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Bio-ethanol as an Alternative Green Aviation biofuel Blend for low Carbon (Greenhouse gas) Environmental Footprint: A Review.

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Abstract**:** *The bio-jet fuel manufacturing process is a process of manufacturing biomass-derived jet fuel that can replace the existing fossil-based jet fuel through fermentation of the hydrolyzed sugar by-product of the plant biomass. It includes an alcohol-to-jet (ATJ) process with bio-ethanol was encouraged by modification with essential aviation fuel additives to the advantages of the physicochemical properties under ASTM D7566 aviation specifications. The main characteristics of the contemporary jet fuel in terms of the boiling point, acid number, aromaticity, sulfur content, flash point, cetane index, freeze point, viscosity and heat of combustion were compared with bio-ethanol with seven sub-components (Anti-Knock, anti-oxidant, static dissipater, corrosion inhibitors, fuel system Icing inhibitor, biocide, and thermal stability) as additives that can actively engage bioethanol as an aviation fuel source with zero greenhouse gasses possibility*.

Keywords: Bio-ethanol, bio-Jet fuel, plant biomass, aviation fuel & greenhouse gas.

1.0 Introduction

Bio-alcohol is an environmentally benign and renewable fuel derivative. It is an approach that controls greenhouse gases that is due to the burning of fossil fuels. Bio-alcohol covers different analogs especially as bio-ethanol that is commercially exploited to substitute the existing hydrocarbon fuels and to other sources of fuel [1]. Bioethanol is generally termed as bio-alcohol with the perspective of direct global contribution as bioethanol is majorly considered in the current research study for production technologies to other fuel formulations [2]. Conversely, as food-oriented feedstock orchestrate negative ecological effects, technical resolutions with the adoption of the nonfood-based production processes are required. Ethanol through lignocellulosic materials includes the application of chemical hydrolysis against the complex chemical attachment of biomass feedstock to enhance the conversion rate. Nonetheless, the cost of production derived from pre-treatment process innovation with the catalyst demand for bio-treatment techniques is another technological obstacle that has to be addressed by the entire production procedures. The USA significantly utilizes 14.4 billion gallons of bio-ethanol annually in the global scene while in the other words both the USA and Brazil are identified for their global bio-ethanol production [3].

1.1 Bio-jet fuel in the Aviation sector

The latest fuel consumption analysis submits that twelve percent of transportation gas is attributed to the aviation sector with two percent of greenhouse global ecological pollutions. In accordance with the 2015 Paris Climate Change Agreement, advance performance, low-carbon energetic source with the rate of fuel consumption in aviation industries are predicted, and such efforts are in progress in various related fields [4]. Airlines and manufacturers voluntarily set desires for balanced carbon objectives with a 50% reduction of greenhouse gases by 2050 in connection with 2005 standards. Generally, solar energy, hydrogen fuel, and electricity are considered as resources of low-carbon energy in transportation [5]. That is, with aviation activities, the handiest technically feasible manner is limited to bio-jet gas and its usage. Consequently, sustainable carbon management can be made viable via the increased consumption of bio-jet gasoline. It has been identified that the reduction of 1.5 percent gasoline is reportedly viable by using both the usage of bio-jet gas, optimization of the airport facility, and flight paths [6]. The most professional method to diminish carbon emissions is to develop biomass-based fuels with their production technologies as most international airlines have released pilot oriented tasks for their utility feasibility. Meanwhile, as the economic feasibility is quite pronounced, issues inclusive of securing financial feasibility, technology development for aviation biofuels, adopting general global standards, imparting incentives for using biofuels, setting up carbon emissions desires and policies for international airlines, and bio-jet gas market in line with the ICAO mandate for the Commission for Aviation Environment Protection (CAEP) with the efforts to reduce aviation greenhouse fuel emission [7].

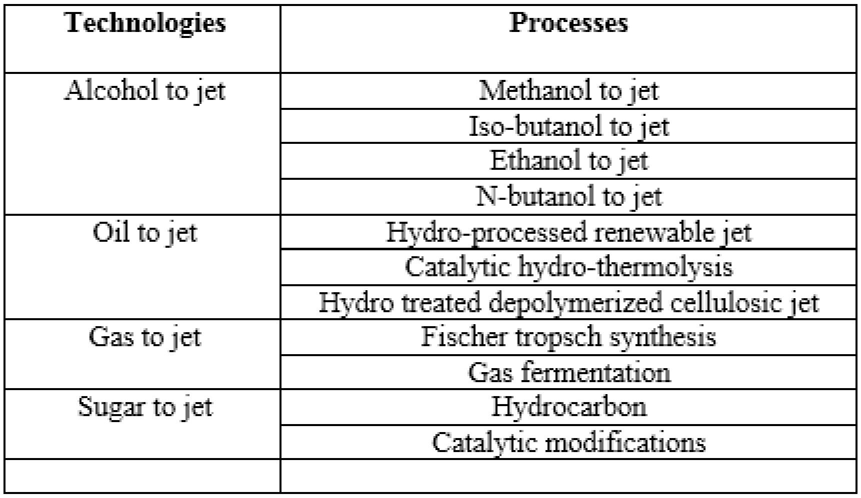
The 38th ICAO conference accepted the prominence of aviation biofuels as against GHG emission with a global framework that ensures the possibility of sustainable aviation biofuel generation [8]. The IATA publicizes the use of energy from renewable sources as the most dependable means that fulfill its greenhouse gas reduction objectives and requires to substitute six percent of renewable aviation fuel requirements [9]. The diverse biofuel guide policies are being promoted by means of dissemination of information that biofuels can make a contribution to greenhouse gas emission reduction, power security enhancement, rural profits, and new market improvement [10]. These aid policies consist of tax exemptions for biofuels in most countries, along with budgetary assist that entail tax exemption and direct subsidies to biofuel manufacturers, sellers, and users with minimum blend ratios, and import tariffs on imported biofuels [11]. In addition, subsidies are being used to help bio-fuel dissemination, resulting in $ 20 billion in grants from governments around the world in 2009, on the whole within the US and EU countries [11].

1.2 Classes of bio-jet fuel

Descriptive production technology for bio-jet gas comprises of oil-to-jet (OTJ), gasoline-to-jet (GTJ), and sugar-to-jet (STJ) and alcohol-to-jet (ATJ) methods. OTJ technique produces bio-jet fuel from animal or plant tallow along with waste vegetable oil, pork tallow, and microalgae [12]. More especially, hydro treated esters and fatty acid (HEFA) techniques, a type of OTJ method, encompasses hydro treated renewable jet (HRJ) techniques among HEFA technology, catalytic hydro-thermolysis (CH), and fast thermal decomposition process (HDCJ). STJ system entails catalytic upgrading and conversion of glucose- or starch-based raw material to hydrocarbons or biological conversion to bio-jet fuel via direct sugar to hydrocarbons (DSHC) and catalytic upgrading. ATJ entails the manufacturing of bio-jet gas through hydrolysis of wooden fiber biomass or glucose into intermediate alcohols (methanol, ethanol, butanol, and fatty acid alcohols), dehydration, and oligomerization. It is split into ethanol-to-jet or butanol-to-jet technology, relying on the nature of the alcohol. GTJ system entails biogas, natural fuel, or syngas from timber fiber biomass to bio-jet gas via bio-chemical or thermos-chemical routes consisting of fuel fermentation and Fischer-Tropsch strategies [12].

Figure 1. Biofuels global market trends and forecasts [13].

Table 1 Production technologies for bio-jet fuel [14].



Technologies	**Processes**
Alcohol to jet	Methanol to jet
	Iso-butanol to jet
	Ethanol to jet
	N-butanol to jet
Oil to jet	Hydro-processed renewable jet
	Catalytic hydro-thermolysis
	Hydro treated depolymerized cellulosic jet
Gas to jet	Fischer tropsch synthesis
	Gas fermentation
Sugar to jet	Hydrocarbon
	Catalytic modifications

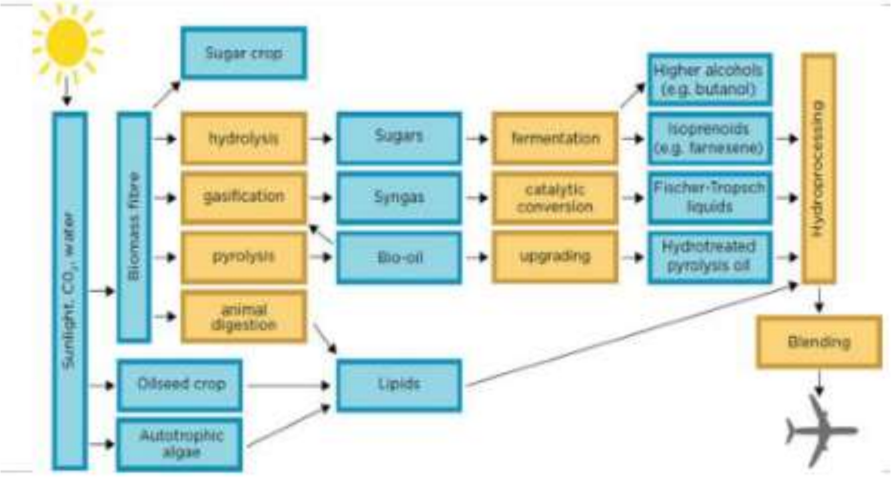


Figure 2. General overview for bio-jet fuel.

In view of its modern production and consumption with worldwide use. As bio-ethanol is mixed to a maximum of 10~15% with gas despite the fact that as the potential marketplace of ethanol for blending with gas appears restrained, expansion and conversion to bio-jet gasoline via bio-ethanol upgrading suggests the opportunity of replacing existing petroleum-primarily based aviation gasoline [16]. Therefore, for many classification methods, bio-jet fuel is divided through manufacturing pathways of fermentation, deoxidation, or thermal decomposition. As of 2016, ASTM 7566 dictates five manufacturing approaches (Fischer-Tropsch Synthetic Kerosene with Aromatics (FT-SPK), HEFA, Synthesized Iso-Parsons (SIP), and ATJ) as means to supply commercially possible bio-jet fuels. It concurrently regulates product standard criteria of 100% assay in addition to mixing proportion in current petroleum-based aviation gasoline. Many other production strategies also are used to supply bio-jet fuel, and the following technologies are beneath assessment by means of ASTM for approval. [15].Bio-ethanol is widely commercialized as a sustainable source of energy to be used in transportation with international production of 104 million m3 and 80% of its fraction as a transportation fuel. The USA and Brazil accounted for 51.8 to 78 million m3 respectively. Worldwide bio-jet fuel amounted to 30 billion m3 with the feasible raw feedstock for the ATJ process consists of methanol, ethanol, and butanol [12]. Such alcohol-primarily based feedstock is converted to bio-jet fuel through polymerization and modification [12]. Among these alcohols, bio-ethanol usage is promising the conversion of bio-ethanol to bio-jet gasoline, the physicochemical parameters of bio-ethanol should be compatible with petroleum-based aviation gas. As a case, the united states is utilizing advanced ATJ generation to make physicochemical homes of bio-ethanol well matched with those of existing petroleum-primarily based gasoline as more specifically, 99.5~99.9% of anhydrous ethanol is blended with current fuel or transformed into bio-jet gasoline [12]. High purity ethanol is used as a feedstock for upgrading the physicochemical parameters of bio-jet fuel. Technically, the ATJ technique is primarily based on bio-ethanol for the manufacturing of bio-jet fuel, as the oxygen contents of bio-ethanol are removed via dehydration, polymerization for dehydration, polymerization of carbon atoms from petroleum-based aviation fuel, and hydrogenation reaction for properties optimizations. [12].

1.3 The concept of Bioethanol as fuel

Bioethanol is the major fuel substitute as a renewable alternative in transportation. It is specifically produced by sugar fermentation procedure and by chemical reaction of ethylene with steam. The principal sources for sugar raw feedstock come from fuel or energy-packed plants. These plants that include corn, maize, wheat vegetation, waste straw, willow, and poplar timber, sawdust, reed canary grass, wire grasses, and sorghum plants are grown especially for active and direct applications. There is likewise ongoing research and improvement in the usage of municipal stable wastes to provide ethanol gas [24]. Bioethanol with a clear colorless, biodegradable, and low toxicity solution or liquid that does not allows ecological pollution if spilled. Ethanol burns to provide water-carbon (ll) oxide with an excessive octane gas that has replaced lead as an octane enhancer in petrol. Blending ethanol with petro based fuels can effectively oxygenate the mixture aggregate for complete reduction with polluting emissions. Ethanol fuel blends are widely bought in the US as the most commonplace combo is ten percent and ninety percent ethanol to petrol respectively (E10). Vehicle engines require no adjustments to run on E10 and car performances are unaffected additionally [17].

1.4 Advantages of Bioethanol as fuel

Bioethanol has a number of applications with merits over conventional fuels as it emanates from a renewable resource as identified above. Another landmark benefit of fossil fuels is greenhouse gas emissions as the transport sector accounts for 22% of all greenhouse gas emissions as bioethanol stands a position with the number of those emissions being significantly reduced [18]. Similarly, mixing bioethanol with fossil petrol will help enlarge the life of the diminishing oil reserves and resources to ensure gas security, avoiding heavy reliance on oil-producing sources. Also, using bioethanol in older engines can assist reduce the quantity of carbon monoxide produced by the car, therefore, preventing toxic air pollution. In portions as much as 5%, bioethanol can be combined with traditional gasoline without engine modifications [18].

1.5 Bio ethanol Production Process

Ethanol is securely manufactured from plant biomass hydrolysis and sugar fermentation approaches. Meanwhile, the biomass wastes incorporate a complex aggregate of carbohydrate polymers from the plant cellular partitions referred to as cellulose, hemicellulose, and lignin. The assessment of sugars from the biomass is pre-processed with acids or enzymes to activate the feedstock and to open up the plant morphology. The cellulose and the hemicellulose structures are broken down (hydrolyzed) by using enzymes or dilute acids into sucrose sugar that is then fermented into ethanol. The lignin which is also present within the biomass is generally used as a gasoline for the ethanol production plants boilers. There are three foremost strategies of extracting sugars from biomass. These are concentrated acid hydrolysis, dilute acid hydrolysis, and enzymatic hydrolysis [18] [19] [20].

1.6 Wet Milling Processes

Corn may be processed into ethanol through either the dry milling or the moist milling. In the moist milling procedure, the corn kernel is steeped in hot water, this helps to break down the proteins and release the starch present within the corn and helps to soften the kernel for the milling process. The corn is then milled to supply germ, fiber, and starch products. The germ is extracted to supply corn oil and the starch fraction undergoes centrifugation and saccharification to produce gluten moist cake. Bio-ethanol is further isolated via the distillation technique. The moist milling procedure is typically used in factories generating numerous hundred million gallons of ethanol each year [21].

1.7 Sugar Fermentation Process

The hydrolysis procedure breaks down the cellulosic part of the biomass or corn into sugar solutions which could then be fermented into ethanol. Yeast is delivered to the solution, that is then heated. The yeast carries an enzyme referred to as invertase, a catalyst that facilitates the transformation of the sucrose sugars into simple fermentable sugars (both C6H12O6) [18].

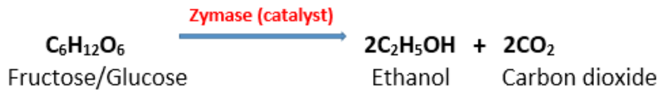
The chemical reaction is shown below:

Equation 1:

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + \underset{\text{Water}}{H_2O} \xrightarrow{\text{Invertase (catalyst)}} \underset{\text{Fructose}}{C_6H_{12}O_6} + \underset{\text{Glucose}}{C_6H_{12}O_6}$$

The sugars of fructose and glucose then combine with another enzyme called zymase which is also included in the yeast to generate ethanol and carbon dioxide.

Equation 2:



$$C_6H_{12}O_6 \xrightarrow{\text{Zymase (catalyst)}} 2C_2H_5OH + 2CO_2$$

The fermentation process takes about three days to complete and is performed at a temperature of 25^{0}C to 30^{0}C.

1.8 Fractional Distillation Process

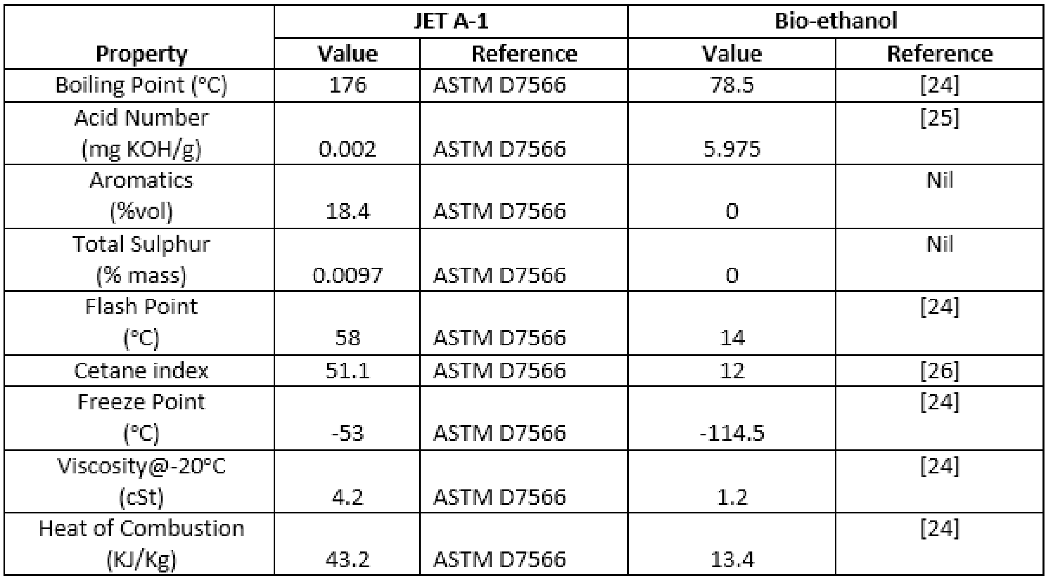
But ethanol, which is from the fermentation process, consists of a certain quantity of water that should be removed. This is achieved through the use of the technique of fractional distillation. The distillation procedure functions by boiling the mixture of water and ethanol. Because ethanol retains a lower boiling factor (78.3^{0}C) than water (100^{0}C), ethanol can be condensed and separated before the gas. [22].

1.9 Dehydration of bioethanol [23].

Molecular sieve

Figure 3. Technical processes of Alcohol to jet for the production of bio-jet fuel with bio-ethanol.

Table 2. Selected physicochemical characteristics of conventional Aviation turbine fuels against bio-ethanol.



	JET A-1		Bio-ethanol	
Property	**Value**	**Reference**	**Value**	**Reference**
Boiling Point (°C)	176	ASTM D7566	78.5	[24]
Acid Number (mg KOH/g)	0.002	ASTM D7566	5.975	[25]
Aromatics (%vol)	18.4	ASTM D7566	0	Nil
Total Sulphur (% mass)	0.0097	ASTM D7566	0	Nil
Flash Point (°C)	58	ASTM D7566	14	[24]
Cetane index	51.1	ASTM D7566	12	[26]
Freeze Point (°C)	-53	ASTM D7566	-114.5	[24]
Viscosity@-20°C (cSt)	4.2	ASTM D7566	1.2	[24]
Heat of Combustion (KJ/Kg)	43.2	ASTM D7566	13.4	[24]

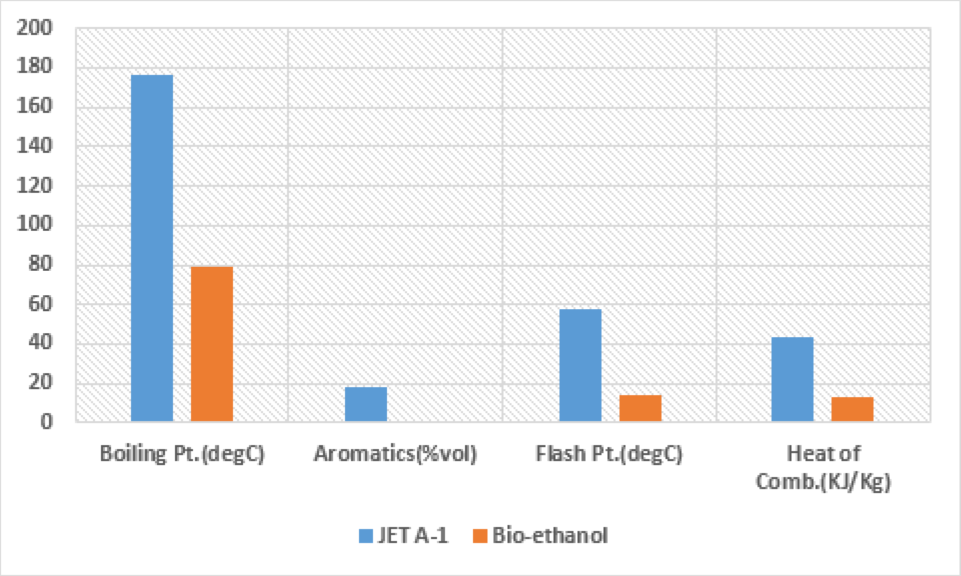


Figure 4. Selected physicochemical characteristics of JET A-1 and bio-ethanol (1).

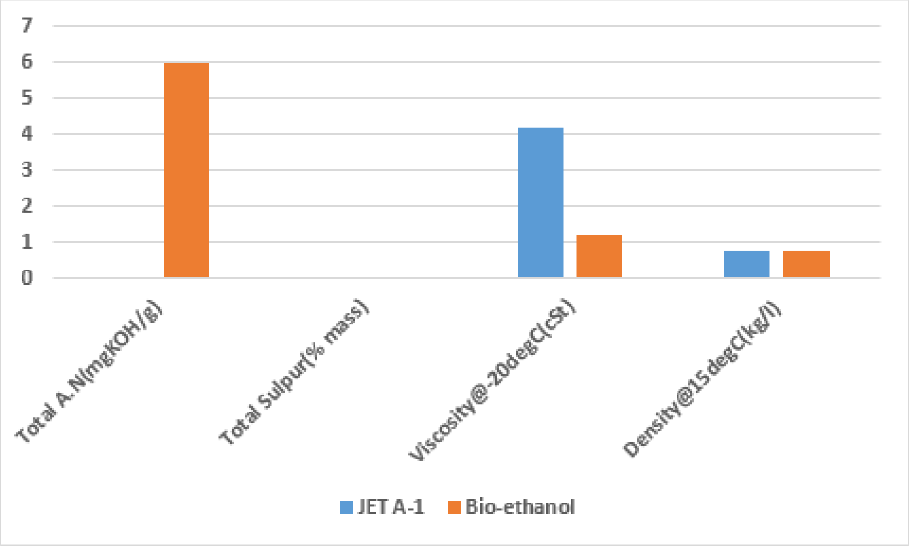


Figure 5. Selected physicochemical characteristics of JET A-1 and bio-ethanol (2).

It has been reported that the global patterns and projections of biofuel with bioethanol inclusive are high in Asia and Australia; intermediate in Europe and North America and negligible in Africa and South America gave their primary feedstock development rate as simple sugars. These portend a wakeup call for Africans and South Americans in the nearest future. The adopted and defined technologies for the production of bio-jet fuel have been categorized into four distinct processes presently. Alcohol to the jet technique as one of the processes is a sustainable and promising development in transport applications. However, aviation-grade fuel and bioethanol from renewable natural resources differ significantly in their physicochemical properties comparatively. The boiling point which declares the temperature at which the saturated pressure of the fluid vapor attains equilibrium with the atmospheric pressure; Aromatics, which identifies the presence of aromaticity(aromatic ring); Flashpoint, the least temperature needed to vaporize the fuel to formulate a combustible concentration at a gaseous state; Heat of combustion, the amount of energy liberated with the oxidation of the material fluid in ideal conditions; Total acid number that measured the magnitude of potassium hydroxide in gram needed to react (neutralize) with an acid in a gram of the material fluid;

Sulphur content and composition; viscosity that determines the fluid resistance to a change of opposing forces and density which is a function of the fuel volatility that affects the fuel energy properties, mainly heat value were all compared. As they are all higher in values to bioethanol, it, therefore, implies that bioethanol requires chemical modifications as additives that will improve the properties for use in aviation industries as it prevents greenhouse gas emission

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Table 3. Aviation fuel additives [27].

S/N	Property	Description
1	Anti-Knock	Reduces the tendency of the fuel to ignite
2	Anti-oxidant	Prevent the formation of gum deposits on fuel system component by oxidation of fuel during storage and prevention of peroxides
3	Static dissipater	Reduces the hazardous of static electricity induced by the fuel movement through modern high flow rate fuel transfer system
4	Corrosion inhibitors	Protect ferrous metals in fuel handling system such as pipelines and fuel storage tanks.
5	Fuel system Icing inhibitor	Reduce the freezing point of water precipitated from jet fuel due to cooling at high altitudes and prevention of ice crystals which oppose the flow of fuel to the engine
6	Biocide	Inhibit microbiological growth in jet fuel
7	Thermal stability	Prevent deposit formation with higher temperature zones of the aircraft fuel systems.

Figure 6. Aviation Fuel Additive Injection

2.0 CONCLUSIONS

The physicochemical properties which are the efficiency parameters of the jet fuel anticipated against renewable bioethanol from fossil resources announce some notable differences. In other words, with favorable physicochemical properties, bio-ethanol as an alternative modified (additives) fuel is much more important. This analysis specifically shows that the manufacturing problems and modifications of alcohol-containing aviation petrol properties have already been widely considered in scientific research. In particular, aviation petrol, developed in the US and produced according to the ASTM D 6227 standard, does not contain tetraethyl lead which causes lead emissions. Due to its hypotoxicity ethanol is also the most applicable. It is less aggressive and hygroscopic in corrosion compared with methanol, and more soluble in hydrocarbons. Ethanol petrol is enriched with oxygen, which is more complete in combustion. Nowadays the additive with the best prospects for aliphatic alcohols is biobutanol. As discovered, it is very suitable and compatible with engine components, it provides the most stabilizing influence for alcohol-petrol mixtures, it increases antiknock characteristics and it reduces the number of toxic emissions with additives.

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