

Bio-enzymes - Innovative Solution for Green and Sustainable Products.

Abstract - As concerns about the environmental and health effects of chemical based household cleaners increase, there is an increase in interest towards finding safer and sustainable alternatives. One effective solution to this is the use of bio-enzymes, which are natural cleaning solutions produced by fermenting organic waste. This study explored the creation of homemade bio-enzymes using discarded orange peels, and tested their potential as environmentally friendly household cleaning products.

To produce the bio-enzyme, orange peels were fermented with brown sugar and water over a three-month period. Throughout the fermentation process, pH measurements were recorded and observations regarding the color, odor, and gas production were noted to monitor the development of the solution. After the fermentation process was complete, the cleaning effectiveness of the homemade bio-enzyme was compared to a commercial household cleaner on a standard surface.

The results show that the pH of the bio-enzyme gradually decreased from 5 on the first day to 3 after a three-month period of fermentation indicating a successful fermentation process. Throughout the experiment, the solution also went through visible changes in color, odor, and gas production. During cleaning tests, the homemade orange peel bio-enzyme effectively removed common household stains and performed similarly to the commercial cleaner.

Overall, the findings suggest that homemade orange peel bio-enzymes can be used as a practical, low-cost and environmentally friendly alternative to conventional household cleaners. In addition to reducing the use of chemical-based cleaning products, this approach demonstrates how citrus food waste can be repurposed into a useful household product, supporting both waste reduction and sustainable cleaning practices.

Introduction - Food waste has become a significant global concern as approximately $\frac{1}{3}$ of all food produced worldwide is discarded. A large portion of this waste is sent to landfills, where it decomposes under anaerobic conditions and releases greenhouse gases such as methane. This gas contributes heavily to climate change and is increasingly an environmental priority. Among the different forms of food waste, citrus peels from oranges, lemons, and limes are frequently tossed out despite containing valuable organic compounds that can be repurposed for sustainable products. Identifying effective methods to utilize this waste has emerged into an important environmental challenge.

When organic waste accumulates in landfills, the resulting methane emissions amplify environmental impacts due to the strong impact of methane gas. This results in significantly higher global warming potential compared to carbon dioxide. As global populations continue to rise, reducing food waste and developing sustainable strategies for managing organic by-products have become priorities regarding environmental sustainability.

Citrus fruits are among the most widely consumed fruits globally. Their peels can consume nearly half of the fruit's total mass. Despite this substantial proportion, citrus peels are typically discarded after the edible portion is consumed. Although commonly treated as waste, citrus peels contain a variety of valuable natural compounds, including enzymes, essential oils, sugars, and organic acids, which have potential to develop environmentally sustainable products.

The beneficial bioactive compounds within the peels are lost rather than recovered for repurposing. Re-using citrus waste and turning them into useful materials or products offers an opportunity to reduce environmental impacts while supporting more sustainable waste management practices. As interest in environmentally friendly products continues to grow, the

utilization of citrus peels represents a pathway for reducing organic waste and enhancing the interest of sustainability.

Many household cleaning products contain synthetic chemicals that can affect both human health and the environment. Chemicals such as ammonia, chlorine, and phosphates can enter waterways after use, which contributes to water pollution. In addition, the regular exposure to these chemicals may cause irritation to the skin, allergic reactions, or respiratory issues especially for people who use them frequently. Because of these concerns, more people are looking for cleaning products that are safer, biodegradable, and made from natural ingredients while offering the same performance.

Bio-enzymes represent a promising alternative to cleaning products with natural cleaning agents. Bio-enzymes are produced through fermentation of fruit or vegetable waste combined with water and sugar over an extended period of time. During this fermentation process, microorganisms break down organic matter and generate compounds that are capable of removing dirt, grease, and odors. Because bio-enzymes are biodegradable and can be produced from food waste, they offer a sustainable alternative to conventional chemical-based cleaning products. Their potential to reduce reliance on synthetic cleaning agents helps promote environmentally responsible waste management and support a regenerative system.

Although bio-enzymes are becoming more popular as environmentally friendly cleaning options, many households continue to rely on commercial cleaners. This is largely due to the limited awareness of bio-enzymes. More research is needed to determine whether bio-enzymes produced from everyday orange-peel waste can serve as an effective and sustainable alternative. A strong understanding of bio-enzymes can help support sustainability and repurposing efforts.

Therefore, this study focuses on producing homemade bio-enzymes from discarded orange peels and evaluating their effectiveness as an environmentally friendly cleaning product. By transforming food waste into a biodegradable cleaner, this research highlights a simple and sustainable method for reducing organic waste while encouraging an eco-friendly household. It also demonstrates how everyday materials can support sustainability efforts.

Literature Review - Study 1: Chen, Hun and Department of Biomedical Engineering and Environmental Sciences, National Tsing Hua University, Hsinchu, Taiwan. “What Are Bio-enzymes Cleaner? And How It Is Used.” *J Biochem Biotech*, journal-article, 5 June 2023, pp. 1–2. www.alliedacademies.org/articles/what-are-bioenzymes-cleaner-and-how-it-is-used.pdf.

Growing concerns about environmental pollution and the heavy use of chemical-based household cleaners have led researchers to look for safer, more sustainable cleaning options. Many commercial cleaning products contain synthetic chemicals such as phosphates, chlorine, ammonia, and nitrates which can contribute to water and air pollution. This poses risks to both human health and the environment. As awareness of these issues increase, the interest has shifted toward natural cleaning products made from organic waste.

A promising alternative is the use of bio-enzymes. Chen describes bio-enzymes as biodegradable cleaning solutions created by fermenting fruit or vegetable waste with sugar and water. During fermentation, naturally occurring microorganisms break down organic matter and produce enzymes and organic acids that help remove grease, stains, and odors. Chen also

mentions that bio-enzymes can be made using simple household materials, making them both affordable and environmentally friendly. They also help reduce food waste by turning discarded fruit peels into a useful cleaning product promoting sustainability and repurposing efforts.

Orange peels are commonly used for bio-enzyme production because they contain natural compounds like citric acid and limonene, which may improve cleaning performance. Using citrus waste in this way creates a biodegradable cleaner and also reduces the amount of organic waste sent to landfills.

While Chen explains how bio-enzymes are made and highlights their environmental benefits, the work mainly provides an overview rather than experimental evidence. The study does not examine the effectiveness of the bio-enzyme solution. By comparing how the bio-enzyme solution cleans to commercial cleaners gives a clear understanding of the potential benefits of bio-enzymes. Without evidence of how well the bio-enzyme works, it cannot be concluded that they are an effective alternative to commercial cleaners.

To address these gaps, this study produces homemade bio-enzymes from discarded orange peels and evaluates their effectiveness as an eco-friendly cleaner. By comparing the cleaning performance of the bio-enzyme to a commercial product using a variety of surfaces and stains, this research aims to provide practical, and experimental data for using orange-peel bio-enzymes as an alternative to commercial cleaning products.

Study 2: Dhavale, Varun, et al. "BIO ENZYMES FROM ORGANIC WASTE." *Journal of Emerging Technologies and Innovative Research*, vol. 7, no. 8, 2020, pp. 196–97.

www.jetir.org/papers/JETIR2008330.pdf.

The increasing concern for organic food waste, and environmental pollution has encouraged researchers to explore sustainable alternatives that contribute to reducing pollution while making use of the discarded waste. Because of these concerns, there has been an increase in interest for using natural, biodegradable cleaning products made from organic waste.

One alternative for these conventional cleaners is bio-enzymes. According to Dhavale, bio-enzymes are produced by fermenting fruit or vegetable waste with sugar and water. During the fermentation process, microorganisms break down the organic material and produce enzymes and organic acids that help remove grease, stains, and unpleasant odors. Since bio-enzymes are made from food waste, they offer an environmentally friendly way to reduce waste while creating a useful household cleaning product.

In addition to their use as household cleaners, bio-enzymes have been studied for several other reasons. Dhavale explained that they have the potential to be used in agriculture, wastewater treatment, soil improvement, and environmental cleanup. Their ability to replace or reduce the use of harsh chemical products makes them great for promoting more sustainable efforts.

The researchers also described the process used to produce homemade bio-enzymes. The mixture is typically prepared by using a ratio of one part sugar, three parts organic waste, and ten parts water followed by the fermentation period for approximately three months. During the fermentation process, microorganisms produce enzymes and organic acids that give the final solution cleaning agents. The study emphasized that maintaining proper fermentation conditions is important for producing a stable and effective bio-enzyme.

Although Dhavale provided a thorough overview of how bio-enzymes are produced and discussed the potential environmental benefits, the paper focused mainly on summarizing existing research rather than testing the performance of homemade bio-enzymes. For example, the paper did not examine how the pH levels change throughout fermentation or compare the cleaning ability to commercial cleaners in typical households. These are important questions because they help determine whether bio-enzymes are effective for everyday use and if they can realistically be used as an alternative to commercial cleaning products. Building on this research, the present study investigates the production of homemade bio-enzymes using discarded orange peels and evaluates their effectiveness as a household cleaning product. By monitoring changes in pH during fermentation and comparing the cleaning performance of the bio-enzyme with a typical household cleaner, this study provides additional evidence on how practical and environmentally beneficial it is to use bio-enzymes.

Research Question - Can homemade orange peel bio-enzymes effectively replace commercial household cleaners while reducing citrus food waste?

Hypothesis - Homemade orange peel bio-enzymes will effectively clean common household stains and will demonstrate properties that make them a sustainable alternative to commercial cleaning products.

Materials and Methods - The materials used in this study included fresh orange peels collected from regular household use, brown sugar, distilled water, plastic containers for fermentation, measuring cups, and pH strips. Once the bio-enzyme solution was ready, they were stored in

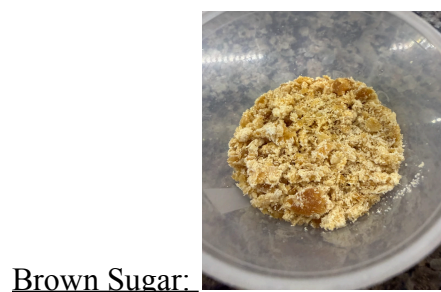
clean glass bottles. Standard household cleaning products were used during the cleaning evaluations. A commercial all-purpose cleaner was chosen as the comparison product for evaluating the cleaning performance of the bio-enzymes.

To make the bio-enzyme, the commonly used fermentation ratio of 1:3:10 was used with brown sugar, orange peels, and water. The orange peels were washed to remove dirt and then cut into small pieces to help them ferment more easily. The brown sugar was dissolved completely in distilled water before adding the orange peels. The mixture was poured into a plastic container leaving about 20% of the space empty in order for gas production during the fermentation process. The container was kept indoors at room temperature in a spot away from direct sunlight. For the first month, the container was opened briefly once a day to release the gases produced. The mixture was stirred once a day to enhance the enzymatic activity. The fermentation continued for 90 days, after which the mixture was strained using a fine mesh filter. The liquid bio-enzyme was collected and stored in glass bottles for testing.

Throughout the fermentation process, both physical and chemical changes were monitored. Once a week, the pH of the mixture was measured using pH strips. All measurements were recorded in a notebook and later organized into tables and graphs for data analysis. Qualitative changes were also observed weekly including color change, smell, bubble formation, and any visible microbial growth. Photos were taken regularly to document how the mixture changed over time.

After fermentation was complete, the solution was diluted with 10 parts water to reduce the acidic nature and the cleaning ability of the homemade bio-enzyme was compared to a commercial all-purpose cleaner. Identical test surfaces were prepared. Each surface was stained

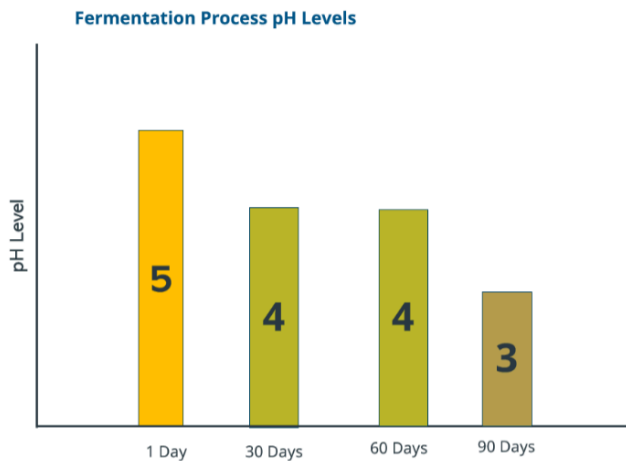
with the same amount and type of grease, to keep the tests consistent. Equal volumes of 2.5 mL of the bio-enzyme and commercial cleaner were applied to test surfaces. Each solution was left on the surface for about 5 minutes, then wiped using identical microfiber cloths with the same cleaning motion. Cleaning performance was judged based on how much of the stain was removed, how easy the surface was to clean, and whether any residue remained on the surface. Each test was repeated 3 times to improve reliability and the average test results were calculated.



Results - Several changes were observed throughout the three-month fermentation process. During the first few weeks, small bubbles formed inside the container, and gas buildup was noticeable when the lid was open. The solution gradually changed from a light orange color to a darker brownish orange color as the fermentation process continued. The fresh citrus smell also became milder and developed a fermented scent over time. By the end of the fermentation

period, most of the orange peels had broken down. No visible mold growth or unusual discoloration was observed during the experiment.

pH results:



The pH of the bio-enzyme was measured at four checkpoints throughout the fermentation process to monitor changes over time. On the first day, the solution had a pH of 5. After 30 days, the pH decreased to 4 and remained at 4 on day 60. By the end of the 90-day fermentation process, the pH had decreased further to 3. The results showed a gradual decrease in pH throughout the fermentation process, indicating that the solution had become more acidic over time.

Cleaning Performance:



After the fermentation process was completed, the homemade orange peel bio-enzyme was tested in comparison to a commercial household cleaning product on the same surface and identical stains. Both cleaning solutions were able to remove the stains, although there were some differences in their overall performance. The first image represents the cups before using any type of cleaning solutions, and the second image shows the after results of using bio-enzyme solution on one cup and dish soap on the other cup.

The homemade bio-enzyme effectively removed grease stains from a dish and left the surface cleaner after wiping. The commercial cleaner produced similar results and was able to remove the stain slightly faster under the same testing conditions. The bio-enzyme solution left a mild citrus scent while the commercial cleaner had left a stronger chemical odor.

Overall, the fermentation process produced a stable bio-enzyme that demonstrated effective cleaning performance. The pH decreased throughout the experiment, and the finished solution performed similarly to the commercial cleaner during the cleaning tests.

Data Analysis - The pH measurements showed a consistent decrease throughout the 90-day period of fermentation. The solution began at 5 on day 1, decreased to 4 by day 30, remained at 4 on day 60, and reached a final pH of 3 on day 90. Although the pH remained stable between days 30 and 60, the overall trend indicates that the solution has become progressively more acidic as

fermentation continued. A lower pH indicates successful fermentation and helps preserve the bio-enzyme by creating an acidic environment that prevents the growth of harmful microorganisms. An acidic environment also helps support the stability of the bio-enzyme, making it ready for long-term storage and a household cleaning solution.

The physical changes observed throughout the experiment showed that the fermentation process was progressing as expected. During the first few weeks, bubbles and gas were produced as the mixture became more active. This is an indication that fermentation was taking place correctly. As time went on, the solution slowly changed from a light orange color to a darker brownish orange color, which suggests that the orange peels were continuing to break down. The fresh citrus smell also became milder and developed a more fermented scent over time, which is another sign that the bio-enzyme was developing properly. Together, these physical observations support the pH trend and indicate that the fermentation process was taking place correctly.

The cleaning tests showed that the homemade bio-enzyme was able to remove common household stains such as grease and visibly clean the test surface. The bio-enzyme produced similar results to a common household cleaner which indicates that the bio-enzyme is able to effectively serve as an alternative to chemical based cleaners on stains such as grease. Future research can add onto this research by testing multiple different types of stains on different surfaces.

Discussion - Changes in pH Fermentation: The pH readings taken throughout the fermentation process helped show how the bio-enzyme mixture changed over time. As the days passed, microorganisms broke down the sugars and organic materials in the orange peels. This process produced organic acids, which caused the pH to slowly drop and the mixture to become more

acidic. The steady decrease in pH showed that fermentation was happening successfully and that microbial activity stayed active throughout the experiment. Once the pH began to level off it suggested that the mixture had reached a stable stage that was ready to be used as a cleaning solution. Overall, the weekly pH measurements were a simple but important way to track the progress of fermentation and confirm that the bio-enzyme was developing successfully.

Cleaning Effectiveness of the Homemade Bio-Enzyme: Cleaning tests were done to see how well the homemade orange peel bio-enzyme worked compared to a commercial cleaner. The results showed that the bio-enzyme was able to remove grease from dish-like surfaces with high effectiveness. The cleaning ability of the bio-enzyme likely came from the natural compounds formed during fermentation. Organic acids can dissolve certain stains and mineral buildup, while citrus oils help break down grease and oily residues. These natural ingredients work together to create a cleaning effect without relying on synthetic chemicals found in many store-bought cleaning products. Although commercial cleaners may have shown similar cleaning performance, the homemade bio-enzyme had several environmental benefits. It was made from food waste, required only simple household materials, and resulted in a biodegradable cleaning solution. These advantages suggest that bio-enzymes can be a sustainable option for everyday cleaning tasks.

Significance of the Findings: The results of this study show that organic food waste, specifically orange peels, can be turned into a useful household product through a simple fermentation process. By converting discarded peels into a cleaning solution, this project demonstrates a practical way to reduce food waste while creating something environmentally friendly. In

addition to cutting down on waste, homemade bio-enzymes may help reduce the use of chemical-based cleaners that can harm the environment. While more research would help strengthen these findings, this study suggests that orange peel bio-enzymes are a promising, low-cost, and eco-friendly alternative for household cleaning. This supports the efforts of repurposing and sustainability.

Limitations - There are a few limitations to consider when interpreting the results. This experiment used only one type of citrus peel and was carried out under basic household conditions, meaning factors like room temperature and natural microbial activity may have affected the fermentations. The cleaning tests also covered only a small number of stain types and surfaces. Future studies could expand on this by testing different food scraps, using more controlled conditions, testing a wider variety of stains, and measuring enzyme-activity more precisely. Doing so would give a more complete understanding of how homemade bio-enzymes perform and how they can be improved.

Future Research - Future research can help further evaluations based on the results of this study and improve the understanding of how homemade orange-peel bio-enzymes can be used as effective, eco-friendly cleaning products. While this project showed that bio-enzymes have potential, there are many ways this concept can be explored further.

One important direction for future studies is testing how different fermentation conditions such as temperature, humidity, and how long the mixture ferments, affect enzyme production and cleaning ability. Finding the best conditions could make the fermentation process more efficient and help produce a more consistent product.

It would also be helpful to measure enzyme concentration and activity throughout fermentation. Knowing how enzyme levels change over time could lead to a consistent guideline for making bio-enzymes, thus improving product consistency, and identifying the ideal fermentation period for the strongest cleaning performance.

Future studies could also explore whether orange-peel bio-enzymes have potential to become a commercial cleaning product. Research on production costs, shelf life, packaging, storage stability, and consumer interest would help determine whether bio-enzymes could be produced on a larger scale as a sustainable cleaning option.

Finally, expanding cleaning tests to include a large variety of stains, surfaces, and real-world cleaning situations would give a better understanding of how versatile bio-enzymes really are. This would help identify where they work best and where improvement might be needed.

Overall, continued research in these areas would deepen the scientific understanding of homemade bio-enzymes and support the development of cleaning products that reduce food waste, limit the use of synthetic chemicals, and encourage sustainable household habits.

Conclusion - This study explored the use of homemade orange peel bio enzymes as a natural alternative to commercial household cleaners. Over the 90-day fermentation period, the bio-enzyme showed clear changes in color, odor, and pH, indicating that the fermentation process was successful. Compared to the commercial cleaner, the homemade bio-enzyme was able to effectively clean common household stains such as grease, producing similar results to common household cleaning products such as dish soap.

These findings suggest that bio-enzymes made from orange peels can be an effective and environmentally friendly cleaning solution. In addition to reducing the use of chemical-based cleaners, they provide a practical way to reuse citrus waste that would have been discarded. While more research could further explore their long-term effectiveness and additional uses, this study shows that simple household materials can be turned into a useful, low-cost product with environmental benefits.

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