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Research Paper

Energy Content of Alcohol Fuels and Blends with Gasoline

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Abstract : *In this research we report the comparative energy content or heat value of alcohol fuels as well as blends with gasoline obtained from both steel and bomb calorimeters. The energy content of the alcohol obtained from the two calorimeters differ widely, with the values of the energies obtained from the steel calorimeter far less than the values obtained from the bomb calorimeter. We observed that the energy content of the alcohol fuels increased from methanol through to pentanol. Meanwhile, the energy of the blend increases with the increase in carbon content of the alcohol, except for blends beyond E15. Additionally, the blend of the fuels gave higher energy values than the pure alcohols using any of the methods.*

Keywords: Alcohol fuels, Gasoline, Blends, Heat value, Calorimeter.

Introduction

In the quest for alternative energy sources, much attention is being directed towards the production of alcohol fuels that will serve as a gasoline exchanger (gasohol) for many purposes in the long run when produced in large scale [1]. Energy is a property of matter that can be converted into work, heat or radiation [2].

Alcohol Fuels: Alcohol fuels are usually of biological rather than petroleum sources. When obtained from biological sources, they are known as bioalcohols (e.g. bioethanol). There is no chemical difference between biologically produced alcohols and those obtained from other sources. Biobutanol has the advantage that its energy density is closer to gasoline than the other alcohols (while retaining over 25% higher octane rating)[3]. Alcohol fuels can be made from renewable resources like domestically grown crops and even waste products such as waste paper or grass and tree trimmings [4,5]. Methanol and Ethanol are two types of alcohol fuels used in cars. Ethanol can be produced from a variety of renewable resources, most commonly corn and sugarcane. Methanol can be made from renewable resources also, but today, methanol is primarily made from natural gas [6]. For the purpose of this research, the following alcohols will be concentrated on for proper analysis of their energy content: methanol, ethanol, 1-propanol, 1-butanol, and 2-pentanol. Methanol is a colorless poisonous liquid with essentially no odor and very little taste. It is the simplest alcohol and has the formula CH_3OH [7]. It is miscible with water and most organic liquids, including gasoline. Methanol may be blended with gasoline, but it requires a cosolvent such as ethanol or higher alcohol to maintain in solution[8].

Material and Methods

Table 1
The materials used in this research are listed in table 1

Materials	Model/Manufacturer
Methanol	99.8% pure. Fluka, Sigma-Aldrich Labochemikalien GmbH
Ethanol	96% v/v. Fisher Scientific, UK
1-Propanol	99%. Fisher Scientific, UK
1-Butanol	99% extra pure. Acros Organics, New Jersey, USA.
2-Pentanol	99%+ pure. Acros Organics, New Jersey, USA.
Analytical balance	Adam PW 254
Bomb Calorimeter	ECO CAL^{2K}
Thermometer	Brannan, UK
PMS (Premium Motor Spirit)	NNPC Mega Station Yola.

Other materials include steel metal calorimeter, alcohol burner, wick, ice water and a retort stand.

In this research, two methods were studied for accuracy and comparison. In the first method, the steel container was used as a calorimeter for heating the ice water. In the second method, a bomb calorimeter was used to obtain more accurate heat values.

Steel Calorimeter:A retort stand was used to hold the steel calorimeter containing the cold water that was heated The initial temperature of the cold water was recorded. About 20ml of each of the sample alcohol was measured and weighed before and after heating the water. The temperature when the source of heat was removed was 40^oC, and the mass of the alcohol was determined.

The heat, q (MJ), as well as the heat of combustion (MJ/Kg) was calculated. While q was calculated from the formula, $C_pm\Delta T$, the heat of combustion is the ratio of the heat to the mass of the alcohol burned in kilograms, with units MJ/Kg. In the formula above, C_p, is the specific heat capacity constant of water, and it equals 4.18J/g^oC, where m, is the mass of the cold water heated to determine the heat of the alcohol samples, and ΔT is the difference between the initial and the final temperatures. The heating of the water was done in a fume hood in order to minimize the heat loss to the sorrounding and its effects towards calculating the heat of combustion of the alcohol fuels.

Bomb Calorimeter: The mass of the volume of each alcohol sample to be used was measured and inputed in the system. A firing cotton was tied across the lid of the bomb calorimeter vessel and allowed to descend into the sample.

The instrument was calibrated using the standard, 0.5g benzoic acid tablets. The vessel was closed and filled with oxygen up to the 3000Pa mark to ignite the content to obtain the energy values. After about 25 minutes, the calorimeter displayed the final heat of combustion obtained[15-16].

In the same manner, the same experiment was carried out on two of the alcohols, methanol blended with gasoline in the following ratio: 95% gasoline and 5% methanol (M5), 90% gasoline and 10% methanol (M10), 85% gasoline and 15% methanol (M15), 80% gasoline with a 20% methanol (M20), Ethanol blended with gasoline in the ratio: E5, E10, E15 and 80% alcohol (ethanol) with 20% gasoline (E80).

Results and Discussion

Steel Calorimeter: From table 2, the average heat of combustion values of methanol and ethanol obtained using steel calorimeter set-up were 9.81MJ/Kg and 12.54MJ/Kg respectively.

1-propanol, was observed to have higher energy values than both methanol and ethanol with an average heat value of 16.97MJ/Kg. This was followed by 1-butanol and 2-pentanol having average of 17.77 and 18.22 respectively. From this trend, it could easily be concluded that the higher the carbon content of the alcohol fuels, the more the energy content of that alcohol fuel[17].

Ethanol is believed to be a very important industrial chemical having great emerging potentials as a biofuel to replace the fossil fuels[9]. The economic evaluation of the different materials used in producing ethanol has been previously studied thoroughly [10,11,12]. Gasoline blends using 90% gasoline and 10% ethanol have been widely used in many areas. Ethyl tertiary butyl ether (ETBE) is a feedstock for reformulated gasoline based on ethanol [8,13]. A major use of alcohol fuel is its use as an alternative motor fuel for gasoline engines[14].

Figure 4 is the graphical representation of the results obtained from steel calorimeter experiment. It could be deduced that, the energy content of the alcohol fuels increased from methanol through to pentanol. This then show that alcohol fuels are very good producers of energy as the carbon content increases, hence, the employment of alcohol fuels as an alternative to gasoline is somewhat visible in all gasoline operated machines and equipment.

Bomb Calorimeter : Energy values obtained from the bomb calorimeter experiment were comparable with the literature values due to the adiabatic state of the calorimeter used, as compared to the steel calorimeter.

From the bomb calorimetric experiment, the following results were obtained for the various alcohol fuels studied: Table 3 highlights the values of heat of combustion obtained from the experiments.

Table 2
The Heat of Combustion of the Alcohols using Steel Calorimeter

Name of Alcohol	Methanol		Ethanol		1-Propanol		1-Butanol		2-Pentanol	
Heat of combustion, in (MJ/kg)	9.71	9.9	13.85	11.13	16.43	17.51	17.59	17.95	18.43	18.01
% efficiency	59.4	60.5	64.1	51.5	53.4	56.9	54.7	54.8	51.1	49.9
Average of each Alcohol (MJ/kg)	9.81		12.54		16.97		17.77		18.22	

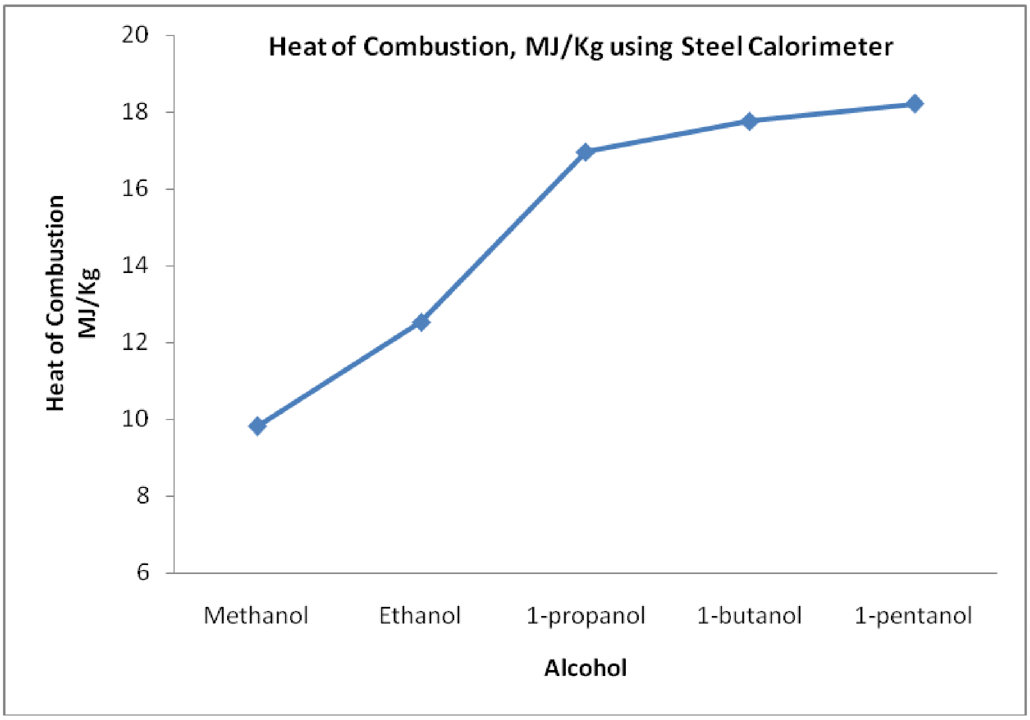

Figure 4: Graph of the Heat of Combustion of the Alcohol Fuels using Steel Calorimeter

Table 3
The Heat of Combustion of Alcohol Fuels using the Bomb Calorimeter

Name of Alcohol	Methanol	Ethanol	1-Propanol	1-Butanol	2-Pentanol
Mass of Alcohol Used, g	0.327	0.321	0.325	0.315	0.327
Heat of Combustion, MJ/Kg	16.36	21.6	30.75	32.13	36.1

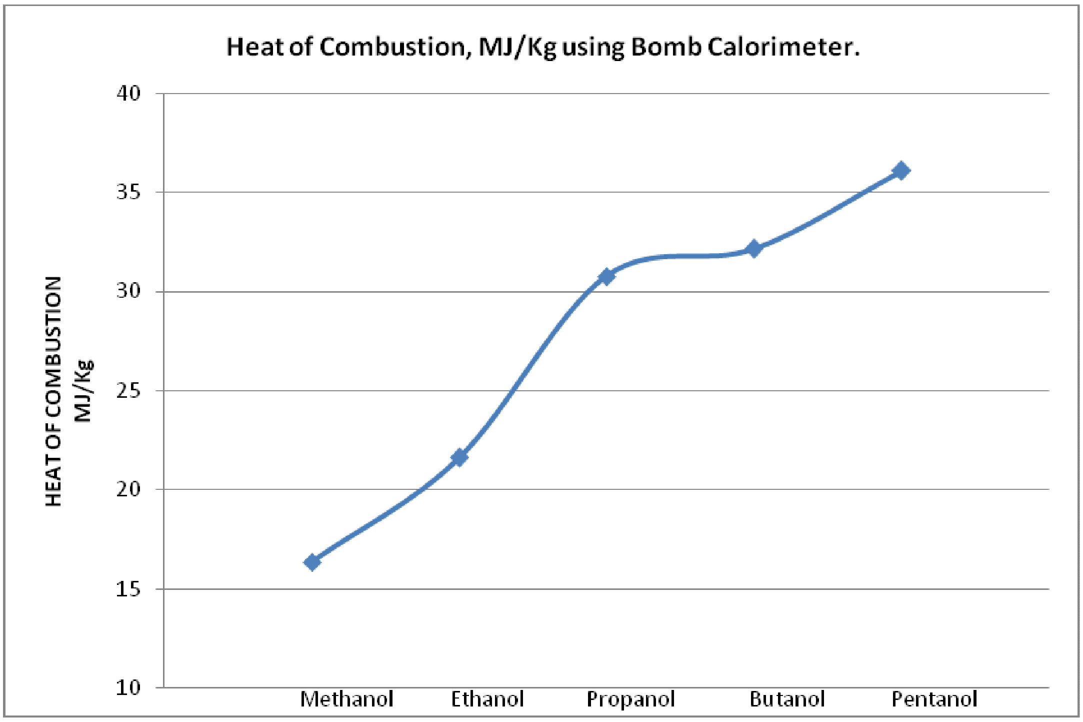

Figure 5: Graph of the Heat of Combustion of the Alcohol Fuels using Bomb Calorimeter

The individual masses of the alcohols used were 0.327g, 0.321g, 0.325g, 0.315g, and 0.327g for methanol, ethanol, 1-propanol, 1-butanol and 2-pentanol respectively. The respective energy values obtained were as follows: methanol 16.36MJ/kg, ethanol 21.6MJ/kg, 1-propanol 30.75MJ/kg, 1-butanol 32.13MJ/kg and 2-pentanol 36.10MJ/kg. The data from table 3 is graphically represented in figure 5, showing the exhibited trend.

Comparison of Steel and Bomb Calorimeter Heat of Combustion Values : The differences in masses of the fuels used in both calorimeters are within negligible variations. However, the energy content of the alcohol obtained from the two calorimeters differ widely, with the values of the energies obtained from the steel calorimeter far less than the values obtained from the bomb calorimeter. A very good reason that could have resulted in this huge difference would be due to the heat lost to the environment from the steel calorimeter[17]. However, it could have resulted from the various initial temperatures of the ice water used as well as the thickness of the steel calorimeter. This could go a long way affecting the readings of the energy contained in each of the fuel as it was calculated using the formula Cp.m.ΔT, where ΔT, is the difference in the initial and final temperatures. The smaller the difference in temperature, the lower the energy that will be realized. Thus, it is always recommended to have a very low temperature at the start of the steel calorimetric experiments with a possibly high final temperature at the end.

Blends of Alcohols with Gasoline: Considering the blend of these alcohol fuels and gasoline, it could be seen from table 4 that the energy content of the blend is far above the realized energy values of the pure alcohol fuels using any of the above-described methods.

The plots of the two alcohol fuels, methanol and ethanol, from the different trials reveal that the energy of the blend increases with the increase in carbon content of the alcohol. The alcohols were blended with 5%, 10% and 15% gasoline respectively. But, reaching E15, the energy values of the ethanol-gasoline blend, as seen in figure 7 started declining. It is known that, the energy values increase as the octane rating increases. However, in the case of the E85, the octane rating is reduced by the percentage content of the alcohol, thus the sudden decline observed in the graph.

Table 4
The Heat of Combustion of Blend of Alcohol Fuels and Gasoline using the Bomb Calorimeter

Alcohol Name	Methanol			Ethanol			
Percentage of Alcohol, %	5	10	15	5	10	15	20
Percentage of gasoline, %	95	90	85	95	90	85	80
Heat of Combustion, MJ/kg	21.09	21.73	21.95	31.03	31.37	31.42	31.61
Average of both trials	21.59			31.35			

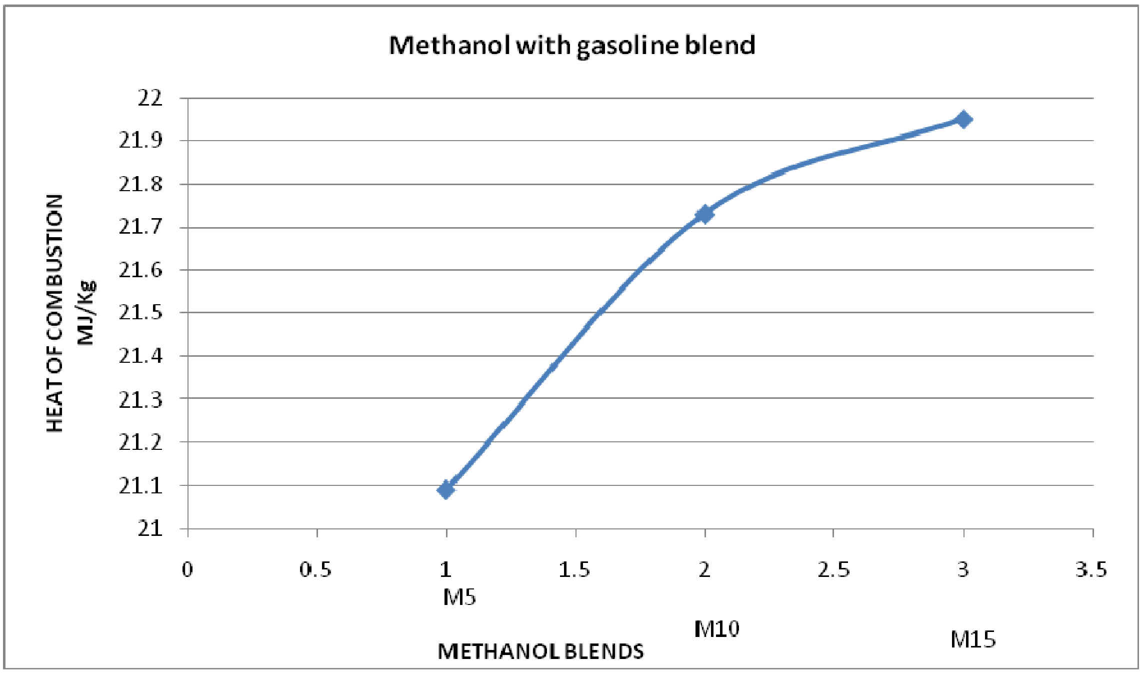

Figure 6: Graph of the Heat of Combustion of Methanol Blended with Gasoline

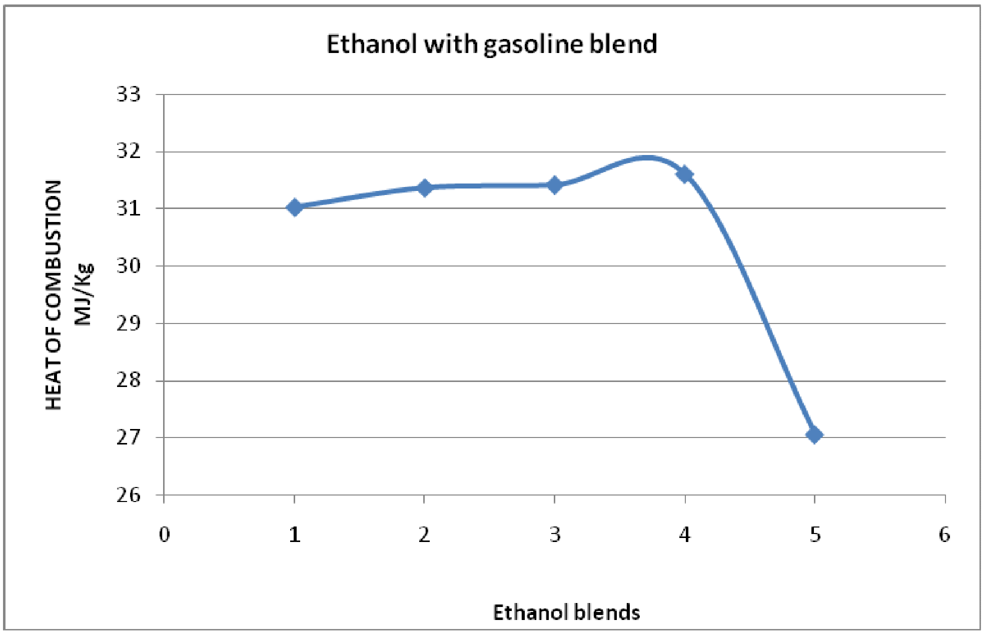

Figure 7: Graph of the Heat of Combustion of Ethanol Blended with Gasoline

Similarly, from the table 4, it was observed that the energy content of the blend of methanol and gasoline increased with the respective percentage blends studied. However, no decline was experienced up to M15, as seen in figure 6.

As explained above, the downward decline observed was because the octane rating in this blend has been affected by the percentage volume of the ethanol. Therefore, it is clear that, blending beyond E15 will lead to decline in the heat value of the blend.

Energy Values of the Blended Alcohol Fuels with Gasoline: Considering the heat of combustion of the blends of the alcohol and gasoline obtained, it is observed that the results from the blends of the two alcohol fuels studied gave higher energy values than those from pure alcohol fuels using either of the two methods highlighted above. Similarly, the average heat of combustion of the blend of the two alcohol fuels, methanol and ethanol gave 21.59MJ/kg and 31.35MJ/kg respectively. Therefore, it is clear that the energy content increased from methanol to ethanol for both the pure and the blended alcohol fuels. However, we observed that the blend of the fuels gave higher energy values than the pure alcohols using any of the methods.

Blend of the Fuels compared with Pure Gasoline: From table 4, the energy values of the alcohol fuels, methanol and ethanol, are 21.59MJ/kg and 31.35MJ/kg respectively, while the widely accepted energy content value of the pure gasoline is known to be at 49.39MJ/kg. Hence, the energy content in the gasoline is still much higher than the energy content of the alcohol fuels. This is as a result of the higher carbon content in the gasoline as compared to that in the various alcohol fuel samples.

Conclusion

The energy content of the various alcohol fuels as well as the blends has been determined. From the results obtained and discussed above, the alcohol-gasoline blends released more energy than the pure alcohol fuel. It is obvious that the energy values increased from the first methanol to pentanol. Hence, production and use of alcohol fuels in blends will be a viable approach to solving, largely the energy problems of the world.

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