Analysis of Ethanol Content in Different Brands of Gasoline

Word count: 4783

Abstract

This research is an examination of the ethanol content, a common antiknock agent, in different brands of gasoline. Due to safety concerns, only ethanol will be tested for, by using an ultraviolet (UV) spectrophotometer. Ethanol supports bacteria that produce acetic acid, so fuels that use more ethanol are more acidic, which corrode metals inside the fuel system and engine of an automobile. Therefore, the gasoline with the lowest ethanol content would be the least corrosive type of gasoline. Finding the brand of gasoline that is least corrosive can help consumers choose which gas stations to refill at in order to avoid costly repairs. To find ethanol content, gasoline samples from different gas stations were prepared by first isolating the ethanol in water, so that it is the only octane booster present in testing. To quantify ethanol content, the isolated samples were added to the contents of an ethanol assay kit. The changes in ultraviolet absorbances were then measured using a UV spectrophotometer. The contents were calculated using Megazyme's Megacalc excel program which integrates an equation for changes in absorbance to quantify ethanol. The results indicate that all samples were near ten percent, with Exxon-Mobil having slightly less than the others.

Introduction

Since most companies advertise their gasoline as being “better” for your engine, these statements were put to the test. According to the Bureau of Transportation Statistics (2016), Americans travel over eleven billion times per day in motor vehicles. That is hundreds of millions of gallons of fuel burned per day. Such a staggering figure shows that it matters what kind of fuel we use in our vehicles. In this study, the amount of ethanol contained in the gasoline of Arco, Exxon Mobil, Shell, Chevron, and Costco will be found and analyzed. Ethanol content will be tested for because not only is it is the most commonly used, but it also makes engines and fuel injectors more prone to corrosion, which can be very expensive to repair.

At the pump, users are faced with the choice of what grade, or octane, of fuel should go in the automobile. Auto manufacturers give recommendations regarding what octane of fuel should be used. Octane refers to the antiknock performance of gasoline, which is its ability to resist detonation and premature ignition (Brudzewski, Kesik, Kołodziejczyk, Zborowska, & Ulaczyk, 2005). Knocking on the engine refers to the premature combustions which harm both the motor and its efficiency, which translates to poor fuel economy and lower horsepower and torque. To combat the problem of knocking on the engine, gasoline companies use additives to increase their octane number.

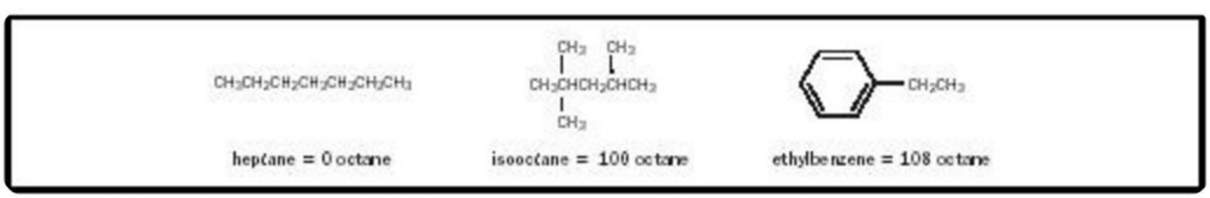

Figure 1: The tendency of a hydrocarbon to ignite before a spark depends on the structure of the molecule.

Octane is not only a measurement of gasoline, but also a family of hydrocarbons. Octane is actually a standard to which gasoline is compared (Brudzewski, Kesik, Kołodziejczyk, Zborowska, & Ulaczyk, 2005). Isooctane is the specific octane to which the measurements are compared. In general, this means that gasoline cannot have an octane greater than 100 due to the proportion of a maximum being isooctane as the benchmark. However, some recent fuels have achieved higher resistance to ignition than octane, reaching even 110 octane. The two most common ratings of octane are Research Octane Number (RON) and Motor Octane Number (MON), with MON being the rating people see at gas stations (Norhasyimi, Ahmad, & Mohamed, 2010). RON is measured by putting gasoline into a test engine with a variable compression ratio and comparing it to a standard of isooctane and n-heptane. MON uses a similar testing procedure to the RON testing, but it uses a higher engine speed and higher temperature of the gasoline. Hong and Huang (2016) further investigated the results of adding only ethanol to fuel as an additive while varying heat, and found that more ethanol and constant heat promote the highest octane rating.

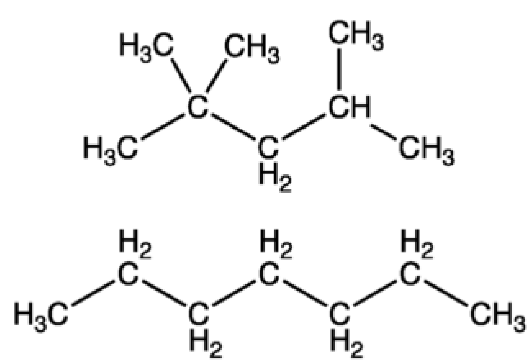

Fig. 2: Isooctane (top) has octane of 100. n-Heptane (below) has octane rating of 0.

In “Motor Gasoline,” Marshall and Owen (1995), explain that since the 1920’s, additives such as tetraethyl lead and Methyl t-butyl ether have been used to make gasoline less prone to detonation. However, these chemicals are harmful and have been banned in several countries, the United States being one of them. Lately, more antiknock agents are being used in gasoline, as well as some being sold aftermarket as fuel additives to increase octane rating. The most common agents include tetraethyl lead (for motor sports only), alcohols, methylcyclopentadienyl manganese tricarbonyl (MMT), ferrocene, iron pentacarbonyl, toluene, and isooctane (Norhasyimi, Ahmad, & Mohamed, 2010). These agents are what most professionals base their assessments of effects on the engine off of, due to existing knowledge about each of their effects. Tetraethyl lead is highly toxic, but works with little residue, and is efficient in the engine (Wills et.al., 2010). Methylcyclopentadienyl manganese is also highly toxic and efficient, but is not as strongly regulated by the government (Rahmani & Kaykhaii, 2011). Alcohols, most commonly ethanol, are not as toxic or pollutant, but instead leave the most residue in an engine, even creating a preferable environment for corrosive bacteria (Williamson, Jain, Mishra, Olson, & Spear, 2015). Benzene is also used to increase octane, but in very low amounts due to government regulation. Benzene is extremely carcinogenic and can cause neurological cancers in gas station workers at exposures as low as 1 ppm (Inoue et al., 2001). The ethanol content will be investigated in this study due to large safety concerns with most of the other agents.

Ethanol is the most common and universal fuel additive due to how inexpensive it is, how readily available it is, how nontoxic it is, and how clean it burns. The government is strongly encouraging the use of ethanol in gasoline to lower emissions harmful to the environment. A study was previously conducted which tested how gasoline with different additives affected their emissions. The results found that compared to all used fuel additives, ethanol and other alcohols produced the lowest emissions (Devos, Combet, Tassel, & Paturel, 2006).

In earlier work, scientists looked at benzene content in gasoline, a major booster of octane that occurs naturally in gasoline, because benzene is believed to be carcinogenic (Temerdasheva and Kolychev, 2007). Using a spectrophotometer and high performance liquid chromatography, the team found benzene content as well as an overall octane rating for the gasoline samples with accuracy and reproducibility (Temerdasheva & Kolychev, 2007).

In Brazil, the public is skeptical of the fuel quality and safety in their local gas stations. A third party study was done where researchers traveled to different random stations and tested the gasoline for what additives and amounts of additives were used in the fuels through high performance liquid chromatography. The results clearly indicated that the gasoline quality of all stations tested was very low, showing in the use of illegal octane enhancers and higher amounts of additives than legally allowed (Wiedemann, d'Avila, & Azevedo, 2005).

Dung and Huynh performed a study using an ethanol assay kit. They worked at Can Tho University to find *Acetobacter aceti* in ethanol and to test for fermentation. In their study, they found that the higher the volume of ethanol, the more *Acetobacter aceti* can grow, and the more ethanol they can produce. It was found that *Acetobacter aceti* can also work with *Bacillus subtilis*, another ethanol tolerant bacteria, to produce up to 24 percent w/v glucose when *Acetobacter aceti* releases acid to adjust pH to 5 (Dung & Huynh, 2013).

Another similar study was analyzing the ethanol content in different alcoholic beverages. Rather than gas, as in this case, the ethanol was detected in an attempt to find if which brands of alcoholic beverages have the highest amount of ethanol. The results indicated that all tested beverages had the exact amount of ethanol as legally allowed (Held, 2012).

Another effective method to test octane is to correlate it with hydrocarbon types, then measure it using gas chromatography, high performance liquid chromatography, or nuclear magnetic resonance (Brudzewski, Kesik, Kołodziejczyk, Zborowska, & Ulaczyk, 2005). Doing so can also yield accurate and reproducible results. The researchers took the data and tried to correlate the data of the octane ratings with the hydrocarbon properties using different correlative methods. Linear regression was adequate, but not optimal according to the researchers, so they tried the neural network classifier approach for artificial intelligence and found a much better non linear correlation (Brudzewski, Kesik, Kołodziejczyk, Zborowska, & Ulaczyk, 2005).

In another work, different brands of gasoline were tested for their ethanol content in 87 octane fuel. Ethanol was chosen from the antiknock agents because it is the most common, cleanest to the environment, and least harmful to humans. However, ethanol is not ideal as an additive in terms of corrosion and residue build up in the fuel system and engine because it allows acetic acid producing bacteria such as *Acetobacter aceti* to thrive in fuel environments and produce acids that corrode metal (Williamson et al., 2015). Fuel starts off in the fuel tank, which in most cases is made out of different types of metal. The fuel then travels down fuel lines to reach the fuel injectors. In older cars, carburetors served the same purpose of as the fuel injectors. From the injectors of carburetor, the fuel travels to the cylinder for compression and combustion. The components of the fuel system mentioned would all be affected by the acetic acid produced by *Acetobacter aceti*, which can cause considerable damage to them. The damage caused will be expensive to repair. To determine the best gasoline for automobile use, the gasoline with the lowest ethanol content will be investigated, which would be the gasoline that allows the least bacteria to corrode metals.

The American Society for Testing Materials (ASTM) sets the government limit at ten percent of ethanol for 87 octane E10 gasoline, so all samples had to have been under that figure, or else they were illegally doping their gasoline with ethanol (ASTM, 1970). Ethanol also starts to become an ideal source of nutrition for *Acetobacter aceti* when over twelve percent (Dung & Huynh, 2013). This means that the samples tested would have to be either under or around this area, so parameters were set accordingly.

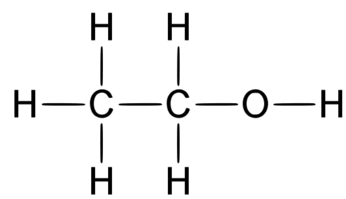

Fig. 3: Molecular structure of ethanol; has high polarity.

On top of that, ethanol is also extremely hydrophilic, which means that it attracts to water very easily. The hydrophilic properties of ethanol are due to the hydroxyl group in which the oxygen is extremely electronegative, thus allowing hydrogen bonding to take place more easily. This means that any water in the gas tank will mix with the ethanol and make it incombustible (Strus, Sobczyńska, & Wiśniewski, 2008). The more ethanol in gasoline, the more water can and will be attracted to mix. For this reason, individuals who use E85 fuel, which is 85 percent ethanol fuel, have to drain their gas tank if the car has not been refilled in over two weeks. If not refilled, water will mix with the ethanol and cause serious damage to engine components through misfires and lack of combustion.

Ethanol is also not ideal for use in fuel because of the economic implications. Ethanol comes mostly from corn in the United States, which will divert consumer corn elsewhere to create ethanol production corn (Barron, 2000). This could cause more crop price adjustments similar to those during the Great Depression, harming the economy. This will have to be addressed with more studies of using cellulose as a primary ethanol producer, which might be best long term. While a factor, the economic effects will not be looked at in depth due to the fact that they are not a chemical reason for assessing ethanol.

The growing use of ethanol is also causing problems at the gas stations themselves. In a study by Billy Thinnes (2014), it was found that acetic acid vapors are slowly corroding the walls of underground gasoline reservoirs. The presence of *Acetobacter aceti* is causing the steel alloy in the reservoirs to corrode at a rate of 1 mm per year. Currently, plans are being made to retrofit the underground reservoirs by both the government and the gasoline companies. The same problem is basically being experienced in the gas tanks from automobiles.

Besides High Performance Liquid Chromatography, ethanol content could be tested for with an ethanol assay kit. The assay works on the principle that enzymes added to samples ferment the ethanol, which cause a change in ultraviolet absorption (Dung & Huynh, 2013). The decrease in absorbance is measured by an ultraviolet (UV) spectrophotometer. Assay kits contain standards of what is tested for, buffers, and enzyme solutions and suspensions. To test for ethanol, a kit would come with an ethanol standard, a 9 pH buffer, Alcohol dehydrogenase, and Aldehyde dehydrogenase.

According to Megazyme, a company who manufactures and sells these kits, amount of ethanol can be quantified by $c = \frac{V \times MW \times \text{-} \Delta A}{\varepsilon \times d \times v \times 2} [g/L]$ where:

V = final volume [mL]

MW = molecular weight of ethanol [g/mol] 5

ε = extinction coefficient of NADH at 340 nm = 6300 [l x mol-1 x cm-1]

d = light path [cm]

v = sample volume [mL]

2 = 2 moles of NADH produced for each mole of ethanol

This equation gives ethanol concentration in percent (w/v), which can also be adjusted to be grams per liter. This is the technique that will be used in this study to quantify the ethanol. However, the reaction cannot take place in the presence of hydrocarbons, which are heavily present in gasoline. To make the ethanol quantifiable in an assay, it and the other hydrophilic substances must be extracted from the hydrocarbons. To do so, a sample of gasoline would be mixed with water in order for the ethanol to leave the gasoline and mix in with the water. Because the enzymes are so sensitive, the ethanol must be diluted 1000 times in this case to be within the measurable parameters. This can also be accomplished in the extraction if a proper amount of water is used to extract the ethanol. Once extracted, the ethanol sample could be treated as any other sample from then on in the kit's procedure.

Shell advertises to have a maximum or ten percent ethanol in its 87 octane gasoline, five percent in 89 octane, and none in 93 octane. They have also patented a method to enrich fuels with nitrogen, helping it burn cleaner and clean up residue in engine components (Shell). Chevron advertises only as ten percent maximum for all of their gasoline. However, they add their patented Techron, which serves to both increase octane and clean engine components (Chevron). Exxon-Mobil also advertises a maximum of ten percent ethanol across all octanes. The too have additives they call Synergy (Exxon-Mobil). Together, these additives increase octane, kill bacteria, and clean engine components. Arco and Costco both advertise a maximum of 10 percent ethanol across all octanes. They do not have any additives that they advertise. Based on this, the latter two should theoretically have the highest ethanol content.

Research Questions

- Which brand of gasoline has the lowest ethanol content?
- Does the advertising and price of the fuel correlate with the ethanol content?

Hypothesis

I hypothesize that there will be minimal differences in ethanol content between the larger companies that advertise their gasoline more, being ExxonMobil, Shell, and Chevron. Brands that emphasize price more than quality, such as Costco and Arco, will likely contain more ethanol than the others.

Null Hypothesis

If the ethanol content is extremely similar between the brands, then the little deviation will be nearly negligible. The only factors that can affect the corrosion would be other additives, which would be tested in further work.

Safety

Gasoline is extremely flammable, so the samples must be carried by an adult onto campus and into the room where experimentation will be done. The flammable container it will be transported in must be locked at all times not in use and the samples must remain under 2 mL per container. Gasoline fumes are also extremely harmful, so all work dealing with gasoline must be done in a fume hood. Gloves and a lab coat must also be worn at all times due to how skin irritant gasoline is, as well as the potential risk of broken glass.

The following safety items were on hand during testing:

- Eye protection
- Gloves
- Lab coat
- Fire extinguisher
- Fire blanket
- Smoke detector
- Fire alarm
- Fume Hood

Materials

- Computer with Excel (Dell and iMac)
- UV Spectrophotometer (Beckman-Coulter)
- Square 3 mL Cuvettes (Flinn Scientific)
- Cuvette stand (Flinn Scientific)
- 2 mL Gasoline samples, one for each brand (Chevron, Arco, Costco, Shell, ExxonMobil)
- Fireproof Case for Samples (Honeywell)
- Glass spectrophotometer cuvettes for storage (Flinn Scientific)
- Vortex Mixer (Vortex Genie 2)
- P1000 Micropipette (BioPette)
- P20 Micropipette (BioPette)
- P1000 Micropipette Tips (BioPette)
- P20 Micropipette Tips (BioPette)
- Latex Gloves (Tuff Grip)
- Megacalc Data Processor (Megazyme)
- Hydrocarbon Separator (OXO)
- Parafilm (Parafilm)
- Fume hood (Fisher Hamilton)
- 5 degree laboratory refrigerator (Thermo-Scientific)
- 1000 mL flask (Flinn Scientific)
- 500 mL beaker (Flinn Scientific)
- Deionized water

- UV Spectrophotometer (Beckman Coulter)
- Ethanol Assay Kit (Megazyme)
    - 9pH buffer
    - NAD+
    - Aldehyde dehydrogenase
    - Alcohol dehydrogenase
    - Ethanol standard

Most materials were readily available in the laboratory; few materials were purchased or donated. The laboratory materials were property of Thousand Oaks High School received from Amgen.

Methods

Sample Collection:

Three samples of gasoline (87 octane) each were collected from Costco, Arco, Exxon-Mobil, Chevron, and Shell. All samples were taken on the same day from the same area. Samples were stored and transported in identical glass containers in a fireproof box. The fireproof box and its contents were transported into the lab by an adult.

Extraction:

To test the samples for ethanol, an ethanol assay kit is an option, but hydrocarbons interfere with readings. To fix this, the ethanol and other hydrophilic substances in gasoline had to be isolated using water extraction. Water extraction is based off of the principle that ethanol is extremely polar and would therefore combine with the water instead of the gasoline. Here, 499.5 mL of deionized water were poured over 0.5 mL of gasoline in a 1000 mL flask. The flask was then vigorously mixed and poured into a liquid-liquid extraction fraction separator, which is essentially a beaker with an opening at the bottom to drain only the hydrophilic components of a substance. A micropipette was then inserted into the bottom opening and extracted 0.1 mL. This process was repeated for three times for each sample. The kit is extremely sensitive, so the ethanol needed to be diluted to be within the quantification range of the assay. This method also served to dilute the amount of ethanol by 1000 times.

Cuvette Preparation:

Since the test was done in a UV spectrophotometer at 340 nm, the samples were prepared directly in cuvettes. First, 0.1 mL of the diluted sample was added to the cuvette, then 1 mL of deionized water on top. Following was 0.2 mL of a 9 PH buffer, 0.2 mL of NAD+, 0.05 mL of Aldehyde dehydrogenase. The cuvettes were then vortexed to thoroughly mix the solution. Then, 0.02 mL of Alcohol dehydrogenase was added.

Absorbance Readings:

The first absorbance was taken after two minutes of adding Aldehyde dehydrogenase. The second absorbance was taken five minutes after adding Alcohol dehydrogenase. Because the reaction continued in these cases, absorbances also had to be taken after six minutes, eight minutes, and ten minutes. These readings were then extrapolated to find a y-intercept, which showed what the actual absorbance was.

UV Spectrophotometer

The UV Spectrophotometer was turned on under the supervision of a teacher. First, the lamp was turned on and allowed to warm up in order to prevent inconsistent absorbance readings. After 45 minutes, the desktop computer it was connected to was turned on. The wavelength was set to 340 nm because that is where the ethanol absorbs best. A cuvette with deionized water was then inserted and was used as a blank for the machine. The spectrophotometer was then used to carry out the assay procedure. To turn off, the lamp was first dimmed and turned off. Then, the rest of the machine and the desktop computer was shut down.

Megazyme Assay Procedure

The ethanol assay component can be summarized by Megazyme as:

-Wavelength: 340 nm

-Cuvette: 1 cm light path (glass or plastic with cap)

-Temperature: ~ 20-25°C

-Final volume: 2.57 mL

-Sample solution: 0.25-12 µg of ethanol per cuvette (in 0.10-2.00 mL sample volume)

-Read against air (without a cuvette in the light path) or against water

1. Add 2 mL of deionized water to cuvette (2.10 mL for blank)
2. Add 0.1 mL of sample (none for blank)

3. Add 0.20 mL of solution 1 (9 pH buffer)
4. Add 0.20 mL of solution 2 (NAD+)
5. Add 0.05 mL of solution 3 (Aldehyde dehydrogenase)
6. Vortex contents to mix thoroughly and read absorbance after two minutes (A_1)
7. Add 0.02 mL of suspension 4 (Alcohol dehydrogenase)
8. Vortex contents again to mix thoroughly and read absorbance after five minutes (A_2)
9. Read absorbance at six minutes, eight minutes, and ten minutes
10. Input the A_1 and A_2 values in Megacalc
11. Input creep absorbances in Megacalc
12. Take percents of ethanol from Megacalc and insert into blank Excel spreadsheet for further data analysis

For calculations, either:

Use the equation $c = \frac{V \times MW \times \Delta A \ [g/L]}{\varepsilon \times d \times v \times 2}$ where:

V = final volume [mL]

MW = molecular weight of ethanol [g/mol] 5

ε = extinction coefficient of NADH at 340 nm = 6300 [l x mol-1 x cm-1]

d = light path [cm]

v = sample volume [mL]

2 = 2 moles of NADH produced for each mole of ethanol

The equation was embedded into an excel spreadsheet to simplify calculations and allow for effective extrapolation for creep calculations. Absorbances were inputted and percent ethanol was given.

Results

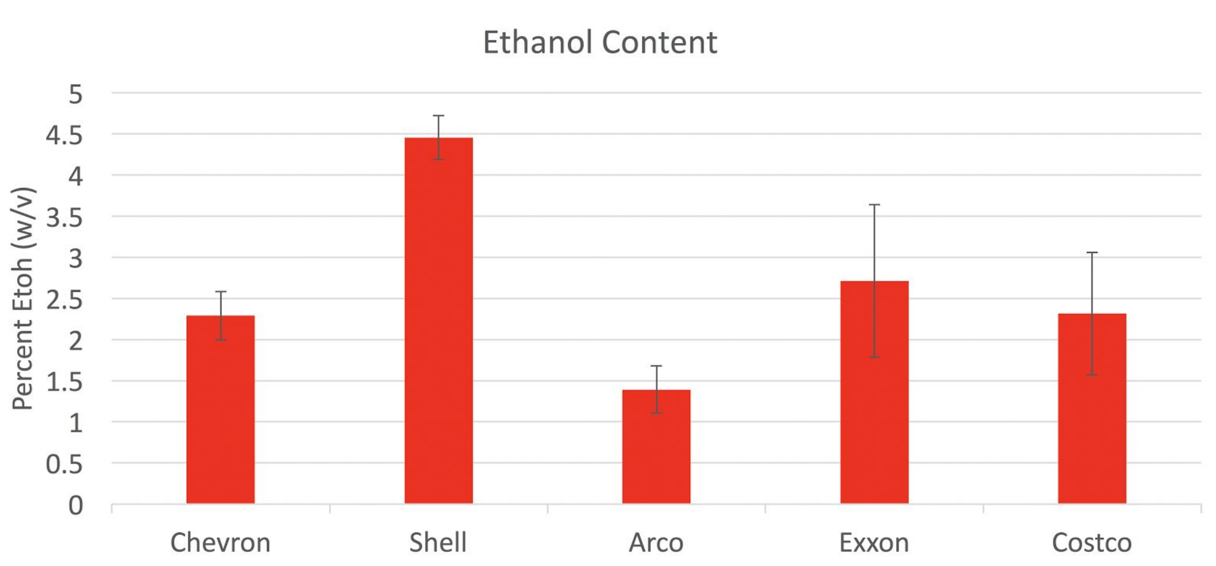

Fig. 1: Interim test with considerable experimental error. Shows ethanol content in percents (w/v)

The first test showed the following ethanol concentrations (least to greatest): Arco, Chevron, Costco, Exxon-Mobil, Shell. The variability of the results raised questions about potential experimental error. Ultimately, the tests were repeated with sources of experimental error accounted for.

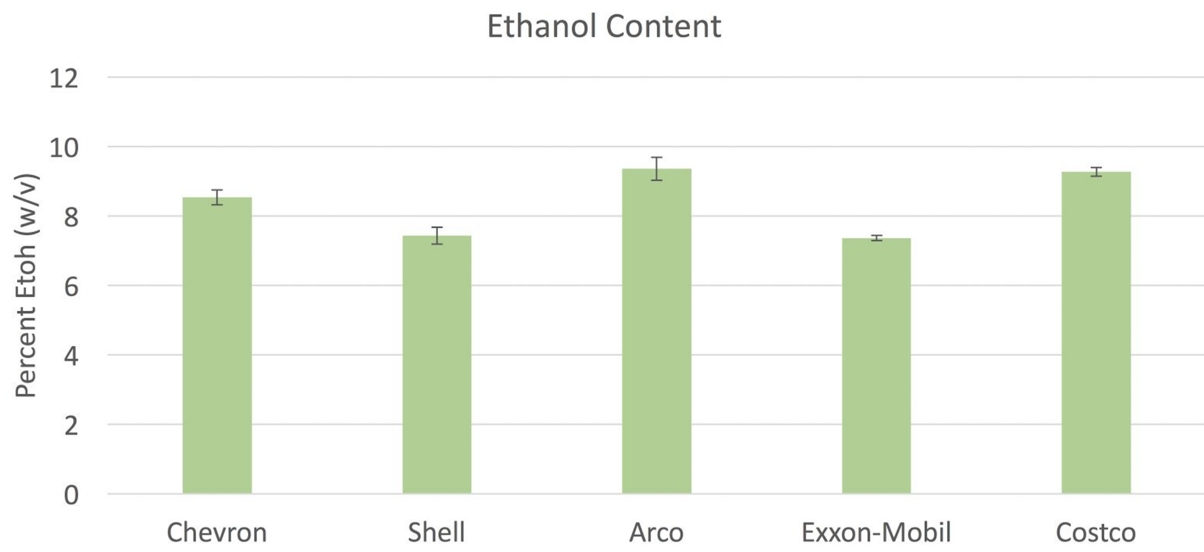

Fig. 2: Final test with corrected experimental error. Shows ethanol content in percents (w/v)

The final test showed the following ethanol concentrations (least to greatest): Exxon-Mobil, Shell, Chevron, Costco, Arco. These results are valid because there is little variation between the tests. This test was used to assess the quality of the different brands of gasoline.

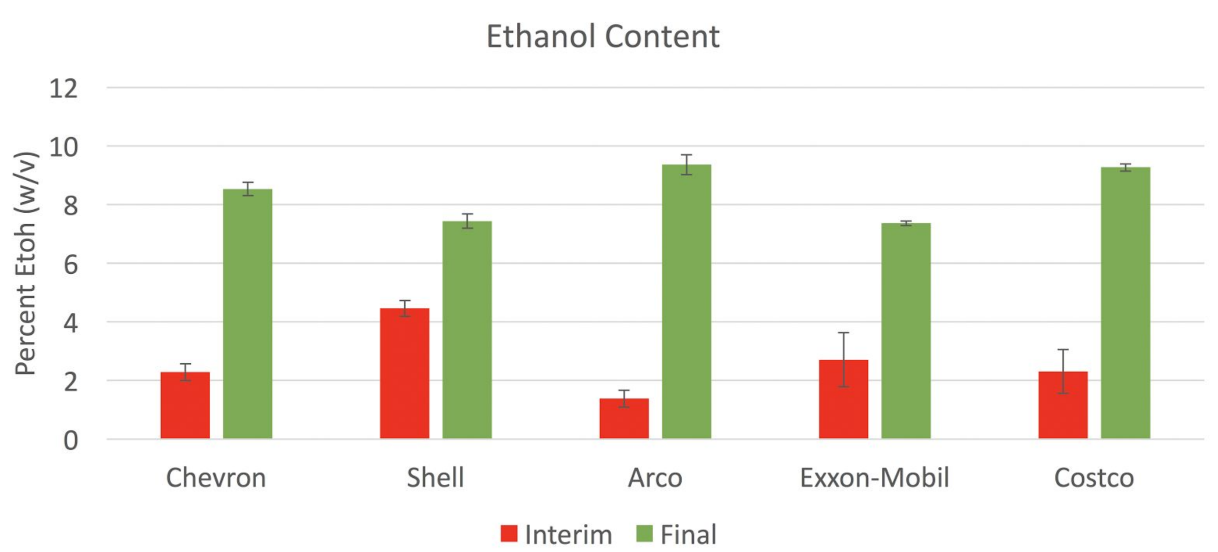

Fig. 3: Interim test plotted against final test. Shows ethanol content in percents (w/v)

The graph shows the difference between the interim test and the final test, which is significant.

Table 1: Final test values in percents (w/v) with average, standard deviation, percent deviation, and t-test p values compared against ASTM Standard of 10%

Value	Chevron	Shell	Arco	Exxon-Mobil	Costco	ASTM Standard
1	8.731065933	7.703973833	9.057141833	7.279542667	9.393867667	10
2	8.572569867	7.384475833	9.312113767	7.4367858	9.1507986	10
3	8.300683333	7.226293	9.7146186	7.3822832	9.265755233	10
avg	8.534773044	7.438247556	9.3612914	7.366203889	9.2701405	10
st dev	0.217666592	0.243337817	0.331485678	0.079845219	0.121593856	0
% dev	2.550350094	3.271440151	3.541025093	1.083939839	1.311672197	0
t test	0.007275995	0.002994124	0.079257438	0.000306205	0.009125297	N/A

The table shows the exact values and statistical analysis of the final test. The p-values are very low compared to the ASTM 10 percent standard which shows that the results are statistically significant.

Discussion

The experimental error in the first test was significant, making the results for the most part inconclusive. The causes of the error was found to be ethanol evaporation in storage, liquid handling, and reaction timings. The extractions took place two to three weeks before the assay, and the samples were stored in a refrigerator at 5 degrees Celsius. The cuvettes were in a cuvette rack covered loosely with parafilm. Even though stored at such a low temperature, evaporation still could have taken place, especially with ethanol, which had a lower melting and boiling point. To fix this, all samples were prepared two hours before the assay, giving very little time to evaporate. Next, liquid handling was another source of error at first. The amount of Alcohol dehydrogenase added to the sample was so small (0.02 mL) that some may have remained in the pipette tip when dispensing. To fix this, the tip was dipped into the cuvette while dispensing in the second test. Lastly, the largest source of experimental error came from reaction timing. During the first test, an assistant helped by timing the reactions to get absorbances at accurate times. However, the time was started at the addition of the first chemical instead of the last. This meant that all of the absorbances were taken earlier than they were supposed to, which gave lower absorbances shown in the first test. A new set of the same gasoline samples was then tested for the final test.

There were also some problems and setbacks experienced during this study. One example is that it was very difficult to find a way to transport gasoline in a container. For the first attempt, the gasoline was stored in plastic centrifuge tubes and taken to school by an adult in a fireproof case. Upon opening, the tubes were empty and deformed. The gasoline dissolved the plastic and the seals and spilled throughout the container. Two days worth of research was put into finding proper materials for storing gasoline, which ended up being a glass container with a polyethylene cap. Another setback, which also may have contributed to the first experimental error, was that a colleague needed the cuvette rack I was using and moved all of my samples to another rack. Since I was not there to see it happen, several problems could have arisen due to this. My samples were basically moved and relabeled without my presence. After that, there were not any major setbacks or problems.

Once accurate data was collected, all samples were under 10 percent, the legal limit, but still fairly close. The results show that the ethanol content is ranked as follows (least to greatest): Exxon-Mobil, Shell, Chevron, Costco, and Arco. The findings indicate that the companies who advertise their patented octane aids have the least ethanol, and therefore are the least harmful to engine components. The results largely support the original hypothesis. For this test, standard deviation was between 0.08 and 0.33, which shows very little variance. Percent deviation was also very low, ranging from 1.1 to 3.5 percent. This statistical analysis indicates that the results were both accurate and reproducible. Although such low standard and percent deviation gives little need for a t-test, one was performed regardless. Since the samples were not compared to a control, nor were they treated, there was not much to compare them to. The values ended up being compared to the ASTM standard for E10 87 octane fuel: 10 percent. The t-test showed that very low p values, which was to be expected from the other data analysis. The low p values indicate that the results were statistically significant.

Conclusion

The results of the experiment indicate that the more widely advertised brands of gasoline tested (Exxon-Mobil, Shell, and Chevron) contained the least amount of ethanol by volume. Therefore, it is recommended that consumers purchase from these companies if faced with a choice. It is more important to keep a well functioning engine than to save a few dollars on bargain gasoline.

Further Work

With more time and resources, this study can greatly be expanded. For example, ethanol content could not only be compared to gasoline brands, but between locations of the same brand. This can show variance between different areas or even countries if there is any. The same gas station of a brand could also be tested for ethanol after each new resupply of gasoline. This could show how gasoline quality could vary based on resupplies. Both of these additions can used the same methods and ethanol assay procedure.

Since one reason ethanol is undesirable is because *Acetobacter aceti* release acids into gasoline, pH could also be tested for. This could be done with a pH probe as well as with precise litmus paper. The pH of the different samples could also be compared to the ethanol content in gasoline to look for correlation between the two. To take this even further, buffers or anti-corrosion agents could be added to the gasoline and tested to see their effect on pH.

Lastly, an entire High Performance Liquid Chromatography (HPLC) aspect could be added to the study. Several more additives could be tested for with HPLC, and can provide a breakdown of everything in a sample, which can be taken and analyzed. Certain additives have their advantages and disadvantages, so those could also be weighed like ethanol to give a more complete sense of which brand of gasoline is truly the best for engines. HPLC could also be used for testing what chemicals are inside the patented octane increasing additives.

Overall, this study can grow with more time and resources into a more complex and complete analysis of gasoline brands.

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