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**Research Article**

# GREEN APPROACH TO KNOEVENAGEL CONDENSATION USING GUAVA LEAF EXTRACT AS A CATALYST

**Balamurugan. A*,[a] Mahalakshmi. M [b] and Rama. M[b]**

[a]Department of Chemistry, School of Arts and Science, Sri Manakula Vinayagar Engineering College, Madagadipet, Puducherry- 605 107, India

[b]Department of Chemistry, Theivanai Ammal College for Women, Villupuram, Tamilnadu - 605 602, India

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**ABSTRACT**

This research emphasizes the development of environmentally friendly methods in organic synthesis, focusing on the Knoevenagel condensation reaction. Utilizing guava leaf extract as a natural catalyst, we aim to present a green and economically viable approach to the synthesis of Knoevenagel products.



## INTRODUCTION

A Knoevenagel condensation reaction has been utilized for synthesis with biological applications[1]. This condensation has been reported using various cabatalysts[2-7], microwave-assisted reactions[8], ultrasound irradiation[9-10], technology-based approaches[11-12], solid-phase methods[13-14], ionic liquids[15-16], and green solvents like water[17-18].

Nitriles serve as versatile intermediates in the synthesis of a variety of products. Unsaturated nitriles play a pivotal role in various pathways proposed for the prebiotic synthesis of various products[19]. Acrylonitriles also demonstrate cytotoxic, antiproliferative, and antitubercular activities, thereby playing a crucial role in biological systems[20]. From a biological perspective, some cyclic and conjugated nitriles have been prepared using Knoevenagel condensation[21,22]. Several Knoevenagel condensation reactions employing natural catalysts, such as Henna leaves[23], clay[24-26], and various fruit juices, have been reported due to the acidic nature of aqueous fruit juices like lemon[27], pineapple[28], and tamarind Indica[29]. Recently the waste material as, natural catalysts used in Knoevenagel reactions include agro-waste extract[30] and wet-copper slag[31]. The current study aims to address these aspects by investigating the potential of green catalysts, with a focus on ethanol as an eco-friendly solvent. This research aligns with contemporary imperatives, emphasizing sustainable, economically viable, and environmentally benign synthetic routes.

## MATERIAL AND METHODS

### Preparation of extract of guava leaf

#### *Collection and Washing of Guava Leaves*

Fresh guava leaves were meticulously collected and rinsed thoroughly with distilled water. **(Fig-1)**

#### *Drying and Powdering*

The washed guava leaves were subjected to drying until complete desiccation. Post-drying, the leaves were finely powdered using a mortar and pestle.

#### *Extraction Procedure*

A 5g quantity of the powdered guava leaf was transferred to a 250ml conical flask. To this flask, 50ml of methanol was added. The mixture was then stirred rigorously using a mechanical stirrer for duration of one hour.

#### *Filtration and Catalyst Preparation*

Following the stirring process, the mixture was filtered through filter paper to obtain the guava leaf extract. This extract served as the primary catalyst for subsequent reactions.

**Corresponding author:* **Dr. Balamurugan. A**
Department of Chemistry, School of Arts and Science, Sri Manakula Vinayagar Engineering College, Madagadipet, Puducherry- 605 107, India

**General procedure for condensation of aromatic aldehydes with malonitrile**

All chemicals utilized in the experiments were procured from reputable suppliers, namely Sigma Aldrich and S.D. Fine Chemicals. These chemicals were employed without the need for additional purification.

In a conical flask, aromatic aldehyde (10 mmol), malononitrile (10 mmol), 2ml of the prepared guava leaf extract, and 10ml of ethanol were meticulously added. The mixture was subjected to stirring using a magnetic stirrer at room temperature. Progress of the reaction was continuously monitored using Thin Layer Chromatography (TLC) until its completion. Upon completion of the reaction, the resultant solid (crude product) was isolated by filtration. This solid was further purified through the re-crystallization process using ethanol as the solvent, ensuring the removal of impurities.

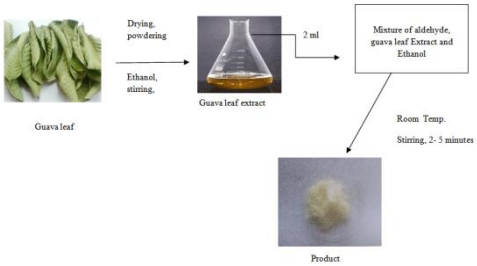



**Fig. 1** Preparation of knoevenagal products using Guava Leaves Extract

## CHARACTERIZATION TECHNIQUES

### *FTIR Spectroscopy*

Infrared spectra of the synthesized compounds were obtained using an 8700 SHIMADZU model FTIR spectrometer. The samples were prepared as KBr discs for analysis.

### *NMR Spectroscopy*

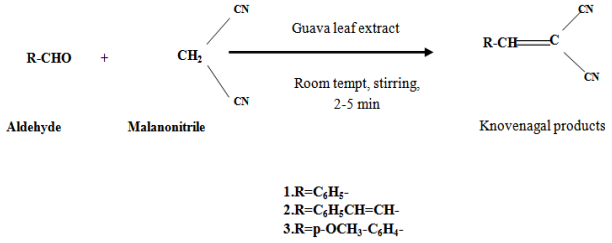
Both 1H and 13C NMR spectra were recorded at room temperature utilizing a 400 MHz Fourier Transform NMR spectrometer. For 1H NMR, about 10 mg of the sample was dissolved in 0.5 ml of chloroform-d containing a few drops of TMS as an internal reference. Similarly, for 13C NMR, 0.5g of the compound was dissolved in 2.5ml of chloroform-d with TMS serving as the internal reference.

## RESULTS AND DISCUSSION

The Knoevenagel condensation, a pivotal carbon-carbon bond-forming reaction, has been extensively studied due to its versatility in organic synthesis. In this study, a novel, efficient, and environmentally benign method employing guava leaf extract as a catalyst for the Knoevenagel condensation between malononitrile and some aromatic aldehydes has been presented.

### *Efficacy of Guava Leaf Extract as a Catalyst*

Guava leaf extract, a natural source rich in various organic acids and bioactive compounds, has been traditionally known for its medicinal properties. Kim et al.[32] identified constituents like ascorbic acid, citric acid, epicatechin, and various other acids in guava leaves. The acidic nature of this extract makes it a potential candidate to catalyze reactions, especially the Knoevenagel condensation. Our findings corroborate this hypothesis, where the guava leaf extract demonstrated remarkable catalytic activity, facilitating the condensation reaction in excellent yields at room temperature within minutes. **(Scheme 1)**




**Scheme -1**

### Characterization of Products

The synthesized compounds 2-(phenylmethylene) malononitrile**(1),** 3-(phenyl allylidine) malononitrile **(2),**2-(4-methoxy benzylidine) malononitrile**(3)** were rigorously characterized employing a plethora of spectroscopic techniques, including IR and NMR spectroscopy. The authenticity of the synthesized products was confirmed by comparing their melting points, IR data, and NMR spectra with the literature values[23]. Table 1 show the formation of high yield and melting points are good agreement with the literature.

**Table1**.Physical data of compounds **1-3**

| Compound | Nature of product | Yield (%) | Time (Minutes) | Melting point | |
|---|---|---|---|---|---|
| | | | | m.pt (°C) | Reported (°C) |
| 1 | White crystal | 95 | 2 | 81 | 80- 82 |
| 2 | Yellow crystal | 85 | 5 | 127 | 126-128 |
| 3 | Green crystal | 88 | 5 | 114 | 112-114 |

At room temperature the high yields were obtained within 2-5 minutes byusing magnetic stirrer. The reactions were monitored by thin layer chromatographic techniques. The melting of the all the compounds are good agree with literature.

### IR Spectral Analysis

Infrared (IR) spectroscopy provided valuable insights into the functional groups present in the synthesized compounds. **Table .2** shows IR data of compounds **1-3.**

**Table .2** IR data of compounds **1-3**

| Compounds | Frequencies($cm^{-1}$) |
|---|---|
| **1** | 3032, 2226, 1448, 1220, 1591,614, |
| **2** | 3032, 2226,1605,1448,1227,863,685 |
| **3** | 3032, 2218.1883,1555,1448,934,834 |

The data showed absorption at 2187- 2226 cm-1 the presence of CN functional group in the products. These characteristic peaks further validated the successful formation of the desired Knoevenagel products, with the absence of a peak around 1720 $cm^{-1}$, indicating the absence of the carbonyl group.

### NMR Spectroscopic Analysis

Both 1H and 13C NMR spectroscopy were employed to elucidate the structural features of the synthesized products. **Table. 3** shows $H^1$ NMR data and Table .4 shows $^{13}C$ NMR data of compounds **1-3.**

**Table .3** $H^1$ NMR data of compounds **1-3**

| Compound | =CH proton (ppm) | Aromatic protons (ppm) | -$OCH_3$ proton (ppm) |
|---|---|---|---|
| **1** | 7.8 s [1H] | 7.91 d [2H]<br>7.56 -7.6 m [3H] | - |
| **2** | 7- 8 ppm m [8 H] | | - |
| **3** | 7.7 s [1H] | 7.01 d [2H]<br>7.92 d [2H] | 3.91 [3H] |

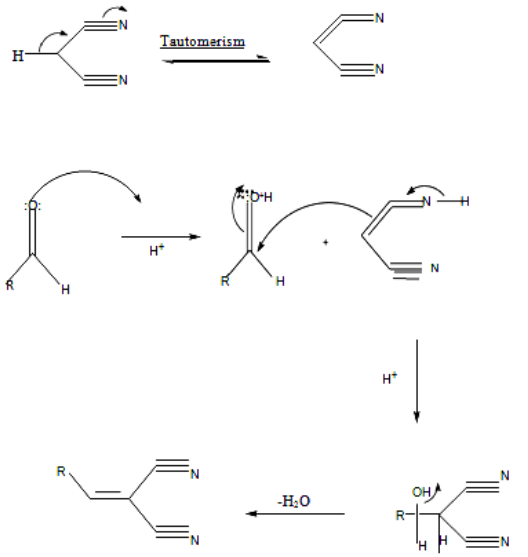
**Table .3**$^{13}$C NMR data of compounds **1-3**

| Compound | CN (ppm) | =C< (ppm) | =CH (ppm) | Aromatic carbons (ppm) | -$OCH_3$ |
|---|---|---|---|---|---|
| 1 | 113,112 | 83 | 160 | 134,131 | - |
| 2 | 113,111 | 83 | 160 | 122,128,132,133,150 | - |
| 3 | 113,114 | 78 | 159 | 164,124 | 55 |

In the $^1$H NMR, A siglet appeared around 7.8 ppm shows aldehydic proton in the compounds 1-3anda singlet at 3.91ppm shows methoxy proton for compound 3.The signals are merged as multiplate for the aromatic and conjugated olefinic protons.The other signals are assigned for aromatic protons. In the $^{13}$C NMR, the signals around 113 ppm shows for presence of carbon of cyano group, the signals appeared around 83 ppm shows methylene carbon (=C<), the signals at 160 ppm assigned to aldehydic carbon(=CH) for compounds 1-3.A signal at 55 ppm shows methoxy carbon for compound 3.The other signals are assigned for aromatic carbons. Both $^1$H and $^{13}$CNMR data are good agree with the literature.

**MECHANISM**

The proposed mechanism for the Knoevenagel condensation, catalyzed by the guava leaf extract, is depicted schematically. The acidic nature of the guava leaf extract facilitates the activation of malononitrile and the aromatic aldehyde, promoting their condensation and subsequent formation of the desired product. **Scheme 2. Shows** Mechanism of acid catalyzed knoevenagel condensation




**Scheme 2.**Mechanismofacid catalyzed knoevenagel condensation

## CONCLUSION

In summary, this research underscores the potential of guava leaf extract as an efficient and eco-friendly catalyst for the Knoevenagel condensation. The synthesized products were meticulously characterized using various spectroscopic techniques, validating their structural integrity. This study not only offers a sustainable approach to organic synthesis but also harnesses the untapped potential of natural resources like guava leaves for chemical transformations.

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