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jvillarroel@uteq.edu.ec

Correspondence:

Evaluation of physical and chemical characteristics of biofuel from tropical fruits

Evaluación de las características físicas y químicas de biocombustible a partir de frutas tropicales

José Villarroel Bastidas
Master in Food Processing, research professor, Faculty of Engineering Sciences, Quevedo, Ecuador jvillarroel@uteq.edu.ec, https://orcid.org/0000-0002-9013-3776

Gissela Rocio Cobeña Cedeño
Agroindustrial Engineer, Faculty of Engineering Sciences, Quevedo, Ecuador gisselarced.cobena@uteq.edu.ec https://orcid.org/0000-0002-0572-8987

Bryan Josué Espinoza-Oviedo
Master, Faculty of Engineering Sciences, Quevedo, Ecuador bespinoza@uteq.edu.ec, https://orcid.org/0000-0002-9013-3739

Abstract
The different wastes generated by farmers engaged in the production of pineapple, papaya and banana generate large amounts of waste without an adequate treatment for them, with a fermentation process, and then applying a distillation method, bioethanol can be obtained from all this type of waste. The present work is focused on obtaining bioethanol from the wastes of three tropical fruits by means of fermentation applying different percentages of yeast. A completely randomized block experimental design was applied with factorial arrangement A x B where factor A is equal to the types of fruits (papaya, guineo and pineapple), while factor B is equal to the three levels of Saccharomyces cerevisiae yeast (0%, 0.05% and 0.10%), which gives a total of 18 experimental units: ° Brix, pH, turbidity, alcoholic degrees, acidity, density and specific heat; for validation of the research, an analysis of combustion power between a mixture of 10% ethanol and 90% gasoline was subjected. The results obtained indicate that the sample (guineo + 0.05% yeast) showed better chemical and physical characteristics Brix (16.5), density (0.9834 g/cc), specific heat (2.398 kJ/ kg), alcoholic (17.33 °GL), acidity (0.820) being the best treatment for bioethanol production.

Key words: Specific heat, density, alcoholic strength, combustion power.

Abstract

Los diferentes desperdicios que generan los agricultores que se dedican a la producción de piña, papaya y guineo generan grandes cantidades de desechos sin que exista un tratamiento adecuado para los mismos, con un proceso fermentativo, para luego aplicar un método de destilación se podrá obtener bioetanol de todo este tipo de desechos. El presente trabajo está enfocado en la a partir de los desechos de tres frutas tropicales mediante la fermentació porcentajes de levadura, Se Aplicó un Diseño experimental de bloques Completamente al Azar con arreglo factorial A x B donde factor A es igual a los tipos de frutas (papaya, guineo y piña), mientras que factor B es igual a los tres niveles de levadura Saccharomyces cerevisiae (0%, 0,05% y 0,10%), los mismos que da un total de 18 unidades experimentales, se realizaron diversos análisis como: ° Brix, pH, turbidez, grados alcohólicos, acidez, densidad y calor especifico; para la validación de la investigación se sometió a un análisis de poder de combustión entre una mezcla del 10% de etanol y 90% de gasolina. Los resultados obtenidos indican que la muestra (guineo+ 0,05% de levadura), mostró mejores características químicas y físicas Brix (16,5), Densidad (0,9834 g/cc), Calor especifico (2,398 kJ/ kg), alcohólicos (17,33 °GL), Acidez (0,820) siendo el mejor tratamiento para la producción de bioetanol.

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Palabras clave: Calor específico, densidad, grados alcohólicos, poder de combustión.

Introduction

Bioethanol has been identified as the most widely used biofuel worldwide as it contributes significantly to the reduction of crude oil consumption and environmental pollution. It can be produced from various types of feed materials such as sucrose, starch, lignocellulosic and algae biomass through fermentation process by microorganisms Borras, (2013) Biofuels currently represent a potential source of renewable energy, in addition to the fact that they could generate new and large markets for agricultural producers (Romo-Fernandez et al., 2013, p. 34).

Biofuels are those biofuels such as alcohols, ethers, esters and other chemical products that come from cellulosic-based organic compounds (biomass) extracted from wild or cultivated plants, which replace to a greater or lesser extent the use of gasoline in transportation or intended to produce electricity Déniz & Verona, (2015).

Second generation (2G) biofuels differ from first generation biofuels in two aspects: They are obtained from vegetables that do not have a food function, and they are produced with technological innovations that will allow them to be more environmentally friendly and advanced than the current ones Romo-Fernandez et al., (2013)

Biofuels of biological origin can replace part of the consumption of traditional fossil fuels, such as oil and coal; this type of fuel is almost always in liquid form and is used to drive combustion engines in land transportation. The most developed and used biofuels are bioethanol and biodiesel; biodiesel, also known as biogas oil or diester, is a renewable fuel that substitutes diesel and comes from the processing of vegetable oils, both natural and recycled (soybean, sunflower, palm, etc.) and animal fats, de Oliveira & Abadía, (2013).

In this way, the accumulation of waste would be reduced, giving an added value to vegetable waste, contributing to the production of clean energy that does not pollute our environment. First generation biofuels refer to those produced from raw materials of edible origin (sugars, starches and vegetable oils) through conventional and commercially well-established technologies, including fermentation, transesterification, etc. (Ramírez, 2013, p. 87).

At present, Borras, lignocellulosic biomass and especially agro-industrial by-products are no longer waste-problem products, but have become potential raw materials for various agricultural and industrial processes, one of the most important being the production of fuel alcohol (2013).

The main disadvantage of first-generation ethanol is that the use of food resources as fuel may threaten the food supply to a large part of the population, while, on the other hand, food prices could also increase. Only if an adequate sustainability strategy is defined for the production and use of biomass, it could be claimed, in the future, that biofuels, as renewable energy, are environmentally and socially convenient Ruiz & Galicia, (2016). These new fuels open up the possibility of obtaining more environmentally friendly fuels that do not compete with food crops, that also collaborate doubly against climate change and that are produced using our own resources and, therefore, reduce our external dependence on fossil fuels (Espinosa-Bueno et al., 2010, p. 34). The purification and enrichment in alcohol of these ethanol-water mixtures is currently carried out using distillation as a separation process, whose energy consumption is high with respect to the energy content of the product achieved Barrasa,(2017).

Materials and methods

We will study 3 types of fruit residues, which are not very industrialized, for which we will apply in this type of research an analysis of variance with the structured tukey significance test with 3 study factors referring to the types of fruit, and different percentages of yeast referring to the times and temperatures.

For the study of the results obtained, a completely randomized block design was used with an AxB factorial arrangement, where Factor A is the fruit used in fermentation and Factor B is the percentage of yeast, giving a total of 18 treatments with two replicates. The variables used are: °Brix, pH, Turbidity, Alcoholic degrees, Acidity, Density and Calorimetry.

Table 1. *Study variables*

Factors	**Symbology**	**Description**
	a0	Papaya

A: Fruit	a1	Guineo
	a2	Pineapple
	b0	0%
B: Percentage of yeasts	b1	0,05%
	b2	

With the 18 samples, the respective analyses were performed on each sample, the physical analyses of: turbidity, density, specific heat and chemical analyses such as pH, °Brix, acidity and alcoholic strength.

In the last analysis, all the samples are distilled, obtaining a single distilled sample as the best treatment. This analysis was carried out by combining ethanol (10%) and gasoline (90%), tested in a mechanical engine of the Quevedo State Technical University.

The pH analyses were carried out in the Unit Operations Laboratory with an equipment called "OAKLON" by inserting the electrode in each sample, and with the pH measuring strips to obtain the pH values of the raw material.

The Brix degrees were measured in an "ATAGO" Brixometer of the raw material received, and of the ethanol, one to two drops of the sample were placed and then the percentage indicated by the equipment was observed.

It was carried out by titration by means of NaOH (Sodium Hydroxide) consumption at 0.1 of Normality in a 10 ml sample of the extracted bioethanol, C20H14O4 (Phenolphthalein) was used as indicator, procedure based on NTE INEN 341 Alcoholic beverages. Determination of acidity. The pH measurement was based on standard NTE INEN 0973 (1984), which consisted of using a pH meter, introducing the electrode into the liquid sample of the product and the oil sample was used directly for the measurement.

$$\text{Acidez}(\%)=\left(\frac{V_{NaOH\ (mL)}\times N_{NaOH}\left(\frac{meq}{mL}\right)\times\left(\frac{0.064g}{meq}\right)}{W_{peso\ de\ la\ muestra}\ (mL\ o\ g)}\right)\times 100 \qquad (1)$$

It was carried out in an equipment called Alcoholimeter, 90 ml was measured for each sample in a 100 ml test tube, and then the alcoholmeter was introduced into the substance and the equipment was rotated in such a way that when it stopped, the level of alcoholic degree of each ethanol sample could be read. The best treatment obtained, the °GL was taken in an "AQUEOUS LAB" equipment, a Portable Refractometer, in the following way: it is placed (1-2 drops) in the device and the value obtained is visualized.

In the determination of the density of a liquid (ethanol) with the pycnometer method, the mass of the liquid in three different situations is needed. The masses must be determined in an analytical balance, the values obtained are the mass of the empty pycnometer, then the mass of the pycnometer with water and finally the mass of the pycnometer with the solution (ethanol) with these 3 data for each sample is placed in the formula, and determine the value obtained from each treatment.

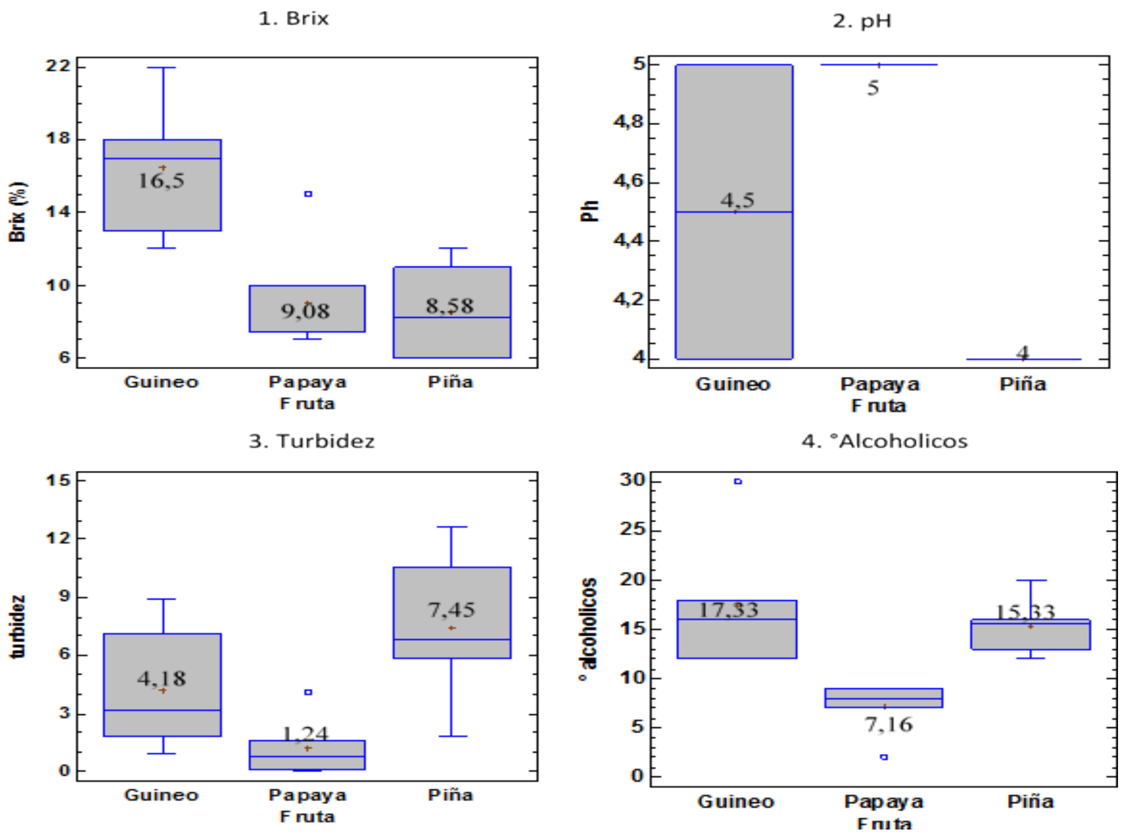
This analysis is performed in a "HACH TURBIDIMETER" equipment, which allows us to obtain the values in NTU (Nephelometric Turbidity Unit). To do this, turn on the equipment, introduce a sample of 30 ml of the substance, press "enter" and wait 60 seconds where the machine automatically gives us the turbidity level of the treatment.

The sample is measured by a test tube, a value of 160 ml, is placed in the equipment, where you will find a thermometer which raises its temperature according to the heat of each sample that is constantly moving with a stirrer, the temperature should start at 25°C and reach maximum 60°C, the solution, reacts to 6 volts, and 1 ampere; which operates at current. The values given by the machine are determined by a stopwatch, which starts at 0 seconds and ends in approximately 1 hour, then the specific heat is determined by means of a physical formula.

The combustion power was determined by distilling all the samples, obtaining only one sample as the best treatment, which had 70°GL. This analysis was carried out by combining ethanol with gasoline and testing it in a mechanical engine of the Quevedo State Technical University.

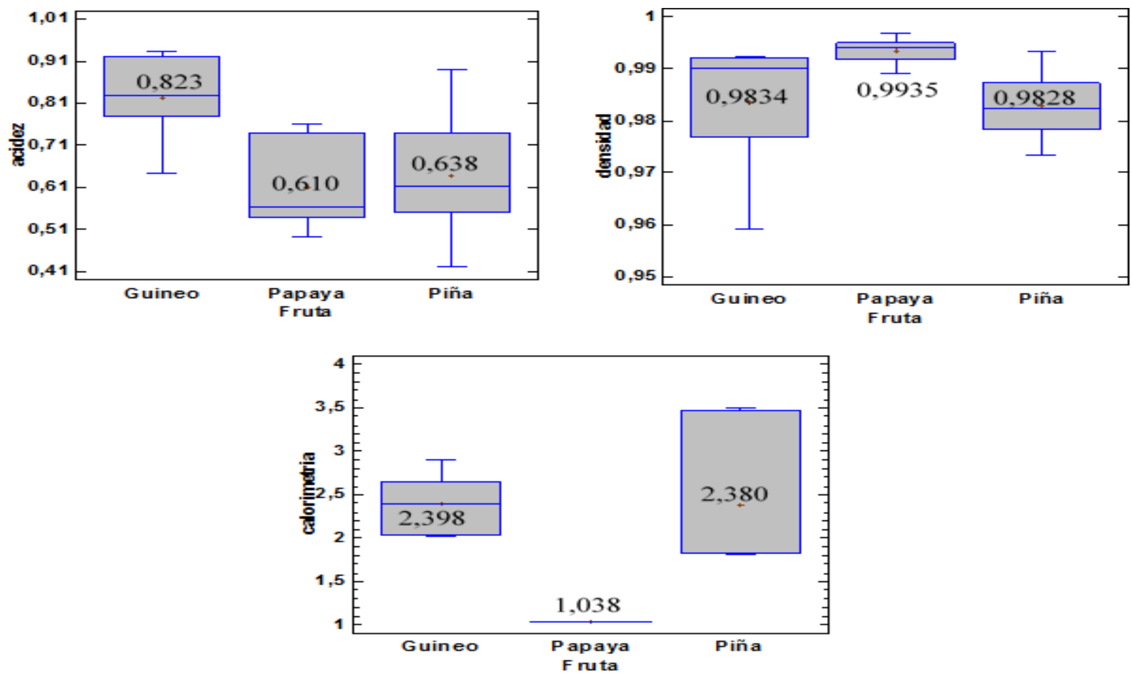
The statistical analysis of the results obtained for the study variables was carried out by means of an analysis of variance (ADEVA) and to determine significant differences, the Tukey significance test was applied ($p \leq 0.05$); this analysis was performed in the statistical program STATGRAPHICS Centurión XVI version 16.2.04.

Result



Graph 1: Results of mean difference between fruit types (papaya, banana and pineapple) in the Tukey significance test ($p < 0.05$). 1. °Brix; 2. pH; 3. Turbidity; 4. ° Alcoholic.

In graph 1, there was a significant difference in the °Brix, the highest value was present in banana = 16.5 and a lower value in pineapple = 8.58; regarding pH, papaya presented the highest value with an average of 5 while pineapple obtained an average pH of 4 with the lowest value; In the turbidity results, there was a significant difference, the pineapple obtained the most relevant value 7.45 NTU while the papaya obtained 1.24 NTU being the lowest value; the guineo had the highest alcohol content with 17.33 °GL and the papaya had the lowest value with an alcohol content of 7.16 °GL.



Graph 2: Results of the difference of means between the types of fruit (papaya, banana and pineapple) in the Tukey significance test ($p < 0.05$). Acidity; 2. Density; 3. Calorimetry.

In graph 2, there was a significant difference in acidity, finding the highest value in Guineo = 0.823, while the lowest value was obtained in Papaya = 0.610, as for density a significant difference was found in the variables where the highest value was found in Papaya = 0.9935 having the lowest value in the factor Pineapple = 0.9828 in calorimetry analysis also found a significant difference between its values had the lowest values Papaya = 1.038 and the highest in Guineo = 2.398.

Table 2. *Mean values of the interactions for each of the analyses.*

Factor A	**Factor B**	**Brix (%)**	**pH**	**turbidity**	**°GL**	**acidity**	**density**	**calorimetry**
Papaya	0%	14,5	4,5	4,945		0,89	0,968045	2,62153
Papaya	0,50%		4,5	5,265		0,8565	0,99112	2,54871
Papaya	1,00%		4,5	2,34		0,7225	0,991195	2,02584

Guineo	0%	7,5	5	2,5		0,64	0,994585	1,03782
Guineo	0,50%	8,5	5	0,865	5,5	0,653	0,992975	1,03952
Guineo	1,00%	11,25	5	0,355		0,5375	0,992975	1,0395
Pineapple	0%	8,5		6,27	17,5	0,78	0,98374	1,82045
Pineapple	0,50%			6,245	14,5	0,554	0,988865	3,4868
Pineapple	1,00%	8,25		9,825		0,58	0,97592	1,83502

Table 2 shows the results of the Tukey significance test ($p<0.05$) applied to the A*B Interaction (Fruit vs. Percentage of yeast) in the following variables: With respect to the °Brix did not present significant difference, standing out as the highest value (20 °Brix) in the interaction Papaya vs 0.05% and in lower value 7.5 °Brix the interaction guineo vs 0%; in relation to pH, no significant difference was observed between the means of the interactions, presenting pH values in the interactions ranging from 4 to 5; According to the Turbidity values, there was no significant difference, with the highest value of 9.825 NTU for the interaction (Pineapple vs. 1%) and the lowest value of 0.355 NTU for the interaction (banana vs. 1%); in the alcohol content, no significant difference was observed, with the highest value of 24 °GL for the interaction (Papaya vs. 0%) and the lowest value of 5.5 °GL for the interaction (banana vs. 0.05%); With respect to acidity, no difference was observed, obtaining the highest value (0.89 %) for the interaction (Papaya vs 0%) and the interaction (Guineo vs 1%) presented the lowest value with an acidity of 0.5375 %; with respect to density, a significant difference was observed, where the interaction (Guineo vs 0%) presented the highest density (0.994585 g/cc) and the interaction (Papaya vs 0%) presented the lowest density (0.968045 g/cc); According to the calorimetry results, there was a significant difference, where the a2b1 interaction (Pineapple vs. 0.05%) had the highest value (3.4868) and the lowest value (1.03782) was the interaction (Guineo vs. 0%).

According to the results of °Brix, papaya = 9.0) and pineapple = 8.58 are within the ranges established (max. 15 °Brix) by Ramírez & Ibarra, (2015). in their study of continuous ethanol production from rejection banana (peel and pulp) using immobilized cells; while (guineo) presented a slightly elevated value (16.5 °Brix) to those established by Ramírez & Ibarra, (2015), this means that the fermentation process was not fully complied with.

In relation to pH, the guineo (a1 = 4.5) and pineapple (a2 = 4) are within the established ranges (max 4.8 pH) by Carvalho Junior, Armando Mariante; Maciel Raimundo, Julio Cesar; In their evaluation of Bioethanol from sugarcane energy for sustainable development; Chapter 5

Advanced technologies in the sugarcane agroindustry. While in papaya = 5) is out of range due to the fact that Papaya contains a higher content of hydrogen ions, so it must undergo a stabilization process, in terms of the pH values given by Ballesteros et al. (2021). In their Obtención de una bebida alcohólica a partir de mucílago de cacao, mediante fermentación anaerobia en diferentes tiempos de inoculación their maximum value is 4.33 leaving the Pineapple = 4 within the ranges, while papaya and guineo contain higher values compared to the referent research.

Regarding Turbidity, the factor Papaya (1.24 NTU) and Guineo (4.18 NTU) are close to the ranges established by Mayor & Martel, (2015), in Caracterización ambiental de las vinazas de residuos de caña de azúcar resultantes de la producción de etanol, mentions that the point of turbidity obtained in their research is maximum 4.745 NTU, while in pineapple (7.45 NTU) is above this range.

As for the results of alcoholic degrees in papaya = 7.16 is within the parameters established by Vazquez, H.J, & Acosta, O. In their evaluation of Alcoholic fermentation: An option for the production of renewable energy from agricultural waste. The alcoholic values have a range of (8 - 12 °GL max), while in guineo = 17.33), and pineapple = 15.33 are not within the established ranges, since the degradation of the sugars of these fruits was in higher percentage.

In the values obtained in the acidity analysis based on the data of Goya Baquerizo, Mariuxi Jessenia in her Obtención de una bebida alcohólica a partir de mucílago de cacao, mediante fermentación anaerobia en diferentes tiempos de inoculación Ruiz & Maldonado, (2014). Where it presents that the maximum acidity values are 1.14 mg, it is considered that the factors studied in this research obtain acidity values within the established range in Papaya = 0.610 and Guineo = 0.823, pineapple = 0.638.

In the density results papaya = 0.9935 guineo = 0.9834 and pineapple (0.9828) show values different from those specified in the density standard (maximum 0.792), in its evaluation of sugarcane bioethanol energy for sustainable development; Chapter 2 (ethanol as vehicle fuel), this means that based on this research the bioethanol extracted from these three tropical fruits obtained lower alcohol content, since the higher the °GL the lower the density, while based on the research (Romo-Fernandez et al., 2013, p. 4), in their study of continuous ethanol production from reject banana (peel and pulp) using immobilized cells. The results of the factors were found to be within the range established by the same (1.05 maximum).

In relation to the specific heat the factors Papaya = 1,038 kJ/kg Guineo = 2,398 kJ/kg and Pineapple = 2,380 kJ/kg, present relatively low values in comparison with the value exposed in the investigated article, it is exposed that the maximum value of the specific heat is 28,225 kJ/kg the results are within the established range, as for the relation with the article Colombia in the fuel era, it indicates that the maximum value of specific heat is 2,386 kJ/kg where the value of the factors papaya = 1.038 and pineapple = 2.380 are within the established range while guineo = 2.398) reflects a small alteration in its result concluding that it is not within the established range, this means that the reduction of the specific heat is due to the oxygen content in the structure of the guineo fruits that compose the bioethanol and, therefore, the percentage of carbon is lower than in the commercial diesel fuel.

Conclusions

With regard to the fruits evaluated in the bioethanol production process, it is concluded that the guineo obtained better physical-chemical characteristics in the bioethanol obtained, standing out in the following variables: °Brix (16.5), Density (0.9834 g/cc), Specific heat (2.398 kJ/ kg), alcoholic (17.33 °GL), Acidity (0.820).

In the percentages of Saccharomyces cerevisina yeast that were studied (0%, 0.05% and 1%), it is concluded that all the factors studied contain the necessary characteristics to obtain an optimum process, in terms of reference with the cited bibliographies, from which a comparison is made with the studies of other fruits based on the established ranges, finding a significant difference in the density and specific heat variable, The optimum density was obtained in relation to the yeast percentage, since the lower the density, the better quality bioethanol will be obtained, while in relation to the specific heat, the most optimum value is 0.05 % of yeast, obtaining the highest value of specific heat, thus concluding that based on this study the most optimum percentage is 0.05 %, which reflects the results with the best characteristics for the final product. By means of the material balance it was concluded that the interaction with (guineo vs. yeast at 0.05%) presented the highest amount of bioethanol extracted (1000g) while the lowest yield was obtained in the interaction (papaya vs. yeast at 0%), concluding that guineo + 0.05% yeast is the most optimal interaction.

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