Ethanol concentration and calorific value of some local distilled Ethiopian alcohol (Areki): an energy potential assessment

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Abstract: This paper deals with determination of the ethanol concentration and its heating value (calorific value in local distilled Ethiopian Areki, which is extracted from Maize, Dagussa (Sorghum) and Gibto (Lupin). The primary target of this paper is assessing the energy potential of some locally produced Ethiopian alcohols by identifying the major parameters like ethanol concentration, calorific value and its acidity. The samples of Areki were prepared in one of the vending houses in Injibara Ethiopia and raw material used for their preparation was measured before preparation. The levels of ethanol concentration among the sample were determined using a UV/vis spectrophotometer. After calibrating with a standard sample (benzoic acid), the GCV of the alcohol samples was determined experimentally using an oxygen bomb calorimeter (IKA® Model C200 bomb Calorimeter). The quantitative analysis of ethanol in the sample was done by preparing an aqueous solution of ethanol to draw by means of absorbance versus concentration calibration line at a wavelength of 986 nm. The investigation shows that maximum and minimum percentages of ethanol concentration (%v/v) in the samples were found for dagim maize (50.17%) and dagim lupin Areki(26.64%), respectively. The gross calorific value of local distilled areki ranges from 6.616 MJ/kg-13.1432 MJ/kg. The highest GCV was obtained by dagim maize alcohol due to the higher ethanol content and dagim lupin alcohol with a small ethanol concentration has the lowest GCV. According to the findings, dagim alcohols extracted from sorghum and maize have high potential energy and can be blended with other fossil fuels with little purification.
1. Introduction

The excessive use of non-renewable petroleum energy resources is causing not only economic problems but also ecological damage. At the same time, fossil fuel reserves are limited, thus resulting in the search for alternative energy sources worldwide. Greater energy efficiency, lower emission effects, foreign exchange savings, and socioeconomic concerns related to the agricultural sector are all advantages of biofuels over conventional fuels. Liquid biofuels such as bioethanol and biodiesel can be used as future alternative transport fuel due to a number of technical and environmental benefits over conventional fossil fuels (Agarwal, 2007; Demirbas, 2008, 2009a). Furthermore, both developing and developed countries will benefit from biofuel technology. As a result, biofuels are projected to expand rapidly in the automotive fuel market over the next ten years (Demirbas, 2009b). The production of ethanol from crops like sugar cane, corn, and sweet sorghum is well-established. Bioethanol can be used in vehicles that are made to run on pure ethanol, or it can be mixed with gasoline. Since blending anhydrous ethanol with gasoline needs no engine modifications, people in rural areas in oil-importing and developing countries will look forward to new economic opportunities thanks to biofuels (Demirbas, 2009a).

Within these alternative energy sources, the bioethanol, that is, the group of materials of biological origin capable of being used energy sources, is becoming an important one. In fact, ethanol-rich alcoholic beverages native to each region are prepared and consumed in every part of the world. Fermented alcoholic drinks are consumed in Africa on a number of occasions, including weddings, naming and rain-making ceremonies, festivals and social gatherings, burial ceremonies, and resolving conflicts (Tafere, 2015).

The Ethiopian Areki is a popular alcoholic beverage among Ethiopia's various ethnic groups. Microorganisms present in the substrates, fermentation vats, or equipment cause Areki and other commonly fermented alcoholic beverages to ferment, since the majority of fermented beverages are acid-alcohol fermentation products (Desta, 1977; Wedajo Lemi, 2020).

1.1. Areki

Areki is a colorless, transparent distilled alcoholic beverage made from fermentation products prepared by concentrated fermentation. Areki is largely brewed in rural and semi-urban areas and primarily consumed with farmers, semi-urban dwellers and lower-class peoples with low income (Desta, 1977). In cities, those who drink Areki are predominantly lower-class people or those who have become dependent on alcohol and cannot afford to buy industrially produced alcohol (Desta, 1977). Traditionally, Areki is classified into two, Terra-Areki and Dagim-Areki. The term Dagim in Amharic refers to “second time” and indicates that it is distilled second time, whereas the term terra in Amharic refers to “ordinary” (Tafere, 2015).

1.2. Terra-Areki

Terra-Areki is a colorless, clear, local alcoholic beverage, which is distilled from a fermentation product known as Yareki-tinsis (Mash). Mash is prepared by mixing powdered Gesho leaves and powdered bikil (1:2 ratios) with water to give a mixture of free flowing consistency, which will be put aside to ferment for about five days. An amount of Sorghum (Elusine coracann), roughly equivalent to four times that of the Bikil (Malt), is powdered and kneaded with water to make dough and baked into cakes (Alemu et al., 1991). The hot cakes are broken into pieces, added to the first mixture and with more water, well mixed and again left aside to ferment for about four days. Portions of the second mixture are transferred to the traditional distillation apparatus and distilled to give what is known as terra-Areki (Tafere, 2015).
1.3. Dagim-Areki
Dagim-Areki is a stronger type of Terra-Areki, which is prepared in the same way as Terra-Areki, except that the distillation process is allowed to proceed for a shorter period of time, or three volumes of terra-Areki are redistilled to give about one volume of Dagim-Areki. The redistilled Areki will then have a higher alcohol content. Since the government has no control over the production of locally brewed alcoholic drinks, it is difficult to estimate the amount of alcohol production and consumption in Ethiopia. However, the unrecorded alcohol consumption is estimated to be 1.0-liter pure alcohol per capita for population older than 15 years of age for the years after 1995 (Alemu et al., 1991; Tafere, 2015).

1.4. Methods of ethanol determination
In industry, the concentration of ethanol determination of ethanol is very important in quality control of alcoholic beverages such as beer, wine, liquor and spirits. Ethanol could also represent a quality indication for food when ethanol is the product of food degradation. Various studies have demonstrated the possibility of determining the ethanol concentration using NIR spectroscopy for quality control of fuels. Methanol (Opekar et al., 2011) and ethanol (Pereira et al., 2012, 2013) have been determined separately in gasoline using NIR spectroscopy. Simultaneous determination of methanol and ethanol is also possible in gasoline using NIR spectroscopy. Gas chromatography (GC) is the analytical technique, which is recommended by the American Society for Testing and Materials for the determination of volatile ethers and alcohols (including ethanol) in gasoline (Pereira, 2012; Teshome, 2017). Also, a simple spectrophotometric method was described for the determination of ethanol in gasohol and Alcoholic beverage (Munchauen et al., 2009). Electrochemical detectors such as contactless impedance (Opekar et al., 2011; Rocha & Simões-Moreira, 2005) and amperometry (Opekar et al., 2011) have been proposed for the determination of ethanol in gasoline.

The Gross Heat of Combustion or Higher Heating Value (GHC or HHV) is obtained by the oxygen bomb calorimeter method. Some researchers have attempted to determine the heating value of Fuel by characterizing its viscosity, density, Cetane number, cloud and Pour points, distillation range, flash point, ash content, sulfur content, carbon residue, acid value, and copper corrosion (Goering et al., 1982).

The competition between food and biofuel production in Ethiopia was studied using a partial equilibrium model and equilibrium model. The model is based on a baseline scenario from Ethiopia’s Social Account Matrix for the year 2000, and it concludes that enough biofuel can be produced for local consumption without limiting agricultural land supply (Lashitew, 2011).

A small number of researchers have recently studied the micro-process biological fermentation (Tafere, 2015; Teshome, 2017), socioeconomic impact, florin concentration as well as methanol and ethanol concentrations (Alemu et al., 1991; Desta, 1977; Tafere, 2015), but none of the studies have looked into the energy potential of Ethiopian local distilled alcohol. The main objective of this work is to determine the ethanol concentration and calorific value of different Ethiopian local distilled alcohols (Areki) as a first step towards identifying its suitability as alternative fuel sources for industrial and domestic use, which could encourage people to use local distilled Areki as fuel instead.

2. Materials and methods

2.1. Sample preparation analysis

2.1.1. Sample
A total of five samples of (terra and dagim) Areki were extracted from sorghum, maize and lupin cereals. Of the total five samples, two samples (dagim and terra) were produced from Maize Areki Mash, the other two samples (dagim and terra) were distilled from Sorghum Areki Mash and the
last one sample was distilled from Lupin Areki Mash. The same amount of inputs and proportions were used for the extraction process of all samples in the same environment.

2.1.2. pH value determination
Experiments were conducted in Bahirdar Institute of Technology Hydraulic Laboratory. The pH of the samples was measured by dipping the electrode of a digital pH meter (BANTI 901-UK PH) to the all samples at 25°C under atmospheric conditions. The calibration of the pH meter was checked by deionized water and buffer solutions of pH values 4, 7 and 9. A digital PT-1 thermocouple instrument was used for all temperature measurements.

2.1.3. Determination of ethanol concentration in the sample
Ultraviolet spectrophotometer UV/Vs have been used for quantifying the ethanol concentration in each collected sample and the experiment was carried out in the chemical research grade laboratory in BIT. Quantification of water using the spectrophotometer may be carried out by preparing the mixture and measuring its absorbance at a suitable wavelength (Alemu et al., 1991; Andrea, 2015). This experiment of quantitative analysis was done by preparing an aqueous solution of ethanol to draw by means of absorbance and calibration line. As the author claimed (Böck et al., 2018), the fundamental law that governs the quantitative spectrophotometric analysis is the Lambert-Beer law. Mathematically, Lambert-Beer law is expressed as

\[ A = abc, \]  
(1)

Where

\[ A = \text{absorbance} \]
\[ a = \text{absorptivity coefficient} \]
\[ b = \text{path length of radiation through the sample (cm)} \]
\[ C = \text{concentration of water in the mixture} \]

\( a \) and \( b \) are constants and \( a \) is directly proportional to the concentration \( C \). The calibration line is the most common methods to determine the unknown concentration of an analyte in the solution (Alemu et al., 1991).

2.1.4. Chemicals and instruments used
In this experiment, particularly distilled water and absolutely pure (99.9%) ethanol were used as a standard and materials like volumetric flask and bickers were used for standard solution preparation.

Specified amounts of ethanol (ml) were mixed with distilled water in a series of 100 ml of volumetric flasks. The percentage of ethanol in standard solutions varies from 0% to 100% with interval 10% in the series of 11 volumetric flasks. Absorbance versus wavelength of standard solutions was scanned in the UV spectrophotometer between 950 and 1050 nm in spectrum mode using ethanol as blank. Distilled water used was from glass still. Table 1 and 2 shows the percentages of ethanol and its absorbance is measured to 986 nm.

2.1.5. Determination of calorific value
Calorific value is the very important feature of fuel, which represents the amount of heat transferred into the chamber during the combustion and indicates the available energy in fuel (Sivaramakrishnan & Ravikumar, 2012). A bomb calorimeter (calibrated using benzoic acid tablets) IKC200 with the pressure vessel with 30 bar filled with C-248 oxygen 99.99995% pure from
Bahirdar institute of technology (Ethiopia) was used to determine the energy contained in the samples by quantifying the heat generated during its combustion. Any heat exchange between the bomb calorimeter and the external environment was prevented by insulation. Corrected temperature rises reading automatically, and the fuse correction would be (0 J) from electrical heating, (50 J) from burning thread for all the tests used this value (Bomb calorimeter C 200 operating instruction manual, 2016). Precise temperature measurements are made using thermistor thermometry, which provide 0.0001 °C resolution over the operating range of the calorimeter.

A sample mass of 0.5 g to 1 g was used for all samples and burned in the bomb calorimeter for 20 minutes. The sample was connected to the ignition system by means of C 710.4 cotton thread and ca. 5010.3 ignition wire and the bomb calorimeter with the sample was then immersed into the water bath, which contained 2 kg of water. The temperature rise measured in every experiment was corrected for stirring and exchange heating.

2.1.6. Determining the calorific value
Combustion is carried out in a calorimeter under specific conditions. The decomposition vessel is filled with a weighed fuel sample, the fuel sample is ignited and the temperature increase in the calorimeter system is measured (IKA, 2005). The specific calorific value of the sample is calculated as follows (A. International, 2012):

\[
H_0 = (C*DT - Q_{Ext1} - Q_{Ext2})m, \tag{2}
\]

\[m = \text{Weight of fuel sample}\]
\[C = \text{Heat capacity (C-value) of the calorimeter system}\]
\[DT = \text{Calculated temperature increase of water in inner vessel of the measuring cell}\]
\[Q_{Ext1} = \text{Correction value for the heat energy generated by the cotton thread as ignition aid}\]
\[Q_{Ext2} = \text{Correction value for the heat energy from other burning aids}\]

2.1.7. Bomb calibration procedure
When the bomb was charged with fuel and oxygen and ignited, it heats the sample; however, the heat generated also heats the mass of water of known weight in the calorimeter vessel and the heavy stainless steel bomb vessel. The calorimeter system must be calibrated before accurate measurements are possible. Therefore, to account for the heat gained by the bomb material, a calibration was done using benzoic acid (C 43 standard reference sample) having a specific energy of combustion under standard bomb conditions of 6319 cal/g (or 26450 J/g).

Since the mass of water in the calorimeter vessel was kept constant, the heat quantity required to raise the temperature of the calorimeter system by one Kelvin is used to determine the heat capacity of the so called “C-value” of the system and determined by

\[
C = (H_0 + Q_{Ext1} + Q_{Ext2})DT. \tag{3}
\]

From five calibrations done with the bomb, the average energy equivalent of the calorimeter was determined using Equ (3) to be 12187.3194 J/K, where the uncertainty quoted is the standard deviation of the mean.
GCV obtained from all the alcoholic samples was subjected to basic descriptive statistical analysis to determine the mean and standard deviation of the calorific values using the following equations (Ioannis Gravalos et al., 2016):

\[
\text{average of } x = \bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i, \quad (4)
\]

\[
\text{Standard deviation of mean of } x = \text{std} = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n(n-1)}}, \quad (5)
\]

where \(x_i\) are the calorific values and \(n\) is the number of measurements. Finally, analysis of variance (sigma plot) was used to determine if there was significant variation in the data obtained for GCV within individual species.

3. Results and discussion

3.1. PH value

PH is specified on a \(\log_{10}\) scale, which allows a very wide range of activities (concentrations) to be specified using a small range of numbers. A difference of one pH number corresponds to a difference of ten times in acidity or basicity. For example, a solution with a pH of 5 is ten times \(10^5\) more acidic than a solution with a pH of 6 and a solution with a pH of 9 is ten times \(10^9\) more basic than a solution with a pH of 8.

For relatively dilute solutions of strong acids and bases, the pH value can be defined using the following formula:

\[\text{pH} = -\log_{10}[\text{H}_3\text{O}^+].\]  

(6)

The concentration of hydronium ion or \([\text{H}_3\text{O}^+]\) ion in mol/L for each sample is given by

\[\text{[H}_3\text{O}^+] = (10)^{-\text{pH}},\]

where

\([\text{H}_3\text{O}^+]\) is the concentration of the hydronium.

pH is experimentally measured power of the hydronium ion

| Table 1. Experimentally measured pH and [H\text{H}_3\text{O}^+] value of samples |
|--------------------------|----------|------------------|
| Samples Areki            | PH values | [H\text{H}_3\text{O}^+] (mol/L) |
| Dagim Sorghum           | 3.534     | 0.000292         |
| Terra Sorghum           | 3.703     | 0.000198         |
| Dagim maize             | 3.514     | 0.000306         |
| Terra maize             | 3.746     | 0.000179         |
| Lupin                   | 3.352     | 0.000444         |
Experimental results of the PH value for the samples are described in Table 1. It is illustrated in Tables 1 that almost all samples are below the pH value of 7. This indicates that all samples have acidic properties (meaning that the concentration of $H_3O^+$ is more than the concentration of $OH^-$) and from all samples, Areki, which is prepared from Lupin mash, is more acidic, whereas a sample of terra Areki, which is distilled from maize mash, has less acidic property. The acidity of Lupin Areki might be due to its higher hydronium ion concentration release in a solution of Lupin ingredient. However, basicity of terra maize Areki is due to the lower hydronium ion concentration in solution than the other samples.

### 3.2. Experimental result of ethanol concentration

#### 3.2.1. Curve of calibration

An eleven-point calibration curve was obtained in the ethanol concentration range from 0 to 100%. The linear regression equation is best fitted and was used to investigate the concentration of ethanol with absorbance for this study.

Table 2 shows the percentage of ethanol concentration and its absorbance measured at a wavelength of 986 nm. The linear regression equation of absorbance versus ethanol concentration for the above has been obtained by using sigma plot software and is given by

\[ Y = 0.1692 - 0.0017x, \]

with a correlation coefficient of 0.9986

All these Areki samples were produced at home with specific ingredients; however, proportion of ingredients and its methods followed for its productions are similar. Thus, the ethanol concentration differs among samples significantly. In previous studies, various methods are used to determine the ethanol concentration in alcoholic beverages via density method (Desto, 1977), Gas chromatography with a flame ionization detector (GC/FID) (Opekars et al., 2011), Gas chromatography mass spectrometer (GCMS), Fourier transform infrared spectroscopy (FTIR) and Ultra violet spectrophotometer (UV/vis) (Aleme et al., 1991). In this study, UV/Vis was used to determine the ethanol concentration due to its high accuracy, simplicity and fast method compared to the density method, but it needs an internal standard or reference for measurement Figure 1 and 2.

Among the samples shown in Table 3, dagim Areki has a relatively high ethanol concentration, but the ethanol concentration varies with the type of ingredient used for mash preparation, time used for distillation and the amount of heat supplied for distillation. Dagim Areki, which is
produced from maize, has the highest ethanol concentration, which is 50.17% (v/v), whereas degim Areki, which is produced from lupin, has a lower ethanol concentration of 26.64% (v/v). This great variation in the ethanol concentration might be due to the high acidic property of lupin ingredient and the lower sugar concentration rather than other ingredients.

Table 3. Ethanol concentration of Areki samples

| Areki samples   | Absorbance | %Ethanol   |
|-----------------|------------|------------|
| Dagim sorghum   | 0.092      | 45.47059   |
| Dagim maize     | 0.084      | 50.17647   |
| Terra sorghum   | 0.098      | 41.94118   |
| Terra maize     | 0.104      | 38.41176   |
| Dagim lupin     | 0.124      | 26.64706   

Figure 1. Calibration line for absorbance Vs %ethanol.

Figure 2. Experimental absorption spectra of samples of Areki in relation to the wavelength.
Table 4. Calorific value of Areki samples

| Types of alcohol | Min calorific value MJ/kg | Max calorific value MJ/kg | Mean calorific value MJ/kg | Uncertainty |
|------------------|---------------------------|---------------------------|-----------------------------|-------------|
| Dagim maize      | 13.135                    | 13.153                    | 13.143                      | 0.073       |
| Dagim sorghum    | 11.779                    | 11.793                    | 11.784                      | 0.060       |
| Terra sorghum    | 10.781                    | 10.794                    | 10.789                      | 0.054       |
| Terra maize      | 9.782                     | 9.790                     | 9.7878                      | 0.056       |
| Dagim lupin      | 6.610                     | 6.620                     | 6.6166                      | 0.043       |

Previous researches observed significant variations in the ethanol concentration of Ethiopian traditional Areki (Desta, 1977; Opekar et al., 2011) and concluded that the difference is due to the variation of ingredients. However, the variation between this research and previous might be due to the method of ethanol determination and also it may differ by Areki producers.

The energy content of alcohol fuel is determined by its calorific value. No investigation has been conducted on the calorific value of local distilled Ethiopian alcohol. The calorific value of alcohol is influenced by its alcohol ethanol concentration. Table 4 shows minimum, maximum, range, mean, and standard deviation of GCV for all the samples of local distilled Ethiopian alcohols. Dagim maize and dagim sorghum alcohol has the highest energy content of 13.1432 MJ·kg⁻¹ and 11.7848 MJ·kg⁻¹, respectively, and terra maize and dagim lupin have relatively the lowest calorific values. The result in Tables 3 and 4 shows that the calorific value of local distilled Ethiopian Areki is directly related to the level of ethanol concentration in the sample. A significant variation in the data obtained for GCV was within individual species at p < 0.074. As a future potential fuel, biofuel must compete economically with petroleum. As a result, biofuel demand is expected to increase significantly in the coming years. Developing countries like Ethiopia have a comparative advantage in biofuel production due to greater land availability, favorable climatic conditions for agriculture, and lower labor costs.

4. Conclusion
In this work, different types of local alcohols from different types of cereals were distilled and their corresponding thermophysical properties like pH, percentage of ethanol concentrations and calorific value were analyzed. The experimental study was found to be varying from the highest ethanol concentration of 50.176% v/v and the highest calorific value of 13.143 MJ/kg to the lowest ethanol concentration of 26.647% v/v and the lowest calorific value of 6.620 from dagim Areki distilled from the maize and lupin, respectively. This finding indicates that dagim samples of alcohol derived from maize and sorghum have a high energy potential, whereas Areki from lupin samples has a low energy potential.

Ethiopia is an energy-scarce country that relies heavily on gasoline and diesel imports, particularly in the transportation sector. With the current rapid expansion of developmental activities, stretched human needs, and recurring fuel shortages, it is imperative to seek out high-yielding crops for biofuel production. Several cereals grown in the country have a high potential for bioethanol production. As a result, the country can use local distilled alcohol as an indigenous and renewable fuel after small purification, which can be used alone or blended with gasoline to reduce gasoline consumption.

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References
A. International. (2012). ASTM D240, Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter.
Agarwal, A. K. (2007). Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. Progress in Energy and Combustion Science, 33(3), 233–271. https://doi.org/10.1016/j.pecs.2006.08.003
Alelu, F., Amhaselassie, T., Kelbessa, U., & Elias, S. (1999). Methanol, fuel oil, and ethanol contents of some Ethiopian traditional alcoholic beverages. Sinet, 14(1), 19–27.
Andrea, C. J. W. (2015). Quantitative analysis of alcoholic drinks. Use of calibration curve method to determine the alcoholic degree of samples of Paesanella, a distillate of the family of Grappa. World Journal of Chemical Education, 3(3), 70–73.
Böck, F. C., Helfer, G. A., Da Costa, A. B., Dessuy, M. B., & Férard, M. F. J. F. A. M. (2018). Rapid determination of ethanol in sugarcane spirit using partial least squares regression embedded in smartphone. Food Analytical Method, 11(7), 1951–1957.
Bomb calorimeter C 200 operating instruction manual. (2016).
Demirbas, A. (2008). Economic and environmental impacts of the liquid biofuels. Energy Education Science and Technology, 22(1), 37–58. https://doi.org/10.1016/j.enconman.2009.05.010
Demirbas, A. (2009a). Biofuels securing the planet’s future energy needs. Energy Conversion and Management, 50(9), 2239–2249. https://doi.org/10.1016/j.enconman.2009.05.010
Demirbas, A. (2009b). Political, economic and environmental impacts of biofuels: A review. Applied Energy, 86, S108–S117. https://doi.org/10.1016/j.apenergy.2009.04.036
Desto, B. (1977). A survey of the alcohol content of traditional beverages. Ethiopian Medical Journal, 15(2), 65–68.
Goering, C., Schwab, A., Daugherty, M., Pryde, E., & Heakin, A. (1982). Fuel properties of eleven vegetable oils. Transactions of the ASAE, 25(6), 1472–1477. https://doi.org/10.13031/2013.33748
IKA. (2005). Operating Instructions for Calorimeter System C 200. Ver. 02/2/06.
Ioannis Gravalos, P. X., Kateris, D., Gialamas, T., Bartzialis, D., & Giannoulis, K. (2016). An experimental determination of gross calorific value of different agroforestry species and bio-based industry residues. Earth and Environmental Science, 7, 57–68. http://dx.doi.org/10.4263/en.2016.71006
Lashitew, A. A. (2011). Competition between food and biofuel production in Ethiopia: A partial equilibrium analysis. Biofuels, 2(6), 611–627. https://doi.org/10.4155/bfs.11.139
Munchaoran, S., Sitanurak, J., Tiyapongpattana, W., Choengchon, N., Ratanawimarnwong, N., Motomizu, S., Wilairat, P., & Nacapricha, D. (2009). Quality control of gasohol using a micro-unit for membraneless gas diffusion. Microchimica Acta, 164 (1–2), 203–210. https://doi.org/10.1007/s00604-008-0058-6
Opek, F., Cabola, R., & Kadlecova, T. (2011). A simple contactless impedance probe for determination of ethanol in gasoline. Analytica chimica acta, 694(1–2), 57–60. https://doi.org/10.1016/j.aca.2011.03.038
Pereira, P. F. (2012). Determinación de etanol e metanol em álcool combustível e gasolina empregando métodos eletroanalíticos. Institutional Repository - Federal University of Uberlândia.
Pereira, P. F., Marra, M. C., Munoz, R. A., & Richter, E. M. (2012). Fast batch injection analysis system for on-site determination of ethanol in gasohol and fuel ethanol. Talanta, 90, 99–102. https://doi.org/10.1016/j.talanta.2012.01.004
Pereira, P. F., Sousa, R. M., Munoz, R. A., & Richter, E. M. (2013). Simultaneous determination of ethanol and methanol in fuel ethanol using cyclic voltammetry. Fuel, 103, 725–729. https://doi.org/10.1016/j.fuel.2012.07.034
Rocho, M. D. S., & Simões-Moreira, J. (2005). A simple impedance method for determining ethanol and regular gasoline mixtures mass contents. Fuel, 84(4), 447–452. https://doi.org/10.1016/j.fuel.2004.09.011
Sivaramakrishnan, K., & Ravikumar, P. (2012). Determination of cetane number of biodiesel and its influence on physical properties. ARPN Journal of Engineering and Applied Sciences, 7(2), 205–211.
Tafere, G. (2015). A review on traditional fermented beverages of Ethiopian. Journal of Natural Sciences Research, 5(15), 94–102.
Teshome, D. A. (2017). Chemical compositions of traditional alcoholic beverages and consumers’ characteristics, Ethiopia. African Journal of Food Science, 11 (7), 234–245https://doi.org/10.5897/AJFS2016.1541
Wedjo Lebi, B. (2020). Microbiology of Ethiopian traditionally fermented beverages and condiments. International Journal of Microbiology, 2020, 1478536. https://doi.org/10.1155/2020/1478536
