Available online at www.pelagiaresearchlibrary.com



Pelagia Research Library

Asian Journal of Plant Science and Research, 2012, 2 (5):643-649



Extraction, Characterization and Determination of Ethanol Fuel Composite Qualities of *Saccharum officinarum*, *Pennisetum purpureum* and *Costus afer*

Jude C. Igwe^{1*}, Kalu E. Agbaeze¹, Anthony I. Obike¹ and Christopher U. Sonde²

¹Department of Industrial Chemistry, Abia State University, P.M.B. 2000, Uturu, Abia State, Nigeria. ²Department of Chemistry, Michael Okpara University of Agriculture, Umudike, P.M.B. 7267, Umuahia, Abia State, Nigeria.

ABSTRACT

Ethanol was extracted from Pennisetum purpureum (Napier grass), Costus afer (Spiral ginger) and Saccharum officinarum (Cane sugar) to determine their respective and comparative yield and also to determine its fuel composite qualities. Samples were selected from water logged area at Uturu, Abia State. They were cut into bits, measuring 1 cm to 5 cm in length and dried under sunlight. The dried samples were pounded to pulp and transferred into 15 L buckets, where it was allowed to ferment with the aid of Saccharomyces cerevisiae and water. Fermentation was completed in four days and the filtrates of the various samples subjected to distillation to yield ethanol. Redistillation of the ethanol was carried out using a reflux condenser to yield a very pure ethanol. Ethanol yield of the three samples were found to be 500 mL/Kg of Saccharum officinarum, 150 mL/Kg of Pennisetum purpureum and 279 mL/Kg of costus afer. Percentage purity of the ethanol was found to be 95.8%, specific gravity (S.G) was 0.7620 Kg/L and the boiling point range was 80°C-90°C. The ethanol-PMS blend showed significant increase in the Rated octane number (RON) with a decrease in the Reid vapour pressure (RVP) as the blend ratio increased. Conversely, increasing the ethanol-PMS blend revealed systematic changes in the distillation profile with respect to Initial boiling point (IBP), Final boiling point (FBP) and Total recovery (TR) with reference to the standard distillation data of pure PMS.

Keywords: Biofuel, Ethanol, Fermentation, % yield, Ethanol-PMS blend.

INTRODUCTION

Biofuel are any kind of fuel made from living things or from the waste they produce. There are very long and diverse list of the sources which includes:

- * Wood chippings and straw
- * Pellets or liquids made from wood
- * Biogas (methane) from animal waste
- * Ethanol, diesel or other liquid fuels made from processing plant material or waste oil [1][2][3][4][5][6].

Biofuel production and optimization of production procedures, is worthy of continued study because of its environmentally beneficial attributes and its renewable nature [1][6][7]. A major hurdle towards widespread commercialization is the high price of biofuel. It has been reported that one of the ways to address the higher price hurdle is to research and develop methods to reduce the cost of its production [1].

In recent years, the term biofuel has come to mean the last category above-ethanol and diesel made from crops including corn, sugar cane, rapeseed and sweet potato [8][9]. Bioethanol, an alcohol is usually mixed with petrol, while biodiesel is either used on its own or in a mixture. Ethanol for fuel is made through fermentation, the same

process which produces it in wine and beer. Other methods of biofuel production have been reported. These include blending of oils, micro emulsion, pyrolysis and transesterification [10][11]. Blending has been reported to be preferred since it does not require a long process and it is simple [12]. Transesterification has been described as a general term used to describe the important class of organic reactions where an ester is transformed into another by interchange of the alkoxy moiety [13]. Transesterification have also been reported to involve stripping the glycerin from the fatty acids with a catalyst such as sodium or potassium hydroxide and replacing it with an anhydrous alcohol that is usually methanol [1]. The resulting raw product is then centrifuged and washed with water to cleanse it of impurities. This yields methyl or ethyl ester (biodiesel) as well as a smaller amount of glycerol, a valuable by-product used in making soaps, cosmetics and numerous other products. The three basic methods of ester production from oil/fat are the base-catalyzed transesterification, the acid-catalyzed transesterification and enzymatic catalysis. The most commonly used method among these is the base-catalyzed transesterification technique as it is the most economical process [14]. Besides bioethanol, there is also interest in trying biobutanol, another alcohol for aviation fuel.

In principle, biofuels are a way of reducing green house gas emissions compared to conventional transport fuels. Burning fossil fuels releases carbon dioxide and if emissions of greenhouse gases, in particular CO₂ continues unabated, the enhanced greenhouse effect may alter the world's climate system irreversibly [9][15][16]. Biofuel has been described as the fuel of the future [17][18]. Also, rapid socio-economic changes in some developing countries like India, China, etc, are influencing dramatically the fuel consumption pattern world over [19][20]. Even if infinite amounts of petroleum were available, the history of alternative energy source is worthy of study from many points of view; not the least of which is the urgent need to find alternatives to oil supply from politically unstable regions of the world. Another note-worthy reason to consider alternative fuels is the risk of continued reliance on oil, relative to global climate change, a problem more recently appreciated. Therefore, these negative effects of fossil fuels on environment and decreasing reserves increase the studies on new fuel types that can be used in motor vehicles [21][22]. It has also been reported that ethanol programme in Nigeria is expected to improve automotive exhaust emission in the country, reduce domestic use of petrol and free up more crude for export and position Nigeria for the development of green field fuels [23].

Bioethanol fuel is simple to use, biodegradable, non-toxic and essentially free of sulphur and aromatics [24]. Bioethanol fuels are virtually inexhaustible, and domestically produced from agricultural resources. It is also oxygenated, thereby providing the potential to reduce particulate emissions in compression-ignition engines [4]. Bioethanol can be used directly on its own as in hydrous ethanol (95% purity) or as an anhydrous ethanol (99.5% purity) blended with gasoline [23]. Interestingly, the blends achieve the same active boasting (or anti-knock effect) as petroleum-derived aromatics like benzene or metallic additives like tetraethyl lead. Researches have increased over the years on how to extract ethanol in commercial quantity from non-edible agricultural products [5][25][26][27][28][29][30]. Eventually, the success in this field of research will go a long way to increase the prospects of ethanol as an essential biofuel component. Of course, the benefits are numerous, one which include checkmating rising global pollution and incessant increases in prices of potential agricultural products. Alternative source of energy derivable from ethanol (bioethanol) other than from edible agricultural products involves studies on juice extracts from non-edible plants such as *costus afer, pennisetum purpureum* and juice extracts from non-edible fruits and seeds of forest products among others. Cellulose materials of some plant species which can undergo fermentation are also potential source of ethanol for biofuel purposes [7][31]. Promising new technologies are being developed that uses enzymes to break down cellulose and release the plants sugar for fermentation into ethanol.

Therefore, this research was focused on accessing the potential yield of ethanol from *costus afer*, *pennisetum purpureum* and *saccharum officinarum* and also determined its fuel qualities with premium motor spirit (PMS) blend. The PMS-ethanol blend quality of the biofuel was determined and changes in fuel properties as the blend ratio was varied from the standard were also determined.

Materials

MATERIALS AND METHODS

Samples of *saccharium officirarum* (sugar cane), *costus afer* (spiral ginger) and *pennisetum purpureum* (Napier grass) were collected from a water logged area in Uturu, Abia State, Nigeria. The yeast *saccharomyces cerevisiae* was obtained from the skins of a grapefruit and plum tree in a wild growing farm at Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria. Sucrose was obtained from BDH limited Poole England and sodium hydroxide (NaOH) was also obtained from BDH limited, Poole England.

Methods

1. Fermentation procedure

The samples were properly identified at the Department of Plant Science and Biotechnology, Abia State University Uturu, Abia State Nigeria. The samples were cut into bits and crushed in a mortar to form pulp. The pulps were transferred into three separate transparent 8 L buckets. Warm water was added to the pulp until it covered the entire pulp in the bucket. The water served as a solvent front that will aid in properly exposing the juice extract of the sample to yeast attack and effective fermentation 10 g of *saccharomyces cerevisiae*, a variety of fermentative yeast was mixed with the pulp and the content was thoroughly agitated. The buckets were properly covered so as to minimize attack by wild yeast on the juice extracts which could yield side reactions and undesirable products. After 48 hrs, pinches of sucrose were added to the pulp and the mixture thoroughly agitated. The aim of this was to catalyze the decreasing activities of the enzymes in the fermenting mixture.

2. Distillation of the Fermentation Syrup

On the fourth day, after which fermentation has ceased, following the drastic reduction of carbon (IV) oxide bubbles that evolved from the fermenting syrup, the fermented juice extract was filtered from the pulp. The filtrate was added to the distillation flasks in bits. Boiling chips (glass chips) were added also to the distillation flasks so as to reduce side swerving of the filtrate during boiling.

The ethanol was collected from the distillation flasks between 80° C and 90° C during the first distillation. In subsequent distillations, the ethanol was collected between 82° C and 84° C. The ethanol obtained was further purified by adding sodium hydroxide and allowing the mixture to stay over night.

3. Preparation of Ethanol – PMS blend and distillation

The ethanol-PMS blend was prepared using 95-5%, 90-10%, 85-15% and 80-20% composites respectively. This was done by measuring 95 mL of PMS and 5 mL of 98% ethanol produced and mixing the two solvents in a 500 mL volumetric flask, where the blend was thoroughly shaken to ensure homogeneity of the blend. The other blends were prepared following the same method.

Each of the respective blends was poured into 100 mL volumetric distillation flasks. Boiling chips were added to the blend in the distillation flasks. The flasks were coupled into the atmospheric distillation equipment where the blend was made to boil and the various distillate volumes with the corresponding temperature measured. The test criteria used was the American Standard Test Method (ASTM No D854), and the mode used include; initial boiling point (IBP), 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, distillate with their corresponding temperatures. End boiling point (EBP) and total recovered (TR) were measured appropriately.

4. Determination of other parameters

The specific gravity (S.G) of the ethanol, PMS and the blends were determined using a pycnometer model SG-16A 2000, by Gilson Company Inc. The refractive index of the ethanol, PMS and the ethanol-PMS blends were determined using a Palm Abbe digital refractometer model PA202. The percentage purity of the ethanol extract was computed by comparing the ratio of the specific gravity of ethanol extracted and ethanol in its purest form by the equation;

% purity = S.G. of ethanol extracted/ S.G. of pure ethanol (1)

The Reid vapour pressure (RVP) test was performed using the American standard Test Method (ASTM No D6751) [32].

RESULTS AND DISCUSSION

The reaction of the ethanol extract with NaOH was to remove any ethyl acetate formed in the ethanol mixture, so as to further purify the ethanol. The equation could be given as:

$$CH_3COOC_2H_5 + NaOH \rightarrow CH_3COONa + C_2H_5OH$$
 (2)

The boiling ranges for the three samples were 80-82, 88-90 and 90-92. The specific gravity (S.G) of the ethanol extract measured at 25° C was 0.7620 Kg/L. The S.G of pure ethanol is 0.7951 Kg/L. The percentage purity of the ethanol extracted after reflux distillations was found to be 95.8%. The refractive index of the ethanol was 1.3449 at 30°C. 1 Kg of sugar cane (*saccharin officinarum*) yielded 500 mL of ethanol; 1 Kg of spiral ginger (*costus afer*) yielded 279 mL of ethanol while 1 Kg of Napier grass (*pennisetum purpureum*) yielded 150 mL of ethanol.

The sample with the highest yield of ethanol was *saccharin officinarum*, followed by *costus afer* and then *pennisetum purpureum*. The reason for this is the varying starch and sugar content of the three samples. Another important factor that may have influenced the ethanol yield was the length of fermentation. As a result of the comparatively low sugar and starchy content of *pennisetum purpureum* and *costus afar*, it was difficult knowing when fermentation was completed, unlike *saccharin officinarum* whose fermentation process was vigorous because of the high sugar content. The highest yield of ethanol from the three samples was noted 3 to 4 days after which the evolution of carbon (IV) oxide stopped which is also an indication of complete fermentation. Fermentation process decreases as sugar and juice content of the various samples reduces [33]. During the fermentation period, enough oxygen was made available because complete exclusion of oxygen inhibits fermentation [34].

Analysis on the first run, collected above 80°C showed high percentage of water in the ethanol and impurities like acetaldehyde with a mixture of pungent volatile alcohols like ethyl and butyl alcohols. However, these impurities were removed by the aid of sodium hydroxide as shown earlier in Equation 2. The rest of the impurities were removed by reflux distillation until an ethanol with 95.8% purity was obtained. Pure ethanol was obtained by using benzene as an estrainer for water contained in the rectified spirit. This increased the purity of the ethanol after further distillation to 98% which was necessary for the ethanol-PMS blend.

The ethanol-PMS blend was prepared using 95-5%, 90-10%, 85-15% and 80-20% composites respectively. The premium motor spirit consists of a blend itself of three major components, which include Reformate, Naphtha and Straight run gasoline [26]. The reformate serves as the bulk fuel for combustion engines. The Naphtha aids in upgrading the octane property of the fuel and desirable energy characteristics such as high heat of combustion while the straight run gasoline improves the volatility characteristics of the fuel. During the blend, it was observed that ethanol mixed excellently well with PMS with little or no agitation. Prior to the analysis of the fuel qualities of this biofuel that is ethanol-PMS blend, a distillation analysis was run for a PMS obtained from a public fuel station. The result showed the octane number to be 90.3, the Reid vapour pressure to be 0.52 psi and the specific gravity to be 0.7468 Kg/L. The distillation data result showed an initial boiling point (IBP) of the distillate to be 38°C. For 5 mL, 10 mL, to 90 mL, the temperature increased uniformly except at 40 mL and 50 mL distillate where the temperature value jumped from 87°C to 104°C. The end boiling point was observed at 194°C and total recoverable distillate was 97% by volume. This is shown in Figure 1 below.



For the 95-5% PMS-ethanol blend, the IBP was observed at 39°C, 1°C higher than that of pure PMS. The other blends showed IBP of 41°C, 41°C and 42°C for 90-10% blend, 85-15% blend and 80-20% respectively. The temperature of the various blends increased uniformly as the distillate volume increased from 99°C to 112°C for the 95-5% blend. For 90-10% blend, the temperature also increased gradually until at 50-55 mL distillate where the temperature jumped from 87°C to 108°C. For the 85-15% blend, the temperature increased uniformly with increase

Jude C. Igwe et al

in the distillate volume until at 60 mL to 65 mL distillate where the temperature again jumped from 98°C to 111°C. Finally, for the 80-20% blend, the temperature also like the other blends increased uniformly with increase in distillate volume until at 60 mL to 65 mL distillate, where the temperature again jumped from 99°C to 114°C. Figure 2 below depicts the variations of distillate volume with respect to temperature changes during the distillation analysis of the various blends.



It could be observed after careful examination of the distillation data that after a certain distillate volume, anomalous changes in temperature occurred. It was also observed that this distillate volume boundary moved progressively upwards from 40 mL to 50 mL in the pure PMS to 60 mL - 65 mL in the 80-20% blend. The reason for this variation in temperature changes at certain distillate volume after a careful study of the results showed that PMS which readily boil in the ethanol-PMS blend get distilled faster than the ethanol after a particular point, resulting in the increase in temperature range due mainly to the higher heat content of ethanol.

Table 1:	Overview	of ethanol -	PMS	blend	result
----------	----------	--------------	-----	-------	--------

Doromotor (units)	Pure PMS	Ethanol-PMS blend %			
rarameter (units)		95-5	90-10	85-15	80-20
RON	90.30	91.40	91.48	91.50	91.52
RVP (psi)	0.52	0.49	0.486	0.484	0.482
S.G (Kg/L)	0.7468	0.7470	0.7471	0.7473	0.7475
IBP (°C)	38	39	41	41	42
EBP (°C)	194	188	192	180	185
T/R (%)	97	97	98	98	98

The results from this ethanol-PMS blend has shown that ethanol could be blended with gasoline in the ratio of 5-95%, 10-90%, 15-85% and 20-80% by volume respectively with little or no agitation. Of course, this blend could further be varied even until a pure ethanol fuel is used in internal combustion engines. An overview of the properties of the ethanol-PMS blend results are shown in Table 1 below. It could be seen that the Rated Octane Number (RON) property of the fuel blend varied by a difference of 1.22 units from pure PMS to 20-80% by volume of ethanol-PMS blend. This is against opponents of biofuel whose fear or argument centers on the drastic reduction of octane number of the fuel, one of the most important factors used in rating a good fuel. Tandon *et al* [4] reported higher values for the octane rating of alcohol and that to reap this advantage; the compression ratio of the engine has to be increased to about 12:1. The results from this study also showed that the difference in initial boiling point (IBP) of PMS blend, that is the 20-80% ethanol-PMS blend is only 4°C, implying that little or no modification need to be done to the combustion engines. Also, little variation was observed in the specific gravity (S.G) values from that of pure PMS to 20-80% ethanol-PMS blend, the value being only 0.0007 Kg/L.

The end boiling point (EBP), that is the point at which the thermometer reading was maximum during the distillation analysis varied only slightly from 194°C to 185°C. The Reid vapour pressure (RVP) of the fuel varied significantly from 0.52 psi for pure PMS to 0.482 psi for the 20-80% ethanol-PMS blend. The extent of its significance arises because of the limiting volatility of any good fuel which it must posses in order to combust uniformly and readily. The total recovery (TR) of the various blends was as high as that of the pure PMS. The total recovery is the total volume of distillate recovered after the distillation analysis. It is a quality control criterion and helps in determining the purity of the fuel as regards to total combustible or volatile matter present in any fuel. Unlike previous reports where agitation was known to have been employed during blend preparation of ethanol-PMS blend, this study has illustrated the excellent blending property of ethanol with PMS even without agitation. This was achieved by using very pure ethanol for the blend preparations. It was observed that little contamination of the ethanol-PMS blend will lead to phase separation, two distinct layers separating PMS and ethanol.

CONCLUSION

The potential source of raw materials for the production of ethanol involves many plants containing carbohydrates in the form of sugar or starches which can be subjected to fermentation. Alcohol fuels as anti-knock blending agents were known long before tetraethyl lead was discovered and their technical qualities have been well characterized. The best part of biofuel is that they are free of sulphur and aromatics, something that cannot be said of traditional fuels. Also, biofuel is not like other alternative fuels that are available today. It is the only alternative fuel that has passed all the health effects testing requirements of the clean Act Amendment. Biofuel that is ethanol-PMS blend in this respect is much better for the environment than the traditional fossil fuel. Bioethanol is made from renewable resources making it a wise fuel choice and ensuring the protection of our environment for future generation. It also has significant lower emissions compared to the petroleum diesel that is still widely used today. Bioethanol is worth studying when one considers the threatening global problems resulting from combustion of fossil fuel. Well established researches have shown that fossil fuel burns cleaner in the presence of ethanol blend. Increasing the role of ethanol in meeting fuel demand will require on-going research and development to improve biomass-ethanol conversion technologies, along with consistent legislative supports for biofuel production and greater fuel efficiency in the automotive industry.

Acknowledgement

The authors are grateful to the management of the Nigeria National Petroleum Corporation (NNPC) for granting us access to their laboratories through K.E. Agbaeze for the experiments.

REFERENCES

- [1] A. A. Refaat, N. K. Attia, HA Sibak, ST Elsheltawy, GI El Diwani, Int. J. Environ. Sci. Tech. 2008, 5, 1, 75-82.
- [2] A. N. Ozsezen, M. Canakcy, A. Turkcan, C. Sayyn, Fuel, 2009, 88, 4, 629-636.
- [3] S. Çaynak, M. Guru, A. Bicer, A. Keskin, Y. Ycingur, Fuel, 2009, 88, 3, 534-538.

[4] A. Tandon, A. Kumar, A. Mondal, P. Vijay, U. D. Bhangale, D. Tyagi, *British J. Environ. Climate Change*, **2011**, 1, 2, 28-43.

- [5] O. K. Agwa, S. N. Ibe, G. O. Abu, J. Microbiol. Biotech. Res, 2012, 2, 1, 35-45.
- [6] A. U. Ofoefule, O. D. Onukwuli, Adv. Appl. Sci. Res., 2010, 1, 3, 98-105.
- [7] M. Mahalakshmi, J. Angayarkanni, R. Rajendran, R. Rajesh, Annals. Biol. Res. 2011, 2, 3, 380-388.
- [8] K. Zhang, H. Feng, Afr. J. Biotechnol., 2010, 9, 37-41.
- [9] K. Balasubramanian, V. Ambikapathy, A. Panneerselvam, J. Microbiol. Biotech. Res., 2011, 1, 4, 158-163.
- [10] F. Ma, and M. A. Hanna, Bioresour. Technol., 1999, 70, 1, 1-15.
- [11] C. Bhushan, P. Hiren, P. Mayank, D. Bharatkumar, J. Microbiol. Biotech. Res., 2012, 2, 1, 90-93.
- [12] A. Altun, H. Bulut and C. Öner, Renew. Energ., 2008, 33, 8, 1791-1795.
- [13] B. Freedman, R. O. Butterfield, E. H. Pryde, J. Am. Oil. Chem. Soc., 1986, 63, 10, 1375.
- [14] A. B. H. Singh, J. Thompson, J. Van Gerpen, Appl. Eng. Agric., 2006, 22, 4, 597-600.
- [15] P. Mondal, A. Kumar, V. Agarwal, N. Sharma, P. Vijay, U. D. Bhangale, D. Tyagi, *British J. Environ. Climate Change*, **2011**, 1, 1, 1-12.
- [16] K. J. Shashi, K. Sunil, C. Alok, Arch. Appl. Sci. Res., 2011, 3, 1, 425-435.
- [17] M. F. Demirbas, *Energy Sources*, **2006**, 28, 779-792.
- [18] M. Rakin, L. Mojovic, S. Nikolic, M. Vukasinovic, V. Nedovic, Afr. J. Biotechnol., 2009, 8, 3, 464-471.
- [19] U. D. Bhangale, P. Mondal, British J. Appl. Sci. Technol., 2011 1, 1, 1-9.
- [20] V. K. Tewari, P. Mondal, British J. Appl. Sci. Technol., 2011 1, 1, 10-15.

[21] Y. Çevik, C. Bulut, M. Karabekta, G. Ergen, 10th International Combustion Symposium Sakarya, Turkey, **2008**, 9-10 October.

[22] F. Aksoy, Int. J. Environ. Sci. Tech., 2011, 8, 1, 57-62.

[23] Port Harcourt Refinery Company (PHRC), An In-House Quarterly Publication, PHRC combined 1st Edition, **2006**, 142.

[24] A. Agarwal, Progress in Energy and Combustion Science, 2007, 33, 233-271.

[25] B. L. Maiorella, H. W. Blanch, C. R. Wilke, Biotech. Bioeng., 1984, 26, 1003-1025.

[26] D. Greg, J. Saddler, Biomass Bioenergy, 1995, 9, 287-302.

[27] A. Sakurai, Y. Nishida, H. Saito, M. Sakakibara, J. Biosci. Bioeng., 2000, 90, 526-529.

[28] L. Mojovic, S. Nikolic, M. Rakin, M. Vukasinovic, Fuel, 2006, 85, 1750-1755.

[29] M. Rakin, L. Mojovic, S. Nikolic, M. Vukasinovic, V. Nedovic, In: Proceedings of the 15th European Biomass conference & Exhibition from Research to market Development. CD Edition, **2007**, 2058-2063.

[30] S. Plessas, A. Bekatorou, A. A. Koutinas, M. Soupioni, I. M. Banat, R. Marchant, *Bioresearch Technol.* 2007, 98, 860-865.

[31] M. Meo, Res. Conserv., 1984, 11, 1-25.

[32] American Society for Testing and Materials (ASTM), Standard Specification for Biodiesel fuel (B100) Blend stock for Distillate Fuels, Designation D6751-02, **2002**, ASTM International, West Conshohocken, PA.

[33] Y. Kourkoutas, A. Bekatrou, I. M. Banat, R. Marchant, A. A. Koutinas, Food Microbial. 2004, 21, 277-397.

[34] C. M. S. G. Baptista, J. M. A. Coias, A. C. M. Oliveira, N. M. C. Oliveira, J. M. S. Roche, M. J. Dampsey, K. C. Lannigan, P. S. Benson, *Enzyme Microb. Technol.* **2006**, 40, 127-131.