Evaluation of Diesel Fuel Product Quality During Storage Processes Using Qualitative Statistical Methods

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Abstract

Fuel quality plays a crucial role in engine performance and emissions, requiring routine testing of its physical characteristics. This study aims to assess the quality of various fuel types used in Indonesia by measuring ash content, density, Specific Gravity (SG), and American Petroleum Institute (API) gravity. The research also evaluates the stability and consistency of these characteristics through repeated tests and identifies the specific properties of each fuel that influence combustion efficiency and engine performance. The study was conducted at the Quality Control Laboratory of the Energy and Mineral Polytechnic Akamigas using standard laboratory procedures. The equipment used includes filter paper, beakers, volumetric pipettes, funnels, porcelain and optical crucibles, analytical balance, tweezers, oven, desiccator, aluminum foil, and other supporting tools. The fuels tested include Pertamax Turbo 98, Pertamax 92, X Mix (92 mixed with 98), Biosolar, Fatty Acid Methyl Ester (FAME), and Dexlite mixed with FAME. Results indicate that FAME, Biosolar, and Dexlite show varied ash content characteristics that influence combustion performance. FAME provides stable combustion with moderate ash content, Biosolar offers cleaner combustion due to its low ash content, while Dexlite exhibits the highest ash content, potentially causing residue buildup. On the other hand, Pertamax Turbo and Pertamax demonstrate high consistency in density, SG, and API gravity, making them reliable for diverse operating conditions. Based on the findings, Pertamax Turbo and Pertamax are recommended as optimal fuels for maintaining efficient engine performance and emission standards.

Keywords: *Analysis; ASH content; Diesel fuel; Performance; Stockpiling*

1. Introduction

In the oil and gas industry, the density of products such as gasoline, diesel, jet fuel, and crude oil significantly impacts various operational aspects (Venriza, O., & Priantoro, D, 2023). Products with different densities exhibit varying combustion characteristics, which affect engine performance, fuel consumption, and exhaust emissions. Therefore, density testing is conducted routinely to ensure that the products meet desired standards and are compatible with the specifications of the engines using them. Density testing also plays a crucial role in the trade and distribution of oil and gas products [1]. The density of a fuel is used to calculate the mass of a specific volume, which serves as the basis for trade transactions, both on a national and international scale. The accuracy of density measurement directly affects the economic value of the oil and gas product. Additionally, density is also used to control quality and the blending process in fuel production, such as determining the correct proportion of additives [2].

Pertamax and Pertamax Turbo are premium fuels from Pertamina designed for modern vehicles with high performance and low emissions. The main difference between them lies in their density (mass per volume) and octane rating. Pertamax has an RON of 92 and a density of around 0.74-0.76 kg/L, making it suitable for conventional to semi-modern engines. This density allows for stable combustion without the risk of premature detonation. Pertamax Turbo, with an RON of 98 and a slightly lower density (0.74 kg/L), is better suited for high-performance vehicles with turbochargers or direct injection technology. The lower density and different chemical composition enable more efficient combustion, enhancing engine power and thermal efficiency while reducing exhaust emissions. Additionally, Pertamax Turbo contains special additives that help keep the engine clean and improve its durability. The choice between Pertamax and Pertamax Turbo depends on the vehicle's specifications. High-performance vehicles benefit the most from Pertamax Turbo, while Pertamax remains optimal for general vehicles.

The determination of ash content in oil and gas (petroleum) products, such as crude oil, fuels, lubricants, and their derivatives, is a crucial aspect in maintaining product quality and efficiency. Ash is the inorganic residue that remains after the complete combustion of an organic sample. Sources of ash content in petroleum products can originate from natural mineral impurities, additives, or contaminants present in crude oil from the start, as well as those that emerge during production, refining, storage, or distribution processes. This ash content significantly impacts the operational performance of engines and equipment. For instance, excessive ash in fuels or lubricants can lead to the formation of deposits in the combustion chamber, reducing combustion efficiency and energy output [3]. In addition, the accumulation of inorganic materials can increase the risk of corrosion, accelerate mechanical wear, and shorten the lifespan of equipment [4].

The measurement of ash content in petroleum products often follows international standards, such as ASTM D482 and ISO 6245, which involve burning a sample at high temperatures of over 500°C to eliminate all organic components. The inorganic residue is then calculated as the ash content, expressed as a percentage of the total sample weight [5]. This test is used not only for quality control of the final product but also to ensure that petroleum products comply with the established technical specifications [6]. In addition, a low ash content also contributes to the reduction of harmful particulate emissions that can impact human health and the environment. A study by [7] showed that particulate emissions from the combustion of fossil fuels with high ash content play a role in air pollution and worsen environmental quality. Stricter regulations regarding vehicle and power plant emissions are pushing fuel producers to maintain the ash content in petroleum products at minimal levels [8]. High ash content not only impacts engine performance but also increases harmful atmospheric pollutants. Therefore, controlling ash content has become a priority to improve operational performance, minimize environmental impact, and comply with applicable industry regulations berlaku [9].

The determination of ash content in oil and gas (petroleum) products is a key indicator in assessing the quality of fuels and lubricating oils. Ash content refers to the inorganic material that remains after complete combustion, typically including metals, oxides, sulfides, and other inorganic compounds. High ash content can affect engine performance, such as the formation of deposits in the combustion chamber, leading to reduced combustion efficiency and accelerated wear of engine components [10]. International standards, such as ASTM D482, are used to measure ash content by burning a sample at high temperatures in a muffle furnace, ensuring that all organic components are completely burned, and weighing the inorganic residue as a percentage of the initial sample weight [11]. In addition to its impact on engine efficiency, ash content also has significant environmental implications. The ash released from the combustion of petroleum products may contain heavy metals or hazardous compounds that can contaminate soil and air. A study has shown that ash from the combustion of fossil fuels contributes significantly to air pollution and ecosystem damage [12]. Therefore, strict limits on ash content are enforced in petroleum industry standards to ensure product performance while minimizing the negative environmental impact.

In the context of petroleum analysis, gravimetric methods are commonly used to determine the hydrocarbon component content in samples. This technique involves isolating components from mixtures using methods such as filtration, liquid-liquid extraction, and drying, followed by weighing to obtain quantitative results. Research indicates that gravimetry offers high accuracy in analyzing heterogeneous samples like crude oil, although it requires more time compared to other methods [13]. Despite its limitations in analyzing volatile components, gravimetry remains a reliable method due to its simplicity and reliability, without the need for expensive or complex equipment [14]. The development of gravimetric technology continues to enhance sensitivity and reduce analysis time, which is crucial in various phases of the petroleum industry, from exploration to refining. These innovations support the need for fast and accurate methods to address the increasingly complex challenges in analyzing petroleum components [15].

The determination of Fatty Acid Methyl Ester (FAME) is a crucial aspect in assessing the quality of biodiesel as an environmentally friendly alternative fuel [16]. Fatty Acid Methyl Ester (FAME) is produced through the transesterification process of triglycerides derived from vegetable oils or animal fats, using either basic or acid catalysts to generate methyl esters of fatty acids and glycerol as byproducts [17]. This transesterification process is influenced by various factors, such as the type of feedstock, the type of catalyst, the methanol-to-oil molar ratio, as well as reaction conditions like temperature and time [18]. Identification and quantification of Fatty Acid Methyl Ester (FAME), are typically carried out using Gas Chromatography (GC), an analytical method known for its high accuracy in separating and detecting compounds based on their volatility and molecular mass [19].

The composition of fatty acids in feedstocks plays a critical role in determining the quality of Fatty Acid Methyl Ester (FAME). Saturated fatty acids provide better oxidative stability, while unsaturated fatty acids affect the physical properties of biodiesel, such as viscosity and flash point. Previous studies have shown that biodiesel with high Fatty Acid Methyl Ester (FAME) content can significantly reduce greenhouse gas emissions, support the decarbonization of the energy sector, and provide substantial environmental benefits compared to fossil fuels [20]. However, the industrial application of biodiesel faces challenges, including the adaptation of storage and distribution infrastructure, as well as meeting international quality standards such as EN 14214 and ASTM D6751 [21]. Optimizing the determination of Fatty Acid Methyl Ester (FAME) is key to ensuring the sustainability of biodiesel as part of the future energy mix. Innovations in analytical techniques and production processes are continually being developed to improve efficiency, reduce costs, and ensure that biodiesel products meet global regulatory [22]. Therefore, Fatty Acid Methyl Ester (FAME) based biodiesel has significant potential to support the energy transition to cleaner and more sustainable resources.

Based on the background that has been explained, the problem formulation in this research covers several aspects. First, how can the correct and accurate method for determining the density of oil and gas using a hydrometer be carried out? Second, how can the proper method for determining the American Petroleum Institute (API) gravity of oil and gas using a hydrometer be conducted? Third, how can the manual filtration process be carried out effectively and correctly? Fourth, how can the ash content in diesel, biosolar, and Fatty Acid Methyl Ester (FAME) fuels be accurately calculated so that the results obtained are trustworthy? Finally, how can the relative standard deviation for each fuel product being tested be calculated, and what is the impact of these calculations on the evaluation of the fuel quality being tested?. This study aims to provide a deep understanding of the experimental techniques used in fuel quality evaluation, particularly in terms of measuring density, American Petroleum Institute (API) gravity, ash content, and statistical analysis of fuels.

2. Method

This research was conducted at the Quality Control Laboratory of Energy and Mineral Polytechnic, with the primary objective of testing fuel samples through laboratory analysis using predefined instruments and materials. The equipment used in this practical work includes various supporting instruments that comply with laboratory standards to ensure accurate and reliable results. The main tools used in this experiment include nine 110 mm Whatman filter papers, three 50 ml beaker glasses, three volumetric pipettes, and three funnels. Additionally, porcelain dishes and optical dishes are used for specific testing processes, supported by an analytical Beoco balance for accurate weighing, as well as tweezers and a bulb as supplementary tools. To facilitate drying and cooling, a Heratherm oven and desiccator are used, while aluminum foil serves as a protective material during certain stages. Other specific instruments include a standard hydrometer with density, Specific Gravity (SG) and American Petroleum Institute (API) Gravity scales; ASTM 12 C or 12 F thermometer; graduated cylinders; constant-temperature baths; funnels; and clamps to effectively support various experimental stages.

The materials used in this practical work consist of various types of fuel samples to support quality analysis and testing. The primary samples include gasoline products such as Pertamax Turbo 98 and Pertamax 92, as well as a mixture sample labeled X (92 mix 98). Additionally, there are supplementary samples of biodiesel (biosolar) and Fatty Acid Methyl Ester (FAME), as well as a mixture of Dexlite with Fatty Acid Methyl Ester (FAME) in a 4:5:6 ratio. These material combinations are designed to ensure the validity and accuracy of the testing, while also supporting further analysis of the characteristics and quality of the fuels being studied.

3. Results and Discussion

Density in Fuel Oil

The results of density and Specific Gravity (SG) analysis for Pertamax Turbo show small but consistent variations based on repetition. In the first to third repetitions, the density at 15°C was recorded as 0.7428. The Specific Gravity (SG) calculated using the linear interpolation method yielded a value of 0.7431. Additionally, the American Petroleum Institute (API) gravity calculated using a similar method showed a result of 58.932. From the fourth to the tenth repetition, the density slightly increased to 0.7430. The Specific Gravity (SG) for this density value resulted in 0.7433, with the American Petroleum Institute (API) gravity remaining stable at 58.88. The small changes in density, Specific Gravity (SG) and American Petroleum Institute (API) gravity indicate that the physical quality of Pertamax Turbo fuel has good stability across multiple repetitions. This stability reflects that the product meets the quality standards applied, ensuring its reliability as a high-quality fuel.

The results of density and Specific Gravity (SG) analysis for Pertamax show consistency and stability across multiple test repetitions. In the first to third repetitions, the density at 15°C was recorded as 0.7332. Using the linear interpolation method, the Specific Gravity (SG) calculation produced a value of 0.7334, while the American Petroleum Institute (API) gravity reached 61.428. From the fourth to the tenth repetition, the density slightly increased to 0.7334. The Specific Gravity (SG) calculation showed a slight increase to 0.7336, while the American Petroleum Institute (API) gravity slightly decreased to 61.376. These small changes suggest that the characteristics of Pertamax fuel remain stable, with minimal fluctuations in key parameters such as density, Specific Gravity (SG) and American Petroleum Institute (API) gravity. This stability indicates that Pertamax maintains consistent quality and meets established quality standards, ensuring its reliability as fuel for use in various conditions.

Statistic Evaluation of Ash Content in Fuel Oil

The results of the statistical evaluation regarding the ash content in fuel oil are shown below.

Table 1. Ash Content Experiment Results

Sample	Trial	Initial Mass (g)	Final Mass (g)
Bio Solar	1	0.8325	1.3946
	2	0.8268	1.3906
	3	0.8295	1.4108
FAME	1	0.8275	1.5947
	2	0.8147	1.5930
	3	0.8069	1.5951
Dexlite	1	0.8038	1.6399
	2	0.8058	1.6405
	3	0.8181	1.6422
Sample-X	1	0.8275	1.5947
	2	0.8147	1.5930
	3	0.8069	1.5951

Based on the table above the average ash content for each fuel sample was calculated by determining the difference between the final and initial mass for each trial, and then averaging these values. For Bio Solar, the average ash content across three trials was found to be 0.5691 g. This indicates a moderate variation in the ash content within this sample. For Fatty Acid Methyl Ester (FAME), the average ash content was 0.7779 g, showing slightly higher ash content compared to Bio Solar. Dexlite had the highest average ash content at 0.8316 g, indicating a relatively greater presence of ash compared to the other samples. Lastly, Sample-X, which showed values identical to Fatty Acid Methyl Ester (FAME), also had an average ash content of 0.7779 g, suggesting similar characteristics in terms of ash content. These results provide insight into the ash content variation across different fuel types, which can be used for further analysis of their combustion properties and quality

Statistic Evaluation of Bio Solar Ash Content

The results of the statistical evaluation of the ash content in Bio Solar can be seen below.

Table 2. Ash Content Results for Bio Solar

Sample	X	X̄ (Average)	X - X̄	(X - X̄)²
Filter Paper 1	56.21	56.90666667	-0.696666667	0.485344444
Filter Paper 2	56.38	56.90666667	-0.526666667	0.277377778
Filter Paper 3	58.13	56.90666667	1.223333333	1.496544444
Average		56.90666667		2.259266667

Based on the table above by using the ash content calculation formula, the practitioner can determine the amount of ash from each filter paper. The calculated results are 56.21, 56.38, and 58.13 for filter paper 1, filter paper 2, and filter paper 3, respectively. These three values are entered and processed first to calculate the standard deviation.

Statistic Evaluation of Fame Ash Content

The results of the statistical evaluation of the ash content in Fatty Acid Methyl Ester (FAME) is shown below:

Table 3. Fame Results

Sample	X	X̄ (Average)	X - X̄	(X - X̄)²
Filter Paper 1	76.72	77.79	-1.07	1.1449
Filter Paper 2	77.83	77.79	0.04	0.0016
Filter Paper 3	78.82	77.79	1.03	1.0609
Average		77.79		2.2074

Based on the table above by using the ash content calculation formula, the amount of ash in each filter paper can be determined. The results obtained are 76.72, 77.83, and 78.82 for filter paper 1, filter paper 2, and filter paper 3, respectively. These three values are entered and processed first to calculate the standard deviation.

Statistic Evaluation of Dexlite Ash Content

The results of the statistical evaluation of the ash content in Dexlite is shown below:

Table 4. Dexlite Results

Sample	X	X̄ (Average)	X - X̄	(X - X̄)²
Filter Paper 1	83.61	83.1633	0.4467	0.1995
Filter Paper 2	83.47	83.1633	0.3067	0.0940
Filter Paper 3	82.41	83.1633	-0.7533	0.5675
Average		83.1633		0.8611

Based on the table above by using the ash content calculation formula, the amount of ash in each filter paper is determined. The results obtained are 83.61, 83.47, and 82.41 for filter paper 1, filter paper 2, and filter paper 3, respectively. These three values are entered and processed first to calculate the standard deviation.

Statistic Evaluation of Sample X (Dexlite x Fame) Ash Content

The results of the statistical evaluation of of the ash content in Sample X (Dexlite x Fame) is shown below:

Table 5. Ash Content Results for Sample X (Dexlite x Fame)

Sample	X	X̄ (Average)	X - X̄	(X - X̄)²
Filter Paper 1	76.72	77.79	-1.07	1.1449
Filter Paper 2	77.83	77.79	0.04	0.0016
Filter Paper 3	78.82	77.79	1.03	1.0609
Average		77.79		2.2074

Based on the table above by using the ash content calculation formula, the amount of ash in each filter paper is determined. The results obtained are 76.72, 77.83, and 78.82 for filter paper 1, filter paper 2, and filter paper 3, respectively. These three values are entered and processed first to calculate the standard deviation.

Statistical Analysis

Standard Deviation of Ash Content

Based on the calculations, a standard deviation of 0.867807 indicates that the data has low variation and is relatively consistent. This reflects good accuracy and precision in the testing process, suggesting that the methods and tools used are effective. The data shows stable measurement results that are within acceptable tolerance limits, ensuring the quality of the testing process.

Relative Standard Deviation (RSD) of Ash Content

Based on the calculations, the Relative Standard Deviation (RSD) is 0.433903, indicating a low level of variation in the test data. This means the data obtained is sufficiently consistent and accurate, with only slight fluctuations between measurements. Therefore, it can be concluded that the methods used in this experiment produce stable and reliable results for product quality evaluation.

Standard Deviation of Fame

Based on the standard deviation (SD) calculation for Fame, the obtained SD value is 0.857788. This value represents the degree of data spread around the mean value. The larger the SD, the greater the variation in the data. In this case, the SD indicates moderate variation in the data being tested, although the results are not significantly far from the mean. While there are fluctuations in the measurements, the data still demonstrates relative consistency, and the results can be used for further analysis, considering the existing level of variation.

Relative Standard Deviation (RSD) of Fame

Based on the standard deviation (SD) calculation for Fame, the obtained SD value is 428894. This value measures the variation relative to the mean data, adjusted by the number of data points (n-1). With an RSD of this size, it can be concluded that the variation relative to the mean is quite small, indicating that the data tested is relatively stable and consistent. Despite minor fluctuations, the variation is not significant, and the results can be considered representative for further analysis.

Standard Deviation of Dexlite

Based on the standard deviation (SD) calculation for Dexlite, the obtained SD value is 0.535745. In this case, the relatively low SD value indicates that the variation in Dexlite data is not too large, meaning that the ash content in Dexlite has a fairly good level of consistency. This suggests that Dexlite tends to maintain its quality stably in the ash content testing, which is crucial in ensuring optimal engine performance and more efficient combustion.

Relative Standard Deviation (RSD) of Dexlite

Based on the calculations, the Relative Standard Deviation (RSD) is 0.267872. This RSD value shows the percentage variation of the data relative to the mean data. With a low RSD of around

0.267872%, it can be concluded that the variation in the sample data is relatively small compared to the mean value. This demonstrates a good level of consistency in the measurement or observation results, as the data fluctuations are not large, and the data tends to be stable or not fluctuate significantly.

Standard Deviation of Sample X (Dexlite x Fame)

Based on the calculations, the Standard Deviation (SD) is 0.857788. This value represents the extent of data spread or variation around the mean. The larger the SD, the greater the variation from the mean value. In this case, the SD indicates a significant level of variation in the sample being analyzed, although still within acceptable limits depending on the context and research objectives. In other words, despite the variation in the data, it still demonstrates relatively good consistency.

Relative Standard Deviation (RSD) of Sample X (Dexlite x Fame)

Based on the Relative Standard Deviation (RSD) calculations, the value is 0.428894. This RSD value is calculated by dividing the standard deviation (SD) by the difference in the number of data points minus one (n-1), then multiplying by 100%. The RSD of 0.428894 indicates that the variation relative to the mean is relatively small, suggesting that the analyzed data has a consistent distribution and is not too widely dispersed. This could be an indicator that the data used in the analysis is stable and does not show large fluctuations.

The research results on the ash content in three types of fuel, namely Fatty Acid Methyl Ester (FAME), Biosolar, and Dexlite, showed significant differences in the average ash content values and their variations, which in turn affect combustion performance and its impact on the engine. Fame, Biosolar, and Dexlite each show distinct characteristics that can be used to evaluate fuel quality. For Fame, the average ash content is 77.79 with a standard deviation (SD) of 0.857788 and a relative standard deviation (RSD) of 0.428894, indicating relatively good stability in terms of ash content variation [23]. The lower RSD value indicates that Fame has stable variation, even though its ash content is not the lowest among the three fuels. The stable ash content in Fame can result in more consistent combustion, making it suitable for engines that require stable performance [24].

On the other hand, Biosolar shows the lowest average ash content at 56.91, with an SD of 0.867807 and an RSD of 0.433903. Although it has lower ash content, its variation is slightly higher compared to Fatty Acid Methyl Ester (FAME), indicating greater fluctuations in ash levels (Putra et al., 2022). This lower ash content makes Biosolar a more environmentally friendly fuel, as it can result in cleaner combustion and reduce greenhouse gas emissions [25]. Therefore, Biosolar may be more suitable for users who prioritize lower emissions and higher combustion efficiency [26].

In contrast, Dexlite has the highest ash content at 83.16, but with an SD of 0.535745 and the lowest RSD of 0.267872. This suggests that, despite its higher ash content, Dexlite shows smaller variation compared to the other two fuels, indicating that Dexlite has relatively good consistency in terms of ash content [27]. However, the high ash content may lead to increased ash residue during combustion, potentially affecting engine performance and accelerating maintenance needs [28]. Overall, the differences in ash content between Fame, Biosolar, and Dexlite reflect the unique characteristics of each fuel. Fame has stable ash content with relatively low variation, making it a good choice for applications requiring consistent combustion. Biosolar, with the lowest ash content, provides cleaner combustion, albeit with slightly more variation. Meanwhile, Dexlite, although consistent, has high ash content that may add residue in the engine. Choosing the right fuel should consider the ash content, particularly concerning engine performance, maintenance frequency, and environmental impact [29]. Therefore, while each fuel has its advantages and disadvantages, the right choice will depend on the user's needs and priorities related to combustion efficiency and ash residue management.

The results of the density and Specific Gravity (SG) calculations, which show the quality stability of Pertamax and Pertamax Turbo, can be further analyzed based on related literature. Density, Specific Gravity (SG) and American Petroleum Institute (API) gravity are important parameters for measuring fuel quality, which are directly related to combustion performance and engine efficiency. The density stability found in Pertamax Turbo and Pertamax reflects effective quality control during production. The small variation observed is consistent with previous studies highlighting the importance of density consistency to ensure combustion efficiency. The ASTM D1298 standard shows that small variations in density can be correlated with fuel quality and performance. The stable American Petroleum Institute (API) gravity values in this study support the finding that fuels with optimal API gravity improve combustion efficiency and reduce carbon emissions. A high American Petroleum Institute (API) gravity, as found in Pertamax, indicates a fuel with low density, which burns more easily, reduces ignition delay, and improves engine efficiency. This is consistent with research highlighting the importance of American Petroleum Institute (API) gravity in the design of high-performance fuels [30]. Research by [31] shows that Specific Gravity (SG) consistency is an important indicator for fuel stability in various operating conditions. Additionally, studies by [32] found that the stability of physical parameters such as density and Specific Gravity (SG) affects combustion efficiency and engine component longevity. This is relevant to the current findings, where Pertamax Turbo and Pertamax show parameter stability that supports their use in various conditions. The small variations in density and Specific Gravity (SG) indicate that Pertamax and Pertamax Turbo meet international quality standards for high-performance fuels. This parameter stability indicates the reliability of the products in supporting engine efficiency and emission reduction. Future studies can evaluate the performance of these fuels in specific applications, such as vehicles with advanced combustion technology.

4. Conclussion

Based on the research findings, it can be concluded that Fame, Biosolar, and Dexlite each have their own distinct characteristics related to ash content, which affects combustion quality and engine performance. Fame has a medium-level average ash content with relatively stable variation, supporting consistent combustion. Biosolar, despite having the lowest ash content, shows slightly more variation, making it potentially capable of producing cleaner and more environmentally friendly combustion, making it a suitable choice for users who prioritize emission reduction. On the other hand, Dexlite has the highest ash content with the smallest variation, indicating good consistency but posing a risk of leaving more ash residue, which could impact engine performance in the long run.

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