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Formulation of Commercial Diesel Fuel at Low Sulfur Content Using the Mixture Design

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Abstract

The purpose of this work is to characterize crude oil, condensate, and their mixtures to predict the qualities of petroleum by-products to formulate a low-sulfur commercial diesel fuel. Experimental characterization by TBP distillation of crude oil and condensate is carried out. Then, the simulation of binary mixtures between the two charges is obtained for different proportions. These results are applied to choose the best blend that gives significant quantities of gas oils with superior quality. Finally, to formulate commercial diesel, the mixture design is used to model the sulfur content property. Two scenarios of commercial diesel formulation are developed; the first scenario is to use by-products obtained from separate feeds of crude oil and condensate, which gives diesel at 463 ppm of sulfur content.The second scenario based on by-product from the optimum mixture (50% crude oil, 50% condensate), gives diesel with lower sulfur content at 294 ppm. Both formulated diesel fuels meet the Algerian specifications, but the required value of 10 ppm sulfur content of the international standard is not achieved. Therefore, the hydrodesulfurization process is necessary.

Keywords: Crude oil; Condensate; Diesel fuel; Sulfur content; Mixture design;

Introduction

The diesel engine offers superior energy and thermal efficiencies, powerful output, more torque and better durability than the spark-ignition engine [1]. It becomes the engine used for heavy machinery to produce electrical energy [2]. It is the engine of choice for on-road and off-road operations such as passenger cars, heavy trucks, buses, trains, boats and ships [3]. Diesel fuels are the product of the progressive distillation of crude oil, which is a mixture of hydrocarbons with aliphatic C6–C20 alkanes such as tetra-, penta- and hexa-decane being the main components, but with small amounts of branched and aromatic alkanes. They contain a whole variety of individual hydrocarbons with boiling points ranging from about 180°C to 370°C [4]. Diesel fuel ignites on average at approximately 350°C (lower limit 220°C), which is very early compared to gasoline [5]. Unfortunately, the major disadvantage of diesel engines is that complete or incomplete combustion of diesel fuel results in emissions of hundreds of pollutants such as CO, CO, NOx, SOx and PM, as well as non-toxic pollutants such as PAHs, VOCs, dioxins and dioxin compounds. These emissions represent a threat to the environment, both atmospheric and ecological [6]. The following features characterize high-quality diesel fuels:

- High cetane number
- Relatively low final boiling point
- Narrow density and viscosity spread
- Low aromatics content particularly polyaromatic
- Low sulfur content.

In many countries of the world, diesel fuel standards are becoming increasingly severe, in Europe, the standard for diesel fuels is EN590 [7]. In this context, the objective of this study is to reduce the sulfur content of diesel fuel by promoting condensate of good quality, mixed with crude oil. Condensate is a mixture of hydrocarbons composed of molecules, which exist in the gaseous state in a deposit of natural gas. It condenses by expansion and cooling during the production of this natural gas. Large quantities of propane and butane (LPG) are thus recovered, but also molecules containing 5 to 10 or 15 carbon atoms. There are two categories of condensate; light condensate from C5 to C10 very close to naphtha and heavy condensate C5 to C15, which can give naphtha and distillates (kerosene and diesel) [8].

Materials and Methods

Materials

The properties of Algerians crude oil and condensate as their petroleum productsare determined by using the standards methods given in (Table 1) [9, 10].

Table 1: Tests Methods of characterization	
Characteristic	**Method**
Density	ASTM D 4052-11 and ISO 12185-96
Kinematic viscosity	ASTM D445/06 and ISO 3104/94
Color	ASTM 1500-04 and ISO2049-96
Distillation TBP “True Boiling Point”	ASTM 2892
Sulfur content	ASTM D 4294-2010 and ISO 8754-2003
Refractive index	ASTM D 1218-12 and ISO 5661-83
Pour point	ASTM D97-11 and ISO 3016
Cloud point	ASTM D2500-11 and ISO 3015-92

Petroleum characterization in Aspen HYSYS

The oil manager in Aspen HYSYS converts the laboratory assay analyses of crude oil and condensate into a series of discrete hypothetical components, which provide the basis for the property package to predict the remaining thermodynamic properties necessary for fluid modeling. Aspen HYSYS produces a complete set of physical and critical properties for the petroleum hypocomponent with a minimal amount of information [11]. The properties studied are the evolution of the sulfur content and the yield of petroleum products for the formulation of commercial diesel. Laboratory data such as True boiling point distillation (TBP) and density at 15°C of crude oil and condensate are required.

For oil, gas, and petrochemical applications, the Peng Robinson Equation of State is generally the recommended property model. It rigorously solves most single-, two-, and three-phase systems with a high degree of efficiency and reliability [11].

Mathematical Modeling

The study of a phenomenon often amounts to being interested in a particular quantity, which depends on a large number of variables. In mathematical form, we can write that the quantity of interest, y, also called a response, is a function of several variables x_1, x_2, ..., x_i also called factors. Each factor is delimited by a high level and a low level [12].

$$y = f\left(x_{1,} x_2, x_3, \ldots\ldots, x_i\right) \quad (1)$$

The mathematical model applied to the mixture design takes into account the fundamental constraint of mixtures. If xiis the percentage content of component i, the sum of all the mixture components is given by the relationship [12]:

$$\sum_{i=1}^{i=n} x_i = 100\% \quad (2)$$

The expression for a second-degree polynomial is as follows:

$$y = \sum a_i x_i + \sum a_{ij} x_i x_j + \sum a_{ii} x_i^2 \quad (3)$$

Where *y* is the response of the system, airepresents the main effect of the factor, aiiis the estimation of the second-order effect and a_{ij} the estimation of the interaction between the factor iand *j*. The finest model and the significance of each coefficient were determined by the analysis of variance (ANOVA), including the sequential *F* test, and other adequate measurements such as regression coefficient R^2. The greater magnitude of the *F*-value gives the smaller P-value, and therefore thehigher significance of the corresponding coefficient. The JMP Statistical Discovery Software (SAS Institute Inc.) was used for data calculation and processing [12].

Results and Discussion

Experimental characterization of crude oil, condensate and petroleum products

Properties of crude oil and condensate

The identification of feeds requires the determination of physicochemical properties according to the standardized tests (Table 2). The results show that the condensate is lighter than crude oil, where its density at 15°C is 0.7098 and has a lower sulfur content in the range of 7 ppm, contrary the crude oil has a sulfur content of 763 ppm. The Kuop factor shows that both are paraffinic.

The TBP distillation is performed for crude oil and condensate by using the laboratory measurement standard ASTM 2892 to obtain petroleum fractions kerosene, light gas oil (LGO) and heavy gas oil (HGO) used to formulate commercial diesel. Figure1 and Figure 2 respectively represent the TBP distillation and the density (ASTM D 4052-11)of each fraction recovered from crude oil and condensate. The condensate contains more light fractions

Table 2: Properties of crude oil and condensate

Properties	Crude oil	Condensate
Density at 20°C	0.7994	0.7098
Density at 15°C	0.8032	0.7144
°API	44.670	66.568
kinematic viscosity at 37.8°C (St)	5.002	1.004
Sulfur content (ppm)	763	7
Refractive index at 20°C	1.4682	1.4275
K_{uop}	12.15	12.23

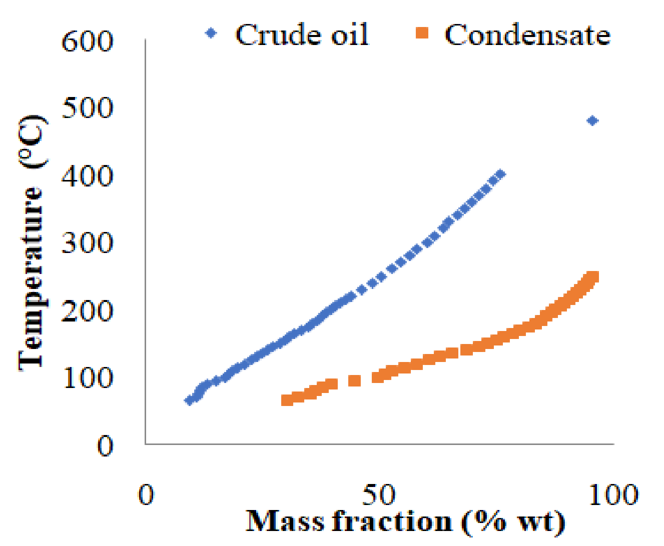


Figure 1: Distillation TBP

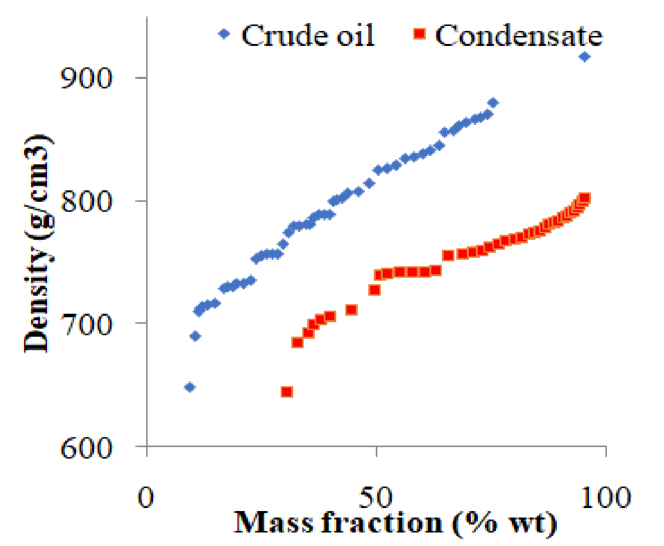


Figure 2: Density

than crude oil, and its content of heavy fractions is negligible compared to crude oil, which the limit of distillation is +400°C and the condensate is 250°C. Furthermore, the densities of fractions obtained from crude oil and condensate have shifted, because the quantity of light fractions is higher in condensate than crude oil.

Proprieties of petroleum products

The physical characteristics of kerosene, light gas oil (LGO) and heavy gas oil (HGO) according to the standards are indicated in (Table 3). The cold behaviour of the kerosene and LGO_{cond} resulting from the condensate is good. These products are used in the commercial formulation of diesel.

Table 3: Properties of petroleum products

Properties	Crude oil		Condensate	
	LGO_{co}	HGO	Kerosene	LGO_{cond}
Distillation range (°C)	250-320	320-380	235-250	250-320
Density at 20°C (kg/m³)	834.1	859.7	797.2	810
Density at 15°C (kg/m³)	837.6	863.1	800.8	813.6
Refractive index at 20°C	1.4665	1.4803	1.4450	1.4507
Sulfur content (ppm)	411	1400	21	28.73
Cloud point (°C)	-14	+7	-32	-17
Pour point (°C)	-15	9	-30	-18
Freezing point (°C)	-18	6	-33	-21

Simulation by Aspen HYSYS of binary mixtures

(Figure 3) shows the sulfur content property for each mixture between crude oil and condensate expected by software Aspen HYSYS. The sulfur content decreases with increasing condensate fraction in the mixture due to its low sulfur content which is around 7 ppm. In addition, the decrease of sulfur content is higher for middle distillates compared to the light and heavy fractions. Whereas, the maximum sulfur content is about 6000 ppm because the totality of sulfur remains trapped in the crude oil residue.

(Figure 4) represents the kerosene, LGO and HGO yields of each mixture between crude oil and condensate. The kerosene yield

Mixture	1	2	3	4	5	6	7	8	9
Crudeoil (%mass)	90	80	70	60	50	40	30	20	10
Condensate (% mass)	10	20	30	40	50	60	70	80	90

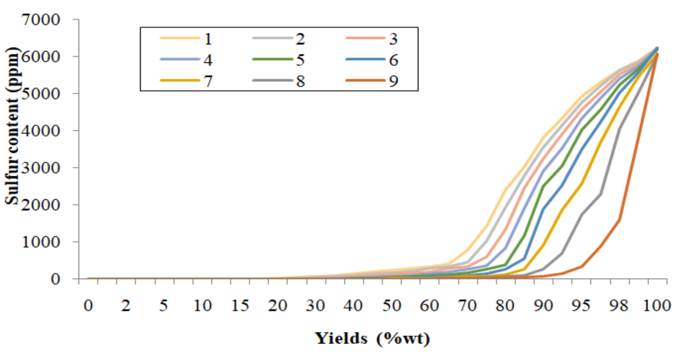


Figure 3: Sulfur content in each mixture

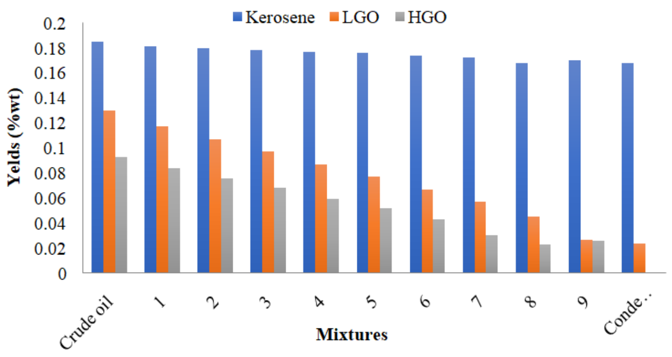


Figure 4: Yields of the petroleum products in the mixture

decreases slightly with the increase of condensate fraction for each mixture. Similarly, for LGO, its decline is higher than kerosene. The proportion of HGO does not exist in the condensate.

The compromise between the sulfur content distribution and the yield of blend stocks kerosene, LGO and HGO, allowed choosing an optimum mixture of 50% crude oil and 50% condensate. The TBP distillation of this mixture is carried out in the laboratory (Table 4).

Table 4: TBP distillation of the optimum mixture

Fractions	Cut point (°C)	Fraction (% wt)
Light gasoline	14.2-80	0.1895
Heavy gasoline	80-165	0.3319
Kerosene	165-250	0.1690
Light gasoil (LGO)	250-320	0.0684
Heavy gasoil (HGO)	320-380	0.0683
Residue	380+	0.1420

The three fractions (kerosene, LGO and HGO) obtained from TBP distillation of the optimum mixture (50% crude oil, 50% condensate) are deeply characterized (Table 5). Their densities respect the normalized values, which explains good separation effected by distillation TBP. The decrease in a sulfur content of kerosene and light gas oil is remarkable. The sulfur content of LGO is divided by almost half, to pass from 411 ppm to 223 ppm, and for HGO it decreased at 300 ppm. The cold behavior of light gas oil remains excellent with a cloud point of -20°C and a freezing point -24°C. The physicochemical properties of the three blend stocks of diesel fuel formulation are compared with blend stocks obtained only by crude oil.

Table 5: Characterization of kerosene, LGO and HGO

Properties	Kerosene	LGO	HGO
Density at 20°C (kg/m^3)	786.8	824.8	845.3
Density at 15°C (kg/m^3)	790.5	828.3	848.6
IR at 20°C	1.4413	1.4473	1.4719
Sulfur content (ppm)	20.64	223	1100
Cloud point (°C)	-	-20	3
Pour point (°C)	-	-21	3
Freezing point (°C)	-	-24	0

Formulation of diesel fuel

At the Algerian refineries, the production of diesel fuel is mainly obtained by a mixture of three intermediate petroleum products, obtained by direct distillation of crude oil, namely: kerosene and light gasoil, heavy gasoil. The formulation of diesel fuel is obtained by mixing different blend stocks. The properties, which interest the refiners, are the following: cold behavior, cetane index and sulfur content [13]. Experimental design of the mixtures is applied to model the property sulfur content in diesel fuel.

Scenario 1: Formulation of diesel fuel from petroleum productsof crude oil and condensate

a) Steps of construction the mixture design (Scenario 1)

The formulation of diesel fuel is prepared by blendstocks recovered from crude oil and condensate separately according to the diagram below (Figure 5). It consists of mixing light gasoil (LGOco and heavy gasoil (HGO) with kerosene and light gasoil (LGO_{cond}).

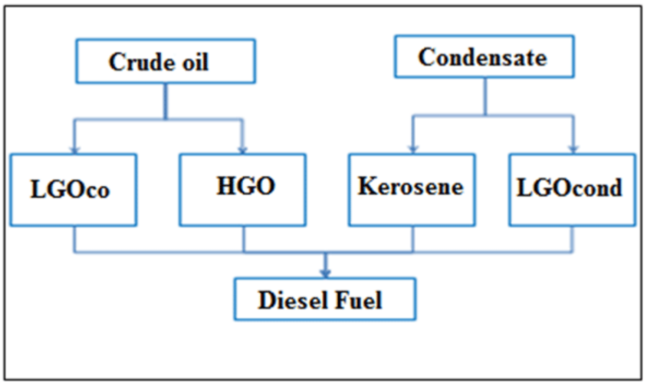


Figure 5: Diagram of formulation diesel fuel (Scenario 1)

The matrix of mixture design is built respecting the fractions of high level (max) and low level (Min) of the various mixtures shown in (Table 6). The tests are carried out according to the matrix to obtain diesel fuel and measure the sulfur content (Table 7).

Table 6: Composition limits of blendstocks (Scenario 1)

Blendstock	Composition (%Vol)	
	Min	Max
Kerosene of condensate	0	0.3
LGO_{cond} of condensate	0.1	0.3
LGO_{co} of crude oil	0.6	0.85
HGO of crude oil	0.1	0.3

Table 7: Mixture design matrix with the experimental results (Scenario 1)

Kerosene	LGO_{cond}	LGO_{co}	HGO	Experimental sulfur content (ppm)
0	0.1	0.8	0.1	535
0	0.1	0.7	0.2	592
0	0.1	0.6	0.3	743
0	0.1667	0.6667	0.1667	551
0	0.2	0.6	0.2	578
0	0.2	0.7	0.1	482
0	0.3	0.6	0.1	416
0.0667	0.1	0.6667	0.1667	560
0.0667	0.1667	0.6	0.1667	508
0.0667	0.1667	0.6667	0.1	437
0.1	0.1	0.7	0.1	464
0.1	0.1	0.6	0.2	518
0.1	0.2	0.6	0.1	438
0.2	0.1	0.6	0.1	401

b) Mathematical model of sulfur content and statistical analysis (Scenario 1)

The mathematical model of sulfur content for commercial diesel fuel as a function of the volume fraction of each blend stock is as follows:

$$\text{Sulfur}(\text{ppm}) = 400.07\left(\frac{KERO}{0.2}\right) + 418.38\left(\frac{LGO_{cond}-0.1}{0.2}\right) + 533.64\left(\frac{LGO_{co}-0.6}{0.2}\right) + 739.47\left(\frac{HGO-0.1}{0.2}\right)$$

$$73.52\left(\frac{KERO}{0.2}\right)\left(\frac{LGO_{cond}-0.1}{0.2}\right) + 6.94\left(\frac{KERO}{0.2}\right)\left(\frac{LGO_{co}-0.6}{0.2}\right) - 10.75\left(\frac{LGO_{cond}-0.1}{0.2}\right)\left(\frac{LGO_{co}-0.6}{0.2}\right)$$

$$154.06\left(\frac{KERO}{0.2}\right)\left(\frac{HGO-0.1}{0.2}\right) - 3.75\left(\frac{LGO_{cond}-0.1}{0.2}\right)\left(\frac{HGO-0.1}{0.2}\right) - 118.32\left(\frac{LGO_{co}-0.6}{0.2}\right)\left(\frac{HGO-0.1}{0.2}\right) \quad (4)$$

Figure 6 represents the variation of the actual responses as a function of the values predicted by models. The observed values of the sulfur content are close to that predicted and even identical for some tests with a correlation coefficient R2equal to 0.98, which shows that response is well correlated by the model. The residuals values of the sulfur content are randomly distributed according to the predicted values (Figure 7), so the model is validated.

Table 8shows the Analysis of variance that the probability on Fisher is less than 0.0048 for the sulfur content's model, so the probability that the model gives values equal to the mean is low. Thus, the variations of experimental values are due to the diesel blendstocks proportions and not to the experimental error, which confirms the linearity of the model.

Table 9illustrates the coefficients of the model, which are strongly significant with ratios of student "t" high and of the weak probabilities (< 0.0001). It is noted that for binary interactions, for example, LGOc and HGO are not very significant, the most influential coefficient is the HGO followed by the LGOco, LGOcond and KERO.

c) Optimisation of diesel composition (Scenario 1)

The prediction diagram of sulfur content is an interactive graph to see the influence of variations of the levels of the factors on responses by using the desirability function, which varies from 0 to 1. The optimization results of the sulfur content model are given in (Figure 10). After maximizing desirability at 0.7883, the optimal composition of commercial diesel fuel is 0.207 of light gas oil from the condensate with 0.693 of light gas oil and 0.1 of heavy gas oil from the crude oil. The predicted content sulfur of diesel fuel is 469.44 ppm. The optimal mixture is carried out at the laboratory and the sulfur content measured is 463 ppm near to the predicted value. The formulated diesel fuel is better because the sulfur content is divided almost by two in comparison with the diesel fuel of the national market, which content is 900 ppm.

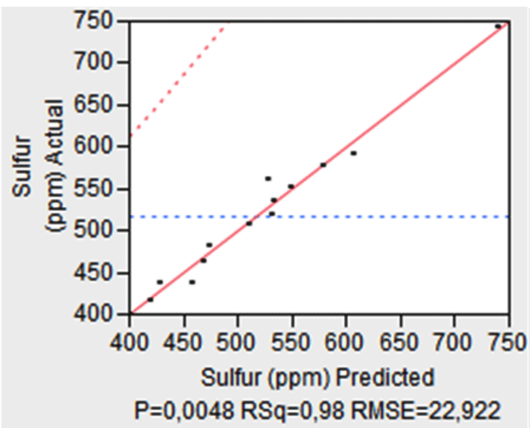


Figure 6: Actual versus predicted values of sulfur content (Scenario 1)

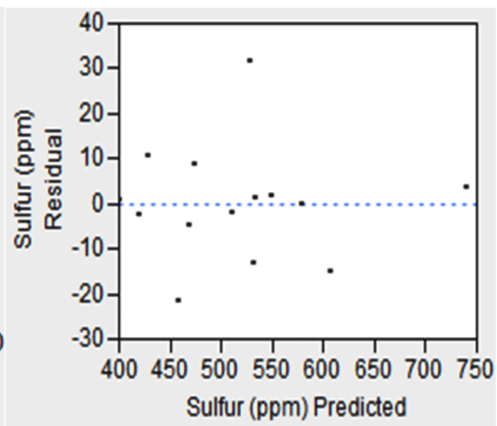


Figure 7: Residual versus predicted values of sulfur content (Scenario 1)

Table 8: ANOVA analysis of the sulfur content model (Scenario 1)				
Source	**DF**	**Sum of squares**	**Mean square**	**F ratio**
Model	9	102047.35	11338.6	21.5811
Error	4	2101.58	525.4	Prob>F
C. Total	13	104148.93		0.0048*

Table 9: Estimated parameter of the sulfur content model according to their influence (Scenario 1)				
Term	**Estimate**	**Std Error**	**t Ratio**	**Prob> |t|**
(HGO – 0.1)/0.2	739.47227	22.70647	32.57	<0.0001*
(LGOco – 0.6)/0.2	533.63894	22.70647	23.50	<0.0001*
(LGOcond – 0.1)/0.2	418.38455	22.70647	18.43	<0.0001*
KERO/0.2	400.06876	22.70647	17.62	<0.0001*
KERO*HGO	-154.0611	98.73758	-1.56	0.1937
LGOco*HGO	-118.3243	98.73758	-1.20	0.2969
KERO*LGOcond	73.517827	98.73758	0.74	0.4979
LGOcond*LGOco	-10.74533	98.73758	-0.11	0.9186
KERO*LGOco	6.9388795	98.73758	0.07	0.9473
LGOcond*HGO	-3.745331	98.73758	-0.04	0.9716

Scenario 2: Formulation of diesel fuel from mixture(50% crude oil, 50% condensate)

a) Steps of construction the mixture design (Scenario 2)

In the second scenario, the diesel fuel formulation is obtained from the kerosene, light gas oil (LGO) and heavy gas oil (HGO) blendstocks of the optimum mixture (50% crude oil, 50% condensate) according to the diagram in (Figure11).

The objective of the mixture design is to respect the constraints imposed on the fraction limits of each blend stock, according to (Table 10). The mixture design and the response of sulfur content measured for scenario 2 are illustrated in (Table 11).

b) Mathematical model of sulfur content and statistical analysis (Scenario 2)

A mathematical model for the sulfur content of commercial diesel fuel, based on the volume fraction of each blend stock, is defined in the formula below:

$$Sulfur(ppm) = 270.41\left(\frac{KERO}{0.3}\right) + 333.46\left(\frac{LGO-0.6}{0.3}\right) + 609.89\left(\frac{HGO-0.1}{0.3}\right) - 64.8437\left(\frac{KERO}{0.3}\right)\left(\frac{LGO-0.6}{0.3}\right) - 97.51\left(\frac{KERO}{0.3}\right)\left(\frac{HGO-0.1}{0.3}\right) - 164.11\left(\frac{LGO-0.6}{0.3}\right)\left(\frac{HGO-0.1}{0.3}\right) \quad (5)$$

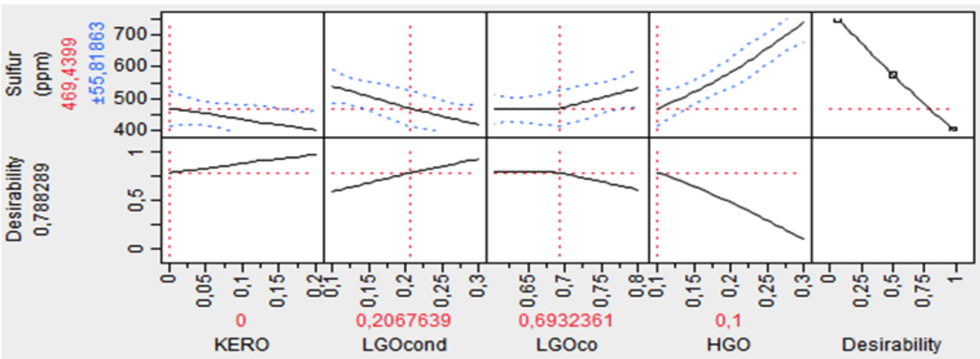


Figure 10: Prediction diagram of sulfur content (Scenario 1)

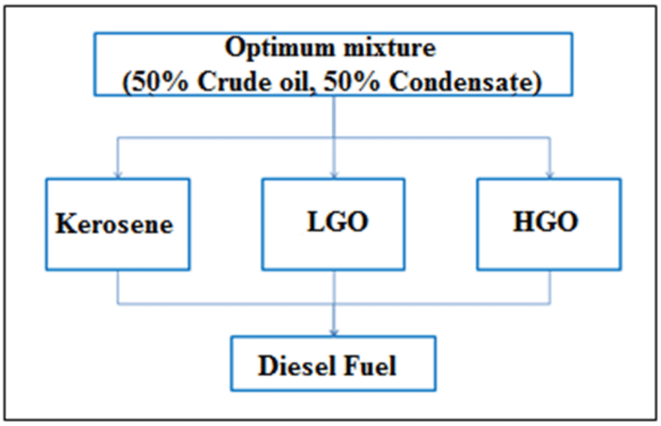


Figure 11: Diagram of formulation diesel fuel (Scenario 2)

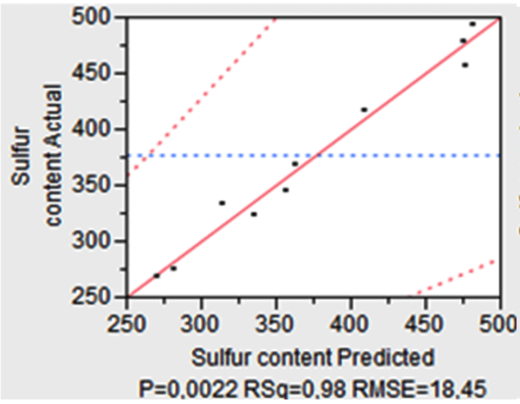
Table 10: Composition limit of blendstocks (Scenario 2)		
Blendstock	Composition (%Vol)	
	Min	Max
Kerosene	0	0.3
LGO	0.65	0.85
HGO	0.1	0.3

Table 11: Mixture design matrix with the experimental results (Scenario 2)

Kerosene	LGO	HGO	Experimental sulfur content (ppm)
0	0.7	0.3	494
0	0.775	0.225	416
0	0.85	0.15	345
0.025	0.85	0.125	323
0.05	0.65	0.3	457
0.05	0.85	0.1	334
0.1	0.6	0.3	478
0.175	0.725	0.1	275
0.2	0.6	0.2	369
0.3	0.6	0.1	269

The observed values of sulfur content are close to those predicted with a correlation coefficient R2 of 0.98, which show that responses are well correlated by the model (Figure 12). The random distribution of the residual relating to the predicted values of sulfur content show the validity of the model (Figure13).

The analysis of variance shows high F ratio of 34.29, indicating that values calculated by the model are due to the variation of the factors and are not close to the mean value. The probability that the coefficients of the model are not significant is low 0.0022 for the model of sulfur content (Table 12). The ratios of student terms (KERO/0.3), (LGO-0.6)/0.3 and (HGO-0.1)/0.3 are high and their probabilities close to zero, therefore their coefficients are influential and significant (Table 13).



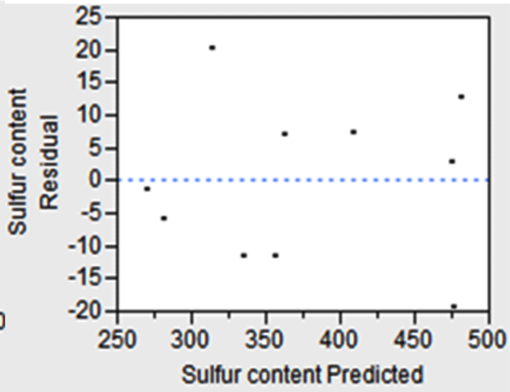


Figure 12: Actual versus predicted values of sulfur content (Scenario 2)

Figure 13: Residual versus predicted of sulfur content (Scenario 2)

Table 12: ANOVA analysis of the sulfur content model (Scenario 2)

Source	DF	Sum of squares	Mean square	F ratio
Model	5	58360.36	11672.1	34.2883
Error	4	1361.64	340.4	Prob>F
C. Total	9	59722.00		0.0022*

Table 13: Estimated parameter of the sulfur content model according to their influence (Scenario 2)

Term	Estimate	Std Error	t Ratio	Prob> |t|
KERO/0.3	270.40851	18.25368	14.81	0.0001*
(LGO-0.6)/0.3	333.45537	24.38633	13.67	0.0002*
(HGO-0.1)/0.3	609.88496	55.87652	10.91	0.0004*
LGO*HGO	-164.108	173.6885	-0.94	0.3982
KERO*HGO	-97.51425	157.191	-0.62	0.5686
KERO*LGO	-64.84371	109.9291	-0.59	0.5870

c) Optimisation of diesel fuel composition (Scenario 2)

Optimisation of the formulation of diesel fuel composition is illustrated in the prediction profiler for sulfur content (Figure 14). The optimum response is achieved for diesel fuel composition of 0.05 in kerosene, 0.85 in LGO, and 0.1 in HGO from the optimum mixture (50% crude oil, 50% condensate). The diesel fuel has a sulfur content of about 313.94 ppm given by the mathematical model and checked in the laboratory, which measured value of 294 ppm better than that of the national market.

Comparison of the characteristics of diesel fuel

Two types of formulations of gas oil are carried out at the laboratory, namely:

- Petroleum fractions resulting from the crude oil and condensate according to scenario 1.
- Petroleum fractions resulting from the optimal mixture with 50% the crude oil and 50% condensate according to scenario 2.

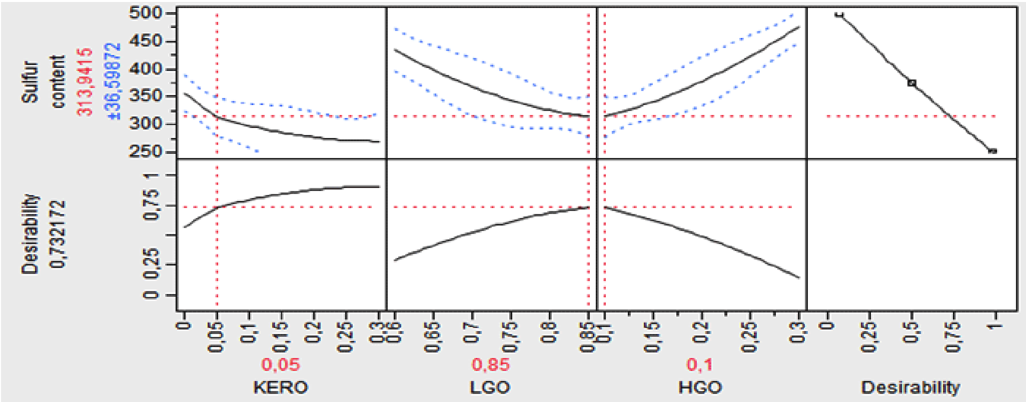


Figure 14: APrediction diagram of sulfur content (Scenario 2)

Table 14: Characteristics of commercial diesel fuel

Properties	Scenario 1	Scenario 2	Reference commercial diesel	National specifications	International specifications
Color	0.5	0.5	< 0.5	< 2.5	0.5
Density	0.8347	0.8288	0.8367	0.81-0.86	0.82-0.845
Viscosity at 40°C (Cst)	3.41	3.13	3.22	< 9	2-4.5
Sulfur content (ppm)	463	294	900	< 2500	<10
Cloud Point (°C)	-13	-20	-6Max. winter -3Max. summer	-9Max. winter-7Max. summer	-5Max. winter +5Max. summer

The characteristics of diesel fuel obtained from the two formulation scenarios are compared with those of the national market and with national and international specifications (Table 14). The properties of the diesel fuel in color, density, viscosity and cloud point are conform to the national and international standards. The value of sulfur content is better for both scenarios compared to the Algerian standard. However, the best result is given by scenario 2, in which the diesel fuel is better than the national market.

Conclusion

The diesel engines are classified among the principal causes of the current air pollution, in particular the oxide emissions of sulfur and nitrogen. Taking into consideration these stakes, the characteristics and the quality standards of the diesel fuel are into full evolution to answer the antipollution regulations, which are increasingly strict, especially the sulfur content. The diesel fuel is obtained starting, from the petroleum fractions of the crude oil alone or mixed with the condensate. However, it must meet the commercial specifications, particularly the reduction in the sulfur content.

The experimental tests of characterization showed that the condensate is lighter and cleaner than the crude oil, where its density is 0.779 g/cm3 at 15°C and sulfur content is about 7 ppm, on the other hand, crude oil presents a sulfur content of 763 ppm. Distillation TBP of crude oil and condensate deduce the yields of the fractions (kerosene, light gas oil and heavy gas oil) which are blends for the pool diesel fuel. The condensate is rich in clear products, and contains less heavy fractions than the crude oil; the limit of distillation is 250°C for condensate and more than 400°C for the crude oil. The gas oils fractions recovered from the crude oil gave sulfur contents raised for LGO (411 ppm) and HGO (1400 ppm), on the other hands for those resulting from the condensate, their contents sulfur are respectively 21 ppm and 28.73 ppm for kerosene and LGO.

The simulation by Aspen HYSYS software of the mixtures between crude oil and condensate allowed studying the sulfur content and the output in petroleum fractions of each mixture. The selected optimal mixture is composed of 50% crude oil and 50% condensate to obtain petroleum fractions for the formulation of commercial diesel fuel with low sulfur content. Distillation TBP of this mixture gave kerosene, LGO and HGO, whose physicochemical properties are better with a sulfur content of LGO decreased by half to go from 411 ppm to 223 ppm, and for HGO the sulfur content was reduced by 300 ppm to move from 1400 ppm to 1100 ppm.

Two scenarios of commercial diesel fuel formulation were elaborated. Scenario 1 was the formulation from the petroleum fractions of crude oil and condensate, and scenario 2 was the formulation from the petroleum fractions of the optimal mixture with 50% crude oil and 50% condensate.

To minimize the number of the experimental tests, a mixture design was applied for the pool gas oil with three bases kerosene, LGO and HGO while optimizing the quantity of kerosene. The mathematical model for the sulfur content was validated because the probability that the coefficients are nonsignificant is very low. The model of the sulfur content gave a probability of 0.0048 (Scenario 1) and 0.0022 (Scenario 2).

The formulations optimized for the two scenarios are compared with the experiments. All the properties of the diesel fuel obtained for the two scenarios met the national and international specifications, except for the sulfur content. The lowest value for the diesel fuel is 294 ppm in the case of the optimal mixture, far from the 10 ppm of the international specification.

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