



THE UTILIZATION OF ARENGA PINNATA ETHANOL IN PREPARING ONE PHASE-AQUEOUS GASOHOL

Hanny F. Sangian, Gerald H. Tamuntuan, Handy I. R. Mosey, Verna Suoth and Beni H. Manialup
Department of Physics, Faculty of Mathematics and Natural Sciences, Sam Ratulangi University, Jalan Kampus Bahu Unsrat
Manado, Indonesia

E-Mail: hannysangian@yahoo.co.id

ABSTRACT

The arengapinnata tree, which grows abundantly in North Sulawesi Indonesia, produces a simple sugar (Brix 14 percent) at a rate 20-35 litre per day that is fermented directly into ethanol without adding an enzyme. Generally, a high purity ethanol (99.5 percent) is blended with gasoline to be gasohol in one phase as an alternative energy for a heat machine fuel. To prepare the dehydrated ethanol, however, is very difficult and costly. This study was aimed to analyse the possibility of mixing the gasoline and impure ethanol becoming one phase substance, or aqueous gasohol, in which ethanol concentration was below 99.5 percent. Firstly, the ethanol was prepared through a natural yeasting of arengapinnata juice and then was separated from water using reflux distillation filled by packing materials. It was found that ethanol purities obtained were 90-96 percent depending on column temperatures. The range of 78.00-78.50°C was the best condition whereby the product purities obtained were of 95 - 96 percent. By applying molecule sieves, ethanol purity could be improved to 99 percent. This work discovered that an aqueous gasohol (gasoline+ethanol+water) in one phase could be formed from various purities of ethanol from 80 until 99 percent. A gasohol E90 meant that fractions of gasoline and ethanol were 0.1 and 0.9 of gasohol, respectively. To blend E90, the ethanol purity at least was 83 percent whose water concentration was 15.30 percent of a gasohol. Meanwhile, an E23 was a 23 part of ethanol and 77 part gasoline of gasohol whereby ethanol purity should be above 96 percent. An E28 could be blended into gasoline and ethanol whose purity was 95 percent and water content was 1 percent. It was discovered if a content of ethanol of gasohol was reduced, the components directly were separated. Since the dehydrated ethanol was very expensive, this study recommended that the aqueous gasohol blended from gasoline and ethanol, which purity was below 96 percent, should be considered for a modified heat machine fuel.

Keywords: aqueous ethanol, distillation, gasohol, gasoline, reflux, yeasting.

INTRODUCTION

Currently, many reports revealed that the scientists are giving an attention on renewable resources [1-2]. The biomass as a renewable material is an important substance and has been developed into sugars, ethanol and bio hydrogen as alternative energy for coming years to substitute fossil based fuels [3-5]. Tropical countries are the biggest producer of biomass, or lignocellulose in which many investigators have been successfully converting them to be more valuable materials, such as composites, sugar, and bio fuel [6-7].

The biomass is generally found in many types of trees whose their compositions consist of cellulose, hemicellulose and lignin that can be hydrolyzed into sugar and then fermented becoming ethanol [9-11]. To obtain ethanol from biomass, however, should follow many steps, such as milling, drying, pretreating, washing, hydrolyzing and fermenting. Prior to enzymatic hydrolysis, the substrate was treated firstly using chemical and physical techniques [12]. After pretreatment, treated biomass was converted into simple sugars using cellulase [13]. The reducing sugars were yeasted into beer and then it was distilled becoming bioethanol [14-15]. To obtain ethanol from lignocellulosic materials is a long path, complicated and very expensive.

The biomass of *Arengapinnata*, a renewable resource, is the most important palm tree in the South East Countries, Indonesia, Philipina, Malaysia and Thailand [16]. Unlike other trees which only produce cellulose, the

arengapinnata produces a simple sugar directly after special treatments and also produces many products, such as, starch, wood, fruit, fibre and ethanol [17]. After tapping process, palm juice starts fermenting naturally without adding a synthetic enzyme that it was an important characteristic of sugar produced by arenga palm [18].

Prior to defining the present work, it would be explained briefly the blended fuels. The story producing the blended fuel including gasohol, whereby ethanol was derived from starch and lignocelluloses, has been conducted for years. Pure ethanol has been blended with diesel and then the mixed fuel was applied on a heat machine [19-20]. Even though, the gasoline (non-polar) and ethanol (polar substance), investigators have succeeded blending them to one phase substances in some combinations, E5, E10, E15, E20 and so forth [21]. One of many investigations had been reported about how to prepare gasohol [22]. Authors [23] prepared an ethanol that was produced from corn and used it for biofuels. The cassava has been successfully converted into ethanol and then it was blended with gasoline becoming gasohol [24]. To prepare the gasohol for engine fuel, ethanol should be purified until 99.5 percent and according to US Patent report that to blend gasohol in one phase, ethanol should be purified approaching dried ethanol [25-26].

However, the preparation of pure ethanol is very difficult and the production cost is expensive if compared with that of petroleum [27]. The question is what gasohol can be prepared from gasoline and ethanol becoming one



phase in which purity of ethanol is below 99.5 percent? This work tried to study the possibility of mixing of gasoline and ethanol to be one phase whereby the ethanol was not pure. The procedures are as follows: the natural yeasting of palm juice, a distillation of ethanol, molecular sieve and gasohol preparation. The ethanol was prepared from palm juice (tapped from *arengapinnata* tree) and was distilled using a home constructed reflux apparatus.

MATERIALS AND METHODS

Many works have been reported how to prepare sugar and ethanol from biomass treated by many techniques [28-29]. The technology used was complicated and followed many steps [30-31]. However, there is a blessed tree, which grows abundantly in Indonesia whereby it can produce a simple sugar (palm juice) after treatment. The sugar whose Brix is a 14 percent can produce a 20-30 litre per day and can be yeasted naturally without adding enzymes.

This study, the palm juice locally called *saguer*, was obtained from a farmer in the South Minahasa Regency, North Sulawesi Indonesia. One hundred litres of juice was put in the plastic fermenter and kept for 4-5 days. After yeasting was finished, beer was poured into the boiler which was connected to reflux distillation as shown in Figure. 1 that was adapted from previous work [32].

The temperature of the boiler was increased until beer's boiling point that it depended on ethanol

concentration of beer. For example, if the ethanol was 5 percent, beer would boil at 95 °C. The vapour flowed into a reflux column filled by thousands of packing materials where stripping of ethanol was occurred thousand times until on the top of the column. The vapour which was rich of ethanol was directed to condenser equipped by a cooler as shown in the figure. The water was circulated by a pump powered by electrical energy. Finally, ethanol reached the collector container after transforming its phase from vapour into liquid. By applying this reflux distillation, ethanol obtained can reach purity 96 percent and depends on the column temperatures.

To increase the product purity above 96 percent, the ethanol was mixed with particles which could absorb water [33-34]. The weight ratio of ethanol and particle was set from 1:1, 2:1, 3:1 and so on. Prior to purification, particles were activated thermally using furnace (Oven Moloney) for an hour. When mass was constant, particles were removed from the oven and then mixed with ethanol under stirring for hours. The ethanol and particle were separated with using simple distillation and ethanol concentration obtained was a range of 97 until 99 percent. The final step was to blend the gasoline and ethanol in many ratios without using a complicated technology. In this step, the ethanol was just mixed with gasoline inside flask in which their volumes were measured correctly. Finally, the aqueous in which ethanol concentrations were altered from 80 until 99 percents.

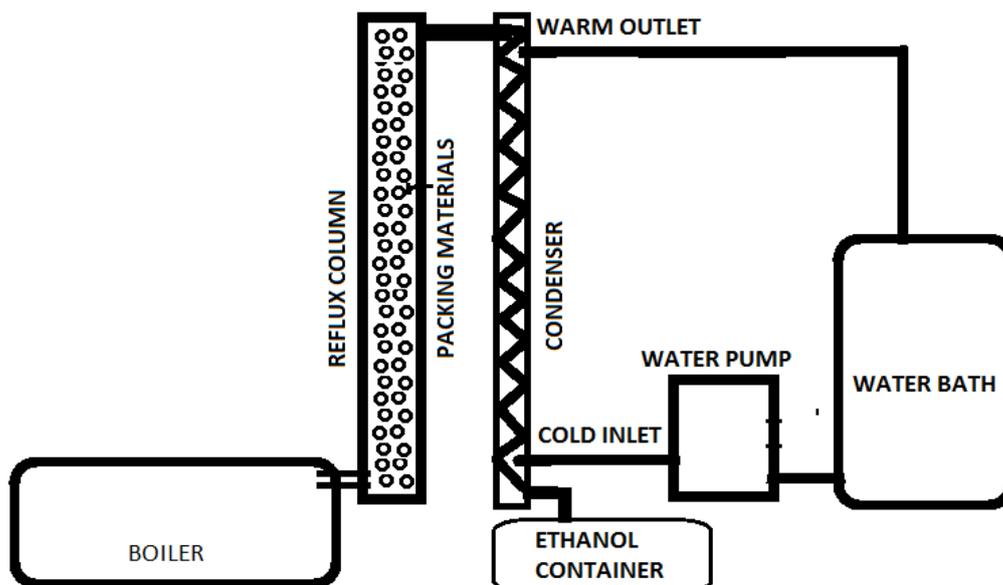


Figure-1. The reflux distillation design used in this study.

RESULTS AND DISCUSSIONS

Natural yeasting

Until now, local investigators are conducting experiments to find why palm sugar directly is fermented into ethanol even though without adding synthetic enzymes. It may have natural microorganisms producing proteins functioning as an enzyme. Figure-2 shows the decreasing of sugar (in Brix percent) toward yeasting time

(h). The average percentage of sugar inside palm juice before the yeasting process was around 12-14 percent [35]; it means that 140 grams pure sugar can be obtained in one-kilogram palm juice. An arengapinnata tree can produce 20-25 kilograms palm juice per 24 hours. When juice was tapped from the tree, it was directly fermented into beer (liquor), whereby the initial conversion rate in the range 0-6 hours, was very low. According to observation, the high conversion rate was occurred in 6



hours and stopped at 105 hours. In some experiments, the final sugar content (in percent) was around 3- 4 percent that yeasting was stopping working. In this stage

microorganisms gradually died and enzymes were not produced anymore [36].

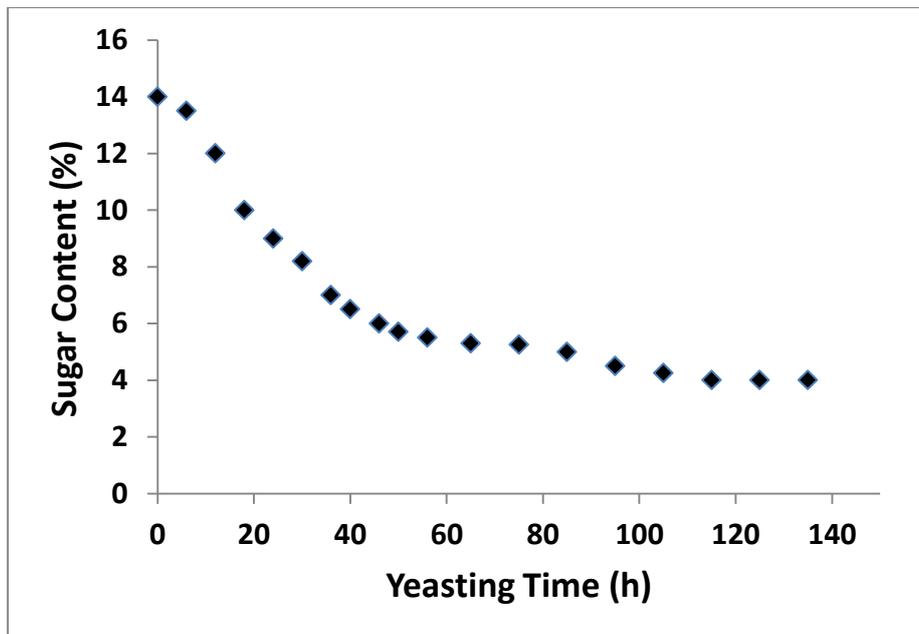


Figure-2.The sugar content (%) with respect to yeasting time (h) in room temperature.

Distillation/separation

The ten litres beer was removed and poured into the boiler for separation using reflux distillation. The liquor was boiled by using the gas stove equipped with regulator. It was found that the ethanol concentration obtained was very sensitive to column temperature [37]. Table-1 shows the ethanol purity as a function of column temperature conducted in triplicate. The temperature was measured on the summit of a column by being inserted the sensor inside the pipe.

Table-1.Relation of the purity of ethanol with respect to column temperature.

Column temperature (°C)	Ethanol purity (percent)
78.40	96.00
78.50	95.00
78.90	93.00
79.00	93.00
80.00	92.00
81.00	91.50
83.00	89.00
87.70	80.00
95.00	60.00
97.00	50.00
98.00	55.00
98.70	35.00
99.90	30.00
99.40	25.00
00.00	00.00

The quality of product depended on heat supplied to the boiler, column temperature, packing materials and room temperature. To obtain 96 percent ethanol, the system must be adjusted until it attained a balance condition and column temperature was 78.4 °C. While the



purity was at 95 percent, the column temperature increased slightly to 78.50 °C that was comparable with previous work [38]. When ethanol content in beer went down, the amount of water vapour increased entering column and reached condenser. The purity of ethanol started decreasing as column temperature inclined which was indicative that beer is going to mostly water. The purity of ethanol that was measured in range temperature from 78 to 100 °C was obtained around 87-90 percent.

Particles Activation

The work was continued with dehydration of ethanol using particles (molecule sieve) adapted from other work [39]. Prior to dehydration, particles were activated thermally using the furnace for hours as previous work [40]. Table-2 shows the amount of water (in gram)

that vaporized from particles towards activation times and initial mass of particles was 103.80 grams. The particles were removed periodically from furnace to measure their mass. To find the mass of water vaporized was that the initial mass was subtracted by the mass at the time.

The mass of water vaporized was 5.80 grams when the heating took 30 minutes and increased to be 8.40 grams at 120 minutes. When heating time was 240 minute, the total mass of water vaporized was 11.50 grams or 11.08 percent of the initial mass of particles. This process was costly since it used very much electrical energy to power the furnace. The gasohol, which was not feasible for fuel was caused by activation of particles used to dehydrate ethanol. This process consumed time and electrical energy and ethanol so it was very expensive.

Table-2. The amount of water that vaporized during particles activating (furnace temperature was of 700 °C).

No	Time (minute)	Mass of particles (gr)	MH ₂ O (gr)	% of H ₂ O
1	30	98.00	5.80	5.59
2	60	96.40	7.40	7.13
3	90	96.10	7.70	7.42
4	120	95.40	8.40	8.09
5	150	94.80	9.00	8.67
6	180	94.20	9.60	9.25
7	210	93.40	10.40	10.02
8	240	92.30	11.50	11.08

Preparation of Ethanol above 96 percent

After particles activation finished, the work was continued with dehydration of ethanol using molecule sieve to catch water, which was still remained and bonded electrically between O and H atoms on both H₂O and C₂H₅OH. Table-3 presents the ethanol purity obtained after dehydration process. Ethanol has been obtained successfully with purities above 96 percent, such as 97, 98 and 99 percent. The initial volume and ethanol purity were

300 mL and 95 percent that were obtained from distillation as previously presented. The data show that the ethanol purity depends on activation time of particles and heating temperature, and added with two variables, reaction time and mass of activated particles, which has been published by authors [41]. When 30 grams particles were added to 95 percent ethanol and were stirred for one day, ethanol purity improved to 97 percent.

Table-3. Improvement of ethanol purity toward reaction time and mass of activated particles.

Volume of ethanol (mL)		Purity of ethanol (%)		Mass of ethanol (gr)		Decrease (%)		Duration of reaction time (h)	Mass of activated particles (gr)
Initial	Final	Initial	Final	Initial	Final	Vol.	Mass		
300	215	95	97	231.6	208.6	28.3	9.9	24	30
300	180	95	98.2	231.6	172.9	40.0	25.3	48	37.5
300	160	95	99	231.6	160.2	46.7	30.8	72	45

The purity inclined to 98.2 percent when ethanol was added with 37.5 grams of activated particles and reaction time increased to 48 hours. But the decrease percentages of the product increased to 40 (volume) and 25.3 percent (mass). Meanwhile, The purity inclined to 99 percent but the decreases were 46.7 and 30.8 percent for the mass of particles 45 grams and duration of reaction 72

hours. The disadvantage of this method was that the mass or volume of product was reduced significantly as shown in the table and this finding was comparable with a previous study [40]. The data in the first row presents that the percentages of product reduction in volume and mass are 28.3 and 9.9 percent, respectively. Even though the



purity improved as reaction time and mass of particles increased, the mass and volume of product decreased.

Aqueous gasohol blending

The final process was to blend gasohol (in one phase) in which gasoline and arengapinnata ethanol that has many purities, were mixed until they become one phase. The term of gasohol uses Ex, it means ethanol with x part, while gasoline part is (100-x) of gasohol. An E25 gasohol is a mixture between 25 unit of ethanol and 75 unit of gasoline and in this study used unit in volume.

Many investigations have been conducted to prepare gasohol for heat machine fuel and most publications reported that ethanol purity should be approaching 99.9 percent [42-43]. Ethanol is a polar molecule, while gasoline is a nonpolar substance in which they are separated into two phases if mixed. However,

according to many studies, gasoline and ethanol, which has relatively high purity, could be blended becoming one phase [44].

Ethanol purity should be increased to be higher than 95/96 percent if we blended gasohol E5-E15. In this stage, despite gasohol E5-E15 used a small part of ethanol, to make pure alcohol was very complicated and expensive [45]. It was seen that gasohol E5-E15 was not feasible to produce in industrial scale since it used huge electrical energy for activating of particles and the amount of ethanol was reduced significantly after mixing as previously described. However, lower purity ethanol (<95/96%) could be blended becoming one phase gasohol. The problem is that all heat machines operating around the world are not suitable with aqueous gasohol and a higher part of ethanol [46].

Table-4. The volume data of gasoline and ethanol until one phase aqueous gasohol formed.

Ethanol Con.	Vol. Gasoline (ml)	Ethanol added (ml)	Part of Ethanol in Gasohol	Vol. of water in Ethanol(ml)	% H ₂ O in Gasohol
80%	15	175	175/190= 0.92E92	35	18.42%
81%	10	110	110/120=0.916 E91.6	20.9	17.42%
82%	10	100	100/110 =0.909 E90.9	18	16.36%
83%	10	90	90/100 = 0.90E90	15.3	15.30%
84%	10	85	85/95 = 0.89E89	13.6	14.32%
85%	10	80	80/90 = 0.85E85	12	13.33%
90%	10	30	30/40 = 0.75E75	3	7.50%
91%	10	28	28/38 = 0.37E73	2.52	6.63%
92%	10	21	21/31 = 0.67E67	1.68	5.42%
93%	10	12	12/22 = 0.54E54	0.84	3.82%
94%	10	9	9/19 = 0.47E47	0.54	3%
95%	10	4	4/14 = 0.28E28	0.20	1%
96%	20	6	6/26 = 0.23E23	0.24	1%

Table-4 displays about gasohol, Ex, which was blended with gasoline and ethanol with different purity. The gasohol E23 and E28, ethanol purities were at least 96 and 95 percent, respectively whereby water concentration was close to 1 percent. If ethanol concentration was below 95, or 96 percent, the gasoline and ethanol were separated directly. When concentration decreased at 94.5 percent, a part of ethanol dissolved with gasoline was 0.37 assigned by gasohol E37. The ten ml gasoline was added into 9ml of 94 percent ethanol, E47 was mixed completely whose water content was 3 percent. The gasohol E85 needed ethanol that its purity was bigger than 85 percent and water was 13.33 percent (12ml). When ethanol concentration was at 90 percent (30ml), gasoline added to form gasohol E75 was 10ml and water concentration was 7.50 percent. Gasohol E90, which was formed in one phase, needed ethanol purity only at least 83 percent.

As described previously that gasohol E23 could be blended with gasoline and ethanol which has the purity minimum at 96 percent. It meant that if a part of ethanol in gasohol decreased, components would be separated, while if increased, the one phase gasohol existed. Thus, ethanol which its concentration was 95 percent could be forming gasohol E28-E99. The minimum ethanol concentration that was still formed one phase gasohol was 80 percent in which water content 18.42 percent. This measurement was conducted duplicate and at room temperature.

If part of ethanol decreased to 10 unit or E10, the ethanol concentration should be increased to around 98.0-99.0 percent. According to author's findings, the gasohol E5-E10 was very expensive because the activating of molecule sieve used very much energy. This work recommended that it is time to produce heat machine which could be consuming aqueous gasohol and could be



occurred perfect combustion with little amount of water and higher part of ethanol.

CONCLUSIONS

It has known for years that ethanol and gasoline can be blended becoming one phase gasohol if ethanol purity is at least 99.5 percent. This work found that gasohol in one phase could be blended whose ethanol purity was lower than 96 percent which the preparation was very simple and cheap if compared to that of an absolute ethanol. The problem is that all heat machines working now were not suitable with aqueous gasohol whose water contents were 1-20 percent. The aqueous gasohol is promising to develop as a fuel for a heat machine in the coming years because of cheap preparation.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Higher Education Department of Indonesia Government for financial assistance and the Rector of Sam Ratulangi University, Prof. Ellen Joan Kumaat and Dean of School of Mathematics and Sciences, Prof. Benny Pinontoan for encouragement and support on the work.

REFERENCES

- [1] Daniyanto, Sutijan, Deendarlianto, and A. Budiman. 2016. Reaction kinetic of pyrolysis in mechanism of pyrolysisgasification process of dry torrefied-sugarcane bagasse. *ARPJ Journal of Engineering and Applied Sciences*. 11(16): 9974-9980.
- [2] F.R.A.A. Wahid, M.B. Muslim, S. Saleh and N.A.F.A. Samad. 2016. Integrated gasification and fuel cell framework: biomass gasification case study. *ARPJ Journal of Engineering and Applied Sciences*. 11(4): 2673-2680.
- [3] M. Asgher, Z. Ahmad, and H.M.N Iqbal. 2013. Alkali and enzymatic delignification of sugarcane bagasse to expose cellulose polymers for saccharification and bio-ethanol production. *Industrial Crops and Products*.44: 488-495.
- [4] A. Widjaja, S.Y. Agnesty, H.F. Sangian, and S. Gunawan. 2015. Application of ionic liquid [dmim] dmppretreatment in the hydrolysis of sugarcane bagasse for biofuel production. *Bull. Chem. React. Eng. Catal.* 10(1): 70-77.
- [5] H.F. Sangian, J. Kristian, S. Rahma, S.Y. Agnesty, S. Gunawan and A. Widjaja. 2015. Comparative study of the preparation of reducing sugars hydrolyzed from high-lignin lignocellulose pretreated with ionic liquid, alkaline solution and their combination. *J. Eng. Technol. Sci.* 47(2): 137-148.
- [6] I. Kong, J.T.B. Shang and K.Y. Tshai. 2016. Study of properties of coconut fibre reinforced poly (vinyl alcohol) as biodegradable composites. *ARPJ Journal of Engineering and Applied Sciences*. 11(1): 135-143.
- [7] M.V. Nagarhalli, V.M. Nandedkar and K.C. Mohite. 2010. Emission and performance characteristics of karanja biodiesel and its blends in a c.i. engine and its economics. *ARPJ Journal of Engineering and Applied Sciences*. 5(2): 52-56.
- [8] S. Mutalik, C.S.V. Kumar, S. Swamy, and S. Manjappa. 2012. Hydrolysis of lignocellulosic feed stock by ruminococcus albus in production of biofuel ethanol. *Indian Journal of Biotechnology*. 11: 453-457.
- [9] A.F. Kehinde, H.A. Shola and A.B. Comfort. 2013. Potential use of jatropha curcas stem for ethanol production. *International Journal of Renewable Energy Research*. 3(1): 65-72.
- [10] Hamaguchi, M. Cardoso and E. Vakkilainen. 2012. Alternative Technologies for Biofuels Production in Kraft Pulp Mills-Potential and Prospects. *Energies*.5: 2288-2309.
- [11] H.F. Sangian, D. Ranggina, G.M. Ginting, A.A. Purba, S. Gunawan and A. Widjaja. 2015. Study of the preparation of sugar from high-lignin lignocellulose applying subcritical water and enzymatic hydrolysis: synthesis and consumable cost evaluation. *Scientific Study & Research Chemistry & Chemical Engineering, Biotechnology, Food Industry*.16(1): 013-027.
- [12] S. Zhu, Y. Wu, Z. Yu, C. Wang, F. Yu, S. Jin, Y. Ding, R. Chi, J. Liao, and Y. Zhang. 2006. Comparison of three microwave/chemical pretreatment processes for enzymatic hydrolysis of rice straw. *Biosystems Engineering*. 93(3): 279-283.
- [13] D.P. Koullas, P.F. Christakofouldo, S.K. Ekos, E.G. Koukios and B.J. Macius. 1993. Effect of alkali delignification on wheat straw saccharification by fusarium oxysporum cellulases. *Biomass Bioenerg.* 4(1): 9-13.
- [14] K. Mirahmadi, M.M. Kabir, A. Jeihanipour, K. Karimi and M.J. Taherzadeh. 2010. Alkaline pretreatment of spruce and birch to improve bioethanol and biogas production. *BioResources*. 5(2): 928-938.



- [15] M. Galbe and G. Zacchi. 2002. A review of the production of ethanol from softwood. *Applied Microbiol Biotechnol.* 59: 618-628, 2002.
- [16] J. Moge, B. Seibert, and W. Smits. 1991. Multipurpose palms: The sugar palm (*Arenga Pinnata* (Wurmb) Merr.). *Agroforestry Systems.* 13(2): 111-129.
- [17] M.R. Ishak, S. M. Sapuan, Z. Leman, M.Z.A. Rahman, U.M.K. Anwar and J.P. Siregar. 2013. Sugar palm (*Arengapinnata*): Its fibres, polymers and composites. *Carbohydrate Polymers.* 91: 699-710.
- [18] U. Usman, A. Suman, L. Hakim and W. Muhaimin. 2014. The impact of home-based business processing palm sugar to increase socio-economic welfare of farmers in south halmahera regency. *Journal of Business and Management.* 16(11): 32-37.
- [19] V.V.R.S. Rao, M.V.S.M. Krishna, T.K.K. Reddy, and P.V.K. Murthy. 2012. Comparative performance evaluation of a high grade low heat rejection diesel engine with carbureted alcohol and crude jatropha oil. *International Journal of Renewable Energy Research.* 2(3): 516-527.
- [20] S. Patel and N. Shrivastava. 2016. Experimental investigation of performance and emission of diesel engine fuelled with preheated jatropha biodiesel and its blends with ethanol. *International Journal of Renewable Energy Research.* 6(4): 1482-1490.
- [21] L.S. King, L.C. Yu and C.J. Khin. 2015. Performance and emission analysis of ethanol-gasoline blended fuel. *International Journal of Engineering and Applied Sciences.* 4(7): 1-6.
- [22] J.L. Baird. 1981. Direct process for the production of gasohol from fermentation mixtures. US Patent 4,251,231.
- [23] D. Pimentel and T.W. Patzek. 2005. Ethanol production using corn, switchgrass, and wood; biodiesel production using soybean and sunflower. *Natural Resources Research.* 14(1): 65-76.
- [24] J. Zhang, Z. Fang, H. Deng, X. Zhang and J. Bao. 2013. Cost analysis of cassava cellulose utilization scenarios for ethanol production on flow sheet simulation platform. *Bioresource Technology.* 134: 298-306.
- [25] W. F. Ginder. 1983. Method of removing water from ethanol, US Patent 4,407,662, Oct. 4.
- [26] L. L. Fornoff. 1981. Process for dehydrating ethanol and for the production of gasohol therefrom. US Patent 4,273,621, Jun. 16.
- [27] M. Balat and H. Balat. 2009. Recent trends in global production and utilization of bio-ethanol fuel. *Applied Energy.* 86: 2273-2282.
- [28] E.C. Bensah, Z. Kádár, and M.Y. Mensah. 2015. Ethanol production from hydrothermally-treated biomass from West Africa. *BioResources.* 10(4): 6522-6537.
- [29] S. Kunthiphun, P. Phumikhet, V. Tolieng, S. Tanasupawat and A. Akaracharanya. 2017. Waste cassava tuber fibers as an immobilization carrier of *saccharomyces cerevisiae* for ethanol production, *BioResources.* 12(1): 157-167.
- [30] L. Liu, P. Li, G. Qin, Y. Yan, Y. Li, J.M. Yao and H. Wang. 2016. Conversion of corn stalk to ethanol by one-step process using an alcohol dehydrogenase mutant of *phanerochaetechrysosporium*, *BioResources.* 11(4): 9940-9955.
- [31] C. Mo, N. Chen, T. Lv, J. Du and S. Tian. 2015. Direct ethanol production from steam-exploded corn stover using a synthetic diploid cellulase-displaying yeast consortium, *BioResources.* 10(3): 4460-4472.
- [32] S.W. Mathewson. 1980. *The Manual for the Home and Farm Production of Alcohol Fuel.* Ten Speed Press, J.A. Diaz Publications. pp. 1-72.
- [33] Q. Kang, L. Appels, J. Baeyens, R. Dewil, and T. Tan. 2014. Energy-efficient production of cassava-based bio-ethanol. *Advances in Bioscience and Biotechnology.* 5(12): 925-939.
- [34] H. Ahn, H. Lee, S.B. Lee, and Y. Lee. 2006. Pervaporation of an aqueous ethanol solution through hydrophilic zeolite membranes. *Desalination.* 193: 244-251.
- [35] M. Kismurtono. 2012. Fed-batch alcoholic fermentation of palm juice (*arengapinnatamerr*): Influence of the feeding rate on yeast, yield and productivity. *International Journal of Engineering and Technology.* 2(5): 795-799.
- [36] R.F. Schwan, A.T. Mendonça, J.J. da Silva Jr., V. Rodrigues, and A.E. Wheals. 2001. *Microbiology and*



physiology of Cachaça (Aguardente) fermentations. Antonie van Leeuwenhoek. 79: 89-96.

gasoline blends on fuel properties characteristics of spark ignition engines. UofKEJ. 1(2): 22-28.

- [37] M.R., Ladisch and K. Dyck. 1979. Dehydration of ethanol: New approach gives positive energy balance. *Science*. 205(4409): 898-900.
- [38] S. Kumar, N Singh, and R. Prasad. 2010. Anhydrous ethanol: A renewable source of energy. *Renewable and Sustainable Energy Reviews*. 14: 1830-1844.
- [39] S. Al-Asheh, F. Banat, and N. Al-Lagtah. 2004. Separation of ethanol-water mixtures using molecular sieves and biobased adsorbents. *Trans Icheme, Part A, Chemical Engineering Research and Design*. 82(A7): 855-864.
- [40] S.K. Wahono, Hernawan, A. Kristiani, S. Tursiloadi, and H. Abimanyu. 2014. Characterization and utilization of gunungkidul natural zeolite for bioethanol dehydration. *Energy Procedia*. 47: 263-267.
- [41] W.C. Chen, C.T. Sheng Y.C, Liu, W.J Chen, W.L. Huang, S.H. Chang, W.C. Chang. 2014. "Optimizing the efficiency of anhydrous ethanol purification via regenerable molecular sieve. *Applied Energy*. 135: 483-489.
- [42] H.S. Yucesu, T Topgul, C. Cinar and M. Okur. 2006. Effect of ethanol-gasoline blends on engine performance and exhaust emissions in different compression ratios. *Applied Thermal Engineering*. 26: 2272-2278.
- [43] A.K. Amirruddin, I.A. Rahim, S. Semin, Firmansyah and A.A.A. Rashid. 2009. Effect of gasohol blends on a four cylinder, port fuel injection engine performance. *International Conference on Applications and Design in Mechanical Engineering (ICADME'09)*,Kangar. pp. 1-10, 11-13.
- [44] M.F. Mohd Ali, M.H. Mazlan, and M.F. Mohideen Batcha. 2010. Effect of hydrated and anhydrous ethanol-gasoline blends on engine performance. *International Journal of Engineering and Technology*. 7(1): 5-11.
- [45] H.J. Huang, S. Ramaswamy, U.W. Tschirner and B.V. Ramarao. 2008. A review of separation technologies in current and future biorefineries. *Separation and Purification Technology*. 62: 1-21.
- [46] A.F. Kheiralla, M. El-Awad, M.Y. Hassan, M.A. Hussien and H.I. Osman. 2011. Effect of ethanol-