



COMPARACIÓN DEL RENDIMIENTO DE BIOETANOL A PARTIR DE DIFERENTES FRACCIONES DEL MANGO Y PIÑA

COMPARISON OF BIOETHANOL YIELD FROM DIFFERENT MANGO AND PINEAPPLE FRACTIONS

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RESUMEN

La búsqueda de alternativas energéticas sostenibles ha adquirido un protagonismo notable, impulsando un renovado interés en la producción de biocombustibles a partir de residuos agroindustriales, como los derivados de frutas como el mango y la piña. Por ello el problema de investigación, se da debido a que existe la necesidad de comparar el potencial de cada fracción de los residuos de mango y piña en la producción de bioetanol, con el fin de optimizar el aprovechamiento de estos recursos y maximizar la eficiencia del proceso de conversión. El objetivo es llevar a cabo una comparación exhaustiva del rendimiento en la obtención de bioetanol a partir de las distintas fracciones de residuos generados por el mango y la piña. La metodología, se realizó mediante una investigación cuantitativa con una revisión sistemática de la literatura científica relevante de los últimos 5 años, para evaluar y comparar de manera objetiva el rendimiento del bioetanol producido a partir de residuos de mango y piña. Los estudios demostraron que tanto los residuos de mango como los de piña son fuentes prometedoras de azúcares fermentables para la producción de bioetanol. Los pretratamientos ácidos y físicos fueron efectivos para incrementar la liberación de estos azúcares, siendo la cáscara de mango ligeramente más eficiente en términos de rendimiento de azúcares reductores. En conclusión, los residuos de piña, particularmente la celulosa, presentaron los mayores rendimientos de bioetanol, llegando a alcanzar hasta un 57.6%, lo que demuestra que los residuos de piña constituyen una materia prima más adecuada y eficiente para la producción de este biocombustible renovable en comparación con los residuos de mango.

Palabras clave

Bioetanol, residuos, azúcares, fermentación, hidrólisis, biomasa

ABSTRACT

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The search for sustainable energy alternatives has acquired a notable prominence, driving a renewed interest in the production of biofuels from agroindustrial wastes, such as those derived from fruits like mango and pineapple. Therefore, the research problem arises from the need to compare the potential of each fraction of mango and pineapple residues in the production of bioethanol, in order to optimize the use of these resources and maximize the efficiency of the conversion process. The objective is to carry out an exhaustive comparison of the performance in obtaining bioethanol from the different waste fractions generated by mango and pineapple. The methodology was carried out by means of quantitative research with a systematic review of the relevant scientific literature of the last 5 years, to objectively evaluate and compare the performance of bioethanol produced from mango and pineapple wastes. The studies showed that both mango and pineapple residues are promising sources of fermentable sugars for bioethanol production. Acid and physical pretreatments were effective in increasing the release of these sugars, with mango peel being slightly more efficient in terms of reducing sugar yield. In conclusion, pineapple residues, particularly cellulose, presented the highest bioethanol yields, reaching up to 57.6%, which shows that pineapple residues constitute a more suitable and efficient raw material for the production of this renewable biofuel compared to mango residues.

Keywords

Bioethanol, waste, sugars, fermentation, hydrolysis, biomass

INTRODUCTION

The search for sustainable energy alternatives has acquired a notable and urgent prominence in the contemporary discourse, especially in a context where the detrimental effects associated with the intensive use of fossil fuels become increasingly evident and alarming. This growing concern about climate change and environmental degradation has driven a renewed interest in the production of biofuels, particularly those generated from agroindustrial residues (1).

These biofuels emerge as a promising solution not only to mitigate the negative effects of global warming, but also to optimize the use of the natural resources available in our environment, thus fostering a more sustainable and circular economy. In this panorama, residues derived from fruits such as mango and pineapple emerge as a potentially valuable source for the production of bioethanol, given that their processing can transform what would otherwise be considered mere waste into a renewable and sustainable biofuel that could contribute significantly to the energy security of the communities and regions involved (2).

Mango and pineapple are two of the most cultivated and consumed fruits worldwide, which results in the generation of enormous quantities of residues, among which peels, seeds, and crowns are included, which are notably rich in carbohydrates, exhibit a high content of cellulose and hemicellulose, components that can be converted into fermentable sugars through pretreatment processes and subsequent hydrolysis. However, it is fundamental to highlight that the chemical composition of these residues

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can vary considerably, depending on the specific fraction used, which can significantly influence the yield of the bioethanol obtained. Therefore, it becomes imperative to investigate and compare the potential of each fraction in the production of bioethanol, in order to optimize the use of the available resources and maximize the efficiency of the conversion process (3).

Despite the evident potential that these residues present, the production of bioethanol faces a series of technical challenges that are related to the complexity of the lignocellulosic matrix that composes these by-products. This structure presents a robust cohesion, which hinders access to the fermentable sugars that are essential for the production of bioethanol. To address this complexity, it is fundamental to implement adequate pretreatments that facilitate the decomposition of the biomass and the effective conversion of the carbohydrates into fermentable sugars (4).

It is crucial to note that there is no universal and homogeneous approach for pretreatment, since the diversity in the composition of the residues demands a careful selection and adaptation of the methods applied, which must be adjusted to the specific characteristics of each type of biomass (1).

In this context, the present research proposes to carry out an exhaustive comparison of the yield in obtaining bioethanol from the different fractions of residues generated by mango and pineapple with the objective of identifying those fractions that present a higher content of fermentable sugars and, therefore, a superior potential for the effective production of bioethanol. By evidencing the variations in the composition and the yield of the bioethanol derived from these fractions, it is expected to contribute significantly to the development of more effective strategies for the utilization of agroindustrial residues in the production of biofuels.

This approach would not only promote a circular and sustainable economy, but would also foster a responsible and efficient use of resources, aligning with the current needs of environmental conservation and sustainable development by taking advantage of mango and pineapple fruits (5).

MATERIALS AND METHODS

Research method:

The present research is classified as a quantitative-type study, given that it is based on the systematic collection and analysis of numerical data extracted from relevant scientific articles. This methodological approach allows evaluating and comparing in an objective manner the yield of the bioethanol produced from mango and pineapple residues. Through this method, the aim is to establish patterns, trends, and correlations that facilitate the formulation of well-founded conclusions supported by the scientific evidence available in the current literature.

Population or sample:



To carry out this research, a systematic search was performed in renowned scientific databases, such as SciELO and Google Scholar. With the purpose of guiding the search and selection of relevant literature, the research question was formulated: “Bioethanol from mango and pineapple residues?”. In the review process, a significant set of studies addressing the production of bioethanol derived from these fruit residues was included.

Inclusion criteria:

The search was limited to scientific articles published in peer-reviewed journals, as well as specialized books covering the last 5 years. Studies that investigated advanced methods of extraction of antioxidant compounds from fruits and vegetables were included, provided that they provided relevant information on bioethanol production.

Exclusion criteria:

Those studies that did not provide pertinent information or that were inaccessible in their entirety were excluded. Likewise, articles that did not focus specifically on bioethanol derived from mango and pineapple residues were discarded, as well as those that did not meet the peer-review standards or that were published in low-quality journals. This ensures that only reliable and pertinent sources that enrich the research database are included.

Setting:

The research was carried out in an academic and research setting, using bibliographic resources accessible through various digital platforms. Although no physical fieldwork was performed, the analysis was based on scientific literature that covers different geographic and productive contexts.

Measurements:

For data collection, relevant data were extracted from the selected studies, such as the antioxidant compounds investigated, the fruits of interest, and the bioethanol applied in each case. In this approach, significant variables were considered, such as the type of residues used, the extraction methods employed, and the bioethanol yields obtained. The collected information was organized thematically, which allowed addressing key aspects such as the nature of fruit residues in bioethanol production and their suitability for said application, thus facilitating a clearer and more precise understanding of the potential of these by-products.

Data analysis:

Descriptive analyses were performed to summarize the characteristics of the reviewed studies, as well as comparative analyses among the different extraction methods used in the selected works. This process allowed highlighting the advantages, limitations, and specific applications of each approach, contributing to a deeper understanding of the methodologies employed in obtaining bioethanol. Finally, a synthesis of the obtained results was prepared, offering a general perspective on the latest scientific advances in advanced methods for the production of bioethanol from mango and pineapple residues.



RESULTS

Fermentable sugars from mango peel



Figure 1. Mango peel

Source: (6)

The studies of (6) demonstrate that mango biomass is a significant source of carbohydrates, which includes fiber (29% soluble and 27% insoluble), sugars (5% sucrose, 2% fructose, and 0.5% glucose), starch (0.3%), and pectin (15–32%). This indicates a great potential for the production of bioethanol from mango residues.

Subsequently, at the Universidad de los Andes (7) an average initial concentration of reducing sugars of 0.98 ± 0.18 g/L was determined, originating from the mixture of mango residues and water. This concentration of monosaccharides is due to the extractable components of the mango residues, especially from the seed and the peel, which contain a higher percentage.

After acid hydrolysis, the sugar concentration reached 1.63 ± 0.14 g/L, which is expected due to the action of the H^+ ions that break the bonds between the sugars of the hemicellulose and the cellulose, releasing a greater quantity of reducing sugars such as glucose, xylose, and mannose. This represents an increase of 66.5% compared to the initial quantity of sugars and a hydrolysis efficiency of 22.61% (8).

Subsequently, in bibliographies of (9), (10), (11) tests were evidenced on the dry raw material, such as the determination of total sugars (Anthrone method), reducing sugars (DNS method), and fiber content, with the objective of obtaining initial data (control) to compare them with those obtained from the hydrolytic process, in addition to a proximal analysis to characterize the mango residue.

Fermentable sugars from pineapple residues



Figure 2. Pineapple peel

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In the case of pineapple residues, the quantification of reducing sugars of the substrate extracted from pineapple with acid methods, in samples A, the concentrations of reducing sugars revealed a maximum of 4.66 g/L at the beginning, subsequently decreasing to a minimum concentration of 3.18 g/L and 2.78 g/L after 108 hours, in samples A and B respectively (18).

Therefore, the concentration of reducing sugars in the pineapple peels hydrolyzed with forced aeration was 2.236 g/L, while in the hydrolysis without forced aeration it was 1.369 g/L. These results indicate that physical pretreatment, such as the reduction of the substrate size, is sufficient to obtain reducing sugars. It is not necessary to perform chemical pretreatments on the substrate due to its low lignin concentration, a polymer that decreases the efficiency of hydrolysis (19).

In addition, hydrolysis was carried out in two stages: a strong one at 72% and a dilute one at 8%, achieving the conversion of both the cellulose and the pineapple bagasse into glucose. The conversion of the bagasse reached 40%, while that of the cellulose reached 78%. This increase is due to the fact that cellulose contains a greater quantity of D-glucose units, while pineapple bagasse contains pectin, lignin, and impurities that interfere with hydrolysis. Through anaerobic fermentation with *Saccharomyces cerevisiae*, the glucose was transformed into ethanol, which was then obtained by distillation. The best fermentation conditions were at 30 °C for 48 hours for the bagasse and 72 hours for the cellulose, with yields of 34.5% and 57.6% respectively (15).

Finally, the results demonstrate that both mango and pineapple residues are promising sources of fermentable sugars for the production of bioethanol. Acid and physical pretreatments have been effective in increasing the release of these sugars, with mango peel being slightly more efficient in terms of reducing sugar yield. However, the specific chemical composition of each residue fraction must be considered to optimize the hydrolysis and conversion processes to bioethanol.

DISCUSSION

The results obtained in the present study evidence significant differences in the bioethanol yield from the different fractions of mango and pineapple residues. These findings agree with what is reported in the scientific literature of (20), where it is highlighted that the chemical composition of agroindustrial residues can vary considerably depending on the specific fraction used.

In the case of mango residues, it was observed that the peel and the seed present a higher content of fermentable carbohydrates compared to other parts of the fruit. This is due to the fact that these components contain a higher proportion of soluble fiber, sugars such as sucrose, fructose, and glucose, as well as starch and pectin, since the reviewed studies (21) indicate that, through adequate pretreatments such as acid hydrolysis, it is possible to significantly increase the concentration of reducing sugars from these residues, reaching increases of 66.5% in some cases.



On the other hand, pineapple residues also showed great potential for the production of bioethanol. Particularly, the pineapple peel proved to be a rich source of fermentable carbohydrates, with concentrations of reducing sugars that reached up to 4.66 g/L in the analyzed studies (22). Unlike mango residues, those of pineapple present a lower concentration of lignin, which facilitates hydrolysis and the release of fermentable sugars. It was even evidenced that, in some cases, physical pretreatment, such as particle size reduction, was sufficient to obtain satisfactory yields without the need for chemical pretreatments.

The highest bioethanol yields were obtained from pineapple cellulose, reaching up to 57.6%, compared to 34.5% for bagasse. This superiority is attributed to the higher content of D-glucose units in cellulose and the lower interference from pectin, lignin, and impurities. Optimal fermentation conditions with *Saccharomyces cerevisiae* (30 °C, 48–72 h) further maximized conversion efficiency.

Overall, while mango peel showed slightly higher efficiency in reducing-sugar release after acid pretreatment, pineapple residues—especially the cellulose fraction—constituted a more suitable and efficient raw material for bioethanol production, supporting their preferential use in renewable biofuel strategies.

CONCLUSIONS

Both mango and pineapple residues are promising sources of fermentable sugars for bioethanol production. Acid and physical pretreatments were effective in increasing the release of these sugars, with mango peel being slightly more efficient in terms of reducing-sugar yield. However, pineapple residues, particularly the cellulose fraction, presented the highest bioethanol yields, reaching up to 57.6%, which demonstrates that pineapple residues constitute a more suitable and efficient raw material for the production of this renewable biofuel compared to mango residues. These findings contribute to the optimization of agroindustrial residue utilization within circular-economy and sustainable-energy frameworks.

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