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# ECOFRIENDLY REDUCTION OF CARBONYL COMPOUNDS BY FREE AND IMMOBILISED BAKER YEAST

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## ABSTRACT

Many industrial processes involve carbonyl compounds, such as aldehydes and ketones. They are recognized to be harmful to both the environment and people's health. As a result, developing strategies for their reduction that are both efficient and sustainable is critical. This paper investigates the reduction of carbonyl compounds using baker yeast, both free and immobilized. The experiment required the preparation of Baker's yeast suspensions and the attachment of yeast cells to a solid support object. The efficiency of carbonyl reduction was evaluated by tracing the conversion of the target carbonyl compounds using gas chromatography-mass spectrometry (GC-MS) research. Several carbonyl compounds, such as aldehydes and ketones, were chosen as model substrates to test the performance of both free and immobilized baker yeast. Immobilized yeast shows potential for long-term, sustainable use due to its increased stability and reusability. The reduction reaction highlighted the ecologically friendly character of the procedure by using water as a green fluid and under mild reduction reaction conditions.It was investigated how several reaction variables, such as temperature, pH, and substrate concentration, affect the effectiveness of baker's yeast as a catalyst. The ideal conditions for a reaction were discovered in order to optimize the reduction yield while minimizing undesired side reactions.

## INTRODUCTION

Carbonyl compounds like aldehydes and ketones are ubiquitous in both natural and manmade chemistry processes. They are widely utilized as intermediates in the production of medicines, fragrances, polymers, and other industrial items. However, releasing carbonyl compounds into the environment can be harmful to ecosystems and people's health. Because of their high reactivity and possible toxicity, effective reduction is critical for sustainable growth and environmental preservation. Traditional carbonyl reduction processes frequently include the use of hazardous and costly reagents such as metal catalysts or reducing agents, which can generate toxic waste and have negative environmental consequences. As a result, there is a growing demand for environmentally friendly and sustainable options that may successfully eliminate carbonyl compounds while using less toxic reagents and producing less waste.

Enzymes, as biocatalysts, have gained considerable attention due to their high specificity, mild reaction conditions, and compatibility with aqueous environments. Baker yeast (Saccharomyces cerevisiae) is a well-known and readily available biocatalyst that possesses the necessary enzymatic machinery, such as alcohol dehydrogenases (ADH), to catalyze the reduction of carbonyl compounds. ADH enzymes facilitate the conversion of carbonyl compounds to their corresponding alcohols by utilizing nicotinamide adenine dinucleotide (NADH) or nicotinamide adenine dinucleotide phosphate (NADPH) as cofactors. (Singh, N.G,2014)

In this study, we explore the potential of baker yeast for the eco-friendly reduction of carbonyl compounds. We investigate the performance of both free and immobilized forms of baker yeast and evaluate their catalytic efficiency, stability, and reusability. Immobilization of yeast cells onto solid support materials offers advantages such as improved enzyme stability, easier separation of the catalyst from the reaction mixture, and the possibility of continuous operation.

The aim of this research is to develop a sustainable and efficient method for carbonyl reduction that utilizes baker yeast as a biocatalyst, thereby minimizing the environmental impact associated with traditional reduction processes. By optimizing reaction conditions and assessing the influence of various parameters, we aim to provide insights into the factors affecting the catalytic performance of baker yeast and its potential for industrial applications.

**NEED OF THE STUDY**

The need for the study on the eco-friendly reduction of carbonyl compounds by free and immobilized baker yeast stems from several important reasons.

Carbonyl compounds such as aldehydes and ketones are widely employed in industrial operations, including the production of pharmaceuticals, polymers, and specialty chemicals. The release of these compounds into the environment can have adverse effects. They have been shown to contribute to air pollution, including smog and secondary organic aerosols, which can have significant effects on air quality and human health. We can decrease the release of these compounds and their detrimental effects on the environment by developing ecologically friendly reduction procedures.

Traditional reduction methods for carbonyl compounds often rely on the use of hazardous reagents and harsh reaction conditions. These methods can generate toxic waste and have a high energy demand. In contrast, biocatalysts using baker yeast offers a more sustainable and environmentally friendly approach. Baker yeast is readily available, cost-effective, and possesses the necessary enzymatic machinery to catalyze the reduction of carbonyl compounds. By utilizing yeast as a biocatalyst, we can reduce the reliance on harmful reagents and promote the use of renewable resources, leading to greener and more sustainable chemical processes. Additionally, the immobilization of yeast cells onto solid support materials provides advantages such as improved stability and recyclability of the catalyst. Immobilized yeast allows for continuous operation and facilitates the separation of the catalyst from the reaction mixture, reducing downstream processing and minimizing waste generation. Exploring the performance of immobilized baker yeast in carbonyl reduction is crucial to assess its potential for large-scale industrial applications. Moreover, this study addresses the need for the development of green chemistry practices. Green chemistry aims to design chemical processes that are more sustainable, energy-efficient, and environmentally benign. By utilizing baker yeast for the reduction of carbonyl compounds, we contribute to the advancement of green chemistry principles and promote the adoption of eco-friendly alternatives in chemical synthesis.( Silva, V.D,2018)

**CARBONYL COMPOUNDS**

Carbonyl compounds are a diverse class of organic compounds that play essential roles in both natural and synthetic chemistry. They contain the carbonyl functional group, which consists of a carbon atom double-bonded to an oxygen atom (C=O). This functional group imparts unique chemical properties to carbonyl compounds, making them highly reactive and versatile. Carbonyl compounds can be broadly classified into two main categories: aldehydes and ketones. Aldehydes have at least one hydrogen atom bonded to the carbonyl carbon, while ketones have two carbon atoms bonded to the carbonyl carbon. This subtle difference in structure leads to distinct reactivity patterns. Carbonyl compounds participate in a wide range of reactions, including oxidation, reduction, nucleophilic addition, and condensation reactions. These reactions allow for the synthesis of various functionalized organic molecules, making carbonyl compounds valuable building blocks in organic synthesis. In addition to aldehydes and ketones, other important carbonyl compounds include carboxylic acids, esters, amides, and acyl halides. Each of these compounds possesses a carbonyl group and exhibits unique chemical properties and reactivity.Carbonyl compounds have significant biological importance as well. Many essential biological molecules, such as sugars, amino acids, and fatty acids, contain carbonyl groups. The reactivity of carbonyl compounds is also crucial in enzyme-catalyzed reactions and metabolic processes. Carbonyl compounds are ubiquitous in nature and synthetic chemistry. Their diverse reactivity and structural versatility make them indispensable in a wide range of applications, including pharmaceuticals, fragrances, polymers, and materials synthesis. Understanding the chemistry of carbonyl compounds is essential for advancing our knowledge of organic chemistry and developing new and innovative chemical processes.(Vitinius, U,2005)

Here are a few examples of carbonyl compounds along with their structural formulas and equations representing their reactions:

Aldehydes:

Aldehydes have a carbonyl group bonded to at least one hydrogen atom. They can undergo various reactions, including oxidation, reduction, and nucleophilic addition.

Example: Formaldehyde ($CH_2O$)

Structure: HCHO

Reaction:

Oxidation:

$HCHO + [O] \rightarrow HCOOH$ (Formic acid)

Ketones:

Ketones have a carbonyl group bonded to two carbon atoms. They typically undergo reactions involving nucleophilic addition.

Example: Acetone ($CH_3COCH_3$)

Structure: $CH_3COCH_3$

Reaction:

Nucleophilic Addition:

$CH_3COCH_3 + HCN \rightarrow CH_3C(OH)(CN)CH_3$ (Cyanohydrin)

Carboxylic Acids:

Carboxylic acids contain a carbonyl group and a hydroxyl group (-OH) bonded to the same carbon atom. They are acidic and can undergo reactions such as esterification and decarboxylation.

Example: Acetic Acid ($CH_3COOH$)

Structure: $CH_3COOH$

Reactions:

Esterification:

$CH_3COOH + CH_3OH \rightarrow CH_3COOCH_3 + H_2O$ (Methyl acetate)

Decarboxylation:

$CH_3COOH \rightarrow CH_3COCH_3 + CO_2$ (Acetone and carbon dioxide)

**LITERATURE REVIEW**

Yadav, S. R., Nainawat, A. K. et al,(2005) Acetophenone, Benzalacetophenone, o-Aminoacetophenone, Benzil, Cinnamaldehyde, Crotonaldehyde, and Salicylaldehyde were used in the bioreduction of some carbonyl compounds, as well as free Baker's yeast (Saccharomyces cerevisiae). The effects of putting these compounds through bioreduction have been compared. Also mentioned are the benefits of bioreduction. Biocatalytic processes often need less expensive tools, so biotransformation is the first step toward making synthetic processes that are better for the environment. So, they are meant to work together with the traditional chemical processes or to replace them when possible. It may be a good idea to keep the biocatalysts from moving. For organic synthesis, this may be performed under various circumstances; immobilization is frequently performed by chemically attaching the biocatalysts to a solid, inert polymer base.

Wolfson, A., Dlugy, C. et al,(2006) Both free and immobilized baker's yeast showed catalytic activity in the asymmetric hydrogenation of prochiral -keto esters and ketones in glycerol as the solvent. Immobilized cells were always more active than free cells, and both catalysts kept a high level of enantioselectivity (99%) with both types of cells. Due to its non-toxic, biodegradable, and reusable nature, glycerol is a good solvent to use because it makes it easy to separate products by simply extracting them with diethyl ether. Through this process, chiral hydroxyl esters and alcohols are made, which are useful intermediates and helpers in making fine chemicals. Enantioselective catalytic reduction of prochiral ketones is a good way to get pure enantiomeric alcohols. Also, adding glucose to the reaction mixture acts as a source of hydrogen and an electron giver for cofactor regeneration. Glucose doesn't dissolve in organic solvents, which is another reason why glycerol is a good choice as a solvent.

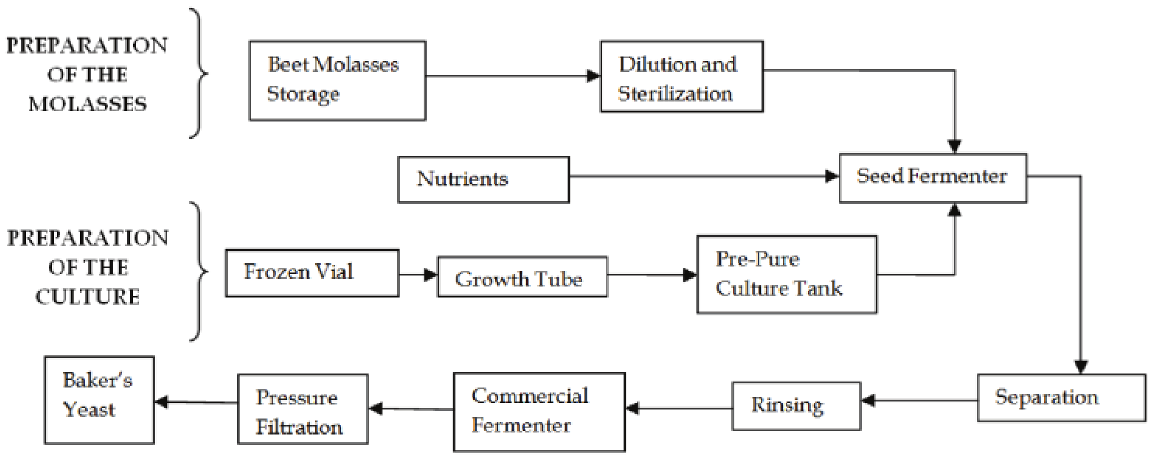
Wolfson, A., &Dlugy, C. (2009) Glycerol has been used as a green reaction medium in several carbonyl reduction procedures successfully. Its high polarity enables for the facile reduction of numerous carbonyl compounds as well as the enantioselective reduction of ethyl acetoacetate using sodium borohydride and catalysts such as Ru-BINAP and baker's yeast. Because it is non-toxic, biodegradable, recyclable, and compatible with other safe chemicals, glycerol is an ideal solvent for electro-reduction and microwave-assisted procedures. Glycerol is widely recognized for usage in food, medicine, cosmetics, and personal care products because of its stability and inertness. It serves as a humectant, plasticizer, emollient, thickener, and other properties. Glycerol esters are one of several glycerol derivatives that are widely employed in a variety of industries.

Plessas, S., Bekatorou, A. et al,(2007) Baking with kefir (a naturally occurring co-culture of yeasts and LAB) immobilized on orange peel and using baker's yeast immobilized in a starch-gluten-milk matrix (traditional fermented cereal food trahanas), containing viable lactic acid bacteria (LAB), was explored. Comparing the quality of the bread to that of typical baker's yeast bread, the use of immobilized cells lengthened the bread's shelf life, postponed staling, and improved it all around. The reduction in pH, the lower rates of moisture loss, and the presence of LAB, which is known to have antimicrobial capabilities, were all credited with these improvements.

Deasy, R. E., O'Riordan, N. et al,(2014) Baker's yeast (Saccharomyces cerevisiae), which has been extensively used in the asymmetric reduction of a wide variety of ketones, is one of the most widely studied and commercially significant whole cell systems used in biocatalysis. This is largely because this bacterium is readily available, simple to use in experiments, and adaptable. The presence and position of sulfur substituents, as well as the use of sulfur-containing compounds, have a significant impact on both the efficiency and stereoselectivity in baker's yeast-mediated reduction of ketones. In a recent article, we discussed how to best optimize the reduction of 2-benzenesulfonyl substituted cyclopentanone and cyclohexanonederivatives by baker's yeast to produce the matching cycloalkanol in enantiopure form. The complementary enantiomeric series has also been reached via a workable technique. Another method for producing enantioenriched new carboxylic acids synthetically successful is base-induced ring breakage of the enantioenriched -keto-sulfones.

**Production of Baker's Yeast**

The production of Baker's yeast involves a complex and controlled process to cultivate and harvest the yeast cells used in baking. Baker's yeast, scientifically known as Saccharomyces cerevisiae, is a single-celled organism that plays a crucial role in the fermentation of dough, resulting in the production of carbon dioxide gas and alcohol.




The first step in the manufacturing process is the selection of yeast strains with desirable characteristics such as high fermentation activity and adaptability to diverse conditions. These strains are often kept alive and propagated in laboratories under sterile conditions. The yeast cells are then transferred to a growth medium containing a carefully prepared blend of nutrients, including carbohydrates, minerals, and vitamins. The yeast cells multiply rapidly during fermentation, which occurs under precisely controlled temperature, pH, and aeration conditions. The nutrients in the medium are utilized by the cells as they develop, and energy and waste products, including carbon dioxide and alcohol, are created by their metabolic processes. When the yeast cells are at their highest concentration, they are collected. The yeast cells are typically separated from the growth medium using centrifugation or filtering procedures. The yeast cells are cleaned, condensed, and packaged for sale after they have been harvested.

**Advantages of Baker's Yeast**

Baker's yeast offers several advantages that make it a preferred choice for baking and other culinary applications. Here are some key advantages of Baker's yeast:

Leavening Agent: Baker's yeast is primarily known for its ability to leaven dough by producing carbon dioxide gas during fermentation. This gas creates air pockets within the dough, resulting in a light and fluffy texture in baked goods. It provides the desired rise and structure to bread, making it soft and airy.

Consistent Results: Baker's yeast provides a reliable and consistent leavening effect, ensuring consistent quality in baked goods. The controlled production and standardized strains of Baker's yeast make it predictable and dependable, allowing bakers to achieve consistent results in terms of texture, volume, and flavor.

Versatility: Baker's yeast is a versatile ingredient that can be used in a wide range of baked goods, including bread, rolls, pastries, and pizza dough. It adapts well to different recipes and flour types, making it suitable for various baking applications. It contributes to the development of flavors and imparts a pleasant aroma to the finished products.

Shelf Life: Baker's yeast has a relatively long shelf life when stored under proper conditions. It can be easily stored and maintained for extended periods, allowing bakers to have a readily available leavening agent whenever needed. Dry active yeast and instant yeast, two common forms of Baker's yeast, have longer shelf lives compared to fresh yeast.

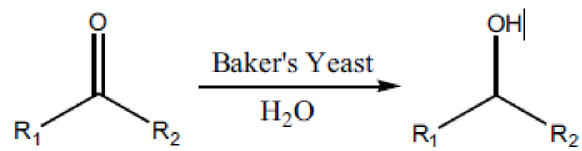
Nutritional Value: Baker's yeast is a good source of essential nutrients, including proteins, B-complex vitamins, and minerals like potassium and phosphorus. It contributes to the nutritional profile of baked goods and adds a mild flavor enhancement. While the yeast is consumed during baking, it leaves behind its nutritional benefits in the final product.

Gluten-free Options: With the increasing demand for gluten-free products, specialized strains of Baker's yeast have been developed to facilitate gluten-free baking. These strains can help improve the texture and rise of gluten-free dough, allowing individuals with gluten sensitivities or celiac disease to enjoy a wider variety of baked goods.

Baker's yeast offers consistent leavening, versatility, extended shelf life, nutritional value, and the ability to cater to gluten-free baking needs. Its use in baking helps achieve desirable textures, flavors, and overall quality in a wide range of baked goods.

**Baker’s Yeast in Organic Synthesis**

Saccharomyces cerevisiae, or baker's yeast, has been employed for purposes other than baking and fermentation in the realm of organic synthesis. Because of its unique enzymatic activities, it is a valuable tool for chemists. Baker's yeast can act as a biocatalyst in a variety of organic reactions, including reductions, oxidations, and the creation of carbon-carbon bonds. Low reaction temperatures, great selectivity, and the ability to function in water are all advantages of these enzymatic systems. Furthermore, employing Baker's yeast as a biocatalyst is consistent with the principles of "green chemistry," as it is derived from a renewable source and reduces the usage of traditional chemical reagents that may be harmful to the environment.

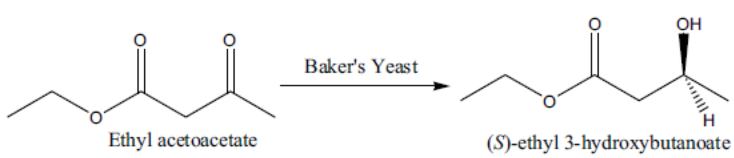



**Synthesis of Pyran Derivatives**

Pyran derivatives can be synthesized using a variety of organic chemistry methods. A common example is the reaction of an aldehyde or ketone with a diene or enol ether in the presence of an acid catalyst. This reaction, known as the Hetero-Diels-Alder reaction, results in the formation of a pyran ring system. Pyran derivatives have a variety of biological properties and are employed in the pharmaceutical and agrochemical industries.

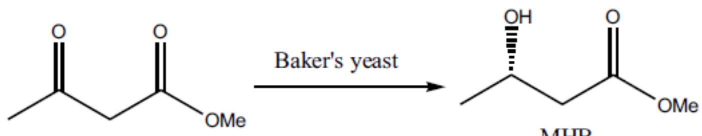
**Reduction of Ethyl Acetoacetate with Baker's Yeast**

The reduction of ethyl acetoacetate (CH3COCH2COOC2H5) with Baker's yeast involves the conversion of the carbonyl group to a hydroxyl group. Baker's yeast, specifically Saccharomyces cerevisiae, contains enzymes such as alcohol dehydrogenase that can catalyze this reduction reaction. The yeast utilizes NADH or NADPH as a cofactor to transfer hydride ions (H-) to the carbonyl group, resulting in the formation of ethyl 3-hydroxybutyrate.




**Asymmetric Reduction of Methyl Acetoacetate (MAA) with Baker's Yeast**

The asymmetric reduction of methyl acetoacetate (MAA) with Baker's yeast involves the conversion of the carbonyl group to a chiral hydroxyl group with high stereochemical selectivity. Baker's yeast contains enzymes such as alcohol dehydrogenase, which exhibit stereoselective activity. The reaction can be performed using NADH or NADPH as a cofactor, resulting in the formation of chiral hydroxyesters. This asymmetric reduction is valuable in the synthesis of chiral building blocks and pharmaceutical intermediates where controlling the stereochemistry is crucial for desired biological activity.




MAA MHB

**PROBLEM STATEMENT**

The reduction of carbonyl compounds is exceedingly difficult due to the threats they pose to the environment and human health. Traditional reduction methods frequently include the use of toxic reagents and the creation of hazardous garbage, both of which contribute to environmental damage. It is critical to develop ecologically friendly and long-lasting methods for the reduction of carbonyl compounds. The purpose of this research is to determine whether baker's yeast, both free and immobilized, can be employed as an environmentally friendly catalyst for the reduction of carbonyl compounds. The purpose is to compare the performance of baker yeast in carbonyl reduction reactions in terms of catalytic efficiency, stability, and reusability to that of traditional reduction methods. The study also seeks to determine the optimal approach to configure the response such that the reduction yield is maximized while undesired side effects are minimized. This issue has a lot of complications. To begin, it is critical to identify a catalyst that is both effective and environmentally friendly. Baker yeast is a natural biocatalyst that can be produced repeatedly. It has a lot of potential, but its performance in carbonyl reduction must be thoroughly verified. It is critical that the reduction process has high catalytic efficiency and selectivity. Carbonyl compounds can react in complex ways, and it can be difficult to get a high yield of the desired reduced products while producing as few undesired by-products as feasible. The stability and reusability of the catalyst are crucial considerations for practical applications. Immobilizing baker's yeast can improve its stability and make it easier to recover and reuse the catalyst, but the optimal method and circumstances for immobilization must be determined.

**CONCLUSION**

The study on the eco-friendly reduction of carbonyl compounds by free and immobilized baker yeast provides insights into practical and sustainable approaches for carbonyl reduction. According to the findings of this study, baker's yeast could be employed as an eco-friendly biocatalyst for the reduction of carbonyl compounds. This contributes to the development of "green chemistry" approaches. The findings reveal that both free and immobilized baker's yeast are excellent catalysts for the reduction of carbonyl compounds. Yeast that has been immobilized is more stable and can be used repeatedly. This makes it an excellent alternative for long-term and sustainable applications. The use of water as a green solvent demonstrates how environmentally benign the reduction process is. The study demonstrates how to enhance reduction yield while minimizing undesired side effects. This is accomplished by fine-tuning reaction parameters like as temperature, pH, and substrate concentration. This knowledge is critical for the effective and selective reduction of certain carbonyl compounds in a variety of commercial situations. The use of baker's yeast as a biocatalyst enables the environmentally friendly reduction of carbonyls. Baker yeast is inexpensive and handy in recipes that require water. It provides a sustainable alternative to current reduction processes that generate damaging waste and rely on toxic chemicals. The study contributes to the development of greener chemical synthesis by promoting the use of renewable resources and lowering the environmental impact of carbonyl compounds. The findings highlight the importance of using organic, renewable catalysts such as baker's yeast and urge for biocatalysis to be used as a key technology in green chemical processes. The eco-friendly reduction of carbonyl compounds by free and immobilized baker yeast is a potential technique for effective and sustainable carbonyl reduction. The study provides useful information regarding baker yeast's stability, enzymatic activity, and reusability in the reduction process. These research promote green chemistry by promoting the use of biocatalysis and renewable resources in chemical synthesis. Implementing these eco-friendly activities can result in a reduction in environmental damage and the construction of a more sustainable future.

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