

A Comparative Study on Sedimentation and Alkaline Starch Extraction on Corn Cobs (*Zea mays*)

Sabina S. Omboy

Abby H. Bartolata

Phoebe Zyann E. Ferrer

Raphael G. Vizcarra

Sofia Reine M. Palarca

Van Adrian C. Mascareñas

Gienny V. Carlote

Basic Education Department - JHS

University of the East, Caloocan Campus

ABSTRACT

This study compares the effectiveness of sedimentation and alkaline processes for extracting starch from corn cobs (*Zea mays*). The sedimentation method allows starch to settle naturally from the solution after separation from other components while the alkaline method uses a sodium hydroxide solution to break down cell walls and release starch. The parameters evaluated included starch percent yield, pH, and amylose content of extracted starch. Both methods tested positive for amylose content, indicated by the blue-black color change observed in Lugol's iodine test. Both methods produced starch with a neutral pH of 7. The sedimentation method produced a higher average yield (1.05%) than the alkaline method (0.30%). Although both methods showed similar outcomes in amylose content and pH levels, sedimentation proved to be more effective in terms of recovering a greater amount of starch. Its simpler, chemical-free process and higher yield make it a more practical, cost-effective, and environmentally sustainable option for starch extraction from corn cobs. These findings support the sedimentation method as a more efficient approach for starch recovery and suggest its potential for wider application in industrial starch production.

Keywords: alkaline, sedimentation, amylose, corn cobs, starch extraction

Corn is one of the world's largest crops, with over 1 billion metric tons produced annually (Food and Agriculture Organization of the United Nations, 2023). Corn (*Zea mays*) is the second most important crop in the Philippines. According to the Corn Production in the Philippines 2022 Statistics, the Philippines a country known for its agricultural industry, is one of the top producers of corn in Asia.

Various by products of maize cultivation, such as corn cobs, corn husks, stalks, leaves, and bran, are produced in significant quantities alongside the primary use of corn kernels for food, feed, and industrial applications like ethanol and corn oil production. Corn cobs, the fibrous central portion of the maize ear, constitute a significant amount of agricultural waste that is frequently underutilized or discarded, raising environmental concerns (Wakudkar *et al.*, 2022). This study is an effort to investigate alternative applications for agricultural residues, particularly corn cobs, which offer a promising feedstock for starch production. It particularly aims to evaluate the efficiency of sedimentation and alkaline methods for extracting starch from corn cobs. Key properties such as amylose content, percent yield, and pH level from the extracted starch need to be assessed and used as bases to enhance sustainable starch production practices and optimize the use of agricultural waste (Sari *et al.*, 2021).

The study aims to determine if there is a significant difference in the properties of the corn cob starch extracted by sedimentation and alkaline methods which could measure the starch extraction efficiency and be used as basis for determining the method to promote efficient use of agricultural byproducts.

REVIEW OF RELATED LITERATURE AND STUDIES

Starch content. Starch is a type of carbohydrate found in plants, including grains, fruits, and vegetables, and it is important for nutrition. It provides glucose, the body's main energy source (Sherrell, 2022). Starch also provides dietary fiber, vitamins, and minerals that are essential to overall health and well-being. Its role in metabolic pathways supports cell growth and function (Jun Han *et al.*, 2023). Aside from nutrition, starch's

renewable and biodegradable nature allows its utilization in the production of bioplastics, offering an eco-friendly alternative to conventional plastic materials (Sherrell, 2022). The usage of starches derived from fruits and crops like corn and wheat highlights their potential and low cost for making bioplastics (Blancia, 2021). Gelatinization which can extract starch, is used in many industries and considered an innovation that does not only address environmental concerns but may help people with diabetes because of its low glycemic index. In addition to its role in bioplastics, starches find widespread application as thickening agents in food products and as raw materials in industries ranging from adhesives to pharmaceuticals. Many organic sources, including corn, jackfruit, and potatoes, are natural sources of starch, making them sustainable (Espineli *et al.*, 2021). This versatility shows how important starch is in daily life, from nutrition to industrial applications, making it a vital resource in today's world.

Corn cob as an agricultural waste. Maize, alongside rice and wheat, stands as a crucial cereal crop globally, with its production soaring to 1136.2 million tons worldwide in the 2020/2021 season, serving diverse purposes such as food, feed, and industrial applications (Aghaei *et al.*, 2022). However, the cultivation of maize generates substantial agricultural residues, including husks, leaves, stalks, and cobs, with corn cobs alone constituting about 14% of grain yield and approximately 16% of total corn stover in a field (Aghaei *et al.*, 2022). Despite being a post-harvest waste residue, corn cobs hold promise for further utilization, particularly in the extraction of starch, production of activated carbon, bioethanol, and biodegradable packaging materials, offering environmentally friendly alternatives to conventional materials (Wakudkar *et al.*, 2022; Santolini *et al.*, 2021).

There are however major challenges in managing this surplus biomass such as the widespread practice of open-field burning in many rural and agricultural areas, which releases greenhouse gases, contributing to air pollution and environmental degradation (Wakudkar *et al.*, 2022). Management of agricultural waste presents both challenges and opportunities for sustainable resource management, with corn cobs offering avenues for green technologies and circular economy practices. In addition to that, maize's significance as the second most important agricultural yield in the Philippines underscores the

magnitude of agricultural residues generated, estimated at 5 million metric tons of renewable biomass annually (Pangan *et al.*, 2021). Effective waste management strategies are imperative in major maize-producing countries like the United States, China, Brazil, and Argentina, where innovative approaches are needed to harness the potential of agricultural residues. Corn cobs, despite their inedibility, hold promise for diverse applications such as animal feed, biofuel production, and industrial processes, aligning with principles of sustainability and resource efficiency (Santolini *et al.*, 2021).

Properties of corn cobs. Corn cobs, a substantial byproduct of corn production, account for an estimated 40 to 50% of total corn biomass and are often classified as agricultural waste. They are typically discarded after harvesting and processing, regardless of the corn variety (Santolini *et al.*, 2021). While corn cobs are biodegradable, their accumulation and improper disposal—particularly open burning—can lead to environmental pollution and health risks. Wakudkar and Jain (2022) emphasize that open burning of corn cobs emits pollutants such as particulate matter, carbon monoxide, and toxic gases, contributing significantly to air pollution. Despite being treated as waste, corn cobs contain valuable phytochemicals and prebiotic compounds with functional properties, including antioxidant, antimicrobial, anticoagulant, anticancer, and blood glucose-lowering effects (Institute of Food, Science + Technology, 2023). These bioactive properties suggest their potential use as raw materials in food and nutraceutical products.

Additionally, their high cellulose (around 40%) and hemicellulose (41.4%) content makes them promising feedstocks for various industrial applications such as heat, energy, fuel, chemicals, and bioplastics production (Lau, 2018). This broad utility highlights the role of corn cobs in promoting sustainable resource management and the development of value-added products. Starch derived from corn cobs typically exhibits a neutral pH of 6 to 7 when dissolved in water, meaning it is neither acidic nor basic. This neutrality makes starch ideal for diverse culinary applications. For example, it functions as a thickener in sauces, soups, and gravies; a gelling agent in puddings, jellies, and gummy candies; a stabilizer in salad dressings and dairy desserts; a binder in gluten-free baked goods; and an encapsulation agent for flavor or nutrient delivery in functional foods (Yazid *et al.*, 2018).

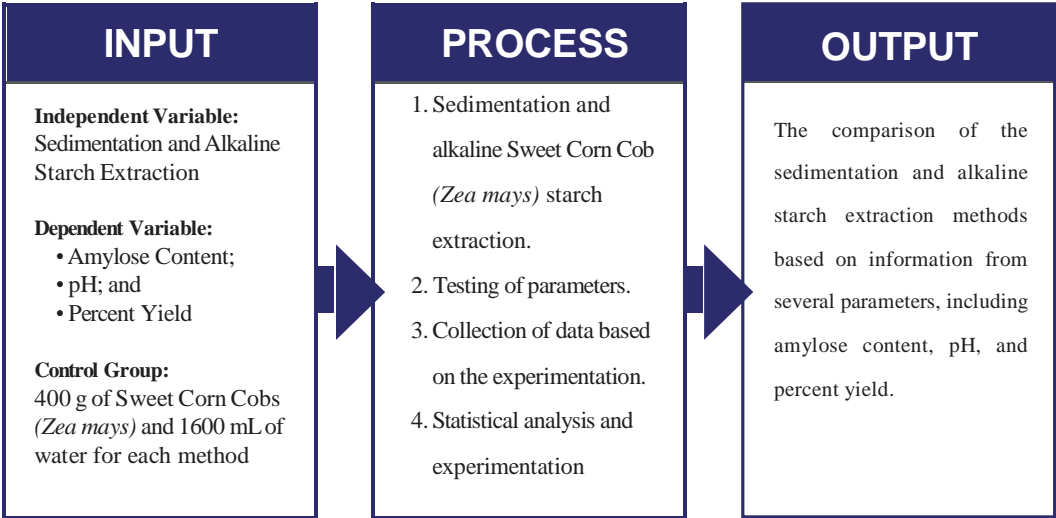
Alkaline extraction methods. Alkaline extraction has emerged as a widely utilized method for isolating valuable biomolecules from agricultural and industrial residues due to its efficiency in solubilizing structural components. This process primarily employs alkaline solutions, such as sodium hydroxide (NaOH) or potassium hydroxide (KOH), to break down lignocellulosic biomass, facilitating the release of compounds like proteins, hemicellulose, and other bioactive molecules (Chen *et al.*, 2019). The alkaline method has been widely used for protein recovery from plant-based materials, enhancing solubility while minimizing denaturation (Zhu *et al.*, 2021). Alkaline extraction has also been extensively used in biomass conversion, offering a sustainable approach for extracting lignin and cellulose, essential for biofuels and biopolymers. Recent advancements in alkaline extraction focus on optimizing yield, purity, and functional properties, leading to improved utilization of agricultural waste (Guo *et al.*, 2020). Additionally, the method has proven effective in starch extraction from plant materials, including corn, where it has been successfully applied in isolating starch from kernels through conventional acidic or alkaline techniques (The Pharma Innovation, 2022). Its versatility makes it a valuable tool in both food and industrial applications.

Sedimentation extraction methods. Sedimentation extraction is a simple yet effective technique for separating solid particles from liquid suspensions based on their density differences. This method is widely used in the food, pharmaceutical, and environmental industries for the purification of bioactive compounds and the recovery of valuable materials. One of its primary applications is in starch extraction, where sedimentation allows for the isolation of high-purity starch from plant sources such as corn, cassava, and rice (Xie *et al.*, 2020). The process enhances starch yield and quality while maintaining its functional properties, making it suitable for use in food and industrial applications. Sedimentation is also effective in wastewater treatment, aiding in the removal of suspended solids, heavy metals, and organic matter from industrial effluents, thereby contributing to environmental sustainability not just by reducing pollution, but by helping protect water sources, minimizing harm to ecosystems, and promoting the responsible use of the natural resources (Singh *et al.*, 2021).

By enabling the efficient separation of solids from liquids without the need for harsh chemicals or a lot of energy, sedimentation promotes environmental sustainability through simpler, more eco-conscious practices. In bio-processing, sedimentation extraction has been optimized for the recovery of proteins, polysaccharides, and other macromolecules, offering a cost-effective alternative to more complex separation techniques (Li *et al.*, 2019). Recent advancements have focused on improving sedimentation efficiency through the integration of flocculants and coagulants, enhancing the separation process for better resource recovery and waste management (Rahman *et al.*, 2022).

Conceptual Framework

Figure 1
Input-Process-Output (IPO) Model



The IPO model was used to analyze the data and variables used in the entire research process. The effectiveness of sedimentation and alkaline starch extraction methods were compared allowing for comprehensive evaluation of the process. The analysis revealed the most reliable method, providing valuable insights for future research.

Objectives of the Study

The objective of this study was to conduct a comparative analysis of the efficiency of sedimentation and alkaline methods for starch extraction from corn cobs (*Zea mays*) by examining key properties such as amylose content, percent yield, and pH level. This research seeks to determine each method's efficiency in starch recovery, assess amylose presence, and determine the extracted starch's acidity. Assessing the viability of these two methods (Sedimentation and Alkaline) for utilizing corn cobs as a raw material in starch manufacturing, can contribute data that can be used as basis for potentially reducing waste and carbon emissions associated with traditional extraction processes, thereby promoting sustainable use of agricultural byproducts and resource efficiency in starch production. The study determined if there is significant difference in the amylose content, percent yield and pH level in the starch extracted from sedimentation and alkaline methods.

Significance of the Study

This study explores the use of sedimentation and alkaline methods for starch extraction from corn cobs (*Zea mays*), that can possibly offer a sustainable and cost-efficient alternative to conventional techniques. Traditional starch extraction often involves intensive mechanical processing, the use of high temperatures or chemical treatments with acids and enzymes, which can be costly, energy-consuming, and less environmentally-friendly. This study promotes waste reduction and proper resource management by allowing starch to be extracted from an agricultural byproduct that would often go to waste. By using corn cobs, a readily available organic material, the extraction process becomes accessible and environmentally friendly, aligning with efforts to minimize agricultural waste.

Results of this study may aid in the development of efficient and environmentally beneficial techniques for extracting starch that could be applied in various industries such as the food industry, the manufacturing of bioplastics/biopolymers, and the pharmaceutical industry.

Scope and Delimitation of the Study

The study was limited to only two alternative extraction methods namely sedimentation and alkaline methods and to corn cobs as the source of starch. Only three parameters were measured namely starch yield, pH and amylose content. Measurement of pH was based on change in color of litmus paper in the absence of a pH meter. Only three trials were conducted for reproducibility of the results. A previous study by Santos *et al.* (2022), on starch extraction from purple yam (*Dioscorea trifida*) used three trials to ensure reproducibility and strengthen the validity of their findings.

MATERIALS AND METHODS

Research Design

A quantitative experimental design was used and descriptive analysis to compare the results and highlight the observable differences.

Materials and Procedures

Starch extraction from corn cobs used the following materials and equipment: acetic acid, sodium hydroxide, distilled water, iodine, mesh cloth, litmus paper, blenders, mortar, pestle, and weighing scales to facilitate cell wall breakdown, release starch, refine particles, and measure the mass of raw materials, reagents, and samples.

Starch Extraction

Alkaline starch extraction and sedimentation techniques were used to extract starch from corn cobs.

A. Sedimentation starch extraction

Four hundred grams of corn cobs were pulped and then mixed with distilled water in a 1:4 ratio, yielding a total volume of 1600 ml. The mixture was blended at high speed until it reached a smooth slurry consistency after

which it was filtered and allowed to settle for a duration of 24 hours (Shahrim *et al.*, 2018). The mixture was then thoroughly washed with distilled water repeatedly until the suspension was clear and free from suspended impurities. Finally, the suspension was dried under direct sunlight, a natural and energy-efficient approach for moisture removal, resulting in a fine, powdery consistency suitable for various applications (Sundaram & Singh, 2018).

The dried residue was scraped off and ground using a mortar and pestle until a fine powder was obtained for analysis and further experimentation.

B. Alkaline starch extraction

Four hundred grams of corn cobs were combined with 1600 m of distilled water in a 1:4 ratio. The mixture was blended to create a smooth slurry and then filtered through a fine mesh cloth to separate the solid residue from the liquid starch solution (Shahrim *et al.*, 2018). The strained slurry was then mixed with 0.1% NaOH and allowed to settle for 24 hours. To neutralize the pH of the alkaline slurry, vinegar containing 5% acetic acid was gradually added until a neutral pH was achieved. The sediment was washed repeatedly with distilled water until the suspension was clear and free of suspended impurities. Once settled, the mixture was decanted, and the remaining solid residue was dried under direct sunlight (Sundaram & Singh, 2018). Finally, the dried residue was scraped off and ground using a mortar and pestle until a fine powder was obtained for analysis and further experimentation.

I. Determination of amylose content

The starch iodine test was used to determine the presence of amylose content as described by Cisneros *et al.* (2017). In a test tube, 0.10 g of the extracted corn cob starch sample was combined with 10 mL of distilled water. The mixture was stirred vigorously until the starch had completely dissolved. Subsequently, three drops of Lugol's iodine (LI) were added to the solution, and any color change was observed to indicate the presence of amylose. Since amylose is a key starch component, it reacts with iodine and forms a blue-black color. The blue-black color that appeared in the solution was taken as a sign that amylose was indeed present indicating the presence of starch.

II. Determination of starch percent yields

The starch percent yield is a measure of the efficiency of starch extraction from raw material. This measurement is essential for evaluating the effectiveness of various starch production processes. The following formula was used to determine the percentage of each extraction yield:

$$\text{Starch Percent Yield (\%)} = \frac{\text{Starch Weight (g)}}{\text{Corn Cob Weight (g)}} \times 100$$

III. Determination of pH

The method described by Wijesinghe and Gunathilake (2020) was used for pH determination with minor modifications. In a beaker, 5 ml of distilled water was combined with approximately 0.10 g of the starch sample. The mixture was stirred for 5 minutes. After allowing the starch to settle, litmus paper was used to measure the pH of the water phase. Quantitative data were obtained by comparing the color change of the litmus paper to a standard pH color chart. The pH values were recorded according to the corresponding colors on the chart, and the results were analyzed to ascertain the pH of the water phase sample.

Data Analysis

Analysis focused on comparing observable differences in amylose presence, and calculating averages and standard deviations for percent yield and pH levels.

Ethical Consideration

Ethical guidelines were observed in the collection, management, and handling of data, and in the appropriate disposal of any hazardous materials utilized during the experimental process. Standard laboratory protocols and safety guidelines were strictly adhered to. All experimental procedures were conducted under the supervision of qualified professionals to ensure the safety of the researchers and maintain the integrity of the study. Precautions were observed to prevent any adverse impact on the environment or living organisms throughout the data collection and analysis process.

RESULTS AND DISCUSSION

Results of the determination of the presence of amylose are shown in Table 1. For the alkaline method employed in samples 1, 2, and 3, a color change was observed, indicating the presence of amylose in the starch samples. Similarly, the sedimentation method yielded a color change for samples 1, 2, and 3, signifying the presence of amylose in the starch samples. The reaction of Lugol's iodine solution with amylose molecules resulted in a blue-black coloration, thus confirming amylose presence in both methods.

No observable differences were found between the two extraction methods in terms of amylose presence, as both showed consistent positive results. This suggests that regardless of the method used, amylose was successfully retained in the extracted starch. The amount of amylose detected on the starch extracted from the two methods could not be quantified however limiting the conclusion to just presence without any hint as to which method is more efficient.

Table 1*Determination of Amylose Content*

	Corn Cob Starch Extraction Method	
Sample	Alkaline method	Sedimentation method
1	Positive (+)	Positive (+)
2	Positive (+)	Positive (+)
3	Positive (+)	Positive (+)

Table 2 presents the percent yield of starch extracted from corn cobs using both the alkaline and sedimentation methods. Sedimentation method produced a higher percent yield compared to the alkaline method. The alkaline extraction resulted in a mean percent yield of 0.33%, with a standard deviation of 0.045, indicating low variability across the trials. In comparison, the sedimentation method yielded a higher mean of 1.05%, although the standard deviation was also higher at 0.318, suggesting greater variation in the results.

These findings suggest that while the alkaline method produced more consistent results, the sedimentation method was more effective in extracting a greater amount of starch. The higher percent yield observed from the sedimentation method shows that it might be the better approach for extracting starch from corn cobs. One possible reason is that sedimentation is a less chemically-disruptive process, which only depends on gravity to let the starch settle naturally. Since it does not use any strong chemicals like NaOH, there's a lesser chance that the starch granules will be damaged or lost. On the other hand, the alkaline method uses chemicals that can help break down other parts of the corn cob, but might also lead to some starch loss. Sedimentation also involves fewer steps, so there are lesser chances of losing starch during the procedure.

These observations are supported when considering the overall efficiency of the two methods based on all tested parameters. While both methods confirmed the presence of amylose and yielded starch with a neutral pH, sedimentation stood out due to its notably higher yield. This indicates that it may be a more effective and practical method for extracting starch from corn cobs.

Table 2*Percent Yield of Corn Cob Starch Extracted Using Alkaline and Sedimentation Methods*

	Corn Cob Starch Extraction Method			
	Alkaline method		Sedimentation method	
Sample	Weight (g)	Yield of Starch (%)	Weight (g)	Yield of Starch (%)
1	1.16	0.290	3.81	0.950
2	1.32	0.330	5.64	1.41
3	1.50	0.380	3.20	0.800
Mean	1.33	0.300	4.23	1.05
Standard Deviation	0.170	0.045	1.27	0.318

Table 3 shows the mean pH level of 7 obtained from the two different starch extractions which denotes a neutral solution.

The results were consistent across all trials, as each sample maintained a neutral pH level throughout the process. This observation suggests that there was no observable difference in pH between the starch extracted using the alkaline method and the starch extracted using the sedimentation method.

Table 3*Mean pH Level of the Alkaline and Sedimentation Method*

Corn cob Starch Extraction pH Level		
Sample	Alkaline Method	Sedimentation Method
1	7	7
2	7	7
3	7	7
Mean	7	7

Results of this study show that both the sedimentation and the alkaline methods are capable of extracting starch from corn cobs based on the presence of amylose. No difference was also shown in pH level. However, the higher starch yield generated by the sedimentation method compared to the alkaline method gave the latter an edge in efficiency. These results suggest that the sedimentation method might be more effective for starch extraction from corn cobs, especially when yield is the main concern.

A better differentiation of the efficiency of extraction of these two methods could have been achieved with more refined methods. The qualitative method of determining amylose through the starch-iodine test could have been improved with more precise values of amylose content generated by spectrophotometric or enzymatic techniques. This could further confirm the starch yield from each extraction method. A pH meter could have provided exact pH values instead of a qualitative assessment by a litmus paper.

The drying process could have also caused undue variation or inconsistency in the results. Starch samples were dried using direct sunlight—a method that, while environmentally friendly, lacks the control and consistency of laboratory-based drying techniques. Uncontrollable factors such as ambient humidity, temperature, and cloud cover may have influenced drying time and moisture content, both of which can affect starch yield and texture.

Lastly, the measurements in this study were performed using manual tools such as basic weighing scales that may not have been professionally calibrated. This could have introduced small but notable errors in mass and volume measurements. These inconsistencies highlight the limitations caused by restricted access to advanced laboratory equipment, and they underscore the need for improved tools and resources to enhance precision and reliability in future research.

The researchers fully acknowledge the limitations encountered in this study, particularly those related to the use of basic tools and qualitative methods. These constraints, while unavoidable given the available resources, may have affected the accuracy, consistency, and depth of the findings. Nonetheless, the findings provide meaningful initial insights into starch extraction and analysis. It is hoped that future research, conducted under more controlled conditions and with access to more sophisticated instrumentation, will build upon these results and contribute to a more accurate and comprehensive understanding of the processes involved.

From a future research perspective, this study can be expanded to investigate the impact of different extraction techniques on starch quality and functionality. Furthermore, future studies can also focus on optimizing extraction conditions by adjusting parameters such as temperature, moisture content, and extraction time to increase starch yield and purity. This approach could improve the efficiency and sustainability of various starch extraction processes. In addition, it is recommended that the methodology employed in this study, including the specific parameters and materials, be replicated to validate the findings and assess their broader applicability. This replication will allow a more comprehensive comparison of various techniques and support in validating the results, ensuring the reliability of the findings.

CONCLUSION

This study compared the sedimentation and alkaline methods in extracting starch from corn cobs. Although both methods yielded amylose and the same pH level, the sedimentation method showed a higher starch yield indicating that it is more effective in starch extraction.

RECOMMENDATION

This study could have benefited from more refined methods such as better drying methods, spectrophotometric methods to quantify the amylose yield and high precision weighing scales. The difference between the sedimentation and alkaline methods could have been quantified and the higher degree of efficiency of the sedimentation method could have been shown in a quantitative rather than qualitative way.

Institutional Acknowledgment

The researchers would like to express their gratitude to the University of the East–Caloocan Campus for the support given to this research.

REFERENCES

- Chen, Y., Li, X., Zhang, R., & Zhang, D. (2019). Alkaline extraction of lignin from biomass and its applications: A review. *Renewable and Sustainable Energy Reviews*. <https://www.sciencedirect.com/science/article/pii/S0960852420300535>
- Chuwa, C., Dhiman, A., Thakur, N., Kathuria, D., Gautam, S., & Sharma, B. (2020). Comparative studies on extraction of starch through physical, enzymatic, and alkaline methods. *International Journal of Food Science and Nutrition*, 5, 2455–4898. <https://www.foodsciencejournal.com/assets/archives/2020/vol5issue6/5-6-36-643.pdf>
- Corn production volume Philippines 2012-2023. (2023). Statista. <https://www.statista.com/statistics/751372/philippines-corn-production/#:~:text=In%202022%2C%20the%20production%20volume>
- Enrica Santolini, Bovo, M., Barbaresi, A., Torreggiani, D., & Tassinari, P. (2021). Turning Agricultural Wastes into Biomaterials: Assessing the Sustainability of Scenarios of Circular Valorization of Corn Cob in a Life-Cycle Perspective. *Applied Sciences*, 11(14), 6281–6281. <https://doi.org/10.3390/app11146281>
- Food and Agriculture Organization of the United Nations. (2023). *FAOSTAT Statistical Database*. <https://www.fao.org/faostat/>
- García-Condado, S., Raúl López- Lozano, Panarello, L., IacopoCerrani, Nisini, L., Zucchini, A., Van, & Baruth, B. (2019). Assessing lignocellulosic biomass production from crop residues in the European Union: Modelling, analysis of the current scenario and drivers of interannual variability. *GCB Bioenergy*, 11(6), 809–831. <https://doi.org/10.1111/gcbb.12604>

- Harsha Wakudkar, & Jain, S. (2022). A holistic overview on corn cob biochar: A mini-review. *Waste Management & Research the Journal for a Sustainable Circular Economy*, 40(8), 1143–1155. <https://doi.org/10.1177/0734242x211069741>
- Jiayue Tang, Dan Yao, Shuaibo Xia, Lingzhi Cheong, Maolin Tu. (2021) Recent progress in plant-based proteins: From extraction and modification methods to applications in the food industry. <https://pmc.ncbi.nlm.nih.gov/articles/PMC11239452/>
- Kumar, P., Sharma, N., Singh, S., & Gupta, R. (2022). Optimization of alkaline extraction for improved biomaterial Recovery. *Journal of Cleaner Production*. (2022). Science Direct. <https://pubmed.ncbi.nlm.nih.gov/25093173/>
- Li, C., Wang, J., & Chen, T. (2019). Efficient sedimentation extraction of bioactive compounds: A novel approach for industrial applications. *Journal of Industrial and Engineering Chemistry*: <https://www.sciencedirect.com/science/article/pii/S002196732031044X>
- Mohammed, Hasan, Z., Omran, B., Kumar, V. Vinod., Elfaghi, A. M., Ilyas, R. A., & Sapuan, S. M. (2022). Corn: Its Structure, Polymer, Fiber, Composite, Properties, and Applications. *Polymers*, 14(20), 4396–4396. <https://doi.org/10.3390/polym14204396>
- Monserrat Escamilla-García, Mónica Citlali García-García, Gracida, J., Hernández-Hernández, H. M., José Ángel Granados-Arvizu, Pierro, P. D., & Regalado-González, C. (2022). Properties and Biodegradability of Films Based on Cellulose and Cellulose Nanocrystals from Corn Cob in Mixture with Chitosan. *International Journal of Molecular Sciences*, 23 (18), 10560 –10560. <https://doi.org/10.3390/ijms231810560>
- Mujtaba, M., Fraceto, L. F., Fazeli, M., Mukherjee, S., SusilaineMairaSavassa, Gerson, Anderson, Mancini, S. D., JuhaLipponen, & Vilaplana, F. (2023). Lignocellulosic biomass from agricultural waste to the circular economy: a review with a focus on biofuels, biocomposites, and bioplastics. *Journal of Cleaner Production*, 402, 136815–136815. <https://doi.org/10.1016/j.jclepro.2023.136815>

- Nogueira, G. F., Fakhouri, F. M., & Augustus, R. (2018). Extraction and characterization of arrowroot (*Maranta arundinaceae* L.) starch and its application in edible films. *Carbohydrate Polymers*, 186, 64–72. <https://doi.org/10.1016/j.carbpol.2018.01.024>
- Orzechowski, S., Compart, J., Edyta Zdunek-Zastocka, & Joerg Fettke. (2022). Starch parameters and short-term temperature fluctuations – Important but not yet in focus? *Journal of Plant Physiology*, 280, 153902. <https://doi.org/10.1016/j.jplph.2022.153902>
- Plachikkattu Parambil Akhila, Kappat Valiyapeediyekkal Sunooj, Basheer Aaliya, Muhammed Navaf, Cherakkathodi Sudheesh, Yadav, D. N., Khan, M. A., Mir, S. A., & George, J. (2022). Morphological, physicochemical, functional, pasting, thermal properties, and digestibility of Hausa potato (*Plectranthus rotundifolius*) flour and starch. *Applied Food Research*, 2(2), 100193–100193. <https://doi.org/10.1016/j.afres.2022.100193>
- Rahman, M. A., Hossain, M. E., & Ahmed, S. (2022). Enhancing sedimentation extraction efficiency through chemical coagulants: Recent developments and future perspectives. *Chemical Engineering Journal*. https://journal.gnest.org/sites/default/files/Submissions/gnest_04380/gnest_04380_published.pdf
- Sanders, J., & Cohen, G. M. (2019). Observation of the Optical & Chemical Properties of Starch Granules. *The American Biology Teacher*, 81(9), 644–648. <https://www.jstor.org/stable/26848583>
- Santos, S. de J. L., Pires, M. B., Amante, E. R., da Cruz Rodrigues, A. M., & da Silva, L. H. M. (2021). Isolation and characterization of starch from purple yam (*Dioscorea trifida*). *Journal of Food Science and Technology*, 59(2), 715–723. <https://doi.org/10.1007/s13197-021-05066-9>

- Sari, N. K., Regita, A. H., Dimas, Dira Ernawati, & Widi Wurjani. (2021). Optimizing Edible Film from Corn Cobs with Surface Response Method. *E3S Web of Conferences*, 328, 08009–08009. <https://doi.org/10.1051/e3sconf/202132808009>
- Siavash Aghaei, Masih Karimi Alavijeh, Marzieh Shafiei, & Karimi, K. (2022). A comprehensive review on bioethanol production from corn stover: Worldwide potential, environmental importance, and perspectives. *Biomass and Bioenergy*, 161, 106447–106447. <https://doi.org/10.1016/j.biombioe.2022.106447>
- Singh, R., Patel, S., & Kumar, M. (2021). Sedimentation-based removal of heavy metals from wastewater: An eco-friendly approach. *Environmental Science and Pollution Research*. <https://pmc.ncbi.nlm.nih.gov/articles/PMC9742998/>
- Starch, Soluble. (2017). *ACS Reagent Chemicals*. <https://doi.org/10.1021/acsreagents.4379>
- Starch extraction: Principles and techniques. (2020). Research Gate. https://www.researchgate.net/publication/362284584_Starch_Extraction
- Steven, S., Fauza, A. N., Mardiyati, Y., Santosa, S. P., & Shoimah, S. M. (2022). Facile Preparation of Cellulose Bioplastic from *Cladophora* sp. Algae via Hydrogel Method. *Polymers*, 14(21), 4699. <https://doi.org/10.3390/polym14214699>
- Yazid, N. S. M., Abdullah, N., Muhammad, N., & Matias-Peralta, H. M. (2018). Application of Starch and Starch-Based Products in Food Industry. *Journal of Science and Technology*, 10(2). <https://penerbit.uthm.edu.my/ojs/index.php/IST/article/view/3022>
- Zhou, H., Mao, Y., Zheng, Y., Liu, T., Yang, Y., Si, C., Wang, L., & Dai, L. (2023). Complete conversion of xylose-extracted corncob residues to bioplastic in a green and low carbon footprint way. *Chemical Engineering Journal*, 471, 144572–144572. <https://doi.org/10.1016/j.cej.2023.144572>

