
FUEL COMPONENTS TO ENHANCE THE ANTIKNOCK PROPERTIES OF GASOLINE

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Abstract: This article aims to examine the influence of oxygenated compounds on the antiknock characteristics of gasoline. Oxygenate additives, including acetone, ethylene glycol ethyl ether, diethylene glycol ethyl ether, and diethylene glycol butyl ether, were incorporated into the original gasoline at quantities of 0.5% to 5%. The physicochemical qualities of blends are evaluated using standard procedures established by the American Society for Testing and Materials (ASTM). Research demonstrates that the use of acetone as an oxygenated addition exerted a minimal effect on the antiknock properties of motor fuel. The addition of 5% acetone elevated the octane rating by 4.5. The incorporation of ethylene glycol ethyl ether into gasoline at concentrations ranging from 0.5% to 5% increases the octane rating from 78.5 to 88.5. In contrast, diethylene glycol ethyl ether increases the octane rating to 91.5. Across the tested concentration spectrum, diethylene glycol butyl ether exhibits the best performance as an addition, markedly elevating the octane rating of gasoline to 93.1. Of the four additives, diethylene glycol butyl ether exhibits the most favorable properties for enhancing the octane number of fuel.

Keywords: gasoline, antiknock properties, oxygenates, fuel, octane number.

INTRODUCTION

Today, oil refining across the globe must comply with stricter regulations regarding gasoline quality and limits on vehicle exhaust emissions, which include carbon monoxide, nitrogen oxides, and unburned hydrocarbons. The production of leaded gasoline is on the decline because its combustion releases harmful lead compounds into the atmosphere. There is an increasing demand for new fuels, particularly reformulated gasoline. These fuels have lower concentrations of volatile matter, benzene, total aromatics, and hazardous compounds. A notable trend in the evolution of the modern fuel industry is the need to produce high-octane motor fuels that offer enhanced environmental benefits [1,2].

Innovations aimed at improving the performance and efficiency of internal combustion engines are associated with the enhancement of knock resistance characteristics in fuels. Aromatics, paraffins, and lead-based additives in gasoline improve octane ratings; however, some are toxic, carcinogenic, or expensive. Currently, other possibilities for octane enhancement are being evaluated, with oxygenated molecules garnering attention [3-5].

The anti-knock characteristics of gasoline, denoted by the research octane number (RON) and motor octane number (MON), are crucial for enhancing the efficiency of spark ignition engines. Diverse blending additives and components can improve gasoline's knock

resistance [6]. The formulation of gasoline substantially influences engine performance and octane rating. The utilization of fuel additives to enhance fuel quality is regarded as a straightforward and economical strategy for energy conservation and pollutant reduction.

Fundamental alcohols and ethers function as gasoline additives to reduce pollutants in automotive exhaust emissions. These oxygen containing compounds increase octane number, exhibit notable anti-knock properties and can be produced from renewable agricultural resources and significantly reduce carbon monoxide and unburned hydrocarbons [7,8].

The escalation of greenhouse gas concentrations in the atmosphere has attained a critical threshold. The daily increment of vehicles follows a geometric pattern, resulting in heightened emissions of carbon monoxide and hydrocarbons from spark-ignition engines [1,9]. The release of gaseous emissions from both gasoline- and diesel-powered internal combustion engines contributes to atmospheric degradation and poses a threat to public health and living organisms and impacts the ecological balance [9-12].

The upgrading of fuel systems has resulted in several alterations to internal combustion engines. However, these alterations have not been sufficient to achieve optimal performance. Consequently, different measurement methods are employed to assess the properties of fuels that help prevent detonation, enhance co-combustion, and prolong engine service life. In this context, the most quantifiable attribute for assessing these benefits in fuels is referred to as the octane number [6,13]. The use of diverse oxygenates with gasoline improves its octane rating and facilitates complete combustion due to the elevated oxygen content, resulting in enhanced combustion efficiency and reduced engine emissions [7,9,14]. Consequently, it is essential to examine fuel additives that markedly improve the fuel efficiency of internal combustion engines, resulting in less exhaust emissions.

Consequently, the examination of the effects of oxygen-containing compounds on the antiknock characteristics of gasoline is compelling. Acetone, ethylene glycol ethyl ether, diethylene glycol ethyl ether, and diethylene glycol butyl ether have been identified as prospective antiknock additives to assess their impact on the octane rating of gasoline.

EXPERIMENTAL PART

The primary focus of the study was the straight-run gasoline fraction (IBP-180°C) produced by the atmospheric-vacuum unit. The octane number of the gasoline fraction, measured by the Research Octane Number (RON), was found to be 78.5.

The following oxygen-containing compounds were evaluated as potential antiknock additives: acetone, ethylene glycol ethyl ether, diethylene glycol ethyl ether, and diethylene glycol butyl ether. Acetone serves as an alternative additive for internal combustion engine fuels. It effectively enhances anti-detonation properties and raises octane numbers, making it comparable to ethanol and similar additives. Consequently, acetone is utilized as a benchmark for evaluating oxygenates [15].

Ethylene glycol ethyl ether is a combustible, colorless, clear liquid characterized by a notable alcoholic scent. It has great solubility in water, alcohol, and various other solvents. Diethylene glycol ethyl ether is a byproduct of the synthesis of monoethylene glycol ethyl

ether, also known as ethyl cellosolve. Cellosolves are monoethers of ethylene glycol. Diethylene glycol butyl ether is a colorless, flammable, hygroscopic liquid that is nearly odorless, also known as ethyl carbitol. It is completely miscible with numerous organic solvents and is chemically soluble in water, exhibiting the qualities characteristic of alcohols and ethers. These oxygenates, inherently organic ethers, are appropriate for use as standalone octane-enhancing gasoline additives.

Table 1

The physicochemical properties of ethylene glycol ethyl ether

Indicators	Values
Density at 20 °C	0.930 q/sm ³
Boiling point	136.0 °C
Autoignition temperature	238 °C
Octane number (RON method)	120

Table 2

The physicochemical properties of diethylene glycol ethyl ether

Indicators	Values
Density at 20 °C	0.805 q/sm ³
Boiling point	202.0 °C
Flash point	94.0 °C
Octane number (RON method)	122

Table 3

The physicochemical properties of diethylene glycol butyl ether

Indicators	Values
Density at 20 °C	0.951 q/sm ³
Boiling point	206.0 °C
Flash point	104.0 °C
Octane number (RON method)	125

Individual samples of oxygenated compounds were added to the original gasoline fraction samples in varying amounts. The octane ratings of the resulting fuel samples, which included these oxygenate additions, were subsequently evaluated. The additives were mixed into the original gasoline at concentrations ranging from 0.5% to 5%.

The fractional composition (boiling range distribution) of gasoline with additives was examined utilizing an ASTM (American Society for Testing and Materials) equipment. This approach provided comprehensive data on the 10%-90% recovery points, crucial for

analyzing the boiling behavior of components. This information is essential for overseeing blending procedures and evaluating the impact of additives on gasoline characteristics.

The sulfur concentration was assessed by the light method. This method is a dependable and regulated methodology for quantifying total sulfur in liquid petroleum products. The process involves combusting the sample in a sealed system, facilitating the absorption of sulfur oxides, subsequently leading to the titration or precipitation of the resulting sulfates.

The concentration of aromatic hydrocarbons was assessed utilizing aniline dots. Equal volumes of aniline and the sample are subjected to heating until complete miscibility is achieved, followed by cooling. The temperature at which the mixture gets turbid, or separates is known as the aniline point. A diminished aniline point signifies more aromatic content, whereas an elevated aniline point indicates reduced aromaticity.

Moreover, the viscosity of the materials was determined with an Ostwald (or Ostwald-Pinkevitch) viscometer. The viscometer was filled with the sample and positioned in a temperature-controlled bath. A pipette or suction bulb was utilized to fill the bulb above the upper mark, and the duration for the liquid level to descend between the two marks was measured with a stopwatch.

Furthermore, the materials' density was ascertained utilizing a hydrometer. This research was based on Archimedes' principle, which asserts that the instrument floats at a depth proportional to the liquid's density. Additionally, the Research Octane Number (RON) of gasoline is assessed at a crankshaft speed of 600 rpm, with an intake valve air temperature of 52°C, at standard atmospheric pressure.

RESULTS AND DISCUSSION

A prevalent pattern noted among all oxygenates is that the octane rating of gasoline escalates with an increase in the concentration of additives.

Table 4 illustrates the variation in octane number resulting from the incorporation of specific volumes of additives into gasoline.

Table 4

Octane rating of gasoline using additives

Additive concentration, %	Octane number			
	Acetone	Ethylene glycol ethyl ether	Diethylene glycol ethyl ether	Diethylene glycol butyl ether
0.00	78.5	78.5	78.5	78.5
0.5	79.0	80.9	81.8	82.5
1.0	79.3	84.5	85.6	87.0
3.0	81.4	86.9	89.0	90.8
5.0	83.0	88.5	91.5	93.1

The table indicates that as the concentration of additives rises from 0.5% to 5%, the relationship between the change in octane number and the concentration is significant, with the extremum occurring at the concentration level of 5%.

The comparison between 1% and 5% concentrations indicates that the addition of 1% acetone has a negligible impact on the antiknock characteristics of motor fuel. At a 5% concentration, the octane number rises by 4.5 as a result of acetone's presence.

Furthermore, the utilization of acetone as an octane enhancer is inadvisable. It is a low-energy fuel constituent that may corrode fuel system components and provides no demonstrable economic advantage, particularly when compared to other octane enhancers that are more effective and less harmful to engine components.

Blending ethylene glycol and ethyl ether with gasoline in concentrations ranging from 0.5% to 5% increases the octane number from 78.5 to 88.5. In contrast, diethylene glycol ethyl ether can raise the octane number to as high as 91.5.

Figure 1 illustrates that the most pronounced enhancement in octane numbers transpires when the examined ethers are incorporated into gasoline at a concentration of 1%. Across the spectrum of concentrations analyzed, diethylene glycol butyl ether demonstrates the highest efficacy as an additive. The incorporation of oxygen into the gasoline portion elevates its octane rating from 78.5 to 93.1.

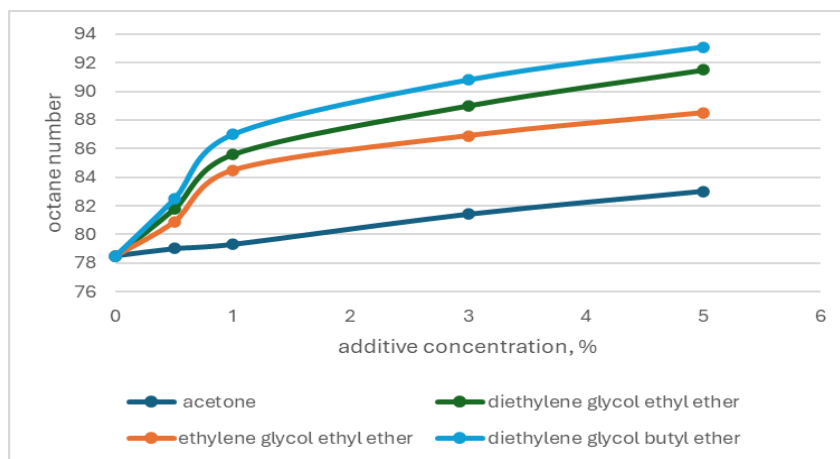


Fig.1. Fluctuation in octane ratings of samples comprising gasoline and additives.

Additionally, the graphs demonstrate a significant correlation between variations in octane number and octane gain for the amounts of the examined oxygenate additions. The assessment of the increase in octane number reveals a significant effectiveness of diethylene glycol butyl ether and diethylene glycol ethyl ether, followed by ethylene glycol ethyl ether, and then acetone.

Table 5 illustrates that the fluctuation in octane number signifies the efficacy of each addition in particular scenarios. The gasoline knock resistance distribution coefficient, reflecting the homogeneity of additive distribution throughout its fractions, is reasonably stable at roughly 0.7 to 0.83. Total sulfur content decreases with higher concentrations of additives. The alterations in aromatic composition are negligible.

Table 5

Indicators of the analyzed fuel samples

Indicators	Original gasoline	Gasoline combined with 5% acetone	Gasoline combined with 5% ethylene glycol ethyl ether	Gasoline combined with 5% diethylene glycol ethyl ether	Gasoline combined with 5% diethylene glycol butyl ether
RON (Research Octane Number)	78.5	83.0	88.5	91.5	93.1
Gasoline knock resistance distribution coefficient	0.72	0.83	0.76	0.73	0.74
Sulfur concentration, mg/kg, no more than	485	425	480	482	483
Volume fraction of aromatic hydrocarbons, %	23.0	23.2	23.5	23.4	23.3
Fractional composition: 50°C, no less than	20	20	23	24	24
90°C, no less than	60	59	55	54	54
Final boiling point, °C	180	184	181	176	177
Density at 15 °C, kg/m ³	727.0	737.0	726.0	729.0	728.0
Kinematic viscosity, mm ² /c	0.4687	0.4781	0.4781	0.4852	0.4865
Acid number, mg KOH/g	0.77	0.79	0.93	0.88	0.85
Appearance	Transparent				

Gasoline fractions consist of diverse hydrocarbon molecules from various homologous series and classes, including alkanes, isoalkanes, naphthenes, and aromatics, each characterized by a certain boiling point. The uneven content and distribution of these compounds throughout narrow fractions primarily determine the fractional composition of the gasoline and, most importantly, the octane ratings of both the original fuel and its narrow fractions.

CONCLUSION

The investigation into the impact of oxygenated compounds on the antiknock properties of gasoline revealed that the most preferred oxygenates evaluated as antiknock additives for motor gasoline are diethylene glycol ethyl ether and diethylene glycol butyl ether. These additives yield substantial improvements in octane ratings, even in little quantities, illustrating the effectiveness of motor fuels that contain them. However, diethylene glycol butyl ether markedly enhances the octane rating of gasoline to 93.1

REFERENCES

1. Tamer M.M.Adellatief, Mikhail A.Ershov, Vsevolod D. Savelenko, Vladimir M. Kapustin, Ulyana A.Makhova & et al. Advanced progress and prospects for producing high-octane gasoline fuel toward market development: State-of-the-art and outlook. *Energy and fuels*. 2023, Vol.37, Issue 23, pp. 18266-18290
2. J. H. Badia, E. Ramírez, R. Bringué, F. Cunill, and J. Delgado. New octane booster molecules for modern gasoline composition. *Energy Fuels*. 2021, 35 (14), pp.10949-10997. <https://doi.org/10.1021/acs.energyfuels.1c00912>
3. Lucimar Venacio Amaral, Nathália Duarte Souza Alvarenga Santos, Vinícius Rückert Roso, Rita de Cássia de Oliveira Sebastião, Fabrício José Pacheco Pujatti. Effects of gasoline composition on engine performance, exhaust gases and operational costs. *Renewable and Sustainable Energy Reviews*. 2021, Vol.135, pp. 110196. <https://doi.org/10.1016/j.rser.2020.110196>
4. Robert K. Niven. Ethanol in gasoline: environmental impacts and sustainability review article. *Renewable and Sustainable Energy Reviews*. 2005, Vol.9, Issue 6, pp. 535-555. <https://doi.org/10.1016/j.rser.2004.06.003>
5. Xiaoteng Zhang, Shouzhen Zhang, Yang Zhao, Jia Liu, Xiang'en Kong, Shihai Zhang, Mingsheng Wen, Haifeng Liu. Effects of different additives on physicochemical properties of gasoline and vehicle performance. *Fuel Processing Technology*.2023, Vol. 242, pp.107668, <https://doi.org/10.1016/j.fuproc>.
6. Changyoul Lee, Ahfaz Ahmed, Ehson F.Nasir, Jihaad Badra, Gautam Kalghatgi, S. Mani Sarathy, Henry Curran, Aamir Farooq. Autoignition characteristics of oxygenated gasolines. *Combustion and flame*. 2017, Vol.186, pp. 114-128. <https://doi.org/10.1016/j.combustflame.2017.07.034>
7. Omar i.Awad, R.Mamat,Obad M.Ali, N.A. C.Sidik, T.Yusaf, K. Kadirgama, Maurice Kettner. Alcohol and ether as alternative fuels in spark ignition engine: A review.*Renewable and sustainable energy reviews*. 2018, Vol.82, Part 3, pp.2586-2605
8. Babazadeh Shayan Soheil, Seyedpour Seyedpour Seyed Morteza, and Ommi Fathollah. Effect of oxygenates blending with gasoline to improve fuel properties. *Chinese Journal of Mechanical Engineering*. 2012, Vol. 25, №. 4, pp.792-798
9. Gopinath Dhamodaran, Ganapathy Sundaram Esakkimuthu, Thennarasu Palani and Arivazhagan Sundaraganesan. Reducing gasoline engine emissions using novel bio-based oxygenates: a review. *Emergent materials*. 2023, 6(10), pp.1-21. <https://doi:10.1007/s42247-023-00470-7>
10. Cheol-Soo Lim, Jae-Hyun Lim, Jun-Seok Cha, Jae-Yong Lim. Comparative effects of oxygenates-gasoline blended fuels on the exhaust emissions in gasoline-powered vehicles. *Journal Environ Manage*. 2019, Vol.239, pp.103-113. <https://doi.org/10.1016/j.jenvman.2019.03.039>
11. Westphal GA, Krahl J, Brüning T, Hallier E, Bünger J.Ether oxygenate additives in gasoline reduce toxicity of exhausts. *Toxicology*. 2010, Vol. 268, Issue3. pp. 198-203. <https://doi.org/10.1016/j.tox.2009.12.016>
12. Simeon Iliev. A Comparison of Ethanol, Methanol, and Butanol Blending with Gasoline and Its Effect on Engine Performance and Emissions Using Engine Simulation Processes. 2021, 9(8), pp. 1322; <https://doi.org/10.3390/pr9081322>

13. A.Demirbas, M.A. Balubaid, A.M. Basahel, W.Ahmad M.H.Sheikh. Octane Rating of Gasoline and Octane Booster Additives. *Petroleum science and technology*, 2015, Vol.33, Issue 11, pp.1190-1197. <https://doi.org/10.1080/10916466.2015.1050506>
14. Xudong Zhen , Yang Wang An overview of methanol as an internal combustion engine fuel. *Renewable and Sustainable Energy Reviews*. 2015, Vol. 52, pp. 477-493, <https://doi.org/10.1016/j.rser.2015.07.083>
15. Muhammad Usman, Talha Khan, Fahid Riaz, Muhammad Ali Ijaz Malik, Muhammad Tahir Amjad, Muhammad Haris Shah, Waqar Muhammad Ashraf, Jaroslaw Krzywanski, Wojciech Nowak. Acetone-gasoline blend as an alternative fuel in SI engines: A novel comparison of performance, emission, and lube oil degradation, *ACS Omega*. 2023, Vol. 8, Issue 12, pp. 11267–11280. doi: [10.1021/acsomega.2c08271](https://doi.org/10.1021/acsomega.2c08271)