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Harnessing Citrus Waste to Create Sustainable Cleaning Products: The Potential of Citrus Eco-Enzymes

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Abstract

Eco-enzyme is a natural substance that is typically extracted from waste materials and citrus fruit peels, among other sources. It is a sophisticated mixture made from fermenting fresh kitchen trash, including fruit and vegetable peels. This kind of vinegar is created by fermenting food scraps and sugar to produce alcohol. Eco-enzyme is a fermented solution mostly composed of water, fruit peels, and sugar in a 1:3:10 ratio. Because of the phenolic profile and antioxidant qualities of citrus fruit extracts and flavonoids, this review focuses specifically on the citrus eco-enzyme. These compounds may have intriguing biological activities. A thorough discussion of the various inventive methods employed to create eco-enzymes from various raw materials has been held. These methods have several uses, are inexpensive, and are environmentally benign. The synthesis of eco-enzyme reduces the accumulation of organic waste and offers an alternative to synthetic chemicals that are detrimental to the environment and human health. Nonetheless, the main uses have been covered in this review, including cleaning floors, dishes, gardening, and other creative ways to recycle and reuse natural waste that can help cut down on fruit waste.

Keywords: Eco-enzyme; Citrus waste; Antioxidant properties; Sustainable cleaning; Phenolic compounds; Biodegradable solutions

1. Introduction

One of the most popular fruits in the world, citrus (Citrus L. from the Rutaceae family) contains potent compounds that have potential health benefits. Peels from citrus fruits are used because they possess distinct properties such as aroma and taste, are rich in vitamin C, and have a high acidity value and therapeutic properties [1] Citrus fruits are frequently eaten raw or juiced, and the peel is usually thrown away as waste even though it has a variety of secondary components with a high level of antioxidant activity when compared to other fruit parts.[2] The production of citrus fruits worldwide has expanded dramatically in recent years, surpassing 144 million metric tons, according to the UN Food and Agriculture Organization. Consequently, a significant amount of peel is generated annually [3] Citrus peels have distinct Mesocarp or albedo (soft white inner layer) and Epicarp or Flavedo (colored peripheral surface). Citrus is a fruit that promotes good health since it includes polyphenols, vitamins, minerals, dietary fiber, essential oils, and carotenoids, according to several studies. [4] Enzymes like lipase, amylase, and protease will be very helpful in reducing the amount of proteins, carbs, and fats throughout the breakdown process.

The resulting enzyme functions as an insecticidal, antifungal, and antibacterial agent [5] it is a useful cleaning agent as well. In the future, producing eco-enzymes will not only help reduce the amount of waste dumped in landfills, but it will also give as an alternative to synthetic chemicals, which are harmful to the environment and human health[6]. Proteins called enzymes function as catalysts. Without being consumed by the reaction, enzymes reduce the amount of energy needed for a reaction to occur. Enzymes are used by a wide range of industries to help in the production of their goods. [7] Many different companies have used enzymatic processes in recent decades due to their specificity, quickness of response, and frequent conservation of chemicals, energy, and raw materials [8]. Over the past 15 years, a number of comparative environmental assessment studies have been carried out to examine if these characteristics of enzymatic activities result in environmental improvements and evaluate whether they could be involved in moving in the direction of greener industrial production [9].However, because they promote selective reactions and are biodegradable, enzymes have gained popularity in cleaning products. A certain amount of lipase and cellulose enzymes are typically present in the compositions of numerous cleaning detergents used in certain applications, such as dishes and cotton clothing [10].Biological agents are being used more and more in industrial and medical settings due to societal pressure to decrease the usage of dangerous chemicals [11]. Enzymes are used in a wide range of businesses to produce items. An industrial approach for producing enzymes is fermentation. Microorganisms such as bacteria and yeast are used in fermentation to manufacture enzymes. Enzymes catalyze and provide energy [12].

Biological response that increases the rate of reaction and has excellent selectivity [13]. Enzyme bio-cleaners are an organic solution made from fresh fruit wastes fermented simply with the addition of water and brown sugar utilizing yeast and other specific microorganisms [14]. Natural chains of proteins, mineral salts, organic acids, alcohol, and enzymes are produced throughout this fermentation process. This solution's ability to break down, alter, generate, and catalyze processes makes it an excellent cleaning tool for use in industrial, medicinal, and residential settings [15]. Food waste is classified as organic solid waste because it contains large amounts of organic matter, which eventually decomposes and produces carbon dioxide and methane. Common methods of disposing of organic waste thrown into landfills have caused serious environmental problems, pollution and health risks to living beings.

Only 1% of residents tend to throw trash into nearby bushes. In-depth health consultation is necessary as the practice may lead to the spread of the disease [16]. It is anticipated that these natural disinfectants would outperform commercial disinfectants due to their lower cost and greater availability [17]. Four primary processes are typically included in the citrus processing industries. Citrus fruits are shipped to production factories after being harvested. The fruits are then graded in a first stage, and then, once the dirt has been removed, they are stored so that the second step water-washing or cleaning can begin. The third process involves pressing and centrifuging the fruit juice to extract the juice. After heating the juice to activate the pectic enzymes, it is transferred to syrup tanks for concentration. To ensure the highest quality, citric acid, enzymes, and vitamin C are added [18]. Some lipids, free sugars (such as glucose, fructose, and sucrose), organic acids, pectinesterase, phosphatase, and peroxidase, flavonoids, essential oils (mostly limonene), and pigments are all included in this composition [19]. The backbone of the chemical and energy industries is catalysis. Catalysts that are energy-efficient has great potential to alter a reaction's rate in a desired manner [20]. A catalyst is used to accelerate a chemical reaction. A poison's addition could negatively impact a catalyst's action. A catalyst won't, however, "poison" a reaction's rate When they are found in two distinct phases, they are referred to as heterogeneous catalysts [21]. When they are found in one phase, they are referred to as homogeneous catalysts. Proteins called enzymes function as biological catalysts and are employed to regulate the rate of chemical reactions Because it is biodegradable, it is one of the finest substitutes for traditional chemical catalysts [22]. One way to characterize fermentation is as a chemical transformation achieved with the use of microbes. A few examples of chemical transformations that involve microbes are food additives, animal feed products, pharmaceutical manufacturing, etc. [23] Conversely, it can also be done in the presence of oxygen, or in aerobic conditions . Molasses help since it serves as a carbon source and a complexing agent during the fermentation process, leaving the treatment of organic chlorides untouched [24]. Larger particles (such as soil and organic waste) are broken down into tiny bits by beneficial bacteria during the fermentation process [25].Additionally, it produces ozone, nitrates, carbonates, and other products Ozone gas lowers the atmospheric concentration of carbon dioxide and heavy metals, which trap heat[26]. Bio enzymes are a complex mixture of different bioactive ingredients, including vitamins, minerals, proteins, and salts. They are created as a by-product of the natural microbial flora fermenting vegetable or fruit scraps. This approach is so straightforward and economical that it utilizes Basic components like jaggery, which is rich in probiotics like Lactiplantibacillus plant arum and serves as both the carbon source and a carbon sink [27]. One strategy to lower the generation of food waste is to use fermentation to turn organic waste from fruits and vegetables into an Eco enzyme [28].

1.1 Manufacturing and Features :

Ingredients: Fresh kitchen waste, such as fruit and vegetable peels, are fermented to produce Eco enzyme [29]. Unique Features: Orange peels, for example, are frequently utilized because of their potent flavor, scent, high acidity, and abundance of vitamin C [30]. Functionality: Eco enzyme can be used as a mopping liquid, kitchen cleaner, vegetable and fruit cleaning, bug deterrent, and fertilizer for plants, among other things [31].The process of making eco-enzymes often involves combining sugar, fruit waste, and water [32]. In general, these enzymes can be made from most kitchen trash, including fruit and vegetable peels. Peels from fruits and vegetables that are high in organic acid are the best source of eco-enzymes [33]. Orange and tomato peels include eco-enzymes that have strong antiseptic qualities. These enzymes can be used to remediate aquaculture sludge, improving aerobic digestion and lowering environmental issues [34].The peels of fruit or vegetables are collected, thoroughly washed with water, and then cut into little pieces [35]. Brown sugar is then added to the water and mixed evenly until it dissolves completely, and the fruit peels are finally chopped [36]. To shorten the fermentation period even more, a small amount of yeast is added. It is then sealed in an airtight container and allowed to incubate for three months [37]. A glass or wooden rod is used to stir the liquid every day in order to release the gas created during fermentation [38].

1.2 Properties of biological enzymes :

These are proteinous molecules with a high molecular weight.By quickening chemical reactions, they function as biological catalysts [39]. They change particular substrates into different molecules through interactions with them [40]. They have special amino acid links that combine to create interesting forms. The co-factor, a non-protein component, is also present in the majority of enzymes [41]. Plant growth is facilitated by the presence of live microorganisms in bioenzymes, which increase the availability of nutrients [42].

2. Production of Bio-enzyme from fruits, vegetables and organic sources

A natural, environmentally friendly cleansing and disinfection, eco-enzyme is derived from fruits and other organic components [43]. It is frequently used as a substitute for abrasive cleaners that contain chemicals. You can use ripe fruits to make eco-enzyme from fruit sources [44]. To create a pulp, the fruits were pureed. To hydrate the pulp, water was introduced to a container containing the pulp. The same quantity of sugar was added, and it was swirled until it totally dissolved [45]. Proteins called enzymes function as biological catalysts. They do not undergo permanent modification; instead, they quicken the pace of a chemical reaction [46]. Fruits, vegetables, and plants are examples of natural or organic resources that are used to make eco enzymes. Food scraps and other organic waste are broken down into smaller, less toxic molecules with the aid of these enzymes [47]. To lessen pollution, they are utilized in composting, bioremediation, and wastewater treatment. Eco enzymes can also be used in the food production process to enhance the flavor, texture, and shelf life of processed goods [48].

3. Characterization of eco-enzyme

Eco-enzymes are multipurpose, high-enzyme solutions made from fermented vegetable or citrus waste. They have special qualities that enable them to be used effectively for wastewater treatment and environmentally friendly cleaning. In order to describe eco-enzymes, this section looks at important factors such as pH, total dissolved solids (TDS), chemical oxygen demand (COD), biological oxygen demand (BOD), and their uses in wastewater treatment.

3.1 Role of pH in eco enzyme:

The pH scale, which ranges from 0 to 14 with 7 representing neutrality, is often used to determine how acidic or alkaline a solution is. Like most proteins, enzymes function best at a specific pH [49]. Although the pH range may differ based on the enzyme and the surroundings, most enzymes function optimally around a pH of 7.0–8.5 [50]. Eco enzymes produced from fruit waste typically have a somewhat acidic pH [51]. Depending on the kind of fruit waste utilized and the mixture's makeup, the pH of the eco enzyme might vary from 4.5 to 6.5 [52]. The amount of water added and the length of the fermentation process will also affect the pH of the eco enzyme. In general, the pH decreases with increased fermentation time [53].

3.2 Total dissolved solids (TDS) and their function in eco-enzyme :

The whole amount of dissolved salts, minerals, and organic materials in the solution is measured by the total dissolved solids (TDS) of eco enzyme. This can vary from 0 to over 1000 ppm, depending on the particular formulation [54]. Eco Enzyme's total dissolved solids (TDS) usually consists of organic matter, vitamins, amino acids, and naturally occurring minerals, with a concentration of 200–400 ppm [55]. Considering its low TDS in comparison to other cleaning agents, Eco Enzyme is a safe and efficient option [56]. The total dissolved solids (TDS) of eco enzyme measure the total quantity of dissolved salts, minerals, and organic components in the solution [57]. This can vary, depending on the specific formulation, from 0 to over 1000 ppm. Total dissolved solids (TDS) in Eco Enzyme often contain 200–400 ppm of organic materials, vitamins, amino acids, and naturally occurring minerals [58]. With its lower TDS than other cleaning solutions, Eco Enzyme is a secure and effective choice [59].

3.3 Eco-enzyme function of biological oxygen demand (BOD) :

Biological oxygen demand (BOD) measures the amount of oxygen microorganisms consume in the oxidation and assimilation of organic matter [60]. Eco enzymes are an enzyme-based bioremediation product used to reduce the BOD levels in wastewater. The enzymes in eco enzymes break down organic matter, releasing oxygen into the water, thereby reducing the amount of oxygen consumed by the microorganisms. This reduces the BOD levels in the water, making it safer for aquatic life and humans [61]. The amount of oxygen needed by microbes to break down organic materials in a particular water sample is measured by biological oxygen demand, or BOD [62]. The amount of oxygen required to break down organic matter increases with BOD, which means that other aquatic life has less oxygen available. An organic, biodegradable substance derived from vegetable waste is called eco enzyme [63]. Its purpose is to disintegrate organic waste into smaller pieces so that microorganisms can more easily eat it. The BOD of the sample rises during the production of eco enzymes from vegetable waste because more oxygen is needed for the microorganisms to break down the organic matter [64].

3.4 Chemical oxygen demand (COD) and its function in eco-enzymes :

The amount of oxygen needed to oxidize the organic and inorganic materials in a sample of water is measured by the chemical oxygen demand, or COD. A naturally occurring microbial product called eco enzyme is used to clean wastewater [65].Eco enzyme is a safe and effective way to reduce COD levels in wastewater, making it an important tool for improving water quality [66]. Fruit waste has been found to have a high Chemical oxygen demand (COD) when used as an eco-enzyme. COD is a measure of the amount of oxygen required to oxidize organic compounds in a given sample [67]. Depending on the kind of vegetables utilized, the chemical oxygen demand (COD) of eco enzyme made from vegetable waste can change dramatically [68]. Since vegetable waste contains a lot less nitrogen and phosphorus compounds than animal waste, the COD levels of eco enzyme produced from vegetable waste are often lower than those produced from animal sources [69]. Furthermore, the kind of vegetables utilized can affect the COD levels of eco enzyme made from vegetable waste [70].

3.5 Possible application of eco-enzyme in the management of wastewater containing metals :

One of the best and most ecologically friendly ways to remediate metal-based wastewater is to utilize eco enzymes. Many other metals, including as cadmium, chromium, copper, lead, nickel, and zinc, can be treated with eco enzyme [71]. The eco enzyme is first added to the effluent to start the process. After that, the eco enzyme is let to react with the effluent's metals to create complexes. The amount of metals in the effluent is decreased in part by this process [72]. Eco enzyme is an efficient and environmentally acceptable method of treating metal-based wastewater. In a separate tank, the effluent should be collected and treated. The pH of the effluent should be adjusted to 6.5–7.5 for maximum eco enzyme activity [73]. Environmental enzymes can be used to degrade and remove metal-based effluents before they cause any environmental harm [74]. This safeguards the security of any water sources that metal-based effluents may have an impact on. Eco enzymes are also a cheap method of cleaning up water sources because they are easy to use and reasonably priced [75].

4. Applications of eco-enzymes

Biological enzymes, or bio enzymes for short, are organic compounds that catalyse a variety of chemical and biological processes [76]. These enzymes are essential for our bodies because they speed up chemical reactions and make digestion easier. They are also becoming more widely known for the many industries that use them [77].

4.1 Importance of Bio Enzymes in Various Applications

Bio enzymes are essential in many industries, including cleaning, waste management, wastewater treatment, and agriculture. They are an excellent option for sustainable practices due to their natural nature and environmentally beneficial qualities [77].

4.1.1 Bio Enzymes for Plants

- **Increasing the Health and Growth of Plants :** Bio enzymes have become a potent tool in agriculture, boosting yields, promoting healthy plant development, and improving overall plant health [79]. By decomposing organic debris in the soil, these enzymes increase plants' accessibility to vital nutrients [80].

- **The Advantages of Bioenzymes in Agriculture :** In addition to encouraging sustainable farming, the use of bioenzymes in agriculture lessens the environmental impact of traditional farming methods [81]. These enzymes support healthier ecosystems, lower chemical inputs, and improve soil health [81].

4.1.2 Bio Enzymes for Cleaning

- **Bioenzymes's Function in cleaning :** The ability of bio enzymes to clean is well known. Their ability to break down complex organic materials like as grease, protein, and starch renders them efficacious in eliminating stains and odors. They are therefore a crucial part of a bioseptic system that helps to break down household waste [83].

- **Utilizing Apps for Cleaning the Home :** Bioenzyme cleaners are a greener substitute for conventional chemical cleaning products in homes. They work just as well to clean drains, sanitize surfaces, and remove stains [85].

- **Advantages of Bio Enzyme Cleaners for the Environment :** By minimizing the amount of hazardous chemicals released into the environment, bioenzyme cleaners help to enhance indoor air quality and minimize carbon emissions. They are less hazardous to human health and biodegradable [86].

4.1.3Bio Enzymes from Organic Waste

- **Conversion of Organic Waste into Bio Enzymes :** One of the most remarkable applications of bio enzymes is in the conversion of organic waste into valuable enzymes [87]. Through a natural fermentation process, organic waste can be transformed into bio enzymes, providing a sustainable solution for waste management [87].

- **Sustainable Approach to Waste Management :** This approach to waste management not only reduces the burden of landfills but also generates useful enzymes for various applications [88].

4.1.4 Bio Enzymes for Wastewater Treatment

- **Function in Wastewater Treatment :** Bioenzymes are essential for treating wastewater. Sewage and industrial wastewater are treated by them to remove organic pollutants, allowing the water to be recycled or released into the environment [89].

- **Benefits of Treating Wastewater with Bioenzymes :** Bio-enzyme-based wastewater treatment is less expensive, more energy-efficient, and less harmful to the environment than conventional chemical treatments [90]. It is suitable for a variety of industrial applications and lessens the production of hazardous by-products [91].

- **Utilization in Commercial Environments :** Bioenzyme-based wastewater treatment is becoming more and more popular across a wide range of industries, including food processing, textiles, pharmaceuticals, and petrochemicals, as a means of lowering carbon emissions and complying with strict environmental laws [92].

4.1.5 Bio Enzymes in Agriculture

- **Enhancing Soil Health and Uptake of Nutrients :** The major benefit of using bioenzymes in agriculture is that they have a significant positive effect on soil health [93].

- **Decomposition of Organic materials:** Crop leftovers and organic mulch are examples of the organic materials that bioenzymes in the soil efficiently break down [94]. These materials break down into forms that plant roots may easily absorb, releasing vital nutrients including potassium, phosphorus, and nitrogen [95].

- **Improved Soil Structure:** Bioenzymes' actions result in better soil structure. They improve aeration and water infiltration by forming pores and channels in the soil through the breakdown of complex organic substances. Consequently, this lessens problems like compaction and waterlogging, which can impede the growth of roots and the absorption of nutrients [96].

- **Microbial Activity:** Beneficial soil microorganisms thrive in an environment that bioenzymes provide. These bacteria get sustenance from the decomposing organic materials, which increases their number and diversity [97].

4.1.6 Production of Bio Enzymes :

- **Procedures for Producing Bioenzymes :** A number of processes are involved in the creation of bio enzymes, such as source material selection, fermentation, extraction, and purification. Depending on the particular enzyme being synthesized, these steps may changes [98].

- **Required Ingredients and Materials :** Equipment for fermentation, appropriate source materials, and an understanding of the enzymatic process are required in order to manufacture bio enzymes. Furthermore, certain enzyme-producing species or microbial strains are essential [98].

4.1.7 Bio Enzyme Products

Commercial Bio Enzyme Products Commercial bio enzyme products are readily available in the market. They include cleaners, soil conditioners, fertilizers, and wastewater treatment solutions [99].

- **Availability and Accessibility :** These products are increasingly accessible to consumers through both physical stores and online marketplaces, making it easier for individuals and businesses to adopt sustainable practices [100].

- **Consumer Benefits :** Using bio enzyme products not only promotes a cleaner and greener lifestyle but can also lead to long-term savings and improved well-being [100].

- **Perspectives for the present and the future :** The production of fruits and vegetables has increased quickly in recent years, yet between 30 and 40% of these produce is lost annually, resulting in significant financial losses. These leftover fruit can be turned into value-added goods since they are a rich source of organic matter, phytochemicals, and compounds with advantageous nutraceutical properties. These leftover fruit can be turned into value-added goods since they are a rich source of organic matter, phytochemicals, and compounds with advantageous nutraceutical properties [101]. The majority of these residues are rich in nutrients and enzymes, including proteases, amylases, cellulases, and pectinase. Therefore, it can be utilized to create these enzymes in order to effectively utilize these lost fruits and vegetables and to stop additional financial loss. Citrus peels are a good source of eco-enzymes because of their high acid content. As a result, it's imperative to devise a productive method for reusing these peels, turn them into eco-enzymes, and research their numerous uses across several sectors and businesses [102].

5. Conclusion

Made from fruit peels, trash, brown sugar, and water, eco-enzyme is a multipurpose liquid that can be used as a cleaning agent. The ingredients utilized for the peels' fermentation, in addition to brown sugar and water, have a big influence on the yield of eco-enzymes. The goal of eco-enzyme manufacturing is to reduce the quantity of waste that ends up in landfills while also producing revenue. financial gain from the environmentally friendly enzyme liquid's many applications. The environment has been used a lot to treat liquid waste, filter lake water, improve air quality, and improve soil quality. Characteristic outcomes of the three-month-fermented eco-enzyme fulfil the criteria for being an excellent disinfectant, specifically the pH of 4 and the distinctive citrus scent of fermentation. Rather than using chemicals to produce the disinfectants, we can use fruit peels and other natural waste, by using this natural waste to produce the disinfectant can benefit the environment as well. Enzyme bio-cleaners are an organic solution made from fresh vegetable and fruit wastes simply fermented with water and brown sugar added, employing microorganisms such as yeast . This fermentation produces organic compounds, mineral salts, and natural chains of proteins . Alcohol, acids, and enzymes. This has been designed so that individuals can use leftover food scraps, vegetable and fruit waste from market stalls, and other wastes to make simple cleaning solutions at home or in small businesses, thereby reducing environmental pollution and contributing to the fight against global warming . One benefit of employing enzyme bio-cleaning solutions is that they are safer than conventional chemical cleaners and odor-control products for both the environment and human health. By quickly eliminating the soil, highly specialized enzyme-producing microorganisms clean and regulate odors. Economically speaking, it is less expensive and requires less production costs . This Bio-Cleaning solution offers steady application and residual cleaning for a longer amount of time. By replacing unfamiliar, potentially dangerous (disease-causing) bacteria with known, healthy microorganisms, this enzyme biocleaning solution helps to improve human health . The suggested effort aims to generate and analyze an enzyme bio-cleaning solution employing agricultural waste, such as fruit waste, and yeast (Saccharomyces sp.). inclusion of less expensive sources of carbohydrates, such as brown sugar and water medium.

Conflict of Interest

The authors declare there is no conflict of interest.

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