A CONDITIONAL SCIENTIFIC INVESTIGATION ON THE POTENTIAL OF BIOETHANOL PRODUCED FROM PINEAPPLE PEEL WASTES AS A BIOCOMPONENT FOR AVIATION GASOLINE

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Abstract

Due to the global energy problem and limited availability of fossil fuels, renewable energy is gaining traction. Nowadays, researchers are focusing in producing bioethanol from crops and agricultural wastes, and the researchers aimed to utilize pineapple peel waste biomass in this study for effective bioethanol production as it provides a fermentable feedstock that can easily be converted into alcohol. A total of 3 liters of extract was generated from 9 kilograms of pineapple peels. A fermenting isolate of broth culture, Saccharomyces cerevisiae, was employed in the fermentation media. Sugar and alcohol content of the embryonic sample was monitored during and after the fermentation, respectively. The Heidolph Hei-Chill 250 rotary evaporator (RotaVap) was used to distill and purify the dilute bioethanol broth, which was then used to oxygenate the Avgas 100LL. Results of the ethanol-admixtured gasoline were derived from limited parameters; sulfur content was analyzed using a Monochromatic Wavelength Dispersive X-ray Fluorescence (MWDXRF), vapor pressure at 37.8 °C was analyzed using a triple expansion tester called Eravap, and the density at 15 °C was investigated using a densitometer. The mixture yielded a result of 3.3 ppm, 40.0 kPa, and 0.7181 kg/L, respectively. It was found that the optimized process parameters of the admixture met the standards for PNS/DOE ASTM and was established that pineapple peel bioethanol is compatible for Avgas blending concerning the above parameters. The results obtained in this study can further be reinforced through elaborate characterization and optimization of the immobilized confoundants to compare different bioethanol and Avgas criteria.

Keywords. Bioethanol, Pineapple (Ananas comosus) peels, Saccharomyces cerevisiae, biofuel, renewable energy

Introduction

In recent times, the world population has depended heavily on fossil fuels and their derivatives. Burning fossil fuels such as oil, coal, and gas to meet energy needs produces large carbon footprints and thus, contributes to the global warming crisis. In 2020, the global airline fleet consumed 360 billion liters of fossil fuels and pumped more than 900 million tons of carbon emissions into the atmosphere (Boyd, 2020). The dramatic increase in global aviation has even made the industry dominate the top emitters of carbon footprint (Klöwer et al., 2021). The study also revealed that the aviation industry could consume up to one-sixth of the remaining temperature budget to limit warming to 1.5 ˚C by 2050 (see Supplementary material1). It is clear that the intensive utilization of fossil fuels is unsuitable due to its adverse environmental impacts such as the rise in greenhouse gases (GHG). These impacts have lent new urgency to the quest for clean, renewable fuels.

Researchers today have tended to various sustainable feedstocks as renewable source of energy, and ethanol has been one of the focuses in studies. Bioethanol is the most excessively used biofuel for transportation in the world. Because lignocellulosic biomass2 such as pineapple peels is abundant and inedible, it is thus preferable for the production of bioethanol (Kumar et al., 2019). Hence, the researchers have turned their focus to analyzing the potential of pineapple peels in becoming a viable biocomponent of aviation gasolines. Based on the foregoing background, this paper attempts to design and verify this potential by investigating on select properties of the bioethanol and aviation gasoline mixture.

Some advantages of bioethanol are reduced emission of nontoxic materials and zero emission of hazardous gases reduces the risks of global warming, thus making it environment-friendly, non-toxic, biodegradable, and provides for efficient combustion due to its high oxygen content, and non-presence of sulfur or aromatics (Malode et al., 2021). This may be the key to sustainable air travel, contributing immensely to the industry's emissions-reduction strategy. The International Air Transport Association (IATA) defines biofuel as:

> 'Biofuels' typically refers to fuels produced from biological resources (plant or animal material). However, current technology allows fuel to be produced from other alternative sources, including non-biological resources; thus, the term is adjusted to highlight the sustainable nature of these fuels. (n.d., p. 1)

Developing biofuels will provide the aviation industry with an alternative to petroleum-based fuels, enable the industry to reduce its carbon footprint by reducing its lifecycle greenhouse gas emissions by up to 80% compared to fossil fuels without significant changes to fuel supply systems or engines, allow it to draw upon a variety of different fuel sources, and be easier to implement than for other transport modes.

The sustainability of this study can be established in the long term because the source material comes from waste biomass. This said, the conflict between food and fuel in this study can be waived as the source material does not compete with the production of food and does not consequently affect the reduction of food supply besides increasing food prices.

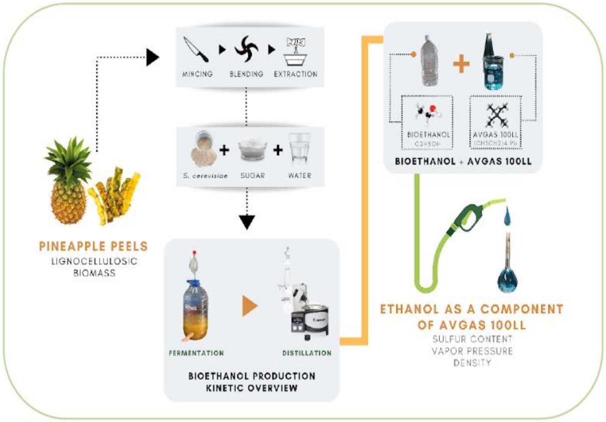
This paper first gives an overview of the extensive impacts of the reliance on petroleum-based fuels and then goes on to discuss the biomass used in bioethanol production. In this study, the researchers hypothesized that bioethanol produced from pineapple peel wastes can be used as a component of aviation gasoline concerning certain parameters namely sulfur content, density and vapor pressure. Fermentation, distillation, along with the analysis of mobilized properties of the bioethanol and aviation gasoline mixture were used to test this hypothesis. To the best of the researchers' knowledge, while there have been several studies on the production of bioethanol from pineapple peels, no attempts have been made on seeking the potential of bioethanol produced from pineapple peels as a biocomponent of aviation gasoline to date.

Materials and Methods

In this study, the experimental research method was utilized to discover valid results or conclusions. It is possible through this method to gather systematic data on the properties of bioethanol and aviation gas admixture and to determine if these satisfy the specific requirement limits of the mixture set forth by the Philippine National Standards and the Department of Energy in accordance with American Society for Testing and Materials specifications.

The admixture underwent certain tests to come up with a proposed understanding of the results which will either prove or refute the research hypothesis. A qualitative analysis was used to provide a detailed interpretation and in exploring the behavior of the primary data gathered.

Project Development



Sample gathering and procedures

A total of 9 kg of pineapple peels were minced using a blender (NutriBullet 1000W) for 1 minute per 200 g. Minced pineapple peels were put inside a muslin cloth and were manually pressed in order to obtain liquid extract to a maximum. The cloth was also used to sieve the extract from pineapple peel debris. To prevent microbial spoilage, they were stored in a refrigerator prior to fermentation.

Fermentation

The three liters of pineapple peel extract were stored in an anaerobic container with the addition of ¼ teaspoon of dry yeast S. cerevisiae per liter of the solution, 1.5 kg of sugar, and two liters of water. This initial mixture was then pasteurized and fermented for a total of six (6) days. An air lock was installed on top of the plastic container in order to prevent the introduction of oxygen into the dilute ethanol broth. Sugar content was observed on the first and fifth day of the fermentation process while the alcohol content was observed on the last day.

Distillation

The distillation of the sample was conducted using a Heidolph Hei-Chill 250 rotary evaporator (RotaVap). The dilute ethanol broth was then distilled at 84 degrees centigrade in order to remove water and concentrate the ethanol in its purity. At the conclusion of the distillation process, a total of 260 mL of anhydrous bioethanol was obtained.

Blending Process

The anhydrous bioethanol obtained from the fermented dilute ethanol broth was blended with the 100LL (low lead) aviation gas. Utilizing a blend of 10% bioethanol per 90% of aviation gas, 50ml of bioethanol was mixed with 450ml of the 100LL aviation gas. The aviation gas was then poured into a volumetric flask together with the bioethanol and thoroughly agitated in order to maintain proper distribution.

Testing and Analysis

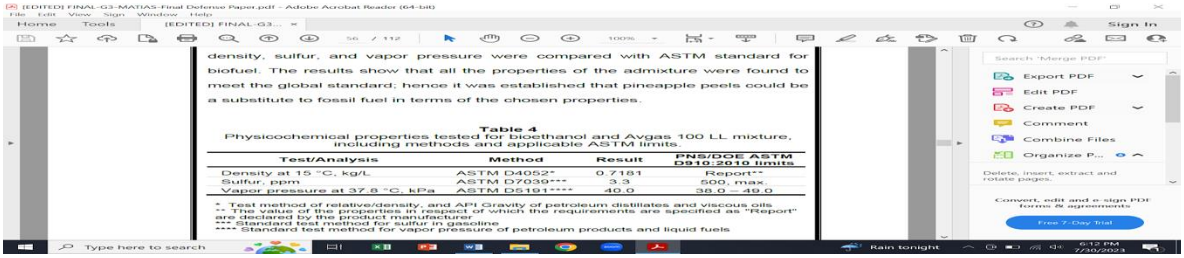
To follow the fermentation development and ensure accurate results, it was necessary to quantify the sugar and ethanol concentration on the dilute ethanol broth. A refractometer was utilized to monitor the sugar content (in degrees Brix) of the solution before and after the fermentation process. The alcohol content was obtained using an ebulliometer. The Heidolph Hei-Chill 250 rotary evaporator (RotaVap) was used to distill and purify the content by separating the components of the admixture at 84 degrees centigrade.

The sulfur content of the Avgas 100LL and bioethanol admixture was analyzed using a Monochromatic Wavelength Dispersive X-ray Fluorescence (MWDXRF) in compliance with ASTM D7039. The vapor pressure was analyzed using a triple expansion tester called Eravap in compliance with ASTM D5191. The density was analyzed using a Densitometer in compliance with the standards of ASTM D4052.

Results and Discussions

Table 1

Physicochemical properties tested for bioethanol and Avgas 100 LL mixture, including methods and applicable ASTM limits



density, sulfur, and vapor pressure were compared with ASTM standard for biofuel. The results show that all the properties of the admixture were found to meet the global standard; hence it was established that pineapple peels could be a substitute to fossil fuel in terms of the chosen properties.

Table 4

Physicochemical properties tested for bioethanol and Avgas 100 LL mixture, including methods and applicable ASTM limits.

Test/Analysis	Method	Result	PNS/DOE ASTM D910:2010 limits
Density at 15 °C, kg/L	ASTM D4052*	0.7181	Report**
Sulfur, ppm	ASTM D7039***	3.3	500, max.
Vapor pressure at 37.8 °C, kPa	ASTM D5191****	40.0	38.0 – 49.0

* Test method of relative/density, and API Gravity of petroleum distillates and viscous oils
** The value of the properties in respect of which the requirements are specified as "Report" are declared by the product manufacturer
*** Standard test method for sulfur in gasoline
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The bioethanol-admixture Avgas was experimentally tested and yielded 0.7181 kg/L in density at 15 °C according to standardized procedure in ASTM D4052. The sulfur content was found to be 3.3 parts per million (ppm) in compliance with the ASTM D7039 method. The ASTM D5191 method was used to determine the vapor pressure of the mixture at 37.8°C which yielded a result of 40.0 kPa.

Table 2
Comparison of the properties obtained from bioethanol and standard specification value of Avgas 100LL with PNS/DOE ASTM D910:2010 limits

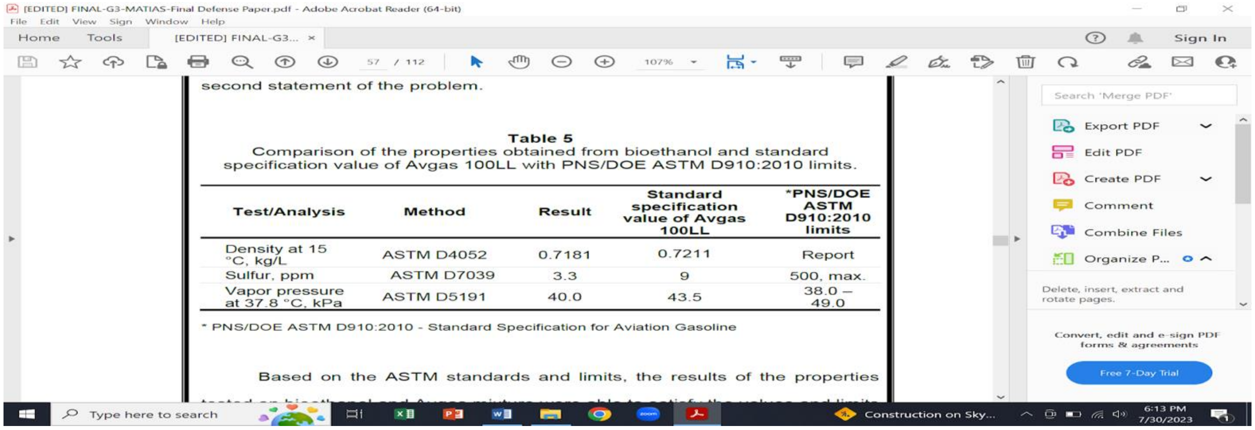

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Table 5
Comparison of the properties obtained from bioethanol and standard specification value of Avgas 100LL with PNS/DOE ASTM D910:2010 limits.

Test/Analysis	Method	Result	Standard specification value of Avgas 100LL	*PNS/DOE ASTM D910:2010 limits
Density at 15 °C, kg/L	ASTM D4052	0.7181	0.7211	Report
Sulfur, ppm	ASTM D7039	3.3	9	500, max.
Vapor pressure at 37.8 °C, kPa	ASTM D5191	40.0	43.5	38.0 – 49.0

* PNS/DOE ASTM D910:2010 - Standard Specification for Aviation Gasoline

Based on the ASTM standards and limits, the results of the properties

* PNS/DOE ASTM D910:2010 - Standard Specification for Aviation Gasoline

Based on the ASTM standards and limits, the results of the properties tested on bioethanol and Avgas mixture were able to satisfy the values and limits of the standard specifications of Avgas 100LL. The test results must not exceed the maximum or fall below the minimum values requirement specified in Table 2. These properties must be carefully balanced to provide a suitable engine performance across a wide variety of conditions. Thus, any adverse effect on engine performance will be prevented.

Density Assays

Since the density of a liquid varies as its temperature changes, the scale is usually adjusted to a certain temperature, usually about 15 °C, at which determinations must be made. The density of the mixture measured at this temperature was determined to be 0.7181 in kg/L.

It is worth mentioning that the relative difference in comparison means that in terms of density, a conventional Avgas, being a less dense fuel, is preferred more than its oxygenated counterpart. This is because it has a higher energy content per unit weight and a lower energy content per unit volume. It is general knowledge that as density increases, the energy per unit volume increases as well. The amount of energy contained in a particular mass determines how far an engine can run with a given fuel. While the change in value is relatively low than the density of the conventional Avgas, the density of the admixture still meets the typical density of the fuel at the same temperature, which complies with the PNS/DOE ASTM D910:2010 limits.

Sulfur Content Assays

It was found that the oxygenated Avgas yielded a sulfur content of 3.3 ppm. This is far less than the typical sulfur content of a conventional Avgas amounting to 0.0009 mass percent (% m/m) or 9 ppm. It has been pointed out by

Ciolkosz that blends are sometimes used to improve the lubricity of petroleum diesels or reduce its sulfur content (2020).

Sulfuric acids are the most corrosive acids produced when high sulfur fuel is used. The total sulfur content of aviation fuels is crucial because the sulfur in fuel generates particles after combustion in the engine, which makes it a major source of air pollution and can cause corrosive wear on the metal surfaces of the engine.

In order to prevent harmful emissions of sulfur, limits have been imposed by government regulations. For the last decade, reduction of sulfur content in gasoline and diesel fuel has been a global trend, with several countries mandating near-zero sulfur emissions. The current global regulatory standard for aviation fuel is a maximum Fuel Sulfur Content of 3000 ppm (Ministry of Defence, 2011; ASTM International, 2012 as cited in Kapadia, ZZ., et al. 2016).

As bioethanol is not a significant source of sulfur content in fuels, and where a requirement limit of 10 ppm sulfur content must be met, the blend could be more environmentally friendly as the sulfur content of the admixture was lower in comparison to conventional aviation gasoline. Furthermore, less sulfur content is beneficial as it constitutes to less probability of corrosion and rust, which in time, is detrimental to the performance, durability and the airworthiness of the engine being used. The harmful emissions of sulfur are also reduced, which lessens the environmental impacts, such as air pollution.

Vapor Pressure Assays

Results showed that the vapor pressure of the mixture produced a yield of 40.0 kPa at 37.8 °C. The value is within the PNS/DOE ASTM D910:2010 limits at 38.0 – 49.0, and below the vapor pressure of a conventional Avgas 100LL at 43.5 kPa. It satisfied the required minimum vapor pressure and enforced the condition that it is volatile enough to vaporize under cold start conditions. This shows that there was a relative decline in the amount of vapor pressure in the two samples. The decline in vapor pressure when bioethanol was blended indicates that there is a lesser tendency for the compound molecules in the mixture to escape the vapor phase because of the presence of great bond among molecules. With this, the mixture has lesser tendency to block the fuel line or interrupt the fuel flow, causing vapor lock in the engine. Furthermore, because the conventional Avgas has higher vapor pressure compared to the mixture, it is more volatile and thus increases the risk of occurring vapor lock, icing, and boil-off issues.

Conclusion

Petroleum products have long been the ideal transportation fuels because they provide the optimum mix of energy content, performance, availability, ease of handling, and price. However, the current rise in oil prices and the environmental impacts that the reliance on petroleum products has led the industry to consider alternatives.

The results discussed in this study were derived from limited parameters and a fermenting isolate of broth culture was employed in the fermentation media. Pineapple peels refuted the null hypothesis as the properties of bioethanol and aviation gas mixture is within the set PNS/DOE ASTM D910: 2010 limits. The findings could further be reinforced should all other properties indicated in Table 2 were tested. Should scientific comparison and parametric assays follow thereafter, this lignocellulosic biomass can finally have the notable capacity to deliver an energy output with the potential to mitigate climate change and present a renewable energy alternative that could help the aviation industry achieve its environmental goal, as well as strengthen the security of supply of a crucial commodity in the country for agriculturists and farmers.

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