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Extraction of Cinnamaldehyde from Cinnamon Bark and its Aldol Condensation Reaction

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Abstract: *Cinnamaldehyde, a major component of cinnamon bark oil, possesses significant industrial applications in the food, pharmaceutical, and cosmetic industries due to its distinctive aroma and biological properties. This study explores the extraction of cinnamaldehyde from cinnamon bark using steam distillation, followed by its aldol condensation reaction to synthesize α, β-unsaturated carbonyl compounds. The extraction process involves heating crushed cinnamon bark in water, generating steam that carries volatile oil components, which are then condensed and collected. The separated oil phase is further purified using solvent extraction and drying techniques to obtain pure cinnamaldehyde. The effectiveness of steam distillation in isolating cinnamaldehyde is evaluated based on yield and purity. Following extraction, cinnamaldehyde undergoes aldol condensation in the presence of a base catalyst, typically sodium hydroxide or potassium hydroxide, resulting in the formation of higher molecular weight carbonyl compounds. This reaction is crucial in organic synthesis, as it leads to the formation of complex molecular structures used in various industrial applications, including fragrance synthesis and pharmaceutical intermediates. The study provides insights into natural product isolation and their subsequent chemical modifications, demonstrating an integrated approach to extraction and organic synthesis. Additionally, it emphasizes the efficiency and sustainability of steam distillation in extracting valuable organic compounds from natural sources. The aldol condensation reaction further highlights the chemical reactivity of cinnamaldehyde, paving the way for its utilization in industrial and laboratory settings..*

Keywords: Cinnamaldehyde, Cinnamon bark, Steam distillation, Essential oil extraction, Aldol condensation

I. INTRODUCTION

Extraction Of Cinnamaldehyde from cinnamon Bark :

Cinnamaldehyde is the primary component responsible for the characteristic aroma and flavor of cinnamon. It is a naturally occurring organic compound classified as an aldehyde and is widely used in the food, pharmaceutical, and cosmetic industries. The extraction of cinnamaldehyde from cinnamon bark (Cinnamomum species) is an essential process for obtaining this valuable compound in its pure form.

Cinnamon bark contains volatile oils, with cinnamaldehyde being the most abundant constituent. The extraction process typically involves steam distillation or solvent extraction, both of which help isolate the essential oil from the plant material. Steam distillation is the most commonly used method as it allows for the efficient separation of volatile compounds without causing degradation.

Cinnamaldehyde from Aldol Condensation Reaction :

Cinnamaldehyde, a naturally occurring aromatic aldehyde found in cinnamon bark, is widely used in the food, pharmaceutical, and chemical industries. Beyond its direct applications, cinnamaldehyde serves as a valuable precursor for various organic synthesis reactions, including aldol condensation.

Reaction :

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Aldol condensation reaction between cinnamaldehyde and acetone lead to the formation of dicinnamalacetone an α,β-unsaturated ketone. This reaction is catalysed by strong base such as NaOH

2 Cinnamaldehyde + Acetone $\xrightarrow{NaOH}$ Dicinnamalacetone + water

Structural formula representation :

$2C_9H_8O + C_3H_6O \xrightarrow{NaOH} C_{21}H_{18}O + H_2O$

Reaction mechanism :

Step 1 : Enolate formation (Deprotonation of acetone) :

Acetone (CH3COOH) has α hydrogen atom. In presence of NaOH, acetone undergoes deprotonation at the α – carbon forming an enolate ion.

$CH_3COCH_3 + OH^- \rightarrow CH_2^-COCH_3 + H_2O$

Step 2 : Nucleophilic attack on cinnamaldehyde :

The enolate ion acts as a nucleophile and attacks the electrophiles carbonyl carbon of cinnamaldehyde . This leads to the formation of a β – hydroxy ketone intermediate .

$CH_2^-COCH_3$ + Cinnamaldehyde → β – hydroxy ketone

Step 3 : Dehydration (formation of α,β-unsaturated ketone) :

β – hydroxy ketone (-H_2O elimination) This result in the formation of Dicinnamalacetone which contains a conjugated system .

β – hydroxy ketone → Dicinnamalacetone + H_2O

II. METHODOLOGY

Extraction Of Cinnamaldehyde From Cinnamon Bark :

Materials:

- Cinnamon bark (ground or crushed)
- Distilled water
- Steam distillation apparatus (round-bottom flask, condenser, collection flask)
- Separatory funnel
- Organic solvent (eg. ether)
- Anhydrous sodium sulfate (drying agent)

Procedure:

1. Preparation of Cinnamon Bark :

Crush or grind the cinnamon bark to increase surface area for extraction.

2. Setting up Steam Distillation :

- Place the ground cinnamon bark in a round-bottom flask.
- Add a sufficient amount of distilled water.
- Connect the setup to a condenser and collection flask.

3. Distillation Process :

- Heat the flask to generate steam.
- The steam will carry volatile components, including cinnamaldehyde, through the condenser.
- The condensed distillate (a mixture of water and cinnamaldehyde) is collected.

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4. Extraction of Cinnamaldehyde :

- Transfer the distillate to a separatory funnel.
- Extract cinnamaldehyde using an organic solvent like ether (shake and allow layers to separate).
- Collect the organic layer and dry it over anhydrous sodium sulfate to remove residual water.
- Evaporate the solvent under reduced pressure to obtain pure cinnamaldehyde.

Cinnamaldehyde from Aldol Condensation Reaction

Materials :

- Cinnamaldehyde
- Acetone
- Sodium Hydroxide
- Ethanol
- Conical flask, Stirrer

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Procedure :

- 50 ml of water is added to a flask followed by 5g of sodium hydroxide.
- Once the sodium hydroxide is fully dissolved , 40 ml of ethanol is added and the mixture is allowed to cool back to room temperature.
- 2 ml of acetone and 5 ml of cinnamaldehyde is rapidly added to flask and allowed to stir for 30 minutes.
- After the 30 minutes, precipitate is filtered off and washed with 100 ml of water.

- The crude product is recrystallized from 200 ml of hot ethanol.
- After being allowed to crystallise overnight the dye cinnamon acetone is filtered off and washed with ice cold ethanol.

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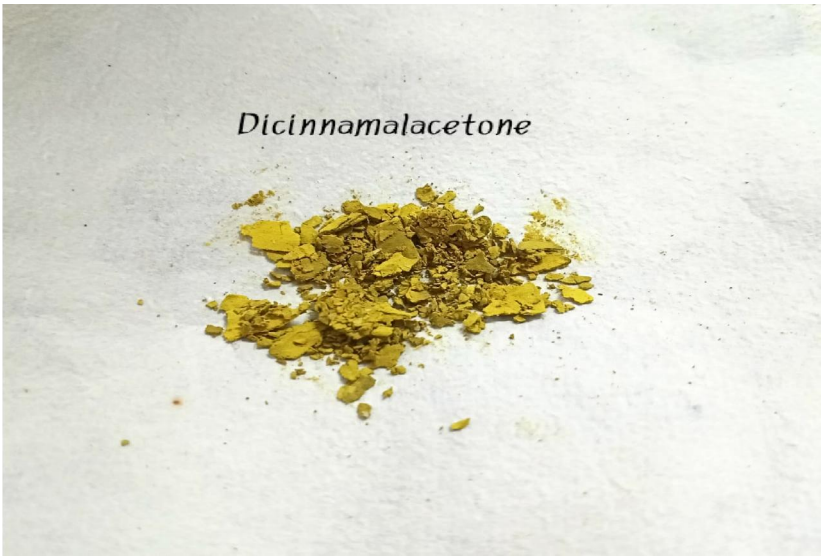

III. LITERATURE REVIEW

A comprehensive literature review on the extraction of oil from cinnamon and clove would delve into various extraction techniques, including steam distillation, solvent extraction. It would explore the optimization of extraction parameters such as temperature, pressure, time, and solvent type to maximize oil yield and quality. Additionally, it would examine the chemical composition of the oils, identifying key compounds such as cinnamaldehyde in cinnamon oil and aldol condensation reaction and their therapeutic benefits and industrial applications. Furthermore, the review would discuss recent advancements in extraction methods and their effectiveness in enhancing oil extraction efficiency. Finally, it would highlight areas for future research, including the development of sustainable and environmentally friendly extraction techniques and the exploration of novel applications for cinnamaldehyde and aldol condensation reaction in various industries .

V. RESULT AND DISCUSSION

Extraction of Cinnamaldehyde from Cinnamon Bark :

Result

- Cinnamaldehyde was successfully extracted from cinnamon bark using the steam distillation method.
- The extracted oil was pale yellow in color with a strong cinnamon-like aroma, confirming the presence of cinnamaldehyde.
- Solubility tests showed that the extracted oil was insoluble in water but soluble in ethanol, confirming its organic nature
- 100 gm of cinnamon powder : 8 ml of cinnamon oil
- Boiling Point of Cinnamon oil : 246^0C

Discussion :

1) Effectiveness of Steam Distillation :

Steam distillation was chosen for extraction because cinnamaldehyde is a volatile compound. The process allowed for the separation of essential oil from cinnamon bark without decomposition. The efficiency of extraction depended on factors like distillation time, particle size of cinnamon bark, and temperature control.

2) Physical and Chemical Properties

The extracted cinnamaldehyde had a characteristic strong aroma, matching its expected properties.The presence of cinnamaldehyde was confirmed by qualitative solubility tests, and further confirmation can be done using spectroscopic techniques.

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Cinnamaldehyde from Aldol Condensation Reaction :

Result :

Dicinnamalacetone was successfully synthesized through the aldol condensation reaction between cinnamaldehyde and acetone in the presence of a strong base (NaOH) in ethanol.

Colour change : initially the solution is pale yellow , after the reaction, a deep yellow to orange solid precipitate .Product appearance : Dicinnamalacetone is a yellow crystalline solid

Melting Point : 120^0C (to confirm purity)

Dicinnamalacetone weight obtained : 1.5 gm

Discussion :

1) Mechanism of Reaction :

The aldol condensation follows a base-catalyzed mechanism. Acetone forms an enolate ion under basic conditions, which then attacks the electrophilic carbonyl of cinnamaldehyde, forming a β-hydroxy ketone intermediate. , dehydration occurs, leading to the formation of Dicinnamalacetone, an α,β-unsaturated ketone with conjugation.

2) Confirmation of Product Formation :

The yellow color and crystalline nature of the product indicate the presence of a conjugated system.

Melting point measurement provides an initial confirmation of product identity.

3)Future Improvements :

Optimizing the reaction conditions (base concentration, temperature, and reaction time) for higher yield.

Using different solvents or catalysts for improved selectivity. Chromatographic techniques (TLC) can be used for better purification and separation.

V. CONCLUSION

Conclusion on the Extraction of Cinnamaldehyde from Cinnamon Bark

The extraction of cinnamaldehyde from cinnamon bark is successfully achieved using steam distillation or solvent extraction methods. Steam distillation is the preferred technique due to its efficiency in isolating volatile compounds while maintaining their chemical integrity. The extracted oil contains cinnamaldehyde as the major component, which can be further purified using drying agents (e.g., anhydrous sodium sulfate) and vacuum distillation.

The process confirms that cinnamon bark is a rich natural source of cinnamaldehyde, which has various applications in flavoring, pharmaceuticals, and organic synthesis. The successful isolation of cinnamaldehyde also provides a starting material for further chemical transformations, such as aldol condensation reactions to synthesize valuable α,β-unsaturated ketones.

Overall, the study highlights the effectiveness of traditional extraction techniques and their relevance in obtaining bioactive compounds from natural sources. Further improvements, such as optimizing yield and purity, can be explored for industrial-scale production.

Conclusion on cinnamaldehyde from Aldol Condensation Reaction :

The aldol condensation reaction between cinnamaldehyde and acetone successfully produces dicinnamalacetone, an α ,β-unsaturated ketone with conjugated double bonds. This reaction follows a base-catalyzed mechanism, where acetone forms an enolate ion, which then undergoes nucleophilic addition with cinnamaldehyde, followed by dehydration to yield the final product.

VI. ACKNOWLEDGMENT

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