EXPLORING THE VIABILITY OF KIGELIA AFRICANA FRUIT AS A FEEDSTOCK FOR BIOETHANOL PRODUCTION AND VEHICULAR FUEL USE

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Abstract
The escalating demand for sustainable and renewable energy sources has intensified research into bioethanol production from non-edible plant materials. This study investigates the feasibility of utilizing Kigelia africana fruit as a feedstock for bioethanol production, aiming to assess its potential as a renewable vehicular fuel. The fruit pulp can undergo fermentation processes to yield bioethanol. Given the abundance of K. africana in tropical regions and its non-edible nature, utilizing its fruit for bioethanol production offers a sustainable approach that does not compete with food resources. This research underscores the potential of K. africana fruit as a novel, sustainable feedstock for bioethanol production, contributing to the diversification of renewable energy sources for vehicular applications.
***Keywords**: Kigelia Africana, Non-Edible Feedstock, Bioethanol Production, Vehicular Biofuel, Biofuel Sustainability*

1) Introduction:

The increasing demand for sustainable and renewable energy sources has led to extensive research into bioethanol production from non-edible plant materials. Bioethanol, a renewable biofuel produced through the fermentation of biomass rich in carbohydrates, serves as a sustainable alternative to fossil fuels, particularly in the transportation sector. The production process typically involves pretreatment of the biomass to release fermentable sugars, fermentation of these sugars by microorganisms to produce ethanol, and purification of the ethanol through distillation.

Kigelia africana, commonly known as the sausage tree, is native to tropical Africa and is recognized for its medicinal properties and rich phytochemical profile [1]. Kigelia Africana (Sausage Fruits) is unexplored fruit for alcohol fuel extraction. Kigelia africana, commonly known as the sausage tree, is a fascinating plant native to tropical Africa. The sausage tree grows up to 20 meters (66 feet) tall and has spreading branches. Its bark is initially smooth and gray, peeling on older trees. The wood is pale brown or yellowish and not prone to cracking. Leaves are opposite or in whorls of three, with oval leaflets. Flowers hang down from branches on long, flexible stems and are bell-shaped, orange to maroon, and about 10 cm (4 inches) wide.

Figure. 1. Kigelia Africana (Sausage) Tree

The most distinctive feature is its fruit. The fruit is a woody berry that can grow up to 60 cm (2 feet) long and weigh about 7 kg (15 pounds). It resembles a sausage in a casing, hence the name "sausage tree." The pulp is fibrous and contains many seeds. The fruit is toxic to humans when raw. Hence can be used for extracting biofuel from its fruits. The fruit pulp of *K. africana* contains carbohydrates that could be fermented to produce ethanol, making it a potential feedstock for bioethanol production. This work aims to explore the viability of *K. africana* fruit as a feedstock for bioethanol production and its potential application as a vehicular fuel.

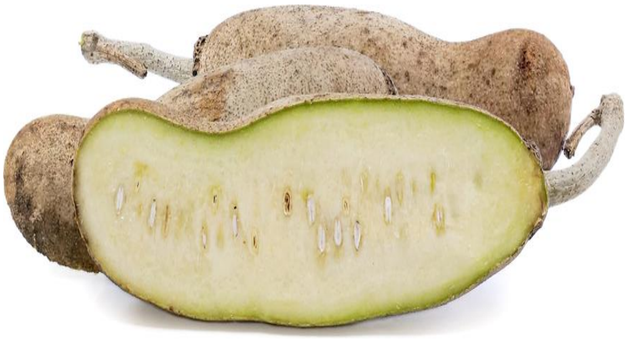

Figure. 2. Fruit of Kigelia Africana (Sausage) Tree

2) Methods and Methodology:

The conversion of Sausage fruit to ethanol methodology and detailed process is illustrated in flow-chart Figure-3. The conversion comprises mainly, Sausage fruits are harvested when fully mature and process by removing the tough outer shell to access the pulp. The pulp is then crushed in the pre-treated and then followed by enzymatic hydrolysis.

The enzymatic hydrolysis process consists of addition of enzymes along with water to the crushed pre-treated Sausage pulp. This facilitate the breakage of the molecular bonds and start the digestion of the crushed pulp. This causes the release of fermentable sugars called as hydrolysates.

The hydrolysates is added with the yeast in the fermentation process, wherein the chemical reaction take place with the help of micro-organisms and convert the fermentable sugars into a fermented mixture of ethanol, water and other impurities.

The fermented mixture is then passed through the distillation process where heat is supplied and separated ethanol in the form of vapors from the water. Thus, the ethanol vapors evolved having some water parts and impurities.

The impure ethanol in the form of vapors are then cooled down in the condensation process with the help of cooling water. Thereof, the vapors are converted into the liquid form of the impure ethanol.

Dehydration process is used to remove the water content of other impurities from the liquid ethanol. And thus obtain the high-grade combustible ethanol fuel with the purity of 99%.

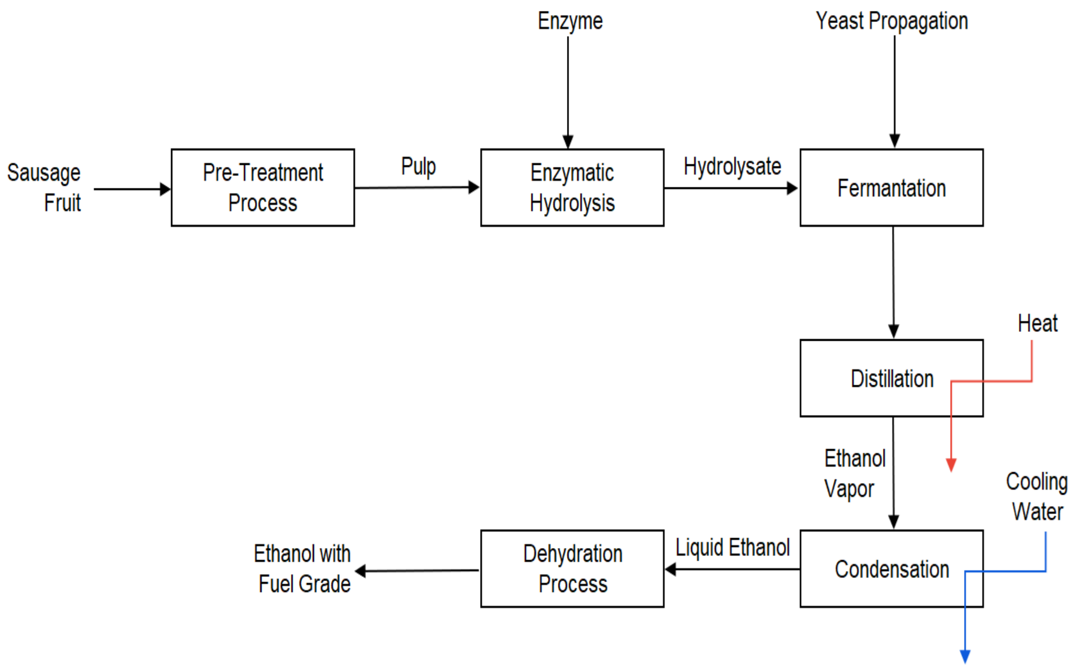

Figure. 3. Flow diagram of conversion of sausage fruit to ethanol

To maximize ethanol yield, several fermentation parameters were optimized. Experiments were conducted by varying key factors and observing their effects on ethanol production major parameters studied for optimization of ethanol yield.

Temperature: Fermentation was tested at different temperatures (25°C, 30°C, 35°C, and 40°C) to determine the optimal temperature for yeast activity.

pH Levels: The pH of the fermentation medium was adjusted to different levels (pH 4.0, 4.5, 5.0, and 5.5) to assess its impact on yeast growth and ethanol yield. 68

Sugar Concentration: Various initial sugar concentrations (10%, 15%, 20%, and 25%) were used to find the optimal concentration for ethanol production.

3] Results

3.1 Ethanol Concentration and Purity

The ethanol concentration in the distillate was measured using a hydrometer and confirmed using gas chromatography (GC) for precise analysis. The ethanol concentration in the distilled product was found to be 90-95% (v/v) after fractional distillation. Multiple distillation cycles were carried out to achieve this high concentration, with the initial distillate containing around 50-60% ethanol before further purification.

3.2 Ethanol Yield

The ethanol yield from sausage fruit was calculated based on the amount of ethanol produced per kilogram of fruit pulp. The average ethanol yield was approximately 200-250 mL of ethanol per kilogram of sausage fruit pulp. This yield is comparable to that obtained from other tropical fruits, such as mango or pineapple, but lower than conventional feedstocks like sugarcane or corn.

The distillation process successfully recovered high-purity ethanol from the fermented broth. The yield of 200-250 mL of ethanol per kilogram of sausage fruit is promising, particularly for an underutilized fruit. However, the yield is lower compared to conventional feedstocks, suggesting that sausage fruit may be better suited for small-scale or regional bioethanol production rather than large industrial applications.

3.3 Initial Sugar Concentration

Initial sugar concentrations of 15-20% were found to be ideal for ethanol production. Higher sugar concentrations (above 25%) resulted in osmotic stress on the yeast, reducing fermentation efficiency.

Optimizing the fermentation parameters is essential for maximizing ethanol yield. The optimal conditions identified in this study—30°C temperature, pH 4.5-5.0, and a sugar concentration of 15-20%—can be used as a reference for future studies on bioethanol production from sausage fruit or similar nonconventional feedstocks.

4] Discussion

Although sausage fruit yields less ethanol compared to sugarcane or corn, its use as a bioethanol feedstock has several advantages, particularly in regions where it grows abundantly and is not used for food. The potential for using underutilized fruits like sausage fruit in bioethanol production supports the move toward more sustainable and diverse energy sources. Major advantages of sausage fuel ethanol conversion is its byproduct that is natural fiber can be recovered which can be used for numerous applications

Environmental and Economic Feasibility: The environmental and economic feasibility of producing ethanol from sausage fruit was assessed based on the following factors:

Environmental Impact: Sausage fruit is a non-edible, underutilized feedstock, making it an ecofriendly feedstock that does not compete with food crops. The production of ethanol from sausage fruit reduces waste, as the fruit has limited commercial applications. The overall carbon footprint of producing ethanol from sausage fruit is lower than that of conventional feedstocks, due to its local availability and minimal processing requirements.

Economic Feasibility: The production of ethanol from sausage fruit can be cost-effective in regions where the fruit is abundant and readily available. However, the lower ethanol yield compared to sugarcane or corn may limit its use to small-scale or regional biofuel production. Major advantages of sausage fuel ethanol conversion is its byproduct that is natural fiber can be recovered which can be used for numerous green applications. Further research is needed to assess the scalability of this process and its potential to contribute to local economies.

Therefore the Sausage fruit presents an environmentally sustainable option for bioethanol production, particularly in regions with abundant resources. However, its lower ethanol yield and potential economic limitations mean that it may be more suitable for localized biofuel production rather than large-scale industrial use.

5] Conclusion

The experimental results demonstrate that sausage fruit can be effectively used as a feedstock for bioethanol production. The key findings include:

- Successful sugar extraction through enzymatic hydrolysis.

- High fermentation efficiency of 85-90%, yielding around 200-250 mL of ethanol per kilogram of fruit pulp.
- Optimal fermentation conditions: 30°C temperature, pH 4.5-5.0, and 15-20% sugar concentration.

The Ethanol yield is comparably less ~ 18% possibility of more yield by further optimization of the process is future scope. Byproduct of the process that is natural fiber is useful for green product manufacturing industries. Biofuel from Kigelia africana fruit has great environmental benefits and economic feasibility, although challenges remain in its availability and scaling production for the vehicular biofuel applications.

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