e-ISSN: 2548-060X

International Journal of Energy Applications and Technologies

journal homepage: www.dergipark.gov.tr/ijeat

Original Research Article

A research on fuel properties of bioethanol produced from waste bread

Bahar Sayın Kul*, Murat Ciniviz

Mechanical Engineering Department, Faculty of Technology, Selçuk University, Konya, Turkey

ARTICLE INFO

* Corresponding author
bsayin@selcuk.edu.tr

Received November 18, 2019
Accepted December 26, 2019

Published by Editorial Board Members of IJEAT

doi: 10.31593/ijeat.647206

ABSTRACT

In this study, fuel properties of two bioethanol fuel, one produced from waste bread (E100b) and the other originated from sugar beet (E100) and base gasoline (E0) were treat as a subject. It was investigated that the properties of fuel blends formed by mixing both bioethanol with gasoline in the same proportions as 5, 10, 15, 85%. The evaluation was based on the fuel properties, which are thought to have the most influence on engine operation, such as density, purity, kinematic viscosity, octane number, heating value. Waste bread based- bioethanol has been found to cause an increasing effect on the density, kinematic viscosity, while decreasing the heating value to some extent. The results showed that differences in fuel properties among both bioethanol that are thought to be related to purity can be ignored for fuel blends with low bioethanol content.

Keywords: Bioethanol; Gasoline; Waste bread, Fuel properties

1. Introduction

Due to the rapid growth of the industry and the population, a large portion of the world's energy demand, which grows exponentially every year, is being met by fossil resources. There are several decades ahead of us to run out of fossil fuel reserves so that according to an econometric model, oil and coal have reserves by of 35 and 107 years by respectively [1]. Resources are needed to compete with fossil fuels to meet energy needs and to fill the gap resulting from the depletion. Being came ethanol into our lives as alternative engine fuel dates back to the 1800s, due to the fact that fossil fuels are depleted, harm the environment and its cost increase day by day [2]. With the feature of having higher octane number, latent heat of vaporization etc., it has been alive since those years. The production of bioethanol is mostly based on agricultural products, which are used for fuel production rather than for using as food stuff, and have been criticized by some authorities. The use of agricultural products to produce ethanol has a history of 80 years [3]. Biofuel production based on agricultural products is being replaced by more ecological, sustainable production options where food waste is used, as it endangers food safety and pave the way for increasing hunger that reaches serious levels. Although various wastes have been used in the literature for bioethanol production such as potato peel [4], waste coffee residues [5], apple pulp [6], banana peels [7], lemon peel [8] and many more, it is difficult to come across studies where these are tested as fuels. The following paragraph summarizes some of the study referring to the fuel properties. Bielaczyc, Woodburn [9] conducted tests to determine the various physicochemical properties of fuel mixtures formed by adding ethanol to the gasoline at the rate of 5, 10, 25 and 50% volumetrically. It was observed that some parameters changed linearly with the addition of ethanol, some have almost never changed. It has been reported that the properties that vary considerably with the participation of ethanol to fuel content are as follows: vapor pressure, density, boiling curve, calorific value, lubricity, volatility index, aromatic content, RON and MON [10] evaluated the effect of ethanol addition to some physical properties of the gasoline-ethanol blends. In the study, it is stated that density data of fuel blends can be calculated by using weighted average according based on volumetric composition. Another important result of the study is that ethanol-rich blends have lower Reid Vapor Pressure than gasoline. In the sturdy belongs to [11], RON and MON properties were examined. When evaluated on a volumetric basis, RON showed a nonlinear relationship with ethanol concentration. The MON values of these blends show very similar trends to those of RON. In a study conducted by [12], for liquid, vapor and saturation states, a formulation is presented which represents the thermodynamic properties of ethanol. With this formulation, it has made possible to calculate densities with accuracy of ± 0.2%, and heat capacities with accuracy of ± 3%.

In this limited number of studies does not include an explanation of which raw material bioethanol is produced from and how raw material and production process affect fuel properties. Although there has been a trend in recent years to use ethanol as its counterpart of gasoline, small differences between the physical/chemical properties of these fuels can make significant differences in engine operation and performance, emission and combustion behavior. Before a fuel is tested in an engine, it is essential to investigate these properties that provide clues to the quality of the fuel.

The annual burden of waste bread is 1,546 billion TL to Turkey's economy [13]. As such, it is aimed to evaluate bioethanol produced from waste bread, being one of the most wasted foodstuffs, as an engine fuel to pave the way for re-evaluation of it. For this purpose, various fuel properties of the fuel blends formed by mixing this bioethanol with gasoline in different ratios are discussed. These are presented in comparison with the properties of fuel blends formed by mixing sugar beet-ethanol with gasoline in the same proportions.

2. Material and Method

2.1. Bioethanol production processes

Waste bread-bioethanol was produced by fermentation method, containing the sub-steps as pretreatment, enzymatic hydrolysis, fermentation and distillation according to directives given in Figure 1. As it can be verified from studies that provide information about the components of bread [14-18], bread is a raw material rich in starch (%45.34-%59.8) and pretreatment of bread is directly related to pretreatment of starch. It is deemed sufficient to be pretreated by drying and breaking into small pieces before being hydrolyzed by enzymes. The bread solutions, which were formed to contain 20% bread, were treated with hot water until the temperature reached 80 °C. When treated with hot water, the hydrogen bonds between the polymer chains of the starch are broken off to form a starch solution. In the next step, enzymatic hydrolysis, α- amylase (for liquefaction) and amyloglucosidase (for saccharification) by of 0.2% was added to solution. Amylases added to the solution for the purpose of liquefaction break the bond between two sugar units randomly, reducing chain length, causing starch to be separated into smaller units, dextrins and oligosaccharides. The glucoamylase enzyme, also known as amyloglucosidase added for saccharification, catalyzes α-1,4 glycosidic bonds and non-reduced α-1,4 glycosidic bonds such that the final product is glucose, separates a sugar unit from the ends of the polymer chains [3, 19-20]. So, with enzymatic hydrolysis, the starch in the polymer structure is converted to the appropriate fermentation feed by degrading it into fermentable monomers. Fermentation of starch-derived sugar is dominated by saccharomyces cerevisiae [21], therefore it was added to bread hydrolyzate by 1% per g waste bread on dry basis and it was fermented for 24 h. Then by distillation following fermentation, ethanol, which is in admixture with water, is purified to obtain a high ethanol content.

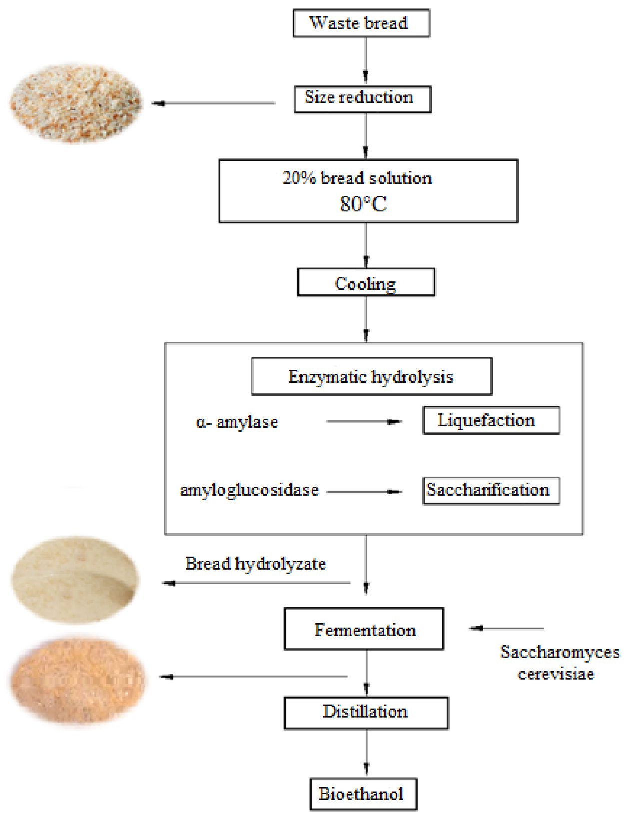

Fig. 1. Bioethanol production process from waste bread

2.2. Preparation of test fuels

While unleaded gasoline was obtained from an oil station to be used as a reference to other fuel blends to be analyzed, 99.99% pure sugar beet-bioethanol was purchased from

Konya Sugar Factory. Other test fuel, waste bread-bioethanol is produced according to the production procedure mentioned above. The blending ratios of both sugar beet based-bioethanol and waste bread-bioethanol with gasoline on volume basis and the abbreviations of them was tabulated as in Table 1. Namely, E and the number next to it indicate volume percentage of bioethanol. The abbreviations of the blends are marked with the letter b to indicate that waste bread-bioethanol is used to form them. Since the gasoline sold from the pump contains 5% ethanol, the fuel blends containing 5% ethanol was taken into of the scope of the tests. However, the addition of bioethanol up to 15% increased the engine performance but with the addition of 20% ethanol engine performance affected badly. Thus, fuel blends containing 20% ethanol or more were not included in the study. The reason why the fuel blend containing 85% bioethanol is investigated is that the presence of vehicles operating with E85 in traffic around the world.

Table 1. Content of test fuels

Test Fuel /Content (%v/v)	Gasoline	E5	E10	E15	E85	E100	E5b	E10b	E15b	E85b	E100b
Gasoline	100	95	90	85	15	-	95	90	85	15	-
Sugar beet-based bioethanol	-	5	10	15	85	100	-	-	-	-	-
Waste bread-based bioethanol	-	-	-	-	-	-	5	10	15	85	100

The aim of study is to evaluate the ethanol production process based on fuel properties and to determine the extent to which bioethanol from waste bread produced by fermentation can approach the properties of ethanol from sugar beet. The reason why two different bioethanol are preferred is to test the success of bioethanol production process from waste bread and to investigate its usage instead of sugar beet-bioethanol. Thus, it is hoped that bioethanol to be produced by using food wastes will decrease bioethanol production based on agricultural products, if the bioethanol production process passes the assessment.

2.3. Fuel properties

Density

The device used to determine the density of test fuels was Kem Kyoto DA 645, sensitivity of which is ± 0.05 kg/m^3. The measuring range of the device is 0-3000 kg/m^3. Densities of all fuel samples were measured at 15°C standard temperature.

Purity

The purities of both bioethanol were measured in an accredited fuel testing laboratory according to EN 13132 standard.

Kinematic Viscosity

Kinematic viscosity measurement was performed by Poliscience-7306A12 device with sensitivity of ± 0.05 °C. Fuel blends were passed through a capillary tube and recorded how long it takes. Using the calibration constant of the viscometer indicated C, and mean flow time represented t, the viscosity was calculated by as follows.

$$v = C.t \tag{1}$$

Octane Number

The standards for RON (research octane number) and MON (motor octane number) measurements performed in the fuel analysis laboratory for pure fuels are ISO 5163 and ISO 5164.

Heating Value

The lower thermal values of all test fuels were determined by the IKA C 200 combustion calorimeter capable of measuring up to 40000 J.

3. Result and Discussion

In this section, the variations in fuel properties are discussed. For fuels containing alcohol, the purity of the fuel is directly related to the water content. Sugar beet bioethanol has 99.99% purity and its water content is removed. But during its contact with the air, it loses its purity due to the absorption of moisture in the air as a result of its high affinity for water and hydroscopic structure of it. Waste bread-based bioethanol (alcohol content by of 90%) is not that purified and the water in its content moves which forms the remaining volume, its concentration away from the bioethanol. Pure ethanol can be blended easily without phase separation unlike gasoline. The low purity of the fuel and its water content suggest that it may cause corrosive effects on the engine body when used by blending with gasoline. This problem can be solved by using various solubility improvers. The water absorbs some amount of heat in the cylinder, so decreasing cylinder temperatures and afterward exhaust temperatures are expected to cause low NOx emissions. It can also prevent heat loss from the cylinder walls. the combustion behavior of hydrous ethanol with higher peak pressures and heat release rates has been proven in many studies: i.e. [22-23]. What caused this effect can be the participation of oxygen in water to the combustion by assisting in complete burning. The oxygenated structure is expected to result in cleaner emissions compared to gasoline as in sugar based bioethanol. Density is a feature that directly affects the blends being rich or poor and thus fuel consumption. The effect of bioethanol types and addition of them to gasoline at different rates on density is presented in Figure 2 with error bars. Ethanol is 8.1% denser liquid fuel than gasoline, which increases the density when added to gasoline depending on the blending ratio. Generally, for blended fuels, the density is expressed as the arithmetic mean based on the volumetric content of the fuels constituting the blend. The results of the measurement revealed that there were nonlinear differences on the density with the addition of bioethanol. The difference between waste bread bioethanol and sugar beet bioethanol is about 6.4%. Comparing those with similar contents between fuel blends, the difference in density for those with low ethanol content was found to be quite low but sugar beet based one is always less. With the addition of ethanol by 85% and 100%, the fuel blends containing waste bread-based bioethanol reach 6.25 and 6.36 % higher density of than those with sugar beet-based ethanol. The higher density of both bioethanol allows fuel pumps to send more fuel to the cylinders. Hereby, the reduction in fuel energy resulting from the use of bioethanol, due to its lower heating value, can be compensated.

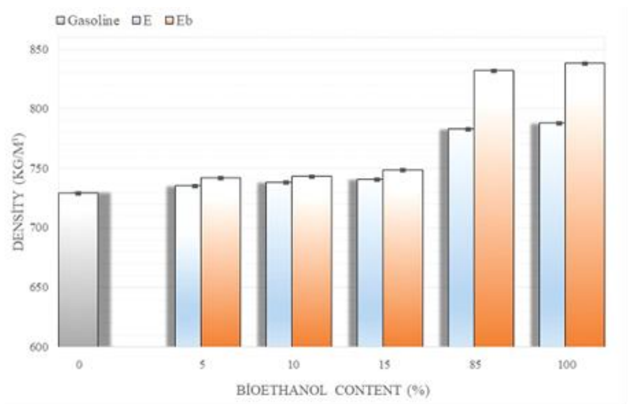

Fig. 2. Density for gasoline-bioethanol blends

Figure 3 represents research octane number (RON) and motor octane number (MON) for gasoline, sugar beet and waste bread-based bioethanol. Both octane number is often used to simulate engine performance such that RON is suitable for low severity (at 600 rpm and 49 °C air temperature), whereas MON is for more severe conditions (at 900 rpm and 149 °C air temperature) [24]. Having high octane number which is an expression of auto ignition resistance, provides to fuel being tested at higher compression ratios by expanding the engine operating range without knocking with higher brake power. It is seen that the octane number of ethanol is not independent of bioethanol type but in both cases, it may be characterized by a higher-octane number than gasoline. Research and motor octane number of sugar beet based-bioethanol were respectively higher by of 9.7, % 4.1% than that of gasoline, respectively. The octane number of the waste bread bioethanol was got out of operating range of the measuring device.

Viscosity for a fluid is a measure of internal resistance to flow only when exposed to gravity. Figure 4 shows that sugar beet-based bioethanol has higher kinematic viscosity than gasoline, kinematic viscosity of waste bread-based bioethanol even bigger than it. Whichever is added to the gasoline, the addition of bioethanol appears to increase in the kinematic viscosity. This increase effect is 1.00, 4.8, 4.9, 22.3, 24.1% more for bread waste based-bioethanol as nonlinear manner.

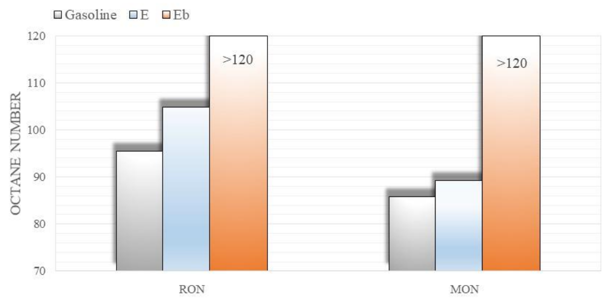

Fig. 3. RON, MON for gasoline, E and Eb

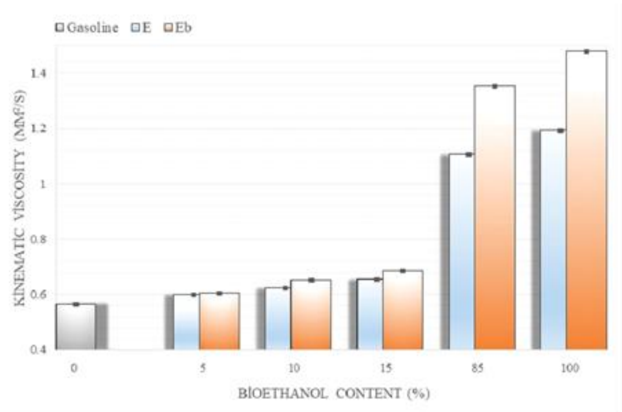

Fig. 4. Kinematic viscosity for gasoline-bioethanol blends

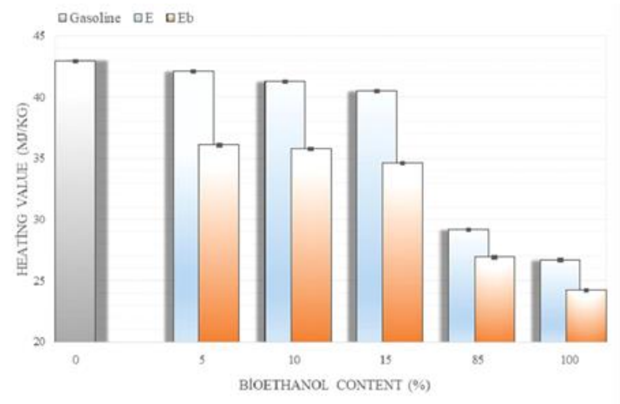

Fig 5. Heating value for gasoline-bioethanol blends

Since it is formed in 38.45% oxygen, the lower heating value of bioethanol is lower than that of gasoline. The oxygen content of waste bread-based bioethanol is 34.35% and the lower heating value of it is expected to be higher than that of sugar beet-based bioethanol. But that is lower by of 9.33% related to the low C and H concentration, means lower specific energy content. Lower C/H also point out lower adiabatic flame temperature. As can be seen in Figure 5, this difference suggests that bread waste-based bioethanol may be a substitute bioethanol when used in higher proportions. It should be noted that for fuel blends containing ethanol at low rates, the gasoline content leads to differences to open between those with similar volumetric content.

In addition to the abovementioned properties, when the fuel blends were evaluated in terms of color, there was no significant difference between them.

4. Conclusions

In this study, it is aimed to determine how close the properties of bioethanol produced by using waste bread as raw material to those of commercially purchased sugar beet bioethanol. Waste bread based-bioethanol has some concessions, but still has similar properties to sugar beet based-bioethanol. There is need to comparison waste food based-bioethanols to others in terms of cost for a more detailed evaluation. Since it targets completely the waste mass, if ethanol production from waste bread is put into practice in large scale, a new waste management application is gained, and the high energy content of the bread is re-evaluated. Testing the bread waste based-bioethanol in other bioethanol usage area such as engine fuel or additive will give direction to further studies.

Acknowledgment

This article is produced from Ph.D. thesis of Bahar Sayın Kul. Appreciations to Selcuk University Scientific Research Projects Unit (Project No:17301012) and Selcuk University Instructor Training Program Unit (Project No: 103) for their support for this study.

References

[1] Singh, B.R. and O. Singh, Global trends of fossil fuel reserves and climate change in the 21st century, in Fossil Fuel and the Environment. 2012, IntechOpen.

[2] Caton, J.A., Implications of fuel selection for an SI engine: Results from the first and second laws of thermodynamics. Fuel, 2010. 89(11): p. 3157-3166.

[3] Kumar, J.V., R. Mathew, and A. Shahbazi, Bioconversion of solid food wastes to ethanol. Analyst, 1998. 123(3): p. 497-502.

[4] Arapoglou, D., et al., Ethanol production from potato peel waste (PPW). Waste Management, 2010. 30(10): p. 1898-1902.

[5] Choi, I.S., et al., Conversion of coffee residue waste into bioethanol with using popping pretreatment. Bioresource Technology, 2012. 125(Supplement C): p. 132-137.

[6] Parmar, I. and H.P.V. Rupasinghe, Bio-conversion of apple pomace into ethanol and acetic acid: Enzymatic hydrolysis and fermentation. Bioresource Technology, 2013. 130(Supplement C): p. 613-620.

[7] Oberoi, H.S., et al., Ethanol production from banana peels using statistically optimized simultaneous saccharification and fermentation process. Waste Management, 2011. 31(7): p. 1576-1584.

[8] Boluda-Aguilar, M. and A. López-Gómez, Production of bioethanol by fermentation of lemon (Citrus limon L.) peel wastes pretreated with steam explosion. Industrial Crops and Products, 2013. 41: p. 188-197.

[9] Bielaczyc, P., et al., An examination of the effect of ethanol–gasoline blends' physicochemical properties on emissions from a light-duty spark ignition engine. Fuel Processing Technology, 2013. 107: p. 50-63.

[10] Rodríguez-Antón, L.M., M. Hernández-Campos, and F. Sanz-Pérez, Experimental determination of some physical properties of gasoline, ethanol and ETBE blends. Fuel, 2013. 112: p. 178-184.

[11] Foong, T.M., et al., The octane numbers of ethanol blended with gasoline and its surrogates. Fuel, 2014. 115: p. 727-739.

[12] Dillon, H.E. and S.G. Penoncello, A Fundamental Equation for Calculation of the Thermodynamic Properties of Ethanol. International Journal of Thermophysics, 2004. 25(2): p. 321-335.

[13] TMOGM, Türkiye'de Ekmek İsrafı Araştırması. 2013.

[14] Leung, C.C.J., et al., Utilisation of waste bread for fermentative succinic acid production. Biochemical engineering journal, 2012. 65: p. 10-15.

[15] Zhang, A.Y.-z., et al., Valorisation of bakery waste for succinic acid production. Green chemistry, 2013. 15(3): p. 690-695.

[16] Melikoglu, M. and C. Webb, Chapter 4 - Use of Waste Bread to Produce Fermentation Products, in Food Industry Wastes. 2013, Academic Press: San Diego. p. 63-76.

[17] Han, W., et al., BioH2 production from waste bread using a two-stage process of enzymatic hydrolysis and dark fermentation. International Journal of Hydrogen Energy, 2017. 42(50): p. 29929-29934.

[18] Han, W., et al., Continuous biohydrogen production from waste bread by anaerobic sludge. Bioresource Technology, 2016. 212(Supplement C): p. 1-5.

[19] Arshadi, M. and H. Grundberg, 9 - Biochemical production of bioethanol, in Handbook of Biofuels Production. 2011, Woodhead Publishing. p. 199-220.

[20] Lam, W.C., T.H. Kwan, and C.S.K. Lin, Enzymes in valorization of food and beverage wastes, in Enzymes in food and beverage processing. 2015, CRC Press. p. 479-501.

[21] Ačanski, M., et al., Bioethanol production from waste bread samples made from mixtures of wheat and buckwheat flours. Journal on Processing and Energy in Agriculture, 2014. 18(1): p. 40-43.

[22] Wang, X., et al., The effects of hydrous ethanol gasoline on combustion and emission characteristics of a port injection gasoline engine. Case Studies in Thermal Engineering, 2015. 6: p. 147-154.

[23] Costa, R.C. and J.R. Sodré, Compression ratio effects on an ethanol/gasoline fuelled engine performance. Applied Thermal Engineering, 2011. 31(2): p. 278-283.

[24] Sadeghbeigi, R., Chapter 8 - Products and Economics, in Fluid Catalytic Cracking Handbook (Third Edition), R. Sadeghbeigi, Editor. 2012, Butterworth-Heinemann: Oxford. p. 169-189.