

**INVESTIGATION OF BIOETHANOL PRODUCTION PROCESSES FROM FOOD
WASTE (CASE STUDY OF QARSHI CITY)****Mahmadiyurov Muhridin Akbarovich**

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Annotatsiya: Oziq-ovqat chiqindilari butun dunyo bo'ylab atrof-muhit uchun asosiy ekologik muammolardan biri hisoblanadi. Bu esa bunday chiqindilar qayta ishlash zaruratini paydo qiladi. Hozirgi vaqtda dunyoda har yili taxminan 1,3 milliard tonna ishlab chiqarilgan oziq-ovqat yo'qoladi yoki isrof qilinadi. O'zbekistonda esa yiliga taxminan 3 million tonna shunday chiqindilar hosil bo'ladi. Oziq-ovqat chiqindilarini qayta ishlash yoki ulardan foydalanish dolzarb muammolardan biri hisoblanadi. Bu turdagi chiqindilarni qayta ishlashda ulardan bioetanol olish va foydalanish samarali hisoblanadi. Tabiatdagi biomassadan olingan bioetanol jahon energiya ta'minotining 10-14 foizini tashkil etadi va global isish va qazilma yoqilg'ining kamayishi kabi global inqirozni hal etishda muhim ahamiyatga ega. Qarshi shahri aholisi oziq-ovqat chiqindilari tarkibi o'rganildi va bioetanol olish bo'yicha ilk tajribalar o'tkazildi. Dastlabki tajribalarga ko'ra, 1 kg oziq-ovqat chiqindisidan alkogol tarkibi 9.13% bo'lgan 50 ml bioetanol olishga erishildi. Bu natijalar shuni ko'rsatadiki, O'zbekiston aholisi tomonidan hosil bo'ladigan chiqindilardan yiliga 4 milliard litr bioetanol olish mumkinligini ko'rsatadi.

Kalit so'zlar: bioyoqilg'i, oziq-ovqat chiqindilari, bioetanol, fermentatsiya, distillatsiya.

**ИССЛЕДОВАНИЕ ПРОЦЕССОВ ПОЛУЧЕНИЯ БИОЭТАНОЛА ИЗ
ПИЩЕВЫХ ОТХОДОВ (НА ПРИМЕРЕ ГОРОДА КАРШИ)****Махмадиев Мухриддин Акбариевич**

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Аннотация: Пищевые отходы во всём мире являются одной из основных экологических проблем окружающей среды. Это обуславливает необходимость их переработки и повторного использования. В настоящее время ежегодно в мире теряется или выбрасывается около 1,3 миллиарда тонн произведённых продуктов питания. В Узбекистане ежегодно образуется примерно 3 миллиона тонн подобных отходов. Переработка и рациональное использование пищевых отходов является одной из актуальных задач современности. Одним из эффективных направлений переработки является получение биоэтанола из данного вида отходов. Биоэтанол, получаемый из

биомассы, обеспечивает около 10–14% мирового энергоснабжения и играет важную роль в решении глобальных проблем, таких как изменение климата и истощение ископаемых видов топлива. В ходе исследования был изучен состав пищевых отходов населения города Карши, а также проведены первичные эксперименты по получению биоэтанола. Согласно предварительным результатам, из 1 кг пищевых отходов удалось получить 50 мл биоэтанола с содержанием спирта 9,13%. Эти результаты показывают, что из пищевых отходов, образующихся населением Узбекистана, потенциально возможно получить до 4 миллиардов литров биоэтанола в год.

Ключевые слова: биотопливо, пищевые отходы, биоэтанол, ферментация, дистилляция.

INVESTIGATION OF BIOETHANOL PRODUCTION PROCESSES FROM FOOD WASTE (CASE STUDY OF QARSHI CITY)

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Abstract: Food waste is one of the major environmental challenges worldwide, posing significant threats to ecosystems and sustainability. This creates an urgent need for effective recycling and utilization of such waste. Currently, approximately 1.3 billion tons of food produced globally is lost or wasted each year. In Uzbekistan, around 3 million tons of such waste are generated annually. The processing and utilization of food waste have become critical issues in modern environmental management. One of the most effective approaches is the production of bioethanol from these types of waste. Bioethanol derived from biomass contributes approximately 10–14% of the global energy supply and plays a crucial role in addressing global challenges such as climate change and the depletion of fossil fuels. In this study, the composition of food waste generated by the population of Qarshi city was analyzed, and preliminary experiments on bioethanol production were conducted. The results showed that 50 ml of bioethanol with an alcohol content of 9.13% can be obtained from 1 kg of food waste. These findings indicate that up to 4 billion liters of bioethanol could potentially be produced annually from food waste generated in Uzbekistan.

Keywords: biofuel, food waste, bioethanol, fermentation, distillation.

1. Introduction.

Due to the rapid depletion of global energy resources, there is an urgent need to turn to alternative energy sources. The decline in petroleum reserves, global warming, and the inevitability of the greenhouse effect are placing the Earth in a critical situation. Furthermore, it is evident that we are highly dependent on fossil fuels derived from limited global resources, which will not be able to meet future energy demands.

As fossil fuel reserves continue to diminish worldwide, fuel prices are steadily increasing, and the pressure for energy independence and environmental sustainability is creating a strong market for biofuels. In addition, the use of conventional fossil-based fuels has led to several significant environmental challenges.

Currently, approximately 57 billion tons of greenhouse gases are released into the atmosphere each year (UNEP, 2024). This has raised global concerns about climate change and the urgent need to reduce greenhouse gas emissions, thereby encouraging the use of bioethanol as a substitute for or additive to gasoline. Another major issue is the improper disposal of waste, which negatively affects the surrounding environment, particularly in landfill areas.

Global bioethanol production has increased significantly over the past few decades. The current global ethanol production capacity is estimated at approximately 6.84 billion liters, primarily derived from molasses, blending processes, and grain-based feedstocks. This production is largely dominated by the United States and Brazil, which together account for nearly 80% of global bioethanol output.

The implementation of the Renewable Fuel Standard (RFS) policy in 2005, which mandates the use of renewable fuels in gasoline, has significantly contributed to the expansion of bioethanol production. In 2021, the United States produced approximately 57 billion liters of bioethanol. Similarly, Brazil's Proálcool program, initiated in the 1970s, has played a crucial role in the development of its bioethanol industry, resulting in an annual production of around 30 billion liters by 2021.

Numerous scientific studies have been conducted worldwide on the production of bioethanol from food waste, and this research continues to expand. Food waste, particularly residues from pineapple and orange, has been identified as a highly efficient feedstock for bioethanol production (Khandaker, 2018). The natural sugars present in fruit waste simplify the fermentation process and, in some cases, eliminate the need for an additional hydrolysis step. However, certain chemical components in the raw material, such as limonene found in orange peels, may negatively affect fermentation efficiency.

The unicellular fungus (yeast) *Saccharomyces cerevisiae* has been identified as a key microorganism for the direct fermentation of juice extracted from fruit waste. It has also been determined that substrate concentration directly influences bioethanol yield (Mtashobya, 2018). Furthermore, studies have shown that the type of fruit waste significantly affects ethanol production efficiency when using *Saccharomyces cerevisiae* (Janani K, 2019–2021). In particular, banana peels have been found to yield higher bioethanol production, whereas natural inhibitors present in orange peels tend to slow down the fermentation process.

Uzbek researchers have also conducted a limited number of studies on bioethanol production. The potential for producing bioethanol from locally cultivated sweet sorghum varieties under the conditions of Uzbekistan has been investigated (A.Sh. Azizov, 2019). The main objective of this study was to analyze the biochemical composition of sweet sorghum, which is widely grown under local agro-climatic conditions, to determine the content of fermentable sugars, and to experimentally substantiate the technology for bioethanol production from this raw material.

In addition, residues generated from grape cultivation and the wine industry—such as grape pomace (including skins, seeds, and fibrous fractions)—represent lignocellulosic biomass that serves as an important feedstock for bioethanol production (Z.Z. Jamalov, 2020). It has been scientifically proven that appropriate pretreatment of such biomass significantly enhances product yield

An analysis conducted by specialists of the Institute for Forecasting and Macroeconomic Research (IFMR) on the potential for biofuel production from food waste in Uzbekistan indicates that approximately 3 million tons of food waste are generated annually in the country. The production of biofuels from food waste can simultaneously address two major challenges. Firstly, it reduces the negative environmental impact through proper waste utilization. Secondly, it helps meet the growing demand for energy resources driven by economic and demographic growth.

According to the analysis, if food waste is fully converted into bioethanol or biodiesel, the potential production volumes could reach approximately 1.11 billion liters and 1.02 billion liters, respectively. The use of biofuels in gasoline- and diesel-powered vehicles could reduce CO₂ emissions by about 1.6 million tons. On average, each kilogram of food waste emits around 2.5 kg of carbon dioxide per year. If 3 million tons of food waste are not properly managed, this could result in the emission of up to 7.5 million tons of greenhouse gases.

The implementation of biofuel technologies would contribute to achieving key targets outlined in Uzbekistan's "Green Economy Transition Strategy for 2019–2030," the Law "On Waste," the law on the ratification of the Paris Agreement, and the additional commitments adopted at the 26th session of the UN Climate Conference to reduce greenhouse gas emissions per unit of GDP by 35% compared to 2010 levels.

Under the conditions of Uzbekistan, the production of bioethanol from food waste is a highly relevant issue, closely linked to energy, environmental, and economic sectors. Although this field has significant potential for development, it is also associated with a number of technical, economic, and policy-related challenges.

From a technical perspective, food waste represents a suitable feedstock for bioethanol production due to its high content of carbohydrates (such as starch and cellulose), which can be converted into ethanol through fermentation. However, a major technical challenge is the heterogeneity of waste composition and the need for complex pretreatment processes. These processes—including hydrolysis, fermentation, and distillation—require advanced technological equipment and skilled personnel. Furthermore, the insufficient development of waste collection, sorting, and logistics systems reduces overall production efficiency.

From an economic standpoint, the main challenges of bioethanol production include high initial investment costs and production expenses. Studies indicate that capital costs for bioethanol production are substantial, and the cost of production varies significantly depending on the type of feedstock and technology used. In particular, the pretreatment stage can account for a large portion of total costs (in some cases up to 40%). In the context of Uzbekistan, the dependence on imported energy resources and technological equipment further increases production costs.

2. Materials and Methods

2.1. Research Object

Bioethanol obtained from food waste was selected as the object of this study. The city of Qarshi has a population of approximately 305,000 people. On average, one person generates about 1 kg of food waste per day. Based on this estimate, the population of Qarshi produces approximately 3 tons of food waste daily. It should also be noted that the rate of waste generation varies depending on the seasons of the year.

This study was carried out using food waste generated by residents of the Cho'lquvar neighborhood, located in Qarshi city.

2.2. Selection of Food Waste



Figure 1. Condition of food waste mixed with other types of waste.

The composition of food waste is a key factor directly affecting the yield of bioethanol. Therefore, food waste requires preliminary sorting. Food waste contains polymers such as starch, cellulose, and hemicellulose. The breakdown of these polymers produces glucose, which plays a fundamental role in bioethanol production. During the fermentation process, glucose is metabolized by microorganisms, resulting in the formation of bioethanol.

2.3. Pretreatment of Food Waste

Results and Discussion

For the experimental study on bioethanol production from food waste, a landfill site located in the Cho'lquvar neighborhood of Qarshi city was selected, and the approximate daily amount of food waste disposed of at this site was determined. Based on observations, it was found that approximately 35–40 kg of food waste is disposed of daily during the spring season (early March).

To carry out the feedstock preparation stage for bioethanol production via the fermentation method, food waste generated over two days was collected in a separate container and analyzed. The analysis revealed that the collected waste consisted of 22 different types of materials.

Table 1.**Composition of Collected Waste for the Experiment**

| No | Composition of Food Waste | | |
|----|---------------------------|----|-------------------|
| 1. | Potato peel | 12 | Tomato peel |
| 2. | Pumpkin peel | 13 | Pear peel |
| 3. | Carrot peel | 14 | Beetroot peel |
| 4. | Banana peel | 15 | Eggplant peel |
| 5. | Orange peel | 16 | Radish peel |
| 6. | Tangerine peel | 17 | Garlic bulb |
| 7. | Cabbage | 18 | Celery |
| 8. | Turnip peel | 19 | Bell pepper |
| 9. | Cucumber peel | 20 | Spinach |
| 10 | Onion peel | 21 | Pomegranate seeds |
| 11 | Apple peel | 22 | Pomegranate peel |

Approximately 10 kg of the collected waste was shredded using a special device (chopper), while about 1.9 kg was further processed through a grinder for pressing purposes. As a result, approximately 900 g of juice and 1 kg of solid residue (pulp) were obtained and collected separately in different containers.



Figure 2. Collected Waste



Figure 3. Weighing Process

By initially weighing food waste separated from other household waste using a scale, it is possible to calculate the potential amount of bioethanol that can be produced from a given quantity of waste.



Figure 4. Grinding Process

For the experiment, the selected and weighed food waste was first ground using a special device (chopper). The ground material was then further processed using a grinder and pressed, resulting in two separate fractions: juice and solid residue (pulp).



Figure 5. Shredded Waste



Figure 6. Juice Obtained During the Pressing Process



Figure 7. Pulp Obtained During the Pressing Process

Fermentation Stage

During the experiment, 5 g of yeast (*Saccharomyces cerevisiae*) was added to 900 g of waste-derived juice. The mixture was then placed in a drying cabinet at 35°C for the fermentation process.



Figure 8. Monitoring of the Fermentation Process

Initially, the pH of the juice was measured using a pH meter, and it was found to be 4. During the process, the pH level of the solution was monitored daily, and Na_2CO_3 was gradually added to adjust and maintain the pH in the range of 5–6. A total of approximately 15 g of Na_2CO_3 was added throughout the process.

Considering that fermentation is an anaerobic process, the solution was placed in a 1.5 L sealed container to prevent the entry of oxygen. To allow the release of carbon dioxide (CO₂) produced during fermentation, a small hole was made in the container lid, and gas release was ensured through a rubber tube.

To promote faster growth of yeast cells during fermentation, the temperature was maintained at 35°C. The release of CO₂ during the process indicates the conversion of glucose into ethanol and carbon dioxide. The final fermentation mixture may contain water, ethanol, and other organic and inorganic compounds. The completion of fermentation is indicated by the cessation of CO₂ release.



Figure 9. Measurement of the pH Level of the Solution

Distillation Stage:

After the completion of the fermentation process, the resulting solution is subjected to distillation to obtain a bioethanol fraction. The ethanol produced during fermentation is in liquid form and contains a mixture of other substances, mainly water. In order to increase the purity and concentration of ethanol, the distillation process is applied.

Distillation is a separation technique based on differences in boiling points of liquids. Ethanol has a boiling point of 78.37°C, which is lower than that of water (100°C). During the distillation process, ethanol vaporizes at a lower temperature, then the vapor is condensed and collected as a liquid. As a result, the concentration and purity of ethanol are increased.



Figure 10. Distillation Process

After distillation, the obtained liquid was analyzed using an optical spectrometer in order to determine the bioethanol content. The results showed that the liquid contained 9.09% bioethanol.

To further increase the bioethanol concentration in the distillate, the solution was treated with 3 Å molecular sieves. As a result, the bioethanol content increased from 9.09% to 9.13%.



Figure 11. Liquid Collected in the Container During the Distillation Process



Figure 12. Treatment Process Using Molecular Sieves



Figure 13. State of the Liquid After Treatment with Molecular Sieves

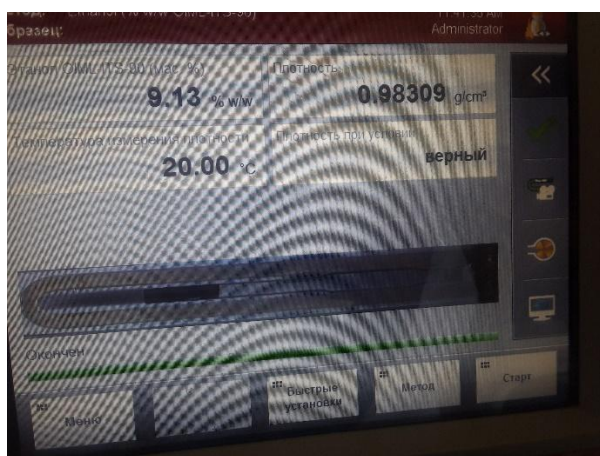


Figure 14. Final Result

Conclusion and Recommendations

In this study, the process of obtaining bioethanol from food waste using the fermentation method was investigated. Based on the experimental results, the following scientific conclusions were drawn.

Food waste was found to contain 22 different components, which serve as an important source of carbohydrates for bioethanol production. As a result of shredding and pressing processes, 900 g of juice was obtained and used as the main feedstock for fermentation. The anaerobic fermentation process conducted with *Saccharomyces cerevisiae* at 35°C was successfully carried out. Maintaining the pH level within the range of 5–6 ensured efficient fermentation. CO₂ release served as the main indicator confirming the progress of the fermentation process.

Through the distillation process, ethanol was separated from water and other impurities, thereby increasing the bioethanol concentration. Using an optical spectrometer, the initial bioethanol content was determined to be 9.09%. After treatment with 3Å molecular sieves, the purity of bioethanol increased to 9.13%. The obtained results demonstrate that food waste is a viable, environmentally friendly, and economically promising feedstock for bioethanol production.

Recommendations

It is recommended to further develop systems for the separate collection and sorting of food waste (logistics chain), as feedstock quality directly affects bioethanol yield. The use of modern sensor systems for automatic control of pH and temperature is advised to optimize the fermentation process. Improvement of pretreatment technologies is necessary to enhance bioethanol yield.

To increase the efficiency of distillation, the implementation of energy-efficient equipment and multi-stage purification systems is recommended. Expanding the use of molecular sieves and other adsorbent materials can further improve bioethanol purity.

Furthermore, it is advisable to establish pilot plants for biofuel production from food waste in Uzbekistan and conduct industrial-scale testing. Strengthening scientific research in this field and enhancing cooperation between local researchers and industry stakeholders is of great importance

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