Analysis of Ethanol Production Potential from Different Types of Fruit Waste

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ABSTRACT

For the survival of the world needs energy. In the present world, most of the activities in every field need various kinds of energy. Among these energy sources, fossil fuels play a vital role. With time fossil fuels are depleting and they are going to end because they are non-renewable energy sources. As a result, we need to move towards a solution. As a solution, most of us pay attention to the Bioenergy section. Due to they are renewable, cheap, and safe energy sources. The objective of this study is to find the ability to produce ethanol from fruit waste generated in fruit juice shop at the University premises. This study was done using three types of fruit waste that are Mango waste, Papaya Waste, and Watermelon waste. These fruit wastes were fermented using Saccharomyces cerevisiae. The mixtures of this fruit waste are fermented with different amounts of yeast and the sample with 5 g produced the highest volume of ethanol. Also, separated fruit waste is fermented. Among them, Watermelon produced the highest value of ethanol and then watermelon waste samples with 5 g of yeast fermented for different numbers of days. Here, the sample fermented for 10 days produced the highest volume of ethanol. All of the fermented samples produced a volume of ethanol with significant levels of Kinematic viscosity, Ethanol %, and Density at a suitable level. Consequently, this Bioethanol can be used for vehicle engines blending with Gasoline due to their properties.

Keywords— Bioethanol, Environmental pollution, Fruit waste, Renewable energy,

INTRODUCTION

Ethanol is mainly used in industry as a biofuel, beverage, and industrial solvent. Ethyl alcohol is another name that we can use to introduce Ethanol [1]. The production process of Ethanol is known as fermentation. The chemical formula of the ethanol is C2H5OH and it is a colorless liquid with order and taste. This formula consists of two carbon atoms, six hydrogen atoms, and an Oxygen atom [2].

There is a potential to produce bioethanol from fruit waste because its consist of sugar and carbohydrates. By adding yeast or bacteria the primary Sugar components in fruit waste like Glucose, fructose, and sucrose can be fermented to produce bioethanol. While producing bioethanol from fruit waste fermentation process needs to be followed it is a biological conversion method with yeast such as Saccharomyces cerevisiae In this process sugar component in fruit waste is converted into bioethanol and carbon dioxide [3]. Optimal temperature and pH range must be maintained in this process and the fermentation process typically takes several days [4].

However, when using fruits directly in ethanol production, it may be a problem due to ethanol by fruits belonging to the first-generation biofuel. Because fruits are edible and therefore it will cause a food crisis. Therefore, it can be used fruit waste generated in various ways for ethanol production because fruit waste is a profitable renewable energy source and easy to find [5].

On the University premises, there is a fresh fruit juice bar at the cafeteria. So here generates fruit waste of around 20kg – 25 kg per day. There is a huge portion of waste generated at the university premises. So, this fruit waste can be used to produce ethanol use as a biofuel. In this study, Mango waste, papaya waste, pineapple waste, and watermelon waste were used to analyze the ethanol production ratios from fruit waste [6]. Results were taken by analyzing the ethanol volume by changing the amount of yeast used for the fermentation process and changing the number of days kept for the fermentation process. Some qualities were checked in the ethanol including Flashpoint, Density, Moisture, and pH value [7].

Ethanol is a good alternative biofuel to replace fossil fuels used in vehicle engines for transportation activities by blending Gasoline or Diesel and or without blending. The blending of ethanol has many advantages improving octane number, reducing hydrocarbon emission, and increasing combustion efficiency. Most countries use ethanol blending fuel E10 (Ethanol 10% and Gasoline 90%) to E85 (Ethanol 85% and Gasoline 15%) with some modifications of vehicle engines. It is more sustainable, and effective and reduces air pollution [8].

This study aims to provide a solution for the energy crisis that will occur in the future and increase waste management practices at the Sabaragamuwa University of Sri Lanka by analyzing ethanol production potential by using fruit waste.

Food waste need to be managed properly unless it will create huge environmental problems. By recycling food waste, bioethanol can be produced. This ethanol can be used as a renewable energy source for electricity generation, and transportation and as a solvent for laboratory uses. Bioethanol, which comes from biomass, makes up 10–14% of the world's energy supply and provides a solution to global issues including global warming and the depletion of fossil fuels. Currently, burning diesel or petroleum, or a mix of the two, is a major contributor to the global issue of bioethanol and efforts to minimize global pollution. Fruit and vegetable waste has a high sugar content that can be used as a raw material for Saccharomyces cerevisiae-based renewable energy production [9] [10]. Even yet, sugar and starch are used to produce 80% of the bioethanol produced today. Recently, lignocellulosic biomass has drawn increased interest. In this research is to provide an overview of the steps required in fermenting fruit and vegetable waste biomass using Saccharomyces cerevisiae to produce bioethanol. Fruits are susceptible to spoilage due to their inherent nature and composition, as well as incorrect handling, transportation, and overripening in fruit markets. These spoilt fruits can be recycled, converted, and used as biofuels in one way or another at a profit. The process of turning damaged fruit into useful technology is being developed in laboratories. An attempt was made to produce ethanol from the spoilt grapes using a fermenter with Saccharomyces cerevisiae present. Production of bioethanol from various spoilt fruits and various fermenter optimization settings to enhance biofuel production were investigated. [11]

This study mainly focuses on identifying how bioethanol production yield varies based on the fruit waste type. By using different types of fruit waste (Mango, papaya and watermelon) measure the bioethanol production yield by keeping other conditions are same. Another aim of conducting this research is to check whether bioethanol production yield varies with the quantity of catalyst and the number of days that the sample has undergone the fermentation process. For that different types of samples were created by adding different quantities of catalysts and measuring the bioethanol production yield. For this research, a rotary evaporator was used to purify the bioethanol sample. By changing the fermentation time measure the ethanol yield to check how is the ethanol yield varies with the number of fermentation dates. After producing bioethanol, kinematic viscosity, pH value, density, and ethanol percentage of these bioethanol were measured to gain an idea about the quality of the produced bioethanol samples [12].

Sri Lanka is facing a huge energy crisis, this bioethanol can be used as a fuel to fulfill the energy requirement of the country. Bioethanol can be used as the solvent for the laboratory. If this bioethanol production process can be developed some amount of solvent requirement for the laboratory in Sri Lanka can be fulfilled using bioethanol. [13]

As an agricultural country, Sri Lanka produces a significant amount of fruit waste and vegetable waste. Without having a proper solution for this waste material it has created huge problems like bad order releases, wild animals coming to eat this waste and affecting the human lifestyle, no proper place to dump these materials and pollute the natural water sources. This bioethanol production from waste materials can be considered as the sustainable waste management solutions to address to the above-mentioned problems.

The knowledge gained through this study will help to solve the organic waste management problem and it will help to introduce alternative renewable fuels to fulfill the energy requirement of the country. [14]

METHODOLOGY

For this experiment, fruit waste was used as the raw material and that waste was collected at the juice bar, at Sabaragamuwa University of Sri Lanka. After collecting these materials, different types of samples were created for the analysis.

Mixed fruit waste samples and individual fruit waste samples were prepared for this study. Mixed fruit waste samples were used to measure the how ethanol production will vary base on the inoculum quantity that is added for fermentation. Using this experiment optimum inoculum quantity for the fermentation process can be found. Applying the fermentation process for individual fruit waste samples, variations of bioethanol production based on fruit waste types and the number of fermentation dates can be found.

Preparation of Mixed Fruit Waste Sample

Collecting Mango, Papaya, and Watermelon fruit waste samples from juice bar at the Sabaragamuwa University of Sri Lanka. Then wash off the fruit waste samples and cut them into small pieces to increase the reaction rate. Then 150 g of the mixed fruit waste sample was measured and grinded using electrical grinder. Then ground fruit waste sample and inoculum are mixed and added into a 1000 ml beaker and the mixture is topped up to 500 ml with water. The mixture was added into the fermenter apparatus sealed and kept in a dark place for 7 days. [15]

Preparation of Inoculum

7.5 g of yeast, 37.5 g of sucrose, and 0.75 g of urea were measured by using an electronic balance. They were added into a beaker and mixed well with adding hot water.

To measure the bioethanol yield variation when changing the inoculum, while maintaining the quantity of other components of the mixture, only yeast quantity was changed as mentioned below [16].

A mixture of fruit waste (Watermelon, Papaya, and Mango) is fermented for 7 days with different amounts of yeast. Four separate mixed fruit waste samples were prepared with 150 g of each sample [17].

Table 1:Yeast quantities are added to the Mixed fruit samples

Components	Sample A(150g)	Sample B(150g)	Sample C(150g)	Sample D(150g)
Yeast (g)	3	5	7.5	10
Urea (g)	0.75	0.75	0.75	0.75
Sucrose (g)	37.5	37.5	37.5	37.5

Preparation of Individual Samples

Collected fruit waste samples of Watermelon, Papaya, and Mango from juice bar were washed and 100g weighed and ground separately [18]. They were added into 1000 ml beakers, separately mixed inoculum, into fermenters, and sealed. They were kept in a cool, dry, and dark place for 7 days. [19]

To measure the variation of ethanol production yield with the number of days that fermentation is done. Five samples were prepared each with 100 g weight of Watermelon waste. Then 5g of yeast, and 0.75 g of urea. Here, Sucrose was not added. Then samples were subjected to fermentation for different numbers of days.

Table 2: Number of dates individual samples are fermented

Sample name	Number of fermented days
Sample 01	2
Sample 02	4
Sample 03	6
Sample 04	8
Sample 05	10

Fermentation and Distillation Procedure

After completing the fermentation process, then samples were filtered to remove solid particles. Then filtered liquid mixer was added to a rotary evaporator (BUCHI Rotavapor R-100) to separate the ethanol [20]. This evaporator was run for 60 minutes for all the samples and after separating the ethanol the ethanol was used for quality testing.

The rotary evaporator is mainly used to separate one material based on its boiling point difference. For this experiment, the BUCHI Rotavapor R-100 module was used. This instrument consists of different parts including a condenser, heating bath, distillation flask, and a rotary transmission device.

Measure the Quality Parameters of Alcohol

After producing and purifying generated bioethanol, to ensure the quality of the generated bioethanol different types of quality parameters are tested using different types of instruments.

As a parameter ethanol percentage of these samples was measured using a portable alcohol meter (SG-Ultra max plus Digital hydrometer 172244 DMA 35). This is very quick and easy instrument to check the alcohol percentage of a sample. Here temperature correction is done automatically. This will measure the ethyl alcohol quantity in the solution. This ethanol percentage will vary based on the substrate, length of the fermentation process, and other process characteristics. [21]

Kinematic viscosity is an important parameter to measure the quality of bioethanol. A kinematic viscosity meter was used to perform this task. The kinematic viscosity is the measure of the internal friction force when the liquid flows under the action of gravity, and its value is the ratio of the dynamic viscosity to the density at the same temperature, which is one of the important physical and chemical properties of oil grade and quality identification. In practical application, the appropriate selection of lubricating oil viscosity can ensure mechanical equipment's normal and reliable work. The instrument is the special test equipment designed and manufactured based on the national standard GB265-88 Petroleum Product Kinematic Viscosity Determination [22]. It is suitable for the determination of the kinematic viscosity of liquid petroleum products, of the instrument has a timer function for sample movement time and an automatic calculation function of the final results of kinematic viscosity.

Temperature and purity will affect the kinematic viscosity of a sample, especially for bioethanol. At room

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temperature (around 25 degrees Celsius or 77 degrees Fahrenheit), the kinematic viscosity of a pure bioethanol sample is around 1.2 × 10(-3) m^2/s, or 1.2 centistokes. Contaminants and other impurities will affect the kinematic viscosity of a bioethanol sample.

Density is another important parameter used to test the quality of a bioethanol sample. It also varies based on the temperature and the purity of a bioethanol sample. At room temperature (around 25 degrees Celsius or 77 degrees Fahrenheit) density of a pure ethanol sample is roughly 0.789 g/cm^3. This value can be used to compare the purity of our generated bioethanol sample.

RESULTS AND DISCUSSION

First, for this analysis, different types of mixed fruit waste samples were used. By changing the inoculum quantity added to the mixture generated ethanol volume was measured. Samples were kept for one week to complete the fermentation process.

Table 3: Generated ethanol quantities for mixed fruit samples

Sample	Ethanol quantity (ml)	Ethanol yield (%ml/g)
Sample A	64	42.7
Sample B	65	43.3
Sample C	60	40.0
Sample D	63	42.0

According to these results, with the changes of yeast quantity, the generated bioethanol quantity has changed but there are no significant variations between these values. However, the highest ethanol quantity is given when the yeast quantity is 5g. When the yeast quantity of the inoculum is changed, there is no significant variation in the generated ethanol quantity.

After measuring the quality parameters of these samples, the mentioned results are shown below.

Table 4:Quality parameters of Mixed fruit samples

Quality parameters	Sample A	Sample B	Sample C	Sample D	ASTM Standards
Ethanol percentage (%)	6.2	5	5.2	6.3	
Kinematic viscosity(m^2/s)	1.2954	1.5971	1.6029	1.3857	1.2
Density (g/cm^3)	0.9472	0.9921	0.9675	0.9360	0.7

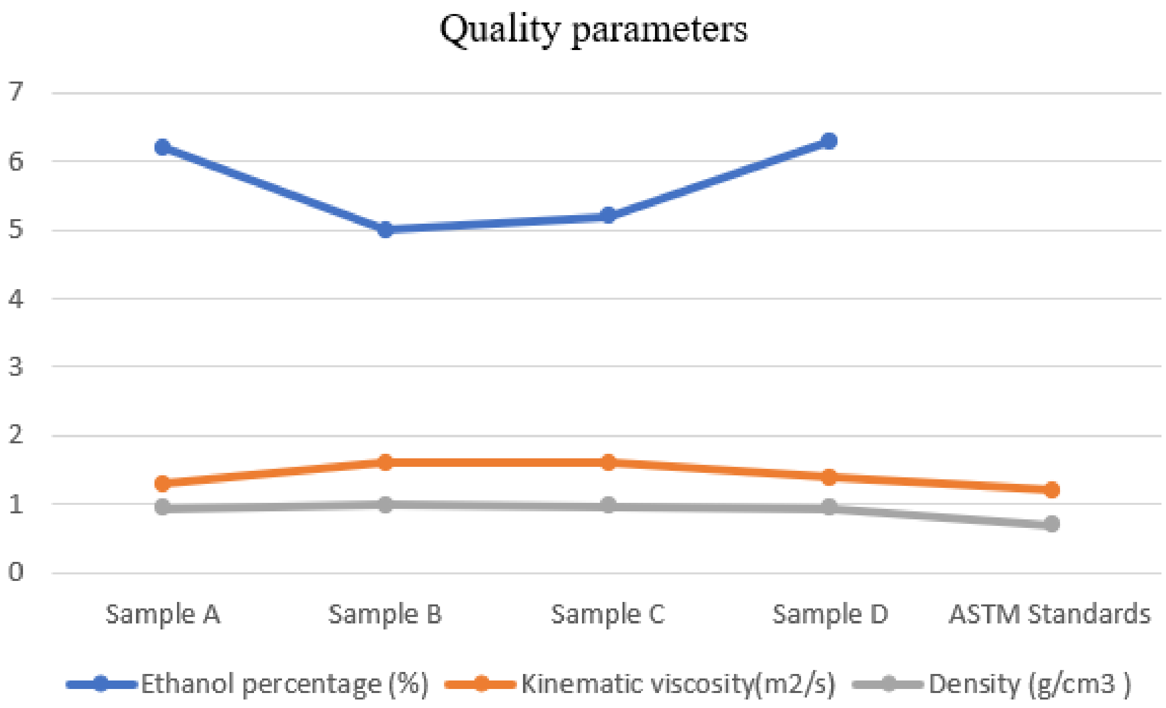

Figure 1: Ethanol percentage, Kinematic viscosity and density of mixed fruit bioethanol samples

According to the above results, the density of all samples are same. However, the kinematic viscosity of these samples varies from sample to sample. The standard kinematic viscosity of a bioethanol sample is 1.2 m^2/s. Among those samples kinematic viscosity of sample A is closer to the standard viscosity value and the ethanol percentage of this sample is also high. Then in terms of quality, the best sample is sample A. Best quality bioethanol was created when 3g of yeast was used for the inoculum.

When separate samples were used those samples generated ethanol quantities as mentioned below after keeping 7 days by keeping other parameters constant. The quality parameters of these samples are measured.

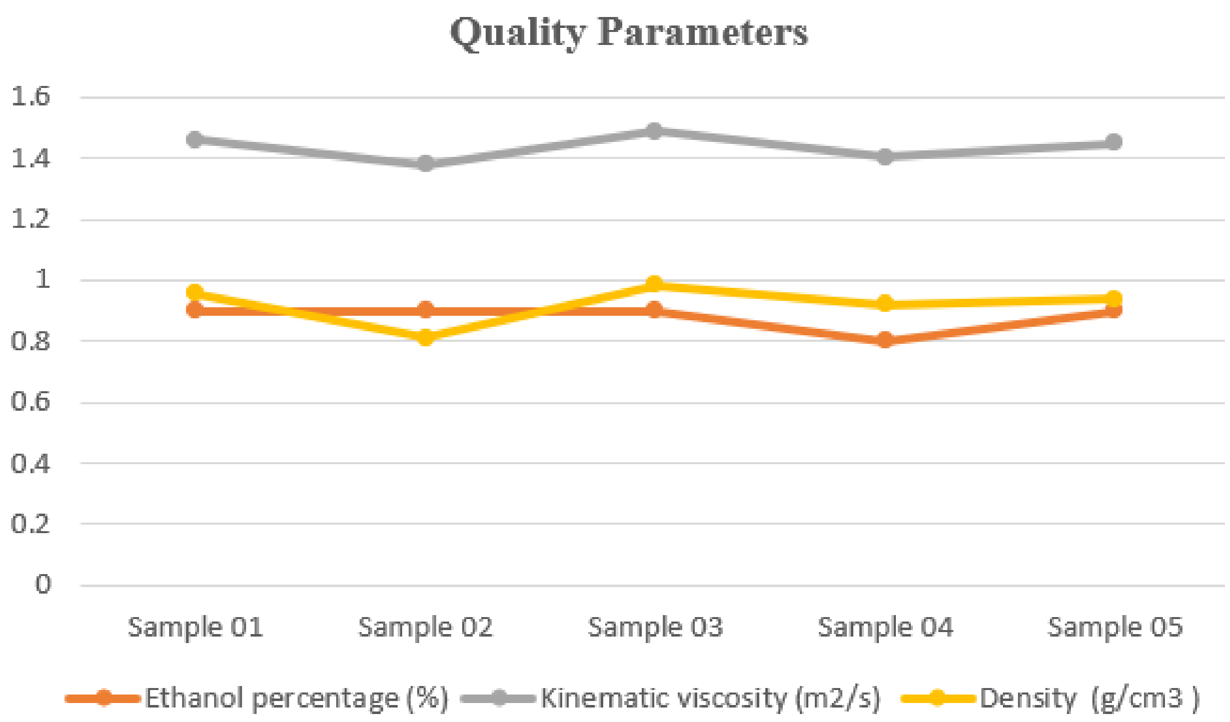

Figure 2: Quality parameters of watermelon samples

Table 5: Quality parameters of individual fruit waste samples

Sample Name	Ethanol quantity (ml)	Ethanol yield (%ml/g)	Ethanol percentage (%)	Kinematic viscosity (m^2/s)	Density (g/cm^3)
Papaya waste	54	54	0.5	1.209	0.924
ango waste	54	54	0.7	1.258	0.932
Watermelon waste	63	63	0.9	1.495	0.975

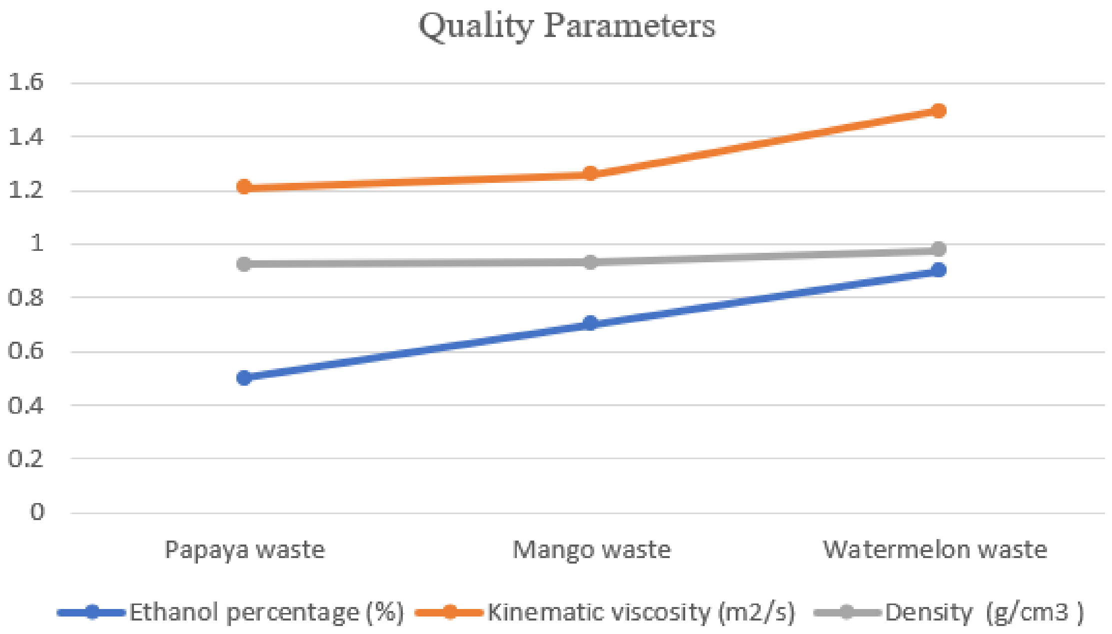

Figure 3: Ethanol percentage, Kinematic viscosity and density of individual fruit samples

As above results, a high amount of ethanol was generated when watermelon waste was used as the substrate. However, we cannot see significant variations in these quantities.

When we consider the volume of generated ethanol samples, a high ethanol percentage is given when watermelon is used as the substrate. But in general, when individual fruit samples were used the ethanol percentage of those ethanol samples was lower than the ethanol percentage of mixed fruit samples. However other quality parameters are almost the same as all the samples.

To measure the ethanol production variation with the fermentation date, Watermelon samples were kept to fermentation on different days then the generated ethanol volume and the quality parameters of those samples as below

Table 6: Quality parameters of watermelon samples

Sample Name	Ethanol quantity (ml)	Ethanol percentage (%)	Kinematic viscosity (m^2/s)	Density (g/cm^3)
Sample 01	56	0.9	1.4587	0.9542

Sample 02	52	0.9	1.3795	0.8103
Sample 03	54	0.9	1.4891	0.9832
Sample 04	51	0.8	1.4045	0.9210
Sample 05	59	0.9	1.4476	0.9375

conferring to the above results highest ethanol volume has received in sample 05. But there is no significant variation of the ethanol volume when change the number of fermentation dates. Not only the volume but other quality parameters also have not changed when change the number of fermentation dates.

Bioethanol production from fruit waste has so many economic and environmental benefits. It will create additional revenue income for fruit processing companies because they can convert waste materials into revenue sources. Then the company can waste disposal costs also. Finally, it will increase the profitability of the company [23] .

When compared with fossil fuel bioethanol produced by fruit waste reduces greenhouse gas emissions. Bioethanol production from fruit waste will reduce organic waste which is disposed of through landfilling then it will reduce methane gas emissions from landfills. It helps to increase the lifetime of the landfilling site [24].This promotes the circular economy concept by producing valuable products using waste organic material. Then this concept will help to reduce the environmental footprint [25].

When we compare bioethanol production from fruit waste with other bioethanol production method, this process has high economical benefits. In this process, fruit waste is used as raw material but when we consider other raw materials that are used to produce bioethanol like sugar cane and corn, those materials need to be purchased then it will increase the production cost. Then bioethanol production from fruit waste provides both economic and environmental benefits [26].

CONCLUSION

As a proper waste management solution fruit waste can be used to produce bioethanol and that bioethanol can be used different types of applications in the institutes. Bioethanol production yield is varying base on the substrate that we used to produce bioethanol. Fruit waste generators generate those materials as mixer waste. If someone can used those material to produce bioethanol using one gram of waste materials around 40ml bioethanol can be generated and also it reduces the waste volume also. When change the yeast quantity in the inoculum, quality of the produce bioethanol is change. Good quality bioethanol can be produced using 3g of yeast for the inoculum.

When we use individual fruit waste samples to produce bioethanol. Watermelon waste has given a higher amount of ethanol volume than the Papaya waste and Mango waste. However, all the quality parameters of those samples are approximately the same.

Bioethanol volume which was produced when changing the number of fermentation dates has not changed significantly. After creating inoculum according to the mentioned ratios in this study, It is enough to keep 02 days to complete the fermentation process of the fruit waste sample.

Normally, the Juice bar at Sabaragamuwa University of Sri Lanka generates more than 20kg-25kg of fruit waste and there is a potential to produce around 800L-1000L of ethanol per day. This ethanol can be used for internal applications of the University as a cleaning solvent, and this can be used as a fuel for vehicles by blending with petroleum fuel. There is a lot of fruit waste generated in Sri Lanka from different places like fruit markets and fruit juice shops and it has created many environmental problems. If we can apply this solution for those waste materials it will be a sustainable waste management solution for those waste. This generated bioethanol can be used as an alternative fuel by blending with petrol for transportation purposes.

And some amount bioethanol can be used as a cleaning material for industries for their cleaning applications. As a country new job opportunities can be created and fuel costs also can be reduced then this will help to develop the country. For a future investigation, it is better to do a cost-benefit analysis for other bioethanol production processes by comparing this method.

REFERENCES

1. M. T. A. T. S. K. D. B. G. K. T. B. M. G. B. T. A. D. S. D. A. A. B. H. a. D. M. Estifanos Hawaz1*, "Bioethanol production from sugarcane molasses by co fermentation of Saccharomyces cerevisiae isolate TA2 and Wickerhamomyces anomalus isolate HCJ2F 19," Annals of Microbiology, no. https://doi.org/10.1186/s13213-024-01757-8, pp. 4-23, 2024.
2. S. I. &. D. G. Mussatto, "Bioethanol production from renewable sources: current perspectives and technological progress," Renewable and Sustainable Energy Reviews, vol. 71, pp. 475-501, 2017.
3. F. Inambao, Bioethanol Production: An Overview, DOI: 10.5772/intechopen.94895 ed., 2020.
4. V. &. R. M. Menon, "Trends in bioethanol production from lignocellulosic biomass," Biofuels, vol. 3(1), no. https://doi.org/10.1016/j.pecs.2012.02.002, pp. 85-102, 2012.
5. Y. Liu, "Utilization of fruit and vegetable wastes as feedstock for ethanol production," Bioresource Technology, vol. 99(17), pp. 5245-5250, 2008.
6. A.M. Amin, "Bioethanol production from mango (Mangifera indica L.) fruit waste using different pretreatments," Renewable Energy, vol. 78, pp. 165-171, 2015.
7. B.S. Kul*, "A research on fuel properties of bioethanol produced from waste bread," International Journal of Energy Applications and Technologies, vol. 6(4), no. e-ISSN: 2548-060X, pp. 96-101, 2019.
8. C.C. Rakopoulos, "Effects of ethanol–gasoline blends on engine performance and emissions: A review," Energy Conversion and Management, vol. 50(4), pp. 877-883, 2009.
9. K. Q. A. M. D. M. H. S. A. S. H. Mohammad Moneruzzaman Khandaker1*, "Bio-ethanol production from fruit and vegetable waste by using saccharomyces cerevisiae," Journal by Innovative Scientific Information & Services Network, vol. 15(3), no. ISSN: 2218-3973, pp. 1703-000, 2018.
10. N. S. A. &. S. N. F. A. Fathy, "REVIEW OF ETHANOL PRODUCTION FROM FRUIT WASTES.," Rome, Italy, 2018.
11. K. H. W. P. S. T. K. A. K. R. &. W. P. R. Kale, "A critical review on food waste management for the production of materials and biofuel," Journal of Hazardous Materials Advances, pp. 1-23, 2023.
12. G. K. K. &. P. S. V, "Bioethanol production from local fruit waste and its optimization," Indian Journal of Experimental Biology, vol. 58, pp. 879-882, 2020.
13. M. &. B. H. Balat, "Bioethanol as a fuel: a review," Applied Energy, vol. 86, no. 10.1016/j.apenergy.2009.03.015, pp. 2273-2282, 2009.
14. R. &. F. V. Liguori, "Bioethanol production from organic wastes: current perspectives and future directions," Bioresource Technology, vol. 215, pp. 190-199, 2016.
15. A. A. &. H. T. M. Mitiku, "Bioethanol Production from Decaying Fruits Peel Using Saccharomyces cerevisiae.," International Journal of Current Research and Academic Review, vol. 8(5), no. https://doi.org/10.20546/ijcrar.2020.805.006, p. 50–59, 2020.
16. S. J. A. U. S. P. R. &. N. A. H. L. R. de Silva, "Production of Bioethanol using Waste Fruits under Acid and Alkali Catalytic Hydrolysis: A Review.," Asian Journal of Chemistry, vol. 34(1), no. https://doi.org/10.14233/ajchem.2022.23466, p. 25–34, 2022.
17. M. G. A. &. S. D. K. Jahid, "Production of Bioethanol from Fruit Wastes (Banana, Papaya, Pineapple, and Mango Peels) Under Milder Conditions.," Journal of Bioprocessing & Biotechniques, vol. 08(03), no. https://doi.org/10.4172/2155-9821.1000327, 2018.
18. M. G. A. &. S. D. K. Jahid, "Production of Bioethanol from Fruit Wastes (Banana, Papaya, Pineapple, and Mango Peels) Under Milder Conditions.," Journal of Bioprocessing & Biotechniques, vol. 08(03), no. https://doi.org/10.4172/2155-9821.1000327, 2018.
19. A.M. Amin, "Bioethanol production from mango (Mangifera indica L.) fruit waste using different pretreatments," Renewable Energy, vol. 78, pp. 165-171, 2015.
20. E. &. A. H. A. Alper, "Fractional distillation of bioethanol: process optimization and energy efficiency," Energy Conversion and Management, vol. 141, pp. 184-192, 2017.
21. A. &. H. C. Dasgupta, "Ethanol Measurement in Alcoholic Beverages Using Hydrometer," Analytical

Chemistry, vol. 77(11), pp. 3837-3842, 2005.
22. M. &. K. P. Kasza, "Viscosity of ethanol–gasoline blends at low temperatures," Journal of Energy Resources Technology, vol. 140(12), 2018.
23. J. B. A. &. G. C. Smith, "Bioethanol production from fruit waste: A cost-benefit analysis.," Journal of Sustainable Energy, vol. 15(2), pp. 123-135, 2023.
24. D. &. G. E. Brown, "Environmental benefits of bioethanol production from fruit waste," Journal of Environmental Science and Technology, vol. 28(4), pp. 410-425, 2021.
25. R. &. W. S. Jones, "Economic and environmental implications of bioethanol production from agricultural waste," Renewable Energy, vol. 45(3), pp. 210-225, 2022.
26. J. B. A. &. G. C. Smith, "Bioethanol production from fruit waste: A cost-benefit analysis," Journal of Sustainable Energy, vol. 15(2), pp. 123-135., 2023.