constant (ml/g/day). c will be positive on the ascending graph of biogas production, while c will be negative on the descending graph.

The kinetic of biogas production can be also modeled using first-order kinetic model as performed previously by Brown et al [12]. The first-kinetic model is stated as follows

$$ln\left(\frac{y_m}{y_m - y_t}\right) = kt \tag{3}$$

where, y_m = biogas yield obtained in 40 days (ml/g/day); y_t = biogas yield obtained at the time *t* (ml/g/day); *k* = biogas rate constant (1/day); t = biogas production time (t)

4. Results and discussion

The kinetic of biogas production was performed by linear and exponential equation models. The kinetic study was divided into two rate periods, namely the ascending rate period and the descending rate period. The linear graph of biogas production is shown in Figure 1.

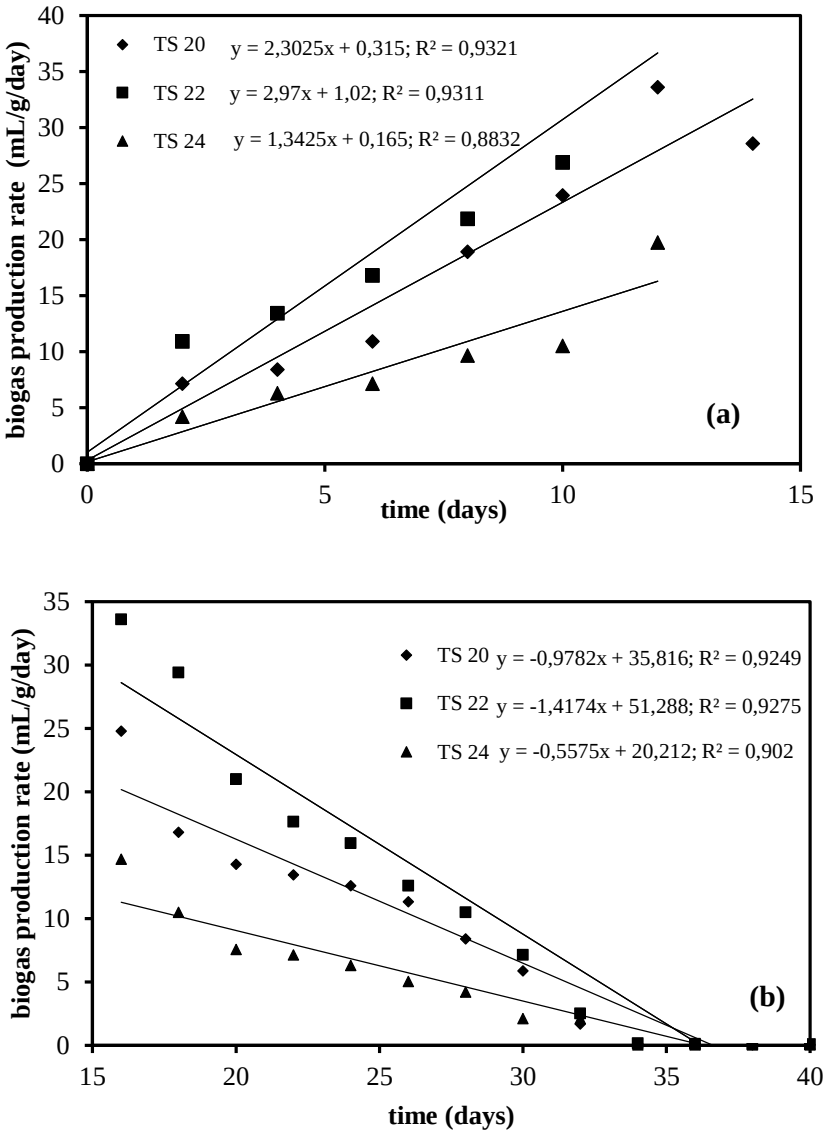


Figure 1. The linear graph of biogas production rate (a) the ascending period of biogas production rate (b) the descending period of biogas production rate.

Figure 1a and 1b shows the linear graph of biogas production rate at the TS contents of 20%, 22%, and 24%. As shown in Fig. 1(a), the regression coefficient (R^2) ranged from 0.88 to 0.93, while in Fig. 1(b) the R^2 ranged from 0.90 to 0.92.

The descending biogas production graph of the linear equation had the $R^2 > 0.9$ at the TS contents of 20%, 22%, and 24%. On the contrary, the ascending biogas production graph obtained the $R^2 > 0.9$ only at TS contents of 20% and 22%.

The exponential graph is presented in Figure 2.

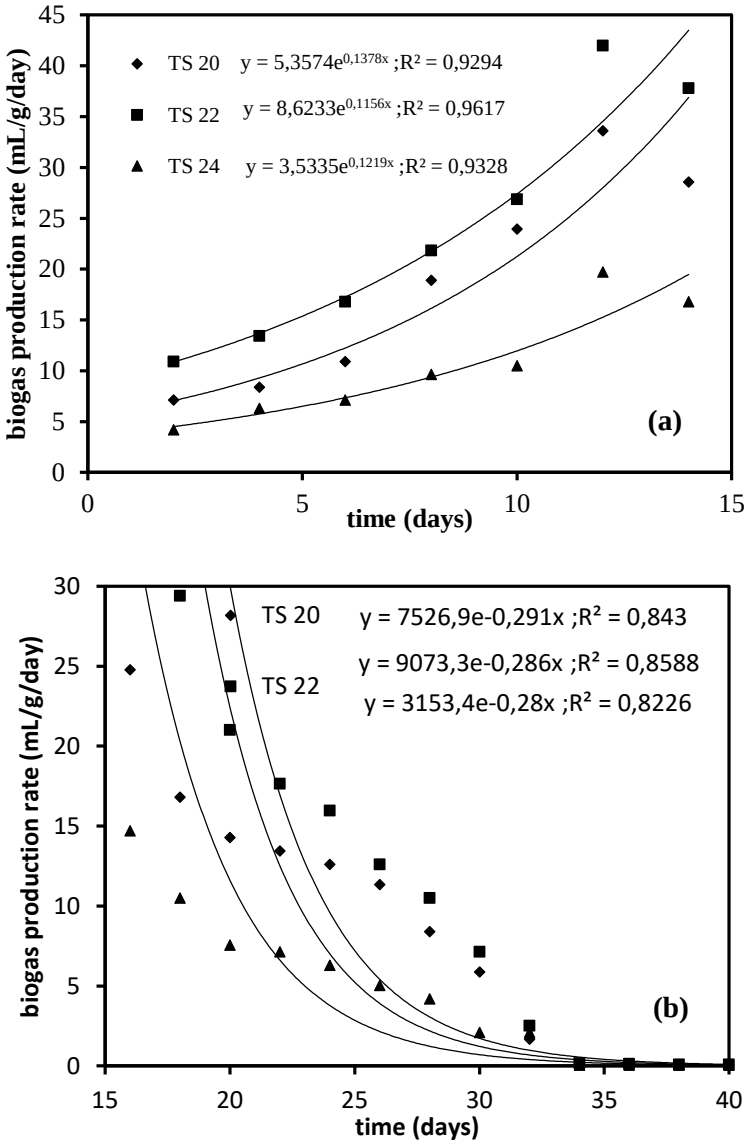


Figure 2. The exponential graph of biogas production rate (a) the ascending period of biogas production rate (b) the descending period of biogas production rate.

As presented in Figure 2, the R^2 ranged from 0.82 to 0.96. The R^2 on the ascending graph using exponential equation was greater than the R^2 on the ascending graph using linear equation. Therefore, the exponential equation had a better simulation than the linear equation on the ascending graph. The similar result was also reported by Lo et al. [11] who stated that the exponential equation model had a larger R^2 compared to the linear equation model.

On the ascending graph of the exponential equation, the $R^2 > 0.9$ was obtained at TS contents of 20%, 22%, and 24%, but on the descending graph of the exponential equation had the $R^2 < 0.9$. As seen in Figure 2b, the R^2 on descending graph was smaller than descending graph using linear equation. Therefore, the linear equation had a better simulation than the exponential equation on the

descending graph of biogas production. The rate constants of biogas production by the first-kinetic model is shown in Table 1.

Table 1. The rate constants and regression coefficient of biogas production from corn cob by a first kinetic model

TS contents (%)	k (1/day)	R^2
20	0.2219	0.8351
22	0.2160	0.8477
24	0.2114	0.8461

The value of k represents the rate constant of biogas. As shown in Table 1, the greatest value of k was obtained at TS content of 20%. However, the value of R^2 had a smaller value compared to the value of R^2 using linear and exponential models. Therefore, the kinetic of biogas production from corn cob was more suitable modeled by linear or exponential models compared to the first-kinetic model

5. Conclusions

The exponential equation has a better correlation value than the linear equation during the ascending period of biogas production. While linear equation has better correlation than exponential equation on the descending period of biogas production. The R^2 obtained by first-order kinetic model has the smallest value than both linear and exponential models.

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