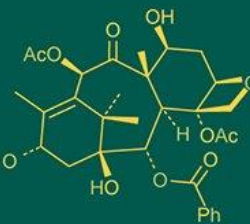
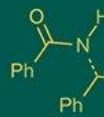
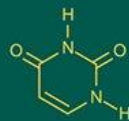


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## Optimization of solvent extraction for curcumin and evaluation of antioxidant and antimicrobial potential in turmeric (*Curcuma longa* L.)

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**Abstract**

Curcumin, the principal bioactive compound of turmeric (*Curcuma longa* L.), possesses significant antioxidant and antimicrobial properties; however, its extraction efficiency largely depends on solvent type and varietal differences. The present study aimed to standardize an efficient extraction protocol for curcumin and evaluate its stability and biofunctional properties across four turmeric varieties (GNT-1, GNT-2, GNT-3, and Sugandham) over multiple years (2023-2025). Curcumin was extracted using methanol, ethanol, acetone, and petroleum ether, and quantified by UV-Visible spectroscopy at 424 nm using a standard calibration curve. The results revealed that ethanol was the most effective solvent for curcumin extraction, yielding the highest content, with GNT-3 exhibiting the maximum curcumin concentration (3.76%), followed by GNT-2 (3.32%) and GNT-1 (3.08%). Total phenolic content (TPC) analysis further supported the superiority of ethanol, with the highest phenolic content recorded in GNT-3 (908.25 mg/100 g). Antioxidant activity assessed through DPPH assay indicated that methanolic extracts showed maximum radical scavenging activity, with GNT-1 demonstrating the highest inhibition (78.53%). In contrast, ferric reducing antioxidant power (FRAP) was highest in ethanolic extracts. Additionally, antimicrobial activity of GNT-3 extracts demonstrated significant inhibitory effects against *Escherichia coli*, *Bacillus subtilis*, *Bacillus megaterium*, and *Streptococcus* spp., with ethanol and methanol extracts showing superior efficacy. Overall, the study highlights that both extraction solvent and varietal selection significantly influence curcumin yield and bioactivity. Ethanol emerged as the most suitable solvent for efficient extraction of curcumin and phenolic compounds, while GNT-3 proved to be the most promising variety. These findings underscore the potential application of turmeric extracts in pharmaceutical, nutraceutical, and functional food industries.

**Keywords:** Curcumin extraction, *Curcuma longa* L., solvent efficiency, antioxidant activity, antimicrobial properties

**1. Introduction**

Turmeric (*Curcuma longa* L.), a perennial rhizomatous herb belonging to the family Zingiberaceae, is widely recognized for its extensive medicinal, culinary, and industrial applications. It has been used for centuries in traditional systems of medicine such as Ayurveda, Siddha, and Unani due to its diverse pharmacological properties, including anti-inflammatory, antioxidant, antimicrobial, and anticancer activities. The bioactivity of turmeric is primarily attributed to a group of polyphenolic compounds known as curcuminoids, among which curcumin is the most studied constituent (Prasad et al., 2014; Hewlings & Kalman, 2017) [9, 12].

Curcumin (diferuloylmethane) is a hydrophobic polyphenol responsible for the characteristic yellow color of turmeric and exhibits a wide spectrum of biological activities. It has been extensively investigated for its therapeutic potential in managing chronic diseases such as cancer, cardiovascular disorders, diabetes, and neurodegenerative conditions (Anand et al., 2008; Kunnumakkara et al., 2017) [1]. In addition to curcumin, turmeric also contains other bioactive compounds including demethoxycurcumin, bisdemethoxycurcumin, and various phenolic compounds, which collectively contribute to its antioxidant capacity (Sharifi-Rad et al., 2020) [10, 14].

The extraction of curcumin and associated phenolic compounds from turmeric is a critical step influencing both yield and bioactivity. Various conventional solvents such as methanol, ethanol, acetone, and petroleum ether have been widely used for extraction; however, their efficiency varies significantly depending on polarity, extraction conditions, and plant matrix (Azmir et al., 2013; Zhang et al., 2022) [3, 17]. Among these, ethanol is often considered a preferred solvent due to its high extraction efficiency, lower toxicity, and suitability for food and pharmaceutical applications (Chemat et al., 2019) [6]. Therefore, optimization and standardization of extraction protocols are essential to maximize curcumin recovery and maintain its stability.

In addition to extraction techniques, varietal differences also play a significant role in determining curcumin content and overall phytochemical composition. Different turmeric genotypes exhibit considerable variation in curcumin concentration, phenolic content, and biological activities due to genetic and environmental factors (Singh et al., 2021) [15]. Identification of high-curcumin yielding varieties is crucial for both commercial cultivation and industrial utilization.

The antioxidant potential of turmeric is primarily associated with its ability to scavenge free radicals and reduce oxidative stress. Commonly employed assays such as DPPH (2,2-diphenyl-1-picrylhydrazyl) and FRAP (ferric reducing antioxidant power) provide insights into the radical scavenging and reducing potential of plant extracts, respectively (Benzie & Strain, 1996; Brand-Williams et al., 1995). Furthermore, turmeric extracts have demonstrated promising antimicrobial activity against a wide range of pathogenic microorganisms, making them potential candidates for natural preservatives and therapeutic agents (Negi, 2012; Rai et al., 2023) [4, 5, 11, 13].

Despite extensive research on turmeric, there is still a need for systematic studies integrating solvent optimization, varietal comparison, and evaluation of biofunctional properties such as antioxidant and antimicrobial activities under uniform experimental conditions. Such studies are particularly important for identifying suitable extraction systems and elite varieties that can be utilized for large-scale production and value addition.

Therefore, the present investigation was undertaken to standardize an efficient extraction protocol for curcumin using different solvents and to evaluate the influence of turmeric varieties on curcumin yield, total phenolic content, antioxidant activity (DPPH and FRAP), and antimicrobial potential. The findings of this study are expected to provide valuable insights for the selection of appropriate extraction methods and superior turmeric varieties for pharmaceutical, nutraceutical, and functional food applications.

## Materials and Methods

### 1. Plant Material and Sample Collection

Rhizome samples of four turmeric (*Curcuma longa* L.) varieties, namely GNT-1, GNT-2, GNT-3, and Sugandham, were procured from the Department of Genetics and Plant Breeding, N. M. College of Agriculture, Navsari Agricultural University (NAU), Navsari, India. The samples were cleaned thoroughly to remove adhering soil and debris, shade-dried, and ground into a fine powder using a laboratory grinder. The powdered samples were stored in airtight containers at room temperature until further analysis.

### 2. Chemicals and Reagents

Analytical grade solvents including methanol, ethanol, acetone, and petroleum ether were used for extraction. Folin-Ciocalteu reagent, sodium carbonate ( $\text{Na}_2\text{CO}_3$ ), 2,2-diphenyl-1-picrylhydrazyl (DPPH), ferric chloride, TPTZ (2,4,6-tripyridyl-s-triazine), and ferrous sulfate were used for antioxidant assays. Standard curcumin ( $\geq 98\%$  purity) was used for calibration. All chemicals were procured from standard suppliers and used without further purification.

### 3. Extraction of Curcumin

Curcumin extraction was carried out using different solvents following a modified conventional solvent extraction method (Azmir et al., 2013; Zhang et al., 2022) [3, 17]. Briefly, 1 g of turmeric powder was accurately weighed and extracted separately with methanol, ethanol, acetone, and petroleum ether. The mixtures were homogenized and allowed for solvent extraction, followed by filtration. The filtrates were evaporated to dryness, and the extract yield was recorded. The dried extracts were re-dissolved in respective solvents and stored at 4°C for further analysis.

### 4. Preparation of Standard Curcumin Solution

A stock solution of curcumin (100  $\mu\text{g/mL}$ ) was prepared by dissolving 10 mg of standard curcumin in 100 mL methanol. Working standards of concentrations ranging from 1-7  $\mu\text{g/mL}$  were prepared by appropriate dilution. These standards were used to generate a calibration curve for quantitative analysis (Hewlings & Kalman, 2017) [9].

### 5. Determination of Maximum Absorption Wavelength ( $\lambda_{\text{max}}$ )

The maximum absorption wavelength ( $\lambda_{\text{max}}$ ) of curcumin was determined by scanning a 5  $\mu\text{g/mL}$  standard solution in the range of 200-800 nm using a UV-Visible spectrophotometer, with methanol as a blank. The  $\lambda_{\text{max}}$  of curcumin was observed at 424 nm, which was used for further quantification.

### 6. Quantification of Curcumin by UV-Visible Spectroscopy

The curcumin content in different extracts was estimated using UV-Visible spectrophotometry at 424 nm based on the standard calibration curve. The absorbance values were recorded in triplicate, and the curcumin content was expressed as g/100 g of dry weight (Prasad et al., 2014) [12].

### 7. Determination of Total Phenolic Content (TPC)

The total phenolic content of turmeric extracts was determined using the Folin-Ciocalteu method (Singleton et al., 1999; Sharifi-Rad et al., 2020) [14, 16]. Briefly, 0.5 mL of extract was mixed with 0.5 mL of Folin-Ciocalteu reagent and incubated for 3 minutes. Subsequently, 2 mL of 20%  $\text{Na}_2\text{CO}_3$  was added, and the mixture was incubated in a boiling water bath for 1 minute. After cooling, absorbance was measured at 650 nm. Catechol was used as a standard, and results were expressed as mg/100 g of sample.

### 8. DPPH Free Radical Scavenging Assay

The antioxidant activity of turmeric extracts was evaluated using the DPPH radical scavenging assay as described by Brand-Williams et al. (1995). In brief, 1000  $\mu\text{L}$  of DPPH solution was mixed with 800  $\mu\text{L}$  of Tris-HCl buffer (pH 7.4) and 200  $\mu\text{L}$  of sample extract. The mixture was incubated in

the dark at room temperature for 30 minutes, and absorbance was recorded at 517 nm. The percentage inhibition was calculated using the formula <sup>[5]</sup>:

$$\% \text{ Inhibition} = A_{\text{control}} (A_{\text{control}} - A_{\text{sample}}) \times 100$$

## 9. Ferric Reducing Antioxidant Power (FRAP) Assay

The FRAP assay was performed according to the method described by Benzie and Strain (1996). Briefly, 100  $\mu$ L of sample extract was mixed with 900  $\mu$ L distilled water and 2 mL FRAP reagent. The reaction mixture was incubated in the dark at room temperature for 30 minutes, and absorbance was measured at 593 nm. A standard curve was prepared using  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ , and results were expressed as  $\mu$ M FRAP values <sup>[4]</sup>.

## 10. Antimicrobial Activity

### 10.1 Preparation of Extracts

For antimicrobial studies, 25 g of dried turmeric powder was extracted with 100 mL of different solvents (methanol, ethanol, acetone, and water). The extracts were concentrated by evaporation and reconstituted to obtain a final concentration of 1 mg/mL. The extracts were stored at 4°C until use.

### 10.2 Test Microorganisms

The antibacterial activity was evaluated against four bacterial strains: *Escherichia coli*, *Bacillus subtilis*, *Bacillus megaterium*, and *Streptococcus* spp. These cultures were maintained on nutrient agar medium.

### 10.3 Agar Well Diffusion Method

Antimicrobial activity was assessed using the agar well diffusion method (Rai et al., 2023). Sterile nutrient agar plates were inoculated with bacterial cultures and incubated at 37°C for 24 hours. Wells were made using a sterile cork borer, and different concentrations of plant extracts were added. After incubation at 37°C for 24 hours, the diameter of the inhibition zones was measured in millimeters <sup>[13]</sup>.

## 11. Statistical Analysis

The experimental data were analyzed using appropriate statistical methods. The results were expressed as mean values of replicates, and analysis of variance (ANOVA) was performed to determine the significance of differences among treatments, solvents, and varieties. Standard error of mean (SEm) and critical difference (CD) at 5% level of significance were calculated (Gomez & Gomez, 1984) <sup>[8]</sup>.

## Results and Discussion

### 1. Curcumin Extraction and quantification

The extraction of curcumin from different turmeric varieties using various solvents is illustrated in Fig. 1, while the standard calibration curve used for quantification is presented in Fig. 2. The calibration curve showed good linearity in the concentration range of 1-7  $\mu$ g/mL, confirming the reliability of the UV-Visible spectrophotometric method.

The curcumin content obtained using different solvents across four turmeric varieties is presented in Table 1. Among the solvents tested, ethanol consistently resulted in the highest curcumin yield in all varieties. The pooled data indicated that GNT-3 recorded the maximum curcumin content (3.76%), followed by GNT-2 (3.32%) and GNT-1

(3.08%), whereas Sugandham showed comparatively lower values.

The superior extraction efficiency of ethanol may be attributed to its optimal polarity, which enhances the solubility of curcumin. Similar observations have been reported by Chemat et al. (2019) and Zhang et al. (2022). The significant variation among varieties suggests genetic differences influencing curcumin biosynthesis (Singh et al., 2021) <sup>[6, 15, 17]</sup>.

### 2. Total phenolic content (TPC)

The total phenolic content of turmeric extracts is presented in Table 2. Among all treatments, the ethanolic extract of GNT-3 exhibited the highest TPC (908.25 mg/100 g), followed by Sugandham and GNT-1. In contrast, petroleum ether extracts showed the lowest phenolic content across all varieties.

The higher efficiency of ethanol in extracting phenolic compounds is consistent with earlier findings that polar solvents are more effective in recovering phenolics due to their ability to form hydrogen bonds with hydroxyl groups (Azmir et al., 2013; Sharifi-Rad et al., 2020) <sup>[3, 14]</sup>. The elevated phenolic content in GNT-3 suggests its strong antioxidant potential.

## 3. Antioxidant activity

### 3.1 DPPH radical scavenging activity

The DPPH radical scavenging activity of turmeric extracts is summarized in Table 3. The results indicated that methanolic extracts exhibited the highest antioxidant activity among all solvents. The maximum inhibition was observed in GNT-1 (78.53%), followed by GNT-3 and GNT-2.

Despite ethanol showing higher phenolic content, methanol demonstrated superior DPPH activity, suggesting that specific antioxidant compounds extracted in methanol may have higher radical scavenging potential. This observation aligns with previous reports (Brand-Williams et al., 1995; Do et al., 2014) <sup>[5]</sup>.

Petroleum ether extracts showed the lowest activity, indicating that non-polar solvents are less effective in extracting antioxidant compounds.

### 3.2 Ferric reducing antioxidant power (FRAP)

The FRAP values of different turmeric extracts are presented in Table 4. Among the solvents, ethanolic extracts exhibited the highest ferric reducing antioxidant power across all varieties. GNT-1 recorded slightly higher FRAP values, followed by GNT-3 and Sugandham.

The higher FRAP activity in ethanol extracts correlates well with their higher phenolic content, as the FRAP assay measures the reducing ability of antioxidants (Benzie & Strain, 1996). The variation between DPPH and FRAP results highlights that antioxidant activity depends on different mechanisms, including hydrogen atom transfer and electron transfer (Apak et al., 2016) <sup>[2, 4]</sup>.

## 4. Antimicrobial activity

The antimicrobial activity of turmeric extracts from GNT-3 against selected bacterial strains is presented in Table 5. The results demonstrated that ethanolic and methanolic extracts exhibited significant antibacterial activity compared to acetone and petroleum ether extracts.

The highest zone of inhibition was observed in ethanol extract against *Escherichia coli* (15.40 mm), followed by *Bacillus subtilis* and *Bacillus megaterium*. Methanolic

extracts also showed substantial inhibitory effects, whereas petroleum ether extracts were least effective.

The enhanced antimicrobial activity of ethanol and methanol extracts can be attributed to the presence of bioactive compounds such as curcumin and phenolics, which interfere with microbial cell membranes and metabolic pathways (Negi, 2012; Rai et al., 2023) [11, 13].

Overall, the results presented in Tables 1-5 and Figures 1-2 clearly indicate that both solvent type and varietal differences significantly influence curcumin yield and associated bioactivities. Ethanol proved to be the most efficient solvent for extraction of curcumin and phenolic compounds, while methanol showed superior radical scavenging activity.

Among the tested varieties, GNT-3 emerged as the most promising genotype due to its higher curcumin content, phenolic content, and antimicrobial activity. The variation observed across antioxidant assays further emphasizes the importance of using multiple evaluation methods to obtain a comprehensive understanding of bioactivity.

These findings are consistent with previous studies highlighting the role of solvent polarity and genetic variability in determining phytochemical composition and biological efficacy (Chemat et al., 2019; Sharifi-Rad et al., 2020; Singh et al., 2021) [6, 14, 15].



**Fig 1:** Extraction of Curcumin in Different solvent from Four varieties of Turmeric

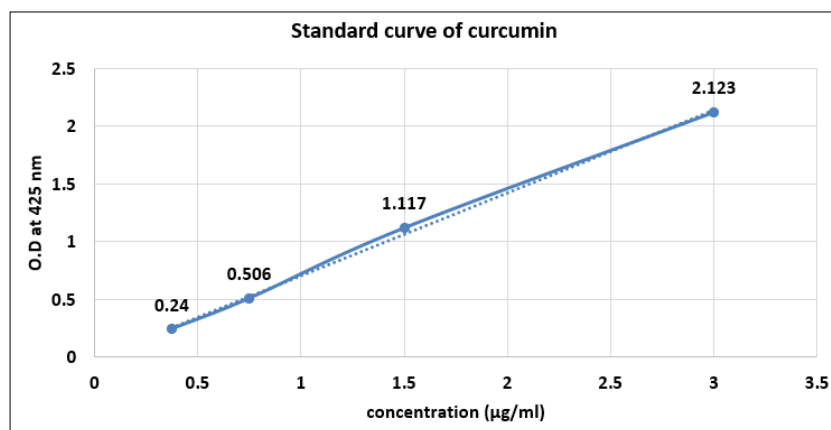


**Fig 2:** Standard curve of curcumin

**Table 1:** Curcumin content extracted in different solvent pooled data

| Solvent         | Variety   | 2022-23<br>Curcumin<br>(gm/100g) | 2023-24<br>Curcumin<br>(gm/100g) | 2024-25<br>Curcumin<br>(gm/100g) | 2025-26<br>Curcumin<br>(gm/100g) | Average<br>Curcumin<br>(gm/100g) | CV%   |
|-----------------|-----------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|-------|
| Methanol        | GNT1      | 2.44                             | 2.68                             | 2.44                             | 2.99                             | 2.64                             | 8.22  |
|                 | GNT2      | 3.01                             | 2.52                             | 2.55                             | 2.43                             | 2.63                             | 8.25  |
|                 | GNT3      | 3.27                             | 3.27                             | 2.94                             | 3.15                             | 3.16                             | 6.87  |
|                 | Sugandham | 1.95                             | 2.12                             | 2.71                             | 2.67                             | 2.36                             | 9.18  |
| Acetone         | GNT1      | 1.86                             | 1.72                             | 1.83                             | 2.35                             | 1.94                             | 11.17 |
|                 | GNT2      | 2.16                             | 2.37                             | 2.56                             | 2.77                             | 2.47                             | 8.79  |
|                 | GNT3      | 1.66                             | 1.82                             | 1.80                             | 2.23                             | 1.88                             | 11.55 |
|                 | Sugandham | 1.47                             | 1.48                             | 1.57                             | 1.78                             | 1.58                             | 13.76 |
| Ethanol         | GNT1      | 2.75                             | 3.19                             | 3.29                             | 3.07                             | 3.08                             | 7.05  |
|                 | GNT2      | 3.41                             | 3.26                             | 3.50                             | 3.12                             | 3.32                             | 6.53  |
|                 | GNT3      | 3.99                             | 3.84                             | 3.70                             | 3.49                             | 3.76                             | 5.77  |
|                 | Sugandham | 2.38                             | 2.23                             | 2.54                             | 2.50                             | 2.41                             | 8.99  |
| Petroleum ether | GNT1      | 1.45                             | 1.62                             | 2.10                             | 1.85                             | 1.76                             | 12.35 |
|                 | GNT2      | 1.88                             | 1.79                             | 1.88                             | 2.10                             | 1.91                             | 11.34 |

|         |           |      |         |      |      |      |       |
|---------|-----------|------|---------|------|------|------|-------|
|         | GNT3      | 2.63 | 2.42    | 1.98 | 2.30 | 2.33 | 9.29  |
|         | Sugandham | 1.34 | 1.18    | 1.37 | 1.35 | 1.31 | 16.55 |
|         | SEm       |      | CD      |      |      |      |       |
| Year    | Y         | 0.03 | 0.08752 |      |      |      |       |
| Solvent | A         | 0.06 | 0.18971 |      |      |      |       |
|         | Y*A       | 0.06 | 0.17504 |      |      |      |       |
| Variety | B         | 0.07 | 0.22435 |      |      |      |       |
|         | Y*B       | 0.06 | 0.17504 |      |      |      |       |
|         | A*B       | 0.10 | 0.28980 |      |      |      |       |
|         | Y*A*B     | 0.13 | 0.35009 |      |      |      |       |

**Table 2:** Total Phenol Content Pooled

| Solvent         | Variety   | 2022-23<br>TPC (mg /100g) | 2023-24<br>TPC (mg /100g) | 2024-25<br>TPC (mg /100g) | 2025-26<br>TPC (mg /100g) | Average<br>TPC (mg /100g) | CV%  |
|-----------------|-----------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|------|
| Methanol        | GNT1      | 720                       | 650                       | 720                       | 745                       | 708.75                    | 2.18 |
|                 | GNT2      | 760                       | 710                       | 690                       | 735                       | 723.75                    | 2.14 |
|                 | GNT3      | 757                       | 738                       | 756                       | 848                       | 774.75                    | 2.00 |
|                 | Sugandham | 763                       | 756                       | 780                       | 721                       | 755.00                    | 2.05 |
| Acetone         | GNT1      | 600                       | 588                       | 610                       | 670                       | 617.00                    | 2.51 |
|                 | GNT2      | 640                       | 654                       | 656                       | 765                       | 678.75                    | 2.28 |
|                 | GNT3      | 520                       | 547                       | 648                       | 760                       | 618.75                    | 2.50 |
|                 | Sugandham | 620                       | 668                       | 710                       | 690                       | 672.00                    | 2.30 |
| Ethanol         | GNT1      | 920                       | 892                       | 790                       | 792                       | 848.50                    | 1.82 |
|                 | GNT2      | 880                       | 865                       | 825                       | 753                       | 830.75                    | 1.86 |
|                 | GNT3      | 960                       | 980                       | 856                       | 837                       | 908.25                    | 1.70 |
|                 | Sugandham | 940                       | 956                       | 890                       | 821                       | 901.75                    | 1.72 |
| Petroleum ether | GNT1      | 280                       | 320                       | 420                       | 494                       | 378.50                    | 4.09 |
|                 | GNT2      | 200                       | 341                       | 456                       | 535                       | 383.00                    | 4.04 |
|                 | GNT3      | 274                       | 312                       | 458                       | 498                       | 385.50                    | 4.02 |
|                 | Sugandham | 400                       | 378                       | 475                       | 467                       | 430.00                    | 3.60 |
|                 | SEm       |                           | CD                        |                           |                           |                           |      |
| Year            | Y         | 2.23                      | 6.251                     |                           |                           |                           |      |
| Solvent         | A         | 34.59                     | 110.664                   |                           |                           |                           |      |
|                 | Y*A       | 4.47                      | 12.503                    |                           |                           |                           |      |
| Variety         | B         | 12.08                     | 38.659                    |                           |                           |                           |      |
|                 | Y*B       | 4.47                      | 12.503                    |                           |                           |                           |      |
|                 | A*B       | 17.11                     | 49.659                    |                           |                           |                           |      |
|                 | Y*A*B     | 8.94                      | 25.006                    |                           |                           |                           |      |
|                 | Y         | 2.23                      | 6.25160                   |                           |                           |                           |      |

**Table 3:** DPPH Assay pooled data

| Solvent         | Variety   | 2022-23<br>Percentage (%) of inhibition | 2023-24<br>Percentage (%) of inhibition | 2024-25<br>Percentage (%) of inhibition | 2025-26<br>Percentage (%) of inhibition | Average<br>Percentage (%) of inhibition | CV%   |
|-----------------|-----------|-----------------------------------------|-----------------------------------------|-----------------------------------------|-----------------------------------------|-----------------------------------------|-------|
| Methanol        | GNT1      | 70.35                                   | 80.12                                   | 78.32                                   | 85.32                                   | 78.53                                   | 7.60  |
|                 | GNT2      | 68.14                                   | 71.32                                   | 70.21                                   | 75.20                                   | 71.22                                   | 8.38  |
|                 | GNT3      | 71.23                                   | 67.45                                   | 72.59                                   | 80.58                                   | 72.96                                   | 8.18  |
|                 | Sugandham | 64.60                                   | 61.26                                   | 69.45                                   | 78.11                                   | 68.36                                   | 8.73  |
| Acetone         | GNT1      | 54.86                                   | 50.36                                   | 48.35                                   | 72.36                                   | 56.48                                   | 10.56 |
|                 | GNT2      | 60.61                                   | 59.47                                   | 50.21                                   | 65.32                                   | 58.90                                   | 10.13 |
|                 | GNT3      | 59.29                                   | 60.34                                   | 55.65                                   | 61.24                                   | 59.13                                   | 10.09 |
|                 | Sugandham | 55.30                                   | 52.98                                   | 49.36                                   | 65.25                                   | 55.72                                   | 10.71 |
| Ethanol         | GNT1      | 73.28                                   | 70.58                                   | 75.85                                   | 72.45                                   | 73.04                                   | 8.17  |
|                 | GNT2      | 72.12                                   | 75.68                                   | 69.84                                   | 70.11                                   | 71.94                                   | 8.29  |
|                 | GNT3      | 76.54                                   | 80.24                                   | 72.35                                   | 78.96                                   | 77.02                                   | 7.75  |
|                 | Sugandham | 69.46                                   | 71.95                                   | 74.65                                   | 76.33                                   | 73.10                                   | 8.16  |
| Petroleum ether | GNT1      | 32.30                                   | 44.50                                   | 49.25                                   | 50.31                                   | 44.09                                   | 13.53 |
|                 | GNT2      | 23.00                                   | 38.64                                   | 46.38                                   | 48.67                                   | 39.17                                   | 15.23 |
|                 | GNT3      | 26.10                                   | 31.87                                   | 48.28                                   | 40.50                                   | 36.69                                   | 16.26 |
|                 | Sugandham | 24.33                                   | 30.24                                   | 41.63                                   | 39.68                                   | 33.97                                   | 17.57 |
|                 | SEm       |                                         | CD                                      |                                         |                                         |                                         |       |
| Year            | Y         | 0.86                                    | 2.4100                                  |                                         |                                         |                                         |       |
| Solvent         | A         | 2.58                                    | 8.2540                                  |                                         |                                         |                                         |       |
|                 | Y*A       | 1.72                                    | 4.8201                                  |                                         |                                         |                                         |       |
| Variety         | B         | 0.86                                    | 2.4100                                  |                                         |                                         |                                         |       |
|                 | Y*B       | 1.72                                    | 4.8201                                  |                                         |                                         |                                         |       |
|                 | A*B       | 1.72                                    | 4.8201                                  |                                         |                                         |                                         |       |
|                 | Y*A*B     | 3.45                                    | 9.6403                                  |                                         |                                         |                                         |       |
|                 | Y         |                                         |                                         |                                         |                                         |                                         |       |

**Table 4:** FRAP value of sample( $\mu\text{M}$ ) pooled data

|                 |           | 2022-23                      | 2023-24                      | 2024-25                      | 2025-26                      | Average                      |       |
|-----------------|-----------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|-------|
| Solvent         | Variety   | FRAP value ( $\mu\text{M}$ ) | FRAP value ( $\mu\text{M}$ ) | FRAP value ( $\mu\text{M}$ ) | FRAP value ( $\mu\text{M}$ ) | FRAP value ( $\mu\text{M}$ ) | CV%   |
| Methanol        | GNT1      | 0.800                        | 0.753                        | 0.652                        | 0.735                        | 0.735                        | 9.62  |
|                 | GNT2      | 0.765                        | 0.820                        | 0.785                        | 0.801                        | 0.793                        | 8.92  |
|                 | GNT3      | 0.826                        | 0.864                        | 0.6.20                       | 0.686                        | 0.792                        | 8.93  |
|                 | Sugandham | 0.794                        | 0.756                        | 0.759                        | 0.857                        | 0.792                        | 8.93  |
| Acetone         | GNT1      | 0.790                        | 0.732                        | 0.711                        | 0.652                        | 0.721                        | 9.80  |
|                 | GNT2      | 0.634                        | 0.761                        | 0.701                        | 0.769                        | 0.716                        | 9.87  |
|                 | GNT3      | 0.799                        | 0.820                        | 0.754                        | 0.828                        | 0.800                        | 8.84  |
|                 | Sugandham | 0.744                        | 0.698                        | 0.723                        | 0.734                        | 0.725                        | 9.76  |
| Ethanol         | GNT1      | 0.967                        | 0.980                        | 0.863                        | 0.783                        | 0.898                        | 7.87  |
|                 | GNT2      | 0.910                        | 0.890                        | 0.846                        | 0.775                        | 0.855                        | 8.27  |
|                 | GNT3      | 0.892                        | 0.865                        | 0.790                        | 0.835                        | 0.846                        | 8.36  |
|                 | Sugandham | 1.000                        | 0.880                        | 0.756                        | 0.786                        | 0.856                        | 8.27  |
| Petroleum ether | GNT1      | 0.905                        | 0.865                        | 0.752                        | 0.682                        | 0.801                        | 8.83  |
|                 | GNT2      | 0.677                        | 0.734                        | 0.832                        | 0.762                        | 0.751                        | 9.41  |
|                 | GNT3      | 0.626                        | 0.684                        | 0.746                        | 0.695                        | 0.688                        | 10.28 |
|                 | Sugandham | 0.599                        | 0.692                        | 0.736                        | 0.652                        | 0.670                        | 10.56 |
|                 |           | SEm                          | CD                           |                              |                              |                              |       |
| Year            | Y         | 0.01                         | 0.0290                       |                              |                              |                              |       |
| Solvent         | A         | 0.02                         | 0.0680                       |                              |                              |                              |       |
|                 | Y*A       | 0.02                         | 0.0581                       |                              |                              |                              |       |
| Variety         | B         | 0.02                         | 0.0614                       |                              |                              |                              |       |
|                 | Y*B       | 0.02                         | 0.0581                       |                              |                              |                              |       |
|                 | A*B       | 0.03                         | 0.0757                       |                              |                              |                              |       |
|                 | Y*A*B     | 0.04                         | 0.1163                       |                              |                              |                              |       |

**Table 5:** The antimicrobial activity of various extract of Turmeric Variety (GNT3)

| Sr. No. | Sample          | Bacteria                   | Zone of inhibition (mm) |      |       | Average Zone of inhibition (mm) |
|---------|-----------------|----------------------------|-------------------------|------|-------|---------------------------------|
| 1.      | Methanol        | <i>Escherichia coli.</i>   | 14.9                    | 12.5 | 12.3  | 13.23                           |
|         |                 | <i>Bacillus subtilis</i>   | 12.0                    | 11.5 | 10.0  | 11.17                           |
|         |                 | <i>Bacillus megaterium</i> | 14.7                    | 13.6 | 12.0  | 13.43                           |
|         |                 | <i>Streptococcus</i>       | 10.9                    | 9.3  | 8.5   | 9.57                            |
| 2.      | Ethanol         | <i>Escherichia coli.</i>   | 16.2                    | 15.2 | 14.8  | 15.40                           |
|         |                 | <i>Bacillus subtilis</i>   | 13.0                    | 12.3 | 11.5  | 12.27                           |
|         |                 | <i>Bacillus megaterium</i> | 11.7                    | 9.9  | 10.4  | 10.67                           |
|         |                 | <i>Streptococcus</i>       | 11.4                    | 10.7 | 11.2  | 11.10                           |
| 3.      | Acetone         | <i>Escherichia coli.</i>   | 12.2                    | 12.8 | 13.6  | 12.87                           |
|         |                 | <i>Bacillus subtilis</i>   | 10.7                    | 9.3  | 8.7   | 9.57                            |
|         |                 | <i>Bacillus megaterium</i> | 13.5                    | 12.7 | 11.7  | 12.63                           |
|         |                 | <i>Streptococcus</i>       | 9.8                     | 8.5  | 7.8   | 8.70                            |
| 4.      | Petroleum ether | <i>Escherichia coli.</i>   | 10.5                    | 9.6  | 8.9   | 9.67                            |
|         |                 | <i>Bacillus subtilis</i>   | 9.45                    | 8.8  | 8.6   | 8.95                            |
|         |                 | <i>Bacillus megaterium</i> | 10.8                    | 10.3 | 11.00 | 10.70                           |
|         |                 | <i>Streptococcus</i>       | 8.2                     | 9.7  | 7.8   | 8.57                            |

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