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The effectiveness of octane booster as additive for fuel quality improvement

Kiagus A. Roni[1,*] and Sri Martini[1]

[1]Chemical Engineering Department, University of Muhammadiyah Palembang, Palembang, Indonesia
[*]Corresponding author: kiagusaroni@gmail.com

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Abstract

Clean energy is predominant topic across several local and international conservation conferences and initiatives. The primary aim of this study is to analyze the effectiveness of octane booster in enhancing fuel quality in automotive gasoline. Research octane number (RON) refers to the octane number of fuel that influences engine performance. This octane number is determined by comparing the knock intensity with the reference fuel mixture during testing. The experimental method is the blending of octane booster and gasoline at different percentage compositions of 0.5:99.5, 1.0:99, 1.5:98.5 and 2.0: 98, respectively. These two organic substances were supplied by Pertamina, a state-owned oil and gas company in Indonesia. The blending results showed a potential increase in octane number in the fuel sample (ASTM D-2699) from 88 to 89.4, 90, 90.5 and 90.8, correspondingly. Furthermore, the effects of involving octane booster on the specific gravity, distillation, and Reid vapor pressure (RVP), as well as gum concentration were also determined. Based on the experimental and analytical data, a reasonable increase was observed in the specific gravity, distillation, and RVP for samples ASTM D-1298, ASTM D-86 and ASTM D-323, respectively. However, excessive use of octane booster has the tendency to enhance gum deposits that slightly influences the engine performance.

Keywords: Gasoline fuel, Octane number, Octane booster, Specific gravity, Distillation

1. Introduction

The rapid growth in global economy and population produced greater demands for petroleum and its derivatives, such as gasoline or diesel. Furthermore, alternatives to the use of regular fossil energy sources, including biofuel and fuel cells have been investigated. However, certain challenges adversely influence environmental quality, mainly crude oil by-products, such refinery wastewater [1,2,3]. Fossil fuels are complex chemical mixtures of various components, including olefinic, paraffinic and aromatic hydrocarbons. These heavy substances also contain minimal proportions of sulfur, oxygen, and nitrogen compounds. The demand for the petroleum product continues to increase, due to its simple usage and other unique natural characteristics. These factors are important in optimizing the inherent properties, using particular novel components. The added materials or boosters are also significant in obtaining greener fuels with high octane rating. Subsequently, the blending of these octane boosters such as bioethanol, prenol, as well as furan mixtures and gasoline potentially generate superior chemical, physical, mechanical and environmental behaviors [4,5]. These hydrocarbons easily combines with oxygenate compounds to determine the specific physico-chemical properties of the resulting product, with substantial influence on engine performance.

In an optimum engine operation, the need to improve performance and energy consumption poses a major challenge. Fuel engines with higher research octane number (RON) generate minimal emissions through spark timing and are very beneficial for high compression ratio and effective operations [6]. Previous studies obtained a thermal efficiency above 40% in boosted fuel engines, compared to diesel [7]. This outcome decreases the CO_2 emission and is very essential in the efforts against global warming [8].

A number of octane boosters have been widely applied to improve fuel characteristics and engine performance. These efforts were equally aimed at boosting octane ratings as previous literatures already showed satisfactory results under different engine specifications in several additives such as methanol and terpineol [9,10].

There are also studies where various octane booster ratios obtained particularly different effects on engine performance and emission level at varying operating conditions along with engine knock and pre-ignition aspects. Furthermore, by adding certain percentage ratio of bio-octane booster, higher engine resistances are observed, without the need for specific modification [11].

Essentially, newly processed gasoline is not utilized immediately, as particular chemicals or petroleum samples are added according to specifications, in order to enrich fuel quality. The gasoline component is obtained from several processes including atmospheric distillation, cracking, catalytic reforming, alkylation, isomerization and polymerization [12].

Octane booster requires appropriate blending procedures as the process involves mixing two or more components to obtain homogeneous and superior characteristics. In terms of automobiles, the blending objective is to enhance fuel quality and engine performance, with reduced emission of toxin substances [13].

Octane number is described as a measure of the propensity of gasoline to contribute to the combustion process and engine breakdown. This knock tendency has a strong correlation to engine compression ratio. Higher octane number indicates an extensive utilization at high compression ratios without experiencing knock. The octane number is also defined as the percentage composition of iso-octane in the fuel sample [14].

This present study provides a comprehensive analysis on octane number and its booster using a cooperative fuel research (CFR) engine. The gasoline was subsequently compared with the reference sample generated from a mixture of n-heptane (octane number 0) and iso octane (octane number 100) with the American Society for Testing and Materials (ASTM) D-2699 method [15].

Apart from octane number, several fuel quality parameters influencing engine performance, including specific gravity, distillation, Reid vapor pressure (RVP) and gum deposit also require adequate evaluation.

Considering the nature of specific gravity as an important determinant in reliable engine function [16], distillation forms an integral aspect of evaporation measurement factors. The variable is possibly determined using ASTM D-86 distillation test at 10, 50 and 90% of the evaporation volume. The 10% category plays a significant role in the ease of vehicle ignition under cold conditions. Meanwhile, the engine’s ability to work effectively in higher temperatures between 80-125ºC is reflected in the 50% segment. This measurement is to determine the heating ease and uniform fuel distribution on each engine cylinder. Eventually, the propensity of fuel to form carbon deposits appears more feasible at 90%.

There is also an important need to ascertain fuel volatility in an effort to obtain a suitable mixture of air and gasoline. Low volatility value tends to exhibit difficulty in attaining operational heat, while a higher estimate results in a substantial steam volume, with certain impacts, including vapor lock and carburetor icing [17]. Therefore, Reid vapor pressure (RVP) test is conducted to evaluate volatility, using ASTM D-323 method [18].

Another important parameter in need of adequate consideration is gum concentration. Gums are formed by vaporize residues, insoluble in normal heptane and are also analyzed using ASTM D-381. This development in automotive fuel adversely impacts its operation and precipitates non-volatile resins in the carburetor [19].

Despite previous research related to octane booster addition, the analysis reports on its effect on specific gravity, gum existent, RVP and distillation are currently limited, with the need for further investigations. Therefore, the main objective of this study is to determine the effects of adding octane booster on octane number of automotive gasoline as well as other important properties, including distillation, RVP, specific gravity, and gum deposit by specifically considering the blending ratio effects between both samples.

2. Materials and methods

2.1 Materials and equipment

Premium gasoline fuel with an initial RON of 88 and octane booster were supplied by Pertamina gas station, Palembang, Indonesia. Figure 1 is an illustration of the computerized CFR F-1 test engine. Primary referrance fuel (PRF) comprising iso-octane (octane number 100) and normal heptane (octane number 0), with toluene standard fuel (TSF), were applied in the check engines.

This engine system exhibits several features for optimal performance, including engine unit mounted to rigid base, synchronous motor fixed to slide base, variable compression ration cylinder, compression ratio change motor, electronic integrated barometer, laser sensor for measuring cylinder height, exhaust surge tank system, and water-cooled exhaust along with computerized data system.

2.2 Testing methods

Table 1 represents the blending of octane booster with gasoline fuel RON 88 at four separate volumetric ratios, termed 0.5, 1.0, 1.5 and 2.0%. The refinery grade of similar samples was subsequently chosen as the base fuel and the characteristics are outlined in Table 2.

The performance of base fuel and its blends with octane booster was compared against a standard pertalite gasoline with RON 90, based on ASTM standard methods. This sample was also supplied by Pertamina gas station, Palembang, Indonesia.

The ASTM D-323 approach was used in the RVP test to determine the volatility. In addition, the vapor pressure was measured in a tube filled with air at a certain temperature. Subsequently, the existent gum was evaluated by ASTM D-381, followed by ASTM-D1298 and ASTM-D4052 processes to ascertain the specific gravity, using glass hydrometers and digital density meter. In the latter analysis, a small volume of the fuel sample was introduced into an oscillating U-tube and undulated by a Piezo element. The oscillating frequency is then directly related to the specific gravity of the filled sample. This specific gravity is further determined by dividing the fuel density by the density of the standard substance.

Table 1 Blending ratio between octane booster with gasoline fuel.

No.	Blending ratio by volume (%)	
	Octane Booster	Gasoline RON 88
1	0.5	99.5
2	1.0	99
3	1.5	98.5
4	2.0	98

Table 2 Characteristics of gasoline fuel RON 88 used in this study [20].

Indonesia Gasoline Specification		
Characteristics	Unit	RON 88
Research Octane Number	RON (min)	88
Distilation: 10% vol. Evaporation Unit: oC		≤74
Unwashed Gum (max)	mg/100mL	70
Washed Gum (max)	mg/100mL	5
Vapor Pressure	kPa	45-69
Oxidation Stability	minutes (min)	360
Sulfur(1)	%m/m (max)	0.05
Lead(2)	g/l (max)	0.013
Oxygen(3) (max)	%m/m	2.7(4)
Density at 15oC	kg/m3	715-770
Copper strip corrosion	Merit	Class I
Sulfur Mercaptan(6)(max)	%mass	0.002
Color		Yellow
Coloring agent content (max)	g/100l	0.13
Specific Gravity	-	0.715

Figure 1 CFR F-1 Combination Octane Rating Unit.

3. Results and discussion

The initial step of this study involved the characterization of the base gasoline sample. This was followed by the measurement of other main properties, including octane number, specific gravity, RVP, distillation, and gum deposit.

3.1 Effect of octane booster on RON

Based on the experimental work, the addition of octane booster solution showed a positive effect on the increase in the gasoline's octane number, as reported in Table 3.

Table 3 Octane booster effect on RON.

Component	Blending ratio (%)				
	0	1	2	3	4
Gasoline RON 88	100	99.5	99	98.5	98
Octane Booster	0	0.5	1.0	1.5	2.0
Octane Number	88	89,4	90,0	90,5	90,8

Table 3 shows that blending 1 with 0.5% octane booster was unable to attain the minimum octane number of the standard Pertalite with RON 90. However, other bl ratios of 1.0, 1.5, and 2.0% matched the specification. Blending type 1 is therefore declared less effective in improving RON level. Conversely, the 10% addition appears as the most efficient and optimum ratio, considering no significant difference of RON for higher proportions.

3.2 Effect of octane booster on specific gravity

Table 4 represents the effects of octane booster addition on specific gravity, while Figure 2 shows that the increase in its volume ratio generates a slight improvement in specific gravity.

Table 4 The effect of octane booster ratio on specific gravity and density.

Component	Blending				
	0	1	2	3	4
Gasoline RON 88	100	99.5	99	98.5	98
Octane Booster	0	0.5	1.0	1.5	2.0
Specific Gravity	0.715	0.729	0.730	0.731	0.732
Density (Kg/m^3)	715	728.9	729.9	731.1	732.2

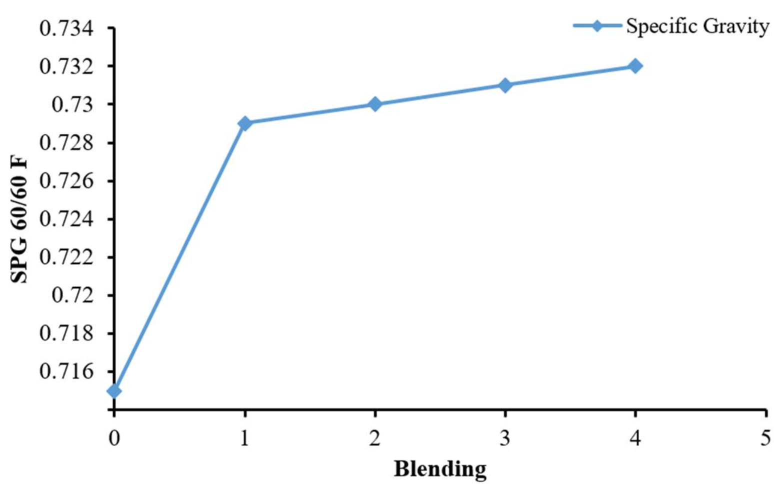

Figure 2 The Effect of Addition of Octane Booster on Specific Gravity.

Based on Table 2, the specific gravity values slightly improved from 0.729 to 0.730 after increasing the octane booster from 0.5 to 1%. Further expansion from 0.731 to 0.732 was observed with increasing additive from 1.5 to 2%, respectively. Figure 2 confirms that the octane booster with higher volume ratio leads to an extensive specific gravity. This condition possibly relates to the weight fraction in more octane booster mixture. Furthermore, specific gravity is defined as the ratio of the density of a substance to the density of a standard sample. The variable is an essential parameter in enhancing gasoline quality. Lower specific gravity indicates faster combustion but shows slower-burning effects at greater values. Therefore, faster-burning fuels mostly need less spark advance, compared to slower-burning components [21].

3.3 Effect of octane booster on distillation

The effect of octane booster ratio on distillation relates to the initial boiling point (IBP). Table 5 shows that the IBP value was influenced by the blending ratio. Based on the data, 0.5% octane booster ratio resulted in an extensive temperature up to 35ºC, while 1.0, 1.5 and 2.0% attained up to 38, 37 and 38ºC, respectively. These results also achieved the Pertalite standard fuel specifications.

Furthermore, at 10% evaporation volume, blending 1 with 0.5% of octane booster ratio achieved a temperature of 50ºC, while at 2, 3 and 4 with higher ratios obtained temperatures of 53, 54 and 57ºC, respectively. These phenomena indicate that higher octane booster ratio tends to directly increase the temperature level. Therefore, the fuel temperature at 10% evaporation volume plays a significant role in the ease of ignition of an automotive engine under cold environment. This engine becomes difficult to start beyond the maximum limit.

Table 5 Distillation Analysis of Blended Fuel.

Component		Blending			
	0	1	2	3	4
Premium	100	99.5	99	98.5	98
Octane Booster	0	0.5	1.0	1.5	2.0
Octane Number	88	89.4	90.0	90.5	90.8
Distillation (° C)					
Initial boiling point		35	38	37	38
10% vol. evaporation		50	53	54	57
20% vol. evaporation		57	59	64	65
30% vol. evaporation		66	68	72	71
40% vol. evaporation		77	79	80	83
50% vol. evaporation		90	93	96	96
60% vol. evaporation		107	110	111	114
70% vol. evaporation		129	129	131	133
80% vol. evaporation		149	147	151	160
90% vol. evaporation		174	171	178	189
End point		193	196	200	201

3.4 Effect of octane booster on RVP

Octane booster addition instigated a slight increase in RVP level. Table 6 shows that all octane booster proportions from blending ratio 0.5 to 2.0% generated higher RVP. These values are comparable to pertalite standard fuel specification, with a range of 45-60 kPa.

Table 6 Distillation Analysis Results from Blending Premium and Octane Booster.

Component		Blending			
	0	1	2	3	4
Premium (mL)	100	99.5	99	98.5	98
Octane Booster (mL)	0	0.5	1.0	1.5	2.0
RVP (kPa)	45	48	53	53	54

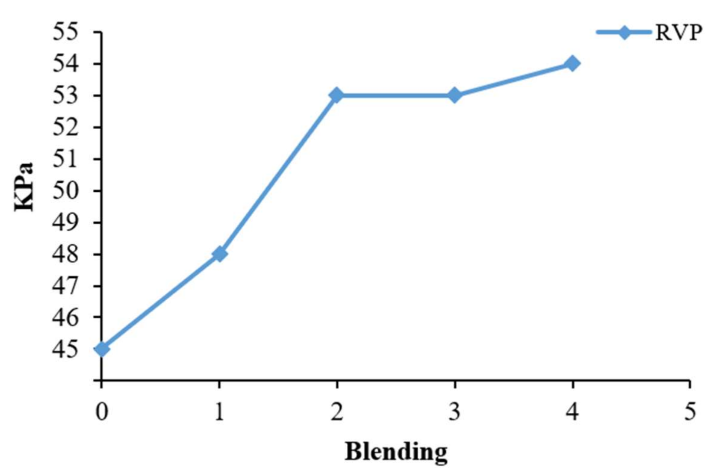

Figure 3 The Effect of cctane booster addition on RVP.

Figure 3 shows that a higher-octane booster ratio leads to superior RVP value. Blending 1 with 0.5 % octane booster ratio obtained the lowest RVP value by 48, while blending 4 with 2.0% demonstrated the highest increase by 54. However, 2 and 3 showed similar RVP value by 53. Apart from inconsistent growth patterns, a higher-octane booster ratio help increase fuel quality and engine performance. Therefore, certain issues related to the tendency of vapor lock occurrence during vehicle ignition process are avoided [13]. Overall, higher octane booster ratios (1.5 and 2.0%) exhibit less impact on the increase in specific gravity.

3.5 Effect on existent gum

The use of octane booster leads to an essential change in the concentration of both unwashed and washed gum deposits. According to Table 7, blending 1 appears to meet the Pertalite standard specifications of unwashed and washed gum by 70 mg/100 mL and 5 mg/100 mL, respectively. Meanwhile, other blending ratios were known to exceed the minimum standard limit. Therefore, higher volume of the octane booster leads to extensive gum concentration.

Table 7 Analysis of Existent Gum from Blending Premium and Octane Booster.

Component	Blending				
	0	1	2	3	4
Gasoline RON 88	100	99.5	99	98.5	98
Octane Booster	0	0.5	1.0	1.5	2.0
Unwashed Gum (mg/100 mL)	70	11.8	21.8	36.2	56.8
Washed Gum (mg/100 mL)	5	1.2	6.2	11	12.6

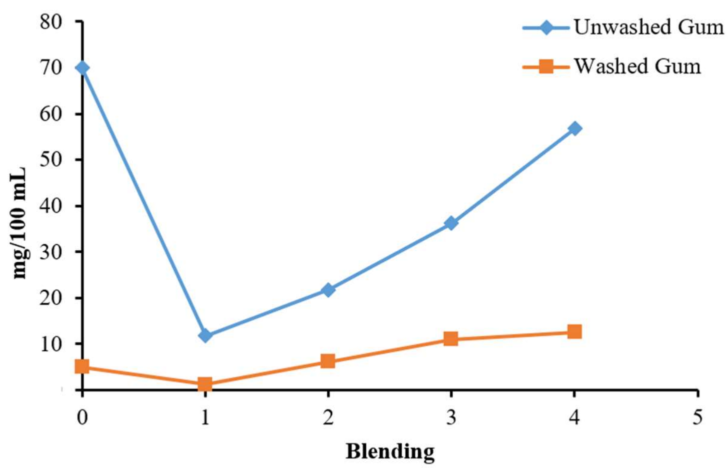

Figure 4 The Effect of octane booster addition on existent gum.

Figure 4 shows that blending 1 with 0.5% ratio of octane booster possibly attained the optimum point, based on gum deposits. This is because higher gum in gasoline tends to negatively impact on the induction system controlling the fuel intake valve. The high gums subsequently form a blockage in the fuel lines, resulting in a faulty engine combustion chamber [6].

4. Conclusion

Based on this study, the application of octane booster showed a significant influence on the octane number of automotive gasoline. The specific gravity, distillation and RVP are also importance factors that contribute positively to petroleum product quality. However, the increasing ratio of octane booster showed a slightly negative effect on gum concentration. Based on this research, blending 2 with 1.0 % of octane booster obtained the optimum ratio in most parameters, compared to higher blending ratios. This observation is exception for the gum deposit parameter where blending 1 served as the effective ratio to avoid more gum samples. Overall, octane booster addition provides a superior alternative in enhancing gasoline performance.

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