# Development of a small-scale reactor system for bioethanol production from agriculture waste geared towards small industries applications in Malaysia

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**Abstract.** Bioethanol derived from agriculture can be an alternative fuel source to petroleum-based fuel as the fuel hike and supply depreciation. In Malaysia, agriculture waste materials especially from chip industries (such as banana/yam/tapioca) are potential to be one of the feedstock for producing bioethanol. The utilization of the waste feedstock for biofuel production does not disturb the food chain as it is a *waste-to-energy* concept based. This paper presents the development of an affordable reactor system that is feasible to be applying in Small and Medium Enterprise (SME) in Malaysia. The reactor system concentrated on the fermentation of the feedstock. Based on the experimental results, it is estimated that the yielding percentage of bioethanol is around 14 % for batch production. Moreover, it is estimated that this reactor is able to produce bioethanol around 0.85 L for each batch of production which implied a petrol fuel cost saving for SMEs around 10 % if bioethanol is blended with the fossil fuel.

## Key words

Bioethanol, Agriculture waste, Waste-to-energy, Bioreactor system

## 1. Introduction

At present, the importance of alternative energy source has become even more crucial matter not only due to the continuous depletion of limited fossil fuel stock but also for the safe, better and greener environment [1]. According to Lang *et al.* [2], bioethanol is an oxygenated fuel that contains 35% oxygen, which reduces particulate and NOx emissions from combustion. In addition, the toxicity of the exhaust emission from bioethanol is much lower compared to the petroleum sources [3]. Bioethanol derived from biomass is the only liquid transportation fuel that does not contribute to the green house gas effect. As a result, the production of bioethanol or ethyl alcohol could be one of the alternatives to replace fossil fuel in the future.

This paper mainly discussed the production of the bioethanol from starch feedstock namely yam, tapioca and banana, under laboratory conditions, via utilizing the yeast and microorganism. Besides, a few design parameters which are crucial for implementing bioreactor in small cottage industries were mentioned. Economical feasibility of the bioethanol is also studied by estimating the quantity of sugar generated and the bioethanol yield. In addition, some recommendations for future development are drawn.

## 2. Generation of the Biofuel

Throughout the years, numerous researches had been done on the biofuel technology [1-3]. As the technology evolved, the biofuel generally can be classified into two major categories by the feedstock nature itself. The first generation biofuel (conventional biofuel) is mainly referred to the fuel that had been derived from sources like starch, sugar, animal fats and vegetable oil. However, the first generation biofuel cannot produce enough biofuel without threatening food supplies and biodiverstiy [4]. As a results, second generation biofuel is developed to extend the amount of biofuel that can be produced sustainably by using biomass consisting of the residual non-food parts of current crops, such as waste agriculture stems, leaves, husks and skins that are left behind once the food crop has been extracted or process [5]. This subsequent generation of biofuel can expect to supply large quantity of biofuel which provide sustainably, affordably and with greater environmental benefits, especially for cottage industries applications.

## 3. Experimental Setup

Fig. 1 shows the experimental setup of a portable small-scale reactor system for bioethanol production from agriculture waste. The overall system was constructed by using used metals and waste materials in order to reduce cost.

As in Fig. 1, the ferment tank is used to sustain the cultivation tank's volume and feedstock tank's volume. The slurry flow in the reactor system is pumpless, viz. based on gravitational force. Besides, the temperature is control by using an aquarium heater (12 V) as the brewing of yeast required constant 30 °C throughout the experiment. The ferment tank has a stirrer operated by using a low energy electric motor to mix the slurry throughout the experiment.

## 4. Bioethanol Yield Process

In this research work, the agriculture waste materials (Fig. 2) were collected from a local small cottage chips industry, Sofia Enterprise, Sarawak. This company generally manufactured banana, yam and tapioca snacks, which continuously contribute a significant amount of waste in the market.

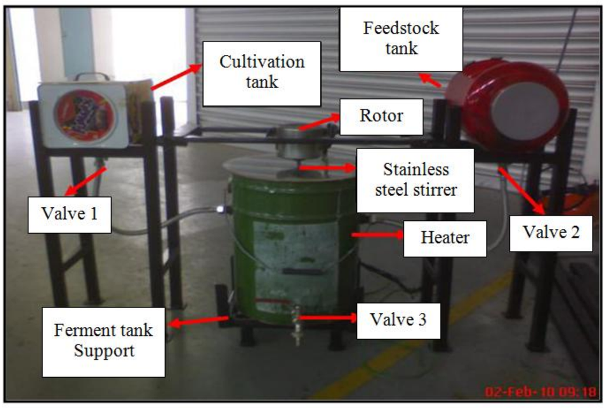


Fig. 1. Construction of a small-scale bioreactor system.


Fig. 2. Raw materials used (a) waste tapioca; (b) waste yam; (c) waste banana.

From these waste materials bioethanol is yield by using bakery yeast (S. cerevisiae) which is easily available in the market. Fig. 3 below illustrated the conversion method to yield bioethanol:

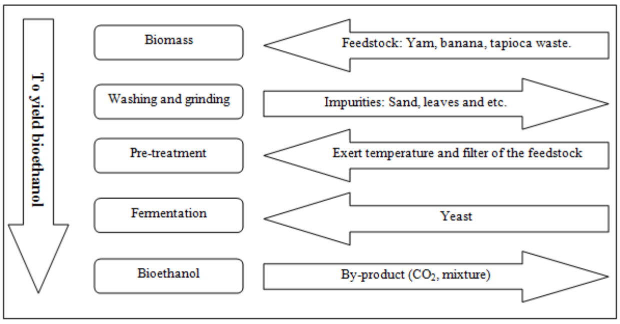


Fig. 3. Steps to yield bioethanol.

Washing and grinding step is aimed to clean and physical resizing of the waste materials from bulky structure to much simple structure (Fig. 4) so that the corresponding procedures are much easier to take place.

In the pre-treatment stage, these agriculture waste materials are dried under the hot sun for 7 days (Fig. 5) and then followed by liquefaction to prolong the storage period. After that, 4 L of water with 400 gram of wastes

Fig. 4. Wastes after undergo resizing and grinding.

Fig. 5. Feedstock after put in direct sunlight for 7 days.

banana, 100 gram of waste yam and 50 gram of waste tapioca were boiled. In addition, 100 gram of commercial sugar was added to the slurry during the boiling period. The slurry is then cooled down to temperature around 30 $^{o}$C. The slurry is filtered and the grinded feedstock is taken out. This feedstock can be used as food in the poultry industry, thus zero-agriculture waste in the industry.

In the reactor system, the feedstock is stored in the feedstock tank whereas the yeast solution is store in the cultivation tank. The yeast solution contains 200 gram of yeast, which was mixed with 2 L of boiled water and then cooled down to room temperature. Valve 1 and Valve 2 were opened to allow both feedstock and yeast solution flow into the fermentation tank. The fermentation temperature was controlled around 30 °C by switching on the heater and rotor. During that period, the slurry was collected through Valve 3 from Day 1 to Day 3 to monitor the changes in slurry.

## 5. Results and Discussions

### *A. Bioethanol yield testing*

The slurry collected is shown in the Fig. 6 from Day 1 to Day 3, respectively. Based on this figure, it is observed that the slurry produced bubbles throughout the experiment. The bubbles show that carbon dioxide was released during the fermentation period.

A clear layer of brewing yeast (bottom), slurry, and clear solution (top) was form in the collected sample. The clear

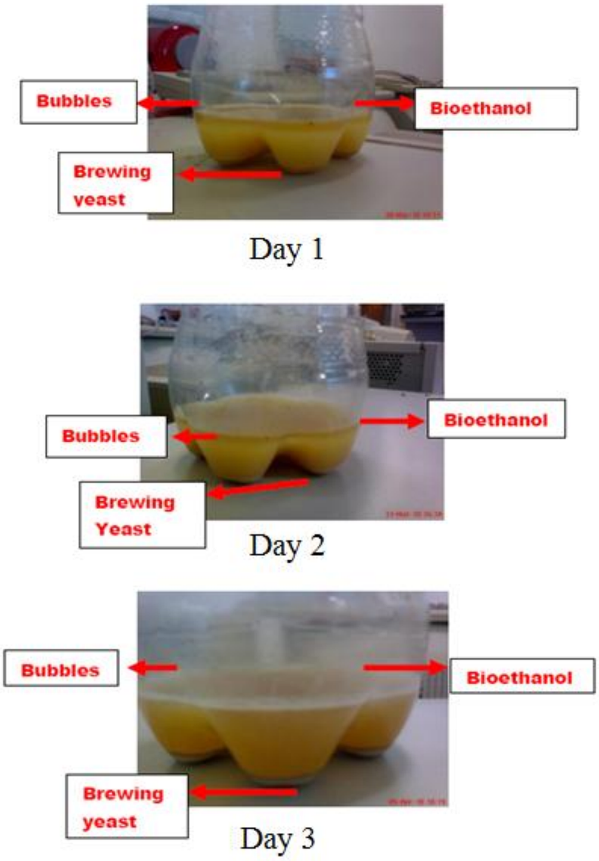


Fig. 6. Slurry collected from the reactor system.

solution is the bioethanol as the density of bioethanol (~0.789 g/cm$^3$) is much lower than the water (1.0 g/cm$^3$). From the perspective of smell, the collected slurry produced an aroma cum with sour smell. However, the bioethanol collected need to undergo another distillation process before it can practical to use as a renewable energy sources. From the experimental observation, the production of carbon dioxide was reduced significantly after 3 days of fermentation process. This showed that the fermentation process reached saturation point after 3 days of fermentation.

*B. Estimation of sugar generated and bioethanol yield*

The assumptions made to estimate the quantity of sugar produced and bioethanol yield are as follows:

1) The efficiency of brewing yeast only 50 % from the total sugar available.
2) No sugar loss during the experiment.
3) All the sugar contents in the feedstock are 100 % converted into sugar during hydrolysis.

It was estimated that ~184 gram of sugar (Table 1) is available in the specimen if the hydrolysis method is 100 % succeeds. As the assumption of the brewing yeast only capable to ferment 50 % of the total sugar to bioethanol, thus ~92 grams of bioethanol is generated. As a result, the yielding percentage of bioethanol from the specimen is ~14 %. It was estimated that ~0.85 L of bioethanol generated from the ferment tank, which is capable storing 6 L of sugar solution. However, the exact percentage and volume of bioethanol yielding could be slightly varied or

Table 1. Estimation of sugar quantity in specimen.

| Specimen | Sugar Content (per 100 grams) | Amount of Specimen (gram) | Sugar Available in the Specimen (gram) |
|---|---|---|---|
| Banana | 20.4 | 400 | 81.8 |
| Yam | 0.49 | 100 | 0.49 |
| Tapioca | 3.355 | 50 | 1.67 |
| Commercial Sugar | 100 | 100 | 100 |
| Total | - | 650 | 183.96 |

lower than the estimation amount due to low efficiency of hydrolysis method.

From the above estimation, a graph of sugar generated with bioethanol formation was plotted as shown in Fig. 7. Initially the amount of sugar available for fermentation is ~184 grams and the amount of sugar decreases with time as the bioethanol is forming.

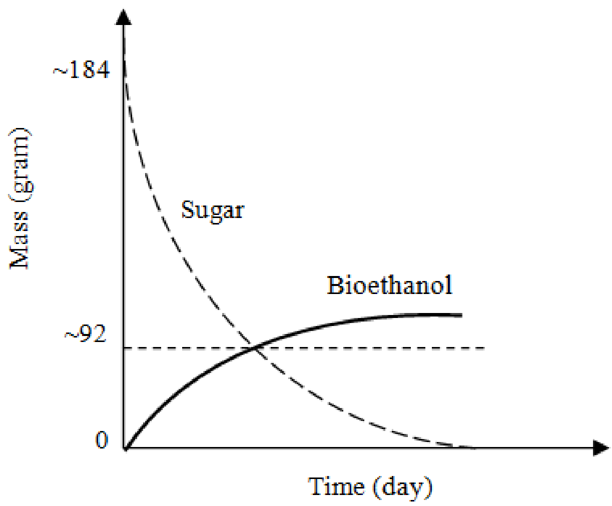


Fig. 7. Graph of sugar generated with bioethanol formation.

*C. Economy feasibility study*

Based on current petrol price in Malaysia, RON 95 will be priced at around RM 1.85 (USD 0.55) per litre. Assume that a SME is using 30 L of petrol in the production line for small-scale production per day, it is estimated that petrol blended with 10 % of bioethanol can save around 10 % of the total cost per day. The amount saves around RM 6.00 (USD 1.80) per day. This amount is considered significant for a small-scale production for SME in Malaysia.

## 6. Conclusions and Recommendations

An affordable cottage-based reactor system has been successfully designed and fabricated to generate bioethanol from agriculture waste which is feasible to be practiced by village- or community-based industries in Malaysia. From the point of bioethanol yield, it is estimated that bioethanol yield is ~ 14 %. It is estimated that this reactor system capable to generate 0.85 L of bioethanol per batch of production and this system is able to save ~10 % of the total usage on the fuel per day. In addition, the filtered feedstock can be used as food for poultry industry.

Some recommendations for future research are drawn as follow:

1) It is suggested that more detail study on hydrolysis method are required to enhance bioethanol production from starch. With this, the starch contents in the waste will transform to sugar and fascinate the fermentation efficiently.
2) There is a need to conduct detail study on the techno-economical aspect of waste agriculture in Malaysia to further convince industry key players to invest into this waste- to-energy application.

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