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DEVELOPMENT OF BIOETHANOL PRODUCTION FROM CANNA (Canna edulis Ker.) RHIZOME

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Abstract—**Bioethanol production from canna (Canna edulis Ker.) rhizome and its character was evaluated at a laboratory scale. The objectives of this research are to make bioethanol from canna rhizome, to assess the characters of bioethanol and to determine the value of burning calor from mixtures of bio-ethanol derived from canna with gasoline. Canna rhizomes were mashed, cooked and fermented by adding ά-amylase, glucoamylase and yeast (Saccharomyces cereviceae). The liquid obtained were then distillated to obtain bio-ethanol. The results showed that one kilogram of canna rhizome can be converted to 120 mL of 75% bio-ethanol. Almost pure bioethanol (97-98%) was obtained after re-distillation and dehydration using molecular sieves. The chemical analysis showed that the value of specific gravity of bioethanol at 60/60°F is 0.8344, level of corrosion is 1b (not corrosive), 10%, 50% and 90% destillate were obtained at 77 °C, 78 °C and 80 °C respectively, and the end point was reach at 98 °C. Burning calor value of bioethanol is 5.633 cal/g whereas gasohol is 10.38 cal/g, thus to retain calor value similar to pure gasohol, the optimum concentration of bioethanol that can be mixed to gasohol is 10%. It was concluded that canna rhizome is promising for bio-ethanol feedstock.**

Keywords-component:* *Canna edulis Ker. rhizome, bioethanol

I. INTRODUCTION

Nowadays, alternative fuels are becoming a major concern of many countries as the reserves of petrochemical fuels decreases year after year, and consequently it increased the price of petrochemicals. The public awareness of environmental problem and petroleum prices has raised considerable interest in the use of bio-ethanol as an alternative transportation fuel. According to DOE energy Efficiency and Renewable Energy, bio-ethanol can be combined with gasoline in any concentration up to pure ethanol (E100)[1]. Along with the public acceptance of bio-ethanol as substitute for gasoline or as an additive to gasoline, there is an increase interest in commercializing technology for bio-ethanol production from potentially inexpensive feedstock. Bioethanol can be produced from biomass materials that contain sugar, starch or cellulose. Feedstocks of agricultural crops like sugar cane, wheat, barley, potatoes, corn or waste paper, sawdust and straw have been utilized to make bioethanol.

To produce ethanol from starchy biomass, steam is applied to break down and decompose the biomass into glucose, and followed by hydrolysis. The glucose then converts into alcohol by fermentation. After fermentation, distillation is required to remove water and other impurities in the alcohol-containing mixture, followed by rectification to attain the desired alcohol concentration. For the ethanol to be usable as a fuel, water must be removed through distillation and dehydration, but the purity is limited to 95-96% due to the formation of a low-boiling water-ethanol azeotrope [2]. The efforts in making cheap bioethanol require system evaluation and development for the whole production and product transportation. A comprehensive process which includes feedstock supply, bioethanol research strategy to improve feedstock yields and lower con-version costs is currently being developed in many countries. The feedstocks for bioethanol production that commonly used in Asian counties are sugar cane, sorghum, or cassava. It has been suggested that cassava pulp is a cheap and promising feed stock for bioethanol production because by using cassava pulp the energy consumption for agitation is reduced. It was also reported that sugar yield from starch based feedstock can be improved by rapid heat up of the feedstock for hydrolysis, and rapid cool down the product to prevent the unwanted decomposition of sugar [3].

Canna (*Canna edulis* Ker.) is one of rhizomous plants which normally cultivated in tropical regions or in sub-tropical highlands as a source of starch. This plant is easy to grow and relatively tolerant to drought [4]. It is also known that this species can be grown under tree canopies or in marginal lands, thus canna is suitable to optimize those land uses. The rhizome yield in unirrigated field is approximately 40 t/ha, whereas in more fertile land and under high nitrogen fertilization, the rhizome yield can reach to about 80 t/ha [5]. In Indonesia, canna often grows on the bank of small dyke in paddy field. There are two cultivars that commonly found, namely those that has red or purple colour of rhizomes and those that has white rhizome [6]. Canna starch seems potential to be developed as feedstock of bioethanol production. It has been reported that an application of growth retardant increased the yield of canna rhizome [7]. Unfortunately, this crop's potential is not being widely recognized and thus cultivation of canna is still unpopular compared to other tuberous plants such as cassava. Canna starch is easy to produce as it settles quickly out of suspension of grated rhizome's tissue. The starch recovery in rural factory is more than 80% of total starch content [8]. The waste products from canna starch extraction probably can also be converted to bioethanol as the slurry water might contain high sugar content whereas the fibres of canna rhizome also contain cellulose. The common method for making bio-ethanol from starch based feedstock involves the fermentation process by yeast *Saccharomyces cerevisiae*. Many studies for the efficiency and enhancement of ethanol production have been conducted. It has been reported that the distribution similarity between starch granule and yeast cells increases the ethanol production rate [9]. It was suggested that increasing α-amylase activity depends on the surface contact between starch granule and yeast cells. Recently, it was reported that repeated batch fermentation up to seven times without any significant loss in ethanol production can be obtained through the utilization of "yeast biocapsules". With this technique approximately 0.3% (v/v) ethanol from 5 g/L starch can be produced in less than 24 h [10].

Bioethanol production at industrial scale is differentiated mainly in four types, namely batch, continuous, fed-batch and semi-continuous. In the study using *Saccharomyces cerevisiae* and sucrose as substrate, it was suggested fed-batch process (in which the feed solution are fed at constant interval) is the most effective and advantageous [11]. However, in batch fermentation, ethanol production can be increased by using co-cultures of *Saccharomyces cerevisiae* 21 and *Saccharomyces diastaticus* [12]. A more complete understanding of enzymes and microbes involved in biomass conversion to ethanol is needed to overcome current inefficiencies in the production process. Another research area concerning the utilization of bio-ethanol is assessment of the effects of bio-ethanol addition towards character of engine fuel. The 96% m/m (93% v/v) ethanol, 4% m/m (7% v/v) water mixture may be used as a fuel, and it is called as hydrated ethyl alcohol fuel. For blending with gasoline, purity of 99.5 to 99.9% is required to avoid separation. To reduce exhaust emissions from engines, satisfactory standard specification concerning fuels are required. Furthermore, the fuel must fulfill the purpose such as enabling car engines to perform properly under varying climatic conditions. Generally, no engine modification is required if less than 10% by volume of ethanol is blended with petrol and used as fuel. Fuel with higher concentration of ethanol will require engine modifications [13]. It has been evaluated that fuel character of a mixture 10% bio-ethanol derived from cassava with gasoline on 10, 50, and 90% volume of distillate product were reached at 53.95 and 158^{o}C, IBP and end point is 42 and 183^{o}C. Vapour pressure, specific gravity and calor are 59.29 kPa, 0.7561 and 42.92 MJ/kg respectively. The character of corrosion is negative and this mixture of 10% bioethanol with gasoline fulfills the specification for fuel engine [14]. The purposes of this research were to utilize canna rhizome as a feedstock of bio-ethanol, to evaluate some characters of bioethanol derived from canna and to measure calor value of bioethanol and gasohol mixture at various concentrations.

II. MATERIALS AND METHODS

Four kilograms of Canna rhizomes were grated using electric grating machine to increase the accessible surface area of carbohydrates for hydrolysis. The mashed was then cooked in 6 L boiling water that already added with α-amylase. The hydrolysis stage breaks down the chains of complex carbohydrates such as starch into simple sugars such as glucose. After one hour liquefaction, the mash was allowed to quickly cool to 80^{o}C for 30 minutes. Before saccharification the pH of the mash was adjusted to 4.5 with phosphoric acid and the glucoamylase enzyme was added. After 2 hours saccharification, the mash was cooled to 30^{o}C and the yeast was added. NPK and urea fertilizers were also added at the rate of 1.5g/Kg and 0.75 g/Kg respectively. The simple sugars are digested in fermenters by the yeast, which produces ethanol as a by-product of its normal metabolism. During 3 - 4 days fermentation, the mash was mixed regularly. Ethanol was separated from beer with a two-phase distillation. The first distillation was in the temperature range 80 – 95^{o}C. The distillate was collected and re-distillated. to a temperature of 80^{o}C. Bio-ethanol produced was further purified using molecular sieves. Ethanol content was determined using ethanol meter, and then some chemical characters of bioethanol were evaluated. Starch and reducing sugar content of Canna rhizomes used as feedstock was determined according to methods described in AOAC (1995).

Determination of fuel characters of bio-ethanol, gasoline, and mixture of bio-ethanol and gasoline under the various concentrations : 5, 10, and 15% volume was carried out by distillation. ASTM D-86, vapour pressure was determined by Reid vapour pressure, ASTM 323 at temperature 37.8^{o}C. Other characters that were determined are : specific gravity by hydrometer, calor by calorimeter bomb, colour by Lovibond colorieter, and corrosion by doctor test and copper strip corrosion inhibitor.

III. RESULTS AND DISCUSSION

Based on Nelson Somogyi method, the starch content average of canna rhizome used in this experiment was found 14 - 16%. The alcohol and reducing sugar content of the liquid during 4 days of fermentation was also measured. It was shown in Fig.1. that the alcohol content dramatically incrased from 0% on day 1 to 36% on day 2 fermentation process. On the third and fourth days of fermentation process, the concentration of alcohol increased slightly to about 39%. These results are due to the growth of yeasts that become limited as the alcohol concentration increased. Thus alcohol accumulated during three or four days fermentation process is ready to be destilled.

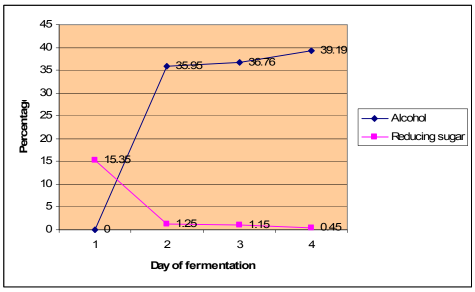

Figure 1. Contents of alcohol and reducing sugar in the liquid during fermentation process

The first destillation process was carried out at temperatur of 80 – 95 ^{o}C and the destillate has ethanol concentration of 60 – 75%. This bioethanol is easy to be burned (Fig. 2) and can be utilized as substitution of kerosene. The availability of kerosene was getting less in many rural areas, thus the utilization of bio-ethanol as kerosene substitution need to be continually promoted. Further distillation was carried out with the maximum temperature of 80oC. The distillate obtained showed ethanol concentration of 95%, and this bio-ethanol was then purified with molecular sieve. From three replicates, it was found that 11 – 12 Kg canna rhizome was required to obtain 1L of 98% - 99% bioethanol. This conversion rate of canna biomass to bio-ethanol is relatively similar to that of sago (12 : 1) but it is less effective compared to cassava (6.5 : 1) or sweet corn (2.5 : 1) [15]. Nevertheless, canna rhizome still can be promoted as the alternative source of bio-ethanol feed stock since this plant can be grown in diverse locations, and it was reported that in good soil condition the yield can reach up to 80 tons/Ha [5]. There are other benefits in utilizing canna rhizome as bio-ethanol feedstock such its capacity to stay fresh after harvest at longer time compared to cassava, and the fact that canna is still considered as underutilized species, its ability to be converted to bio-ethanol will boost the diversity programme for bioethanol feedstock that does not compete with food diversity programme.

Figure 2. Cotton wetted with 75% bioethanol burned easily.

The utilization of bioethanol as a blending ingredient at 5%-10% concentrations in gasoline to produce high-octane fuel increases lately as more peoples become aware of its positive value compared to that of gasoline. Its high natural 'octane' rating prevents premature detonation under load. The engine life can also be extended as ethanol burns slightly cooler. In addition, it also causes less carbon monoxide emissions. Thus a 10% blend requires no engine modification while making a contribution to reducing emissions. Anything more than 10% requires engine modification [13]. From this research it is clear that ethanol up to 95% strength can be produced using simple distillation.

Some character of bioethanol derived from canna rhizomes have been evaluated at laboratory scale. It was found that bioethanol has clear colour with specific gravity of 0.8344 at 60/60 ^{o}F. Based Doctor test and Copperstrip corrosion (3 hrs/50 ^{o}C), bioethanol is classified as non-corrosive. The temperature in which bioethanol destillate reach 10, 50 and 90% is 77^{o}C, 78 ^{o}C and 80 ^{o}C respectively, with the end point at 98 ^{o}C and total residu of 0.5%. This low value of total residu indicates that the percentage of water is less than 0.5%. The calor value of bioethanol is 5.63 cal/g, whereas gasoline has twice as high calor value of bioethanol. Similar evaluation has been carried out on bioethanol derived from cassava, and it was suggested that calor value decreased as more bioethanol is mixed to gasoline [14]. Thus to attain calor value that is not less than 10 (value of pure gasoline), the maximum concentration of bioethanol that should be mixed with gasoline is 10% (Fig. 3).

Two type of wastes were produced from processing canna rhizome to bioethanol. Those wastes are liquid waste that still contain alcohol up to 20% and solid waste that mainly composed of canna fibers. These wastes do not contain harmfull materials, but if it do not managed well, it may also cause pollution to the surrounding environment. The value of nitrogen, phosphor, and kalium content, as well as total carbon and total organic matter from those wastes were evaluated and data are presented in Table 1.

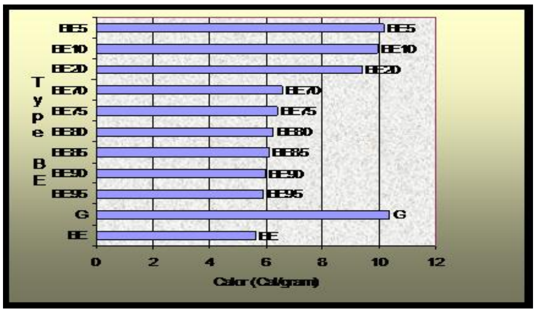

Figure 3. Calor value of Bioethanol (BE), gasoline (G) and several BE concentrations

TABLE 1. MAJOR COMPONENT OF SOLID AND LIQUID WATES FROM PROCESSING CANNA RHIZOMES TO BIOETHANOL

Waste type	Water content	Carbon	Organic matter	N total	P total	K total
	%	%%	%	%	ppm	%
Solid	12.61	53.25	91.80	3.72	710.42	1.54
Liquid	-	0.96	1.66	0.04	50.98	4.41

When the solid waste was dried up, it becomes like mulch and contains relatively high P total (710.42 ppm) compared to the liquid waste. On the other hand, liquid waste contains slightly higher K compared to solid waste. It seems that these NPK content obtained from both solid and liquid waste are the left over of NPK and urea that were added during fermentation process. Based on its NPK content, both solid and liquid wastes might be good to be applied as fertilizer. The effect of applying those solid and liquid wastes on the growth of vegetables or other crop plants warrant further examination. As solid waste contains cellulose, it can be further processed to bioethanol or it may be used as feed for animal. These alternatives also warrant further evaluation, so that zero waste from bioethanol production can be implemented.

IV. CONCLUSION

From the results and discussion it can be inferred that bio-ethanol can be made from canna rhizome with simple fermentation procedure. The conversion of canna biomass to bio-ethanol of 75% and 97-98% are 8 : 1 and 12 : 1 respectively. The quality of bio-ethanol (98%) fullfils the standard for fuel substitution, and the maximum concentration of bio-ethanol that can be added to gasoline is 10%. Liquid waste from bio-ethanol processing could be used as fertiliser, whereas solid waste could be used either for animal feed, or bioethanol feedstock which based on cellulosic material.

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REFERENCES

[1] http://www1.eere.energy.gov/biomass/bio-ethanol

[2] USDA Foreign Agricultural Service, Global Agriculture Information network Report No. E36081, 5/17/2006

[3] Yamaji K., Matsumura, Y., Ishitani, H., Yamada, K., Wyman, C.E. and Tolan, J.S. "Production of low-cost bioethanol to be a rival to fossil fuel", 2003.

[4] Brück, H., C. Jureit, M. Hermann, A. Schulz and B. Satte macher. Effect of water and nitrogen supply on water use efficiency and carbon isotope discrimination in edible canna (Canna edulis Ker-Gawler). Plant Biology vol 3, 2001, pp: 326 – 334

[5] Hermann, M., Quynh, N.K., and Peters, D. Reappraisal of edible canna as a high-value starch crop in Vietnam. CIP Program report 1997 – 1998. pp : 415 – 424

[6] Lingga P."Cultivation of tuberous plants". Bertanam Ubi-ubian. Cetakan ke VII. P.T. Penebar Swadaya, Jakarta. pp : 222 – 238.

[7] Dewi, K., 1999. The effect of CCC and saw-dust of coconut fibre as mulch on the growth and rhizome yield of edible canna (Canna edulis Ker.). Research Report, funded by Indonesia Toray Science Foundation Year 1998/1999.

[8] Hermann, M. Starch noodles from edible canna (Canna edulis). In: progress in new Crops. Ed. Janick, J. American Society for Horticultural Science, 1996, pp: 507 – 508

[9] Khaw, T.S., Katakura, Y., Ninomiya, K., Moukamnerd, C., Kondo, A., Ueda, M. and Shioya, S. Enhancement of ethanol production by promoting surface contact between starch granules and arming yeast in direct ethanol fermentation. Journal of Bioscience and Bioengineering vol:103(1) 2007, pp: 95 – 97

[10] Peinado, R.A., Moreno, J.J., Villalba, J.M., Gonzáles-reyes, J.A., Ortega, J.M. and Mauricio, J.C. Yeast biocapsules: A new immobilization method and their applications. Enzyme and Microbial Technology vol :40, 2006, pp: 79 – 84

[11] Çaylak, B. and Vardar Sukan, F. Comparison of different production processes for bio-ethanol. Turki Journal of Chemistry vol : 22 ,1998, pp: 351 – 359

[12] Verma, G., Nigam, P., Singh, D. and Chaudhary, K. Bioconversion of starch to ethanol in a single-step process by coculture of amylolytic yeast and Saccharomyces cerevisiae 21. Bioresource Technology vol : 72 (3), 2000, pp: 261 – 266

[13] DOE Energy Efficiency and Renewable Energy. Biofuels, Ethanol Overview. (http://www.doe.gov.ph/AF/Bioethanol.htm).

[14] Garjito, Triyono and Trisunaryanti, W. The effects of bioethanol addititon towards characters of motorcyle's Fuel. Research Report of Chemistry Study Programme. Department of Mathematics and Natural Science. Post Graduate Programme. Gadjah Mada University, 2006.

[15] Prihandana, R., Noerwijari, K., Adinurani, P.G., Setyaningsih, D., Setiadi, S. and Hendroko, R. "Bioethanol from Cassava : Future fuel", Bioetanol Ubi Kayu. Bahan Bakar Masa Depan. Agro Media Pustaka, 2007, Jakarta