Production of Gasoline by using Gas Condensate from Khor-Mhor Gas Fields in Kurdistan Region of Iraq.

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Abstract

Gas condensate is a natural gas liquid (NGL) that is often found in association with natural gas deposits. It consists of hydrocarbon compounds such as ethane, propane, butane, and pentane. To produce gasoline from gas condensate, a refining process called fractional distillation is typically employed. This process separates the different components of the gas condensate based on their boiling points. The condensate is heated, and as the temperature rises, different hydrocarbons vaporize and are collected at different stages. The results of the analysis of gas condensate derived from the Khor-Mhor field, located near Cham-chamal in the Kurdistan region of northern Iraq, were assessed through the determination of their physical properties. The atmospheric distillation process was employed to separate the sample into two distinct boiling fractions, referred to as straight run gasoline and heavy naphtha. The former corresponded to the fraction boiling at a temperature range of initial boiling point (IBP) to 80°C, while the latter corresponded to the fraction boiling at 80°C to 150°C. It was observed that the addition of xylene, an aromatic organic solvent, to the straight run gasoline and heavy naphtha had a significant impact on their anti-knock index. The anti-knock index, a measure of a fuel's resistance to engine knocking or detonation, increased by 19.75 and 19.35 points, respectively, upon increasing the volume of xylene by 20%. These findings suggest that blending xylene with the straight run gasoline and heavy naphtha has the potential to produce a high-quality gasoline with improved performance characteristics

Keywords: Octane rating, Gasoline blending, Gas condensate, Aromatic, Oxygenate compound.

1- Introduction

Refineries are industrial facilities that produce a wide range of petroleum derivatives, including gasoline, aviation fuel, and kerosene [1]. Gasoline is a primary source of refinery profits, contributing approximately 60% to 70% of total revenue [4,5]. It is a complex mixture of hydrocarbons with a molecular structure ranging from 4 to 12 carbon atoms and boiling points within the interval of 25℃ to 225℃ [2,3]. The key performance metric of gasoline under varying engine conditions is its Octane Number (ON) [6,7,8], which indicates its resistance to knocking. An increase in the ON value leads to a corresponding improvement in the smoothness of engine operation [9,10,11].

In the past, lead compounds were employed as octane enhancers to reduce engine wear, but they have been discontinued due to their adverse impact on the environment and the ability to cause permanent degradation of modern catalytic converters in vehicles [12,13,14]. Currently, other additives such as oxygenates and aromatic compounds are utilized to augment gasoline performance [15,16]. Blending different fuel streams from various production processes produces gasoline [11,17]. The high portion of gasoline is produced by processing the light gas condensate.

Gas condensate is a valuable feedstock for the production of various fuels, including gasoline, diesel, and jet fuel [18] and [19], as well as chemicals and petrochemicals. It is known for its high quality and high-octane number, making it an attractive option for refineries looking to produce gasoline in an environmentally responsible manner [20]. The production of gasoline from gas condensate is a complex process that involves several stages, including distillation, refining, and blending. In the distillation stage, the condensate is separated into its different components based on boiling point. The lighter fractions, such as gasoline, are then further processed to meet specific fuel specifications. This process typically involves the removal of impurities, such as sulfur and nitrogen compounds, as well as the adjustment of the gasoline's octane number to meet regulatory requirements.

The main objective of this project was to prepare blending gasoline using gas condensate from Khor Mhor gas field with alternative additives, such as oxygenates and aromatics, to enhance its octane rating.

2. Experimental Part

2.1. Gas condensate and Material

Gas condensate were used and obtained from Khor Mhor Gas field which have properties are clearly defined in the table 5, absolute ethanol 99%, Methyl tertiary butyl ether (MTBE) 99%, Xylene and Toluene of 99.9% purity were of analytical reagent grade and were obtained from Fluka.

2.2. Experimental procedure

Gas condensate from the Khor Mhor gas field was subjected to fractionation based on its boiling range using a fraction distillation apparatus. This process resulted in two major fractions: the first fraction, collected in the boiling range of initial boiling point (IBP) to 80 ºC, was designated as straight run gasoline (SRG), while the second fraction, collected in the range of 80-150 ºC, was called heavy naphtha (HN).

To enhance the properties of these fractions, various additives including methyl tertiary butyl ether (MTBE), ethanol, toluene, and xylene were added using the additive method. The volumes of these additives were mixed with the volumes of the respective fractional distillates of the gas condensate, as detailed in Tables 1-4.

The properties of the gas condensate, as well as the resulting products, were determined using an ERASPEC fuel analyzer. The parameters assessed included Research Octane Number (RON), Motor Octane Number (MON), mass percent of oxygenates (Ox), aromatics (Ar), saturates (Sa), and benzene (Be). The total sulfur content was determined using a Rigaku NEX QC energy dispersive X-ray fluorescence instrument, following the ASTM D4294-16 standard test method for sulfur in petroleum and petroleum products.

This comprehensive analysis aimed to assess the impact of these additives on the properties and composition of the gas condensate, providing valuable insights into the potential improvements in fuel quality and environmental characteristics.

Table (1) Addition of MTBE to SRG and HN, vol% Xylene & Toluene: 5ml

No	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
SRG	80	75	70	65	-	-	-	-
HN	-	-	-	-	80	75	70	65
MTBE	0	5	10	15	0	5	10	15
Ethanol	10	10	10	10	10	10	10	10

Table (2) Addition of Ethanol to SRG and HN, vol% Xylene: 5ml, Toluene: 5ml.

No	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
SRG	85	80	75	70	65	60	-	-	-	-	-	-
HN	-	-	-	-	-	-	85	80	75	70	65	60

MTBE	5	5	5	5	5	5	5	5	5	5	5	5
Ethanol	0	5	10	15	20	25	0	5	10	15	20	25

Table (3) Addition of Toluene to SRG and HN, vol% Xylene: 5ml, MTBE: 5ml.

No	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
SRG	80	75	70	65	60	55	-	-	-	-	-	-
HN	-	-	-	-	-	-	80	75	70	65	60	55
Toluene	0	5	10	15	20	25	0	5	10	15	20	25
Ethanol	10	10	10	10	10	10	10	10	10	10	10	10

Table (4) Addition of Xylene to SRG and HN, vol% Toluene: 5ml, MTBE: 5ml.

No	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
SRG	80	75	70	65	60	55	-	-	-	-	-	-
HN	-	-	-	-	-	-	80	75	70	65	60	55
Xylene	0	5	10	15	20	25	0	5	10	15	20	25
Ethanol	10	10	10	10	10	10	10	10	10	10	10	10

3. Result and Discussion

3.1. Formulation Base Gasoline

Gas condensate has several advantages over conventional crude oil as a feedstock for gasoline production. Firstly, gas condensate is typically produced more efficiently than conventional crude oil, making it an attractive option for refineries seeking to produce gasoline in an environmentally responsible manner. Secondly, gas condensate has a relatively low sulfur content and high-octane number, which leads to cleaner burning gasoline with improved fuel efficiency. Finally, gas condensate is a highly versatile feedstock that can be used in the production of a wide range of fuels, chemicals, and petrochemicals, making it a valuable resource for the energy and petrochemical industries.

The Khor Mhor gas field, located in Cham chamal-Sulaimani city within the Kurdistan Region of Iraq (KRI), holds significance for the energy and petrochemical industries. Currently, the field is undergoing expansion to increase its production capacity and is recognized as the largest privately operated upstream gas operation in Iraq.

One of the primary contributions of the Khor Mhor gas field is the supply of natural gas to power plants in the Chem chemal and Erbil areas. Additionally, the field produces 15,000 barrels per day (bpd) of gas condensate and 1,000 metric tons per day (Mt/d) of liquefied petroleum gas (LPG).

Table 5 presents the values of various properties determined for the straight run gasoline (SRG) and heavy naphtha (HN) derived from the gas condensate. These properties include the anti-knock index, specific gravity, benzene content, sulfur content, and others., the specific gravity of gas condensate samples is close to the specific gravity of conventional gasoline components, such as SRG or alkylate gasoline and the average value is 0.697 g/cm^3.

The resistance of gasoline to motor thump, as expressed by its octane number, is a fundamental fuel property for internal combustion engines. The octane number and autoignition temperature of different hydrocarbons are indicators of their ability to withstand pre-ignition conditions and avoid auto-ignition before the flame front arrives. The Research Octane Number (RON) and Motor Octane Number (MON) methods employ two reference fuels, 2,2,4-trimethylpentane and n-heptane, which are assigned octane numbers of 100 and 0, respectively. By comparing the knocking intensity of the test fuel to that of reference fuel mixtures, the octane rating of the test fuel can be determined.

In the context of using gas condensate as a potential component in gasoline blends, it is important to consider the obtained results. The straight run gasoline (SRG) and heavy naphtha (HN) fractions derived from gas condensate demonstrated relatively low anti-knock index (AKI) values of 81.5 and 76.25, respectively. Therefore, incorporating these components into gasoline blends would necessitate the addition of high-octane components to achieve the desired octane rating.

3.2 Octane Enhancing Additives

3.2.1 Oxygenated Components

In order to increase the octane number of the gas condensate fractions, namely straight run gasoline (SRG) and heavy naphtha (HN), various anti-knock additives were blended with the gas condensate. The addition of oxygenated compounds, including MTBE and ethanol, as well as aromatic compounds such as toluene and xylene, was carefully performed in different volume percentages (0-25%).

Table (5) Properties and composition of SRG and HN

Fraction	**SRG**	**HN**
RON	85	79.8
MON	78	72.7
AKI	81.5	76.25
Aromatic%	2.7	8.5

Oxygenate%	0.02	0.31
Saturate%	97.3	89.9
Sp.gr @15.6 ºC	0.667	0.728
API	80.6	62.8
Sulfur, wt/wt%	482	574
Benzene%	0.40	0.38

MTBE and ethanol were specifically chosen as anti-knock agents to enhance the octane rating of the gas condensate. It was found that blending MTBE with the gasoline effectively raised the octane number without any adverse impact on other fuel properties. However, it should be noted that the octane improvement achieved with MTBE was not as significant as that obtained with tetraethyl lead compounds. The addition of 5 to 15 vol% MTBE resulted in a research octane number increase of 1 to 3.4 degrees for both SRG and HN fractions, as highlighted in Table 6. Additionally, the inclusion of MTBE led to a reduction in the distillation temperature, which could potentially enhance drivability and cold engine operation. Importantly, MTBE-gasoline mixtures exhibited favorable characteristics such as the absence of gums and peroxides even after storage, and they did not show any phase separation issues in the presence of water. However, caution must be exercised in using higher concentrations of MTBE to prevent excessive gasoline volatility. Therefore, it is recommended to limit the amount of MTBE used in the blending process.

Ethanol, whether utilized as a blend with gasoline or as pure ethanol, is widely employed in numerous countries as a fuel additive to promote cleaner combustion and reduce air emissions. Ethanol possesses a higher-octane rating, faster flame speeds, and increased heats of vaporization compared to pure gasoline [21]. Consequently, ethanol can be considered an effective octane booster for the production of high-quality gasoline. The oxygen content ratio in the fuel mixture was identified as a significant factor influencing the Research Octane Number (RON) of the blended gasoline with alcohol components. The impact of ethanol on the octane rating of SRG and HN fractions can be observed through Figure 1 and Figure 2.

Table (6) effect addition of MTBE on SRG and HN properties

No	RON	MON	%Ox	%Sa	%Be
1	98	91.4	10.8	63.6	0.30
2	99	91.7	16.7	54.5	0.30
3	100.3	91.8	25.3	44.1	0.25

4	101.4	92.2	32.4	40.5	0.27
5	99	91.6	10.6	60.4	0.26
6	99.7	90.3	13.7	55	0.24
7	101.6	91.4	22.8	45.6	0.20
8	102.6	92.1	29.9	37	0.19

The results obtained from the study demonstrate a positive correlation between the concentration of ethanol and the enhancement of the Anti-Knock Index (AKI) in gas condensate blends. Table 7 presents the ethanol volume percentages in the ethanol-condensate blends, which were adjusted to achieve a consistent oxygen content. It was observed that higher ethanol concentrations in the blends resulted in higher oxygen content within the gas condensate. The relationship between ethanol concentration and oxygen content exhibited a linear pattern.

However, it is important to consider certain limitations associated with ethanol as an octane enhancer. Firstly, ethanol has a lower energy density compared to gasoline, which may lead to reduced fuel efficiency when used as a blending component. Additionally, ethanol possesses a lower boiling point, leading to increased evaporative emissions from the fuel. The miscibility of ethanol with water can also pose challenges, potentially causing phase separation issues and compromising the quality of the fuel. Moreover, the potential ecological toxicity of ethanol should be taken into account [22].

While ethanol offers the advantage of improving the octane rating of gas condensate blends, it is crucial to carefully evaluate and address the aforementioned disadvantages. Appropriate strategies should be employed to mitigate concerns related to lower energy density, higher evaporative emissions, water miscibility, and potential ecological impacts.

3.2.2. Aromatic Components

Aromatic compounds are widely recognized as a valuable source of fuels with high energy content and possess high octane ratings. Consequently, the addition of aromatic compounds to gasoline can significantly enhance the octane number, leading to improved fuel performance. Aromatic compounds typically exhibit excellent octane ratings, often surpassing 100, and undergo complete combustion to produce water and carbon dioxide as byproducts. This characteristic ensures that the emissions control systems, including catalysts and oxygen sensors, in vehicles remain unaffected.

Toluene, a transparent and non-polar liquid hydrocarbon with a distinctive odor resembling paint thinners, is an example of a mono-substituted benzene derivative with a chemical formula of C_7H_8. The impact of increasing the toluene content in gas condensate-based fuel, ranging from 5% to 25% by volume, on the Research Octane Number (RON) and Motor Octane Number (MON) gains is presented in Table 8. The results indicate that the inclusion of toluene has a significant effect on increasing the octane value of the mixed gas condensate blend.

Overall, aromatic compounds, particularly toluene, offer promising prospects for enhancing the octane rating of gas condensate blends. Their octane ratings and ability to convert completely to water and carbon dioxide during combustion make them compatible with emissions control systems in vehicles.

Xylene is a highly effective aromatic additive that demonstrates a remarkable ability to enhance the Octane number of Straight Run Gasoline (SRG) and Heavy Naphtha (HN). Its exceptional sensitivity in gasoline combustion makes it a valuable choice for achieving substantial Anti-Knock Index (AKI) improvements. For instance, incorporating xylene at concentrations of up to 20% by volume results in an AKI increase of 19.75 and 19.35 points for SRG and HN, respectively, as illustrated in Figure 1 and 2.

Table (7) effect addition of Ethanol on SRG and HN properties

No	RON	MON	%Ox	%Sa	%Be
9	96.1	90.1	4.94	70.3	0.37
10	96.1	90.1	11	62.1	0.33
11	98.5	89.5	15.7	58.7	0.26
12	99.7	89.3	19.9	54.7	0.25
13	105.3	95.4	23.6	50.2	0.21
14	106.2	95.7	27.5	48.1	0.24
15	96.5	90.3	5.09	65.9	0.32
16	97.5	90.1	10.4	59.4	0.29
17	99.1	90.4	17.3	53.7	0.25
18	100.5	91	19.4	52.1	0.23

19	105.2	95.4	22.6	49.6	0.20
20	107.6	96.7	27.6	45.1	0.22

However, it is important to note that the addition of xylene as an aromatic additive may impact combustion efficiency and lead to higher carbon monoxide (CO) emissions in gasoline. While xylene offers benefits in terms of octane enhancement, it is crucial to consider the potential drawbacks associated with aromatic compounds. Aromatic compounds, including xylene, are well-known for their harmful and carcinogenic properties.

Therefore, when utilizing xylene or any aromatic additive, it is essential to carefully assess the trade-offs between improved combustion efficiency and the potential health and environmental risks associated with increased CO emissions and the presence of harmful aromatic compounds. Appropriate measures and regulatory guidelines should be implemented to ensure the safe use of aromatic additives and minimize their negative impact on human health and the environment.

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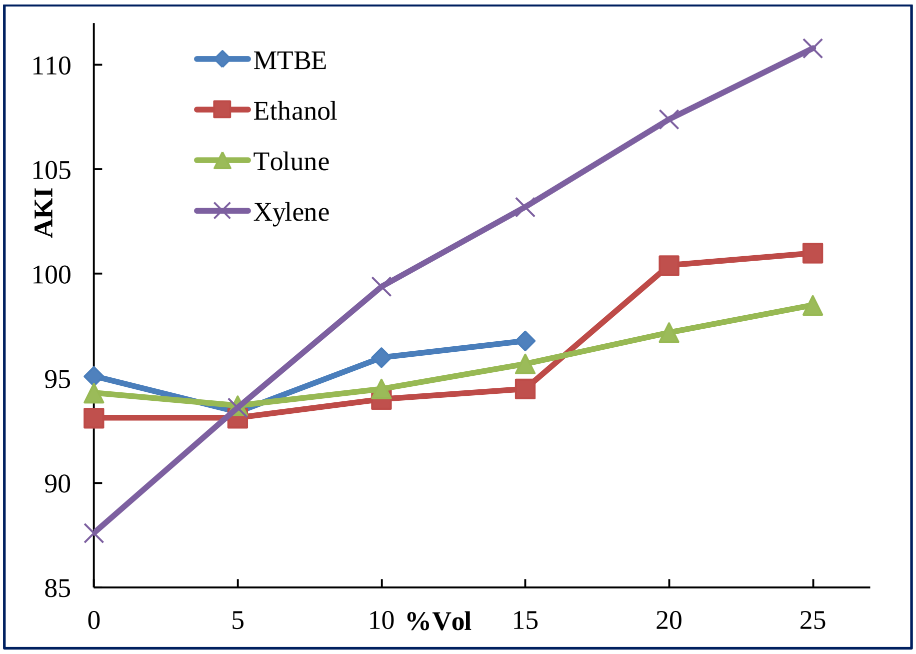

Fig. (1) Effect of additive on AKI SRG.

The obtained results demonstrate that the Research Octane Number (RON) and Motor Octane Number (MON) of all Straight Run Gasoline (SRG) and Heavy Naphtha (HN) blends show a clear increase when oxygenates and aromatic compounds are added. Among the additives investigated, xylene exhibits the highest effectiveness as an Octane enhancer, surpassing the performance of MTBE, ethanol, and toluene.

The findings suggest that the inclusion of xylene in the blends leads to the most significant improvements in both RON and MON values. It can be inferred that xylene demonstrates superior properties in enhancing the octane rating of SRG and HN compared to the other tested additives, such as MTBE, ethanol, and toluene.

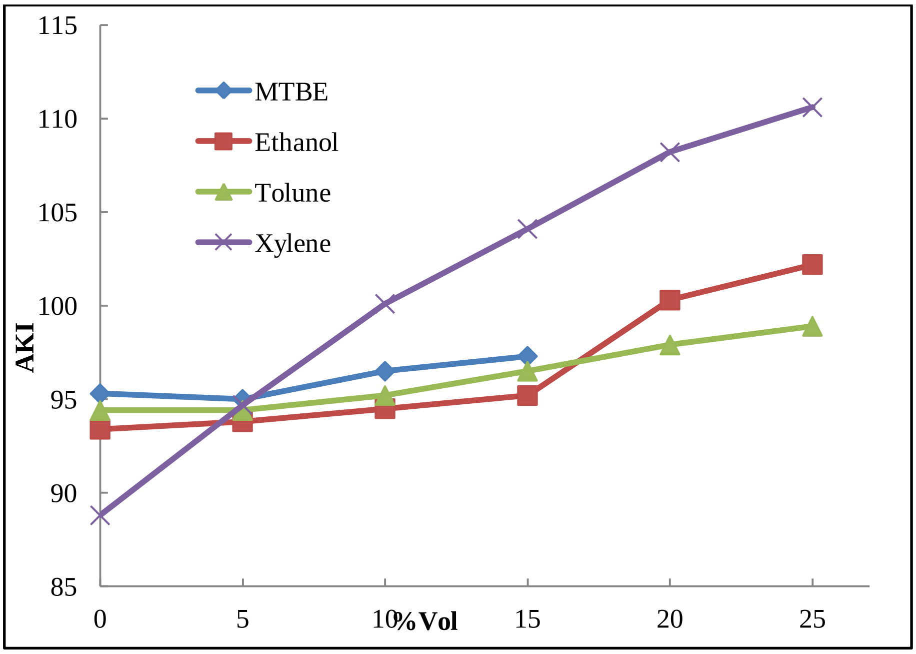

Fig. (2) Effect of additive on AKI HN.

Table (8) Effect addition of Toluene on SRG and HN properties

No	RON	MON	%Ar	%Ox	%Sa	%Be
21	98.1	90.6	21.2	16.3	62.5	0.3
22	97.7	90.7	28.3	16.7	55	0.3
23	99.1	90.8	34.7	16.4	48.9	0.27
24	101.1	90.4	39.2	17.4	43.4	0.27
25	103.1	91.3	44.2	17.3	38.6	0.23
26	104.8	92.3	49.5	14.2	36.3	0.23
27	98.4	90.4	22.1	16.7	61.2	0.24
28	98.9	89.8	29.9	16.8	53.3	0.23
29	100.5	90	35.2	16.6	47.9	0.23
30	102.2	90.8	40.4	16.4	43.2	0.21
31	104.1	91.7	45.2	16.4	38.4	0.21
32	105.4	92.3	47.6	13.7	38.7	0.20

Table (9) Effect addition of Xylene on SRG and HN properties

No	RON	MON	%Ar	%Ox	%Sa	%Be
33	91.4	83.8	9.3	15.7	75	0.28
34	97.2	90	27.8	18.2	54	0.29
35	103.8	94.9	39.9	18	42.1	0.26
36	107.2	99.3	53.9	17.9	28.3	0.32
37	111.9	102.8	59.3	18	22.7	0.27
38	115.1	106.5	67	15.3	17.7	0.26
39	92.7	84.9	15.6	17	66.7	0.26
40	99.3	90	29.8	16.6	53.7	0.24
41	105.2	95.1	41.3	17.5	41.2	0.21
42	109.1	99.1	50.2	16.5	33.3	0.24
43	113.1	103.2	59.3	14.6	26.1	0.23
44	115.5	105.6	63.5	14.2	22.3	0.20

4. Conclusions

In conclusion, gas condensate is a valuable feedstock for the production of gasoline, diesel, and other fuels, as well as chemicals and petrochemicals. The observation revealed that the straight run gasoline derived from the Khor Mhor gas condensate possesses a lower sulfur content and a higher-octane number compared to the heavy naphtha fraction**.** The octane number of gas condensate can be improved by incorporating oxygenates and aromatic compounds. Nevertheless, the addition of xylene resulted in the highest Research Octane Number (RON) and Motor Octane Number (MON) among the tested additives, indicating superior performance in terms of anti-knock properties. These results highlight the potential of xylene as a preferred choice for boosting the octane numbers of gas condensate blends. Further research and evaluation may be necessary to explore the underlying mechanisms and optimize the application of xylene as an effective Octane enhancer in the fuel industry.

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