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Synthesis, and A Novel High-Performance Liquid Chromatographic Method for the Determination of Naproxen in Pharmaceutical Formulations

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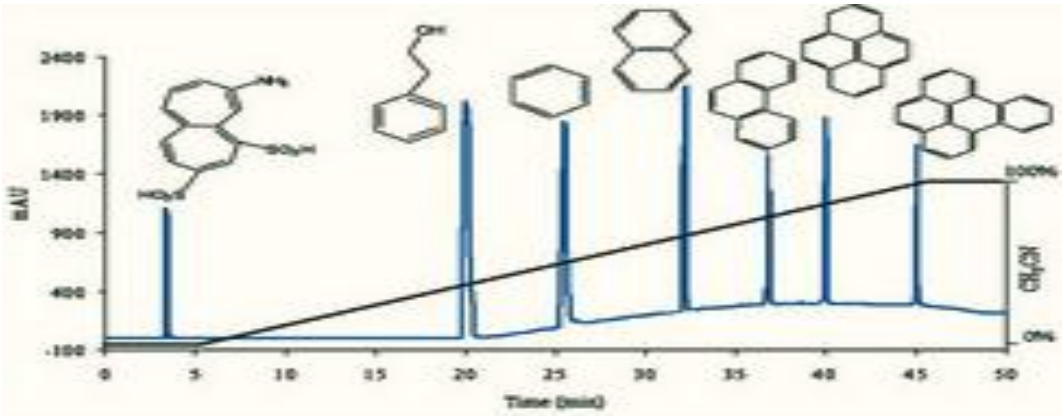
Graphical Abstract



ABSTRACT
We established a simple and accurate optimised RP-HPLC method for quantitative estimation of naproxen in pharmaceutical dosage forms. The method was developed using an Agilent SCX-300 column (250 × 4.6 mm, 5 µm) at room temperature. The mobile phase consisted of methanol, water, and acetonitrile in a volumetric ratio of 60:20:20, supplemented with 7 mM docusate sodium and perchloric acid, adjusted to a pH of 3.We calibrated a UV detector at 254 nm to detect column washing, and adjusted the flow rate to one millilitre per minute to ensure proper column cleaning. The naproxen retention time in this experiment was 3.4 ± 0.1 minutes; this was considered good. The fact that the recovery rate exceeded 100% in this case confirmed the accuracy of the technique. But the new technique failed to meet the high degrees of precision stipulated by the ICH and the FDA; it had an RSD percent of 2.0. The technique yielded a linear response, with a correlation coefficient of one. Technological advancements that demonstrate precise analysis of naproxen in trademarked prisms are credible, repeatable, delicate, and time-efficient, thereby enabling routine analysis of naproxen in pharmaceutical formulations.

Keywords: Novel Chromatographic Method for NaproxenICH, USP and FDA guidelines.

INTRODUCTION

Naproxen matches codeine in substance and form although it belongs to the NSAID drug class. Despite its existence, naproxen provides stronger pain alleviation than codeine but works independently from brain receptors for serotonin and dopamine. Naproxen demonstrates better results than opioid drugs in handling many types of pain. The main benefits of this drug help patients manage their pain and fight both fever and swollen tissue. Doctors use naproxen to treat three main issues: kidney stones, osteoarthritis and rheumatoid arthritis

which is an inflammatory joint disease. The data in Appendix Figure 1 shows Naproxen has 230.26 grams in one molecule and acts as C2H2O2 [1,2]. Its boiling point reaches 403.9 degrees Celsius.

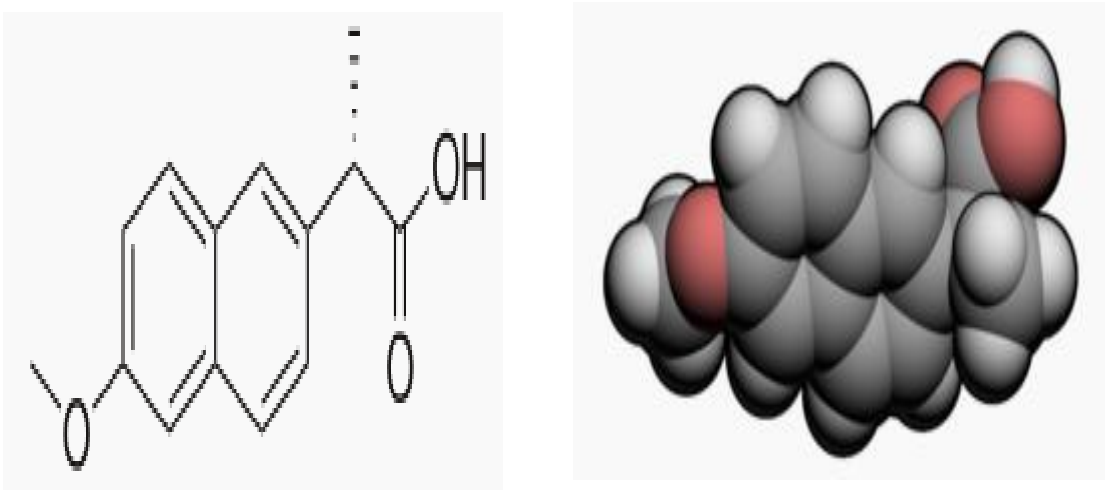


Figure 1: Chemical Structure of Naproxen

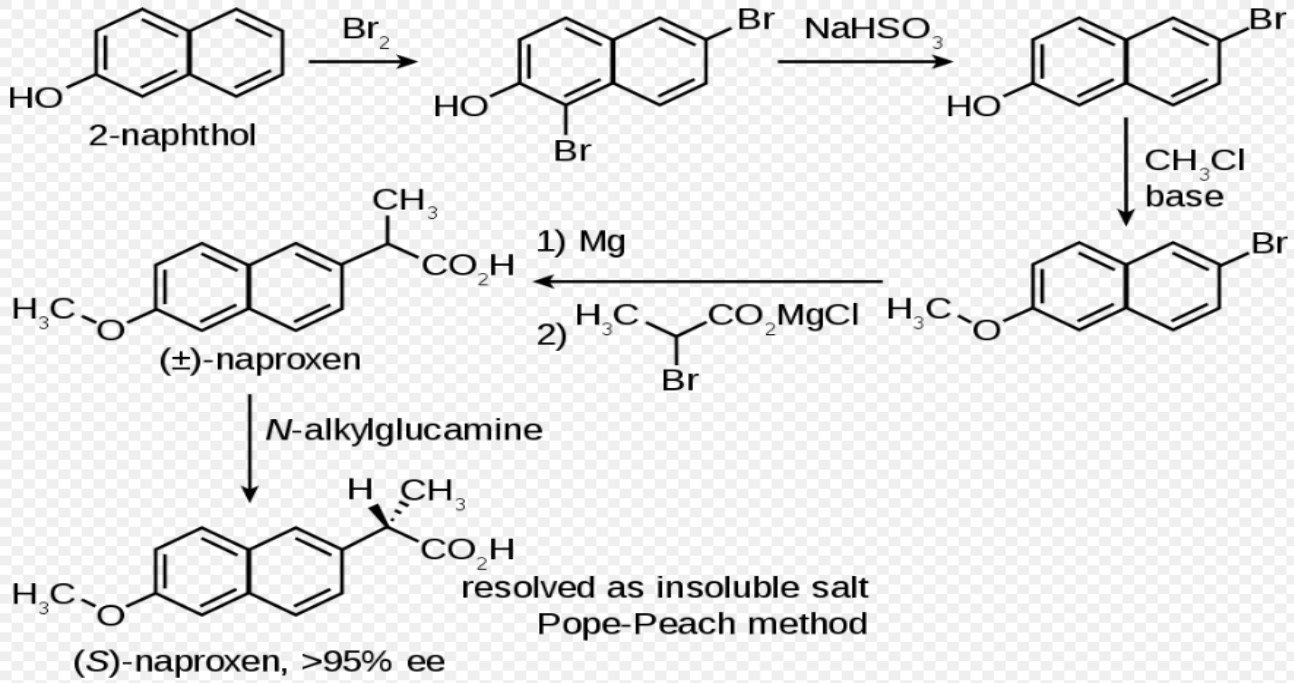
The $C_{14}H_{14}O_3$ structure defines pharmaceutical experts to classify naproxen as a 2-arylpropionic acid compound belonging to the nonsteroidal anti-inflammatory drugs (NSAIDs). Naproxen appeared globally in 1976 under Xenobid Inaprol then obtained several trade names Multiple brands sell Naproxen: Aleve, Anaprox, Antalgin, Feminax Ultra, Flanax, Inza, Midol Extended Relief, Miranax, Nalgesin, Naprogesic, Naprosyn, Narocin, Proxen, Synflex and Nexorpan. The medicinal use of naproxen began after receiving worldwide approval for prescription in 1976 and it rapidly became well-known because of its strong anti-inflammatory capabilities and pain-blocking effects and its ability to reduce fever [3,4]. As a NSAID product naproxen obstructs enzymes that assist arachidonic acid in prostaglandin synthesis.The ability of naproxen to inhibit pain and inflammation and reduce fevers makes it a popular choice for treating osteoarthritis along with rheumatoid arthritis and juvenile arthritis and ankylosing spondylitis and tendonitis and bursitis and acute gout. The enzyme component thromboxane A2 becomes a target for naproxen enabling this drug to affect platelet functionality. Naproxen stands out as a preferred prescription medicine because it has an attractive safety profile with fewer unwanted side effects than alternative NSAIDs such as aspirin and indomethacin. Quantitative naproxen measurements within pharmaceutical formulations remain important for both therapeutic effectiveness and product approval exams. The analysis of naproxen employs multiple contemporary techniques through ultraviolet (UV) spectroscopy and liquid chromatography-mass spectrometry (LC-MS) and high-performance liquid chromatography (HPLC) and high-performance thin-layer chromatography (HPTLC) (Gondalia and Dharamsi, 2010; Shubhangi et al., 2010; Palavai et al., 2011; Haque These established methods work well yet develop drawbacks like extended analytical period requirements along with elevated maintenance costs which make them less suitable for pharmaceutical laboratory use. A thorough development of reverse-phase high-performance liquid chromatography (RP-HPLC) must be pursued because it would provide a simple and cost-itting forcadu capacity analysis approach for naproxen pharmaceutical products quality testing. This research quantifies the proposed RP-HPLC approach through validations that obey both U.S. Food and Drug Administration (FDA) and International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use (ICH) regulatory criteria [5-7]. This method validation establishes the new RP-HPLC technique as a reliable precise method which follows Standards for the monitoring of naproxen content in pharmaceutical formulations on an international level.

The operational duration of traditional high-performance liquid chromatography (HPLC) columns determines analysis costs because sample stock solution acid and salt concentrations affect this lifespan. Participating salts in dilutions occur infrequently but they drive up upkeep costs for HPLC pump systems. Operations costs in pharmaceutical analysis become crucial because routine organic chemical use adds to overall spending while strategic cost reductions need to be implemented [8,9]. Scientists evaluated naproxen concentrations by implementing a liquid chromatography instrument with UV detection setup at 254 nm wavelength parameters. The Agilent Zorbax-SCX-C18 reversed-phase column served as the analysis platform because it provided efficient separation of samples while operating at 5 μm 250 mm × 4.6 mm dimensions. Peak asymmetry became a significant problem during chromatographic analysis [10,11] because it affects both analytical precision and measurement reliability. Naproxen analysis generates substantial academic research but current procedures face ongoing technical challenges that affect their effectiveness. The analysis technique of choice is HPLC especially

when used as spectrophotometric HPLC because it tells precise details about samples using very small amounts of material. The combination of high-performance liquid chromatography with ultraviolet spectrophotometry enables efficient quantitative naproxen measurements in pharmaceutical and biological matrices. Sample pre-treatment and cleaning processes require extensive diligence since they extend analysis times and increase expenses as major disadvantages. Effective naproxen calibration requires the creation of solid and dependable analytical methods which prioritize quantitative precision and regulatory conformance. UV-Vis spectrophotometry stands as a preferred choice for laboratory-based analysis in both pharmaceutical industries and research facilities because of its beneficial operation characteristics and affordable setup. The broad application reveals an ongoing need for enhanced analytical technique development which aims to improve efficiency and reduce costs in standard quality control procedures [12-15].

Synthesis of Naproxen [16]

Naproxen is manufactured by Syntex through the following industrial processes:



Scheme 1: Synthesis Process of Naproxen

The Objective of the Research

The research established and verified an accurate method that utilized RP-HPLC equipment with UV detection for naproxen measurement in pharmaceutical preparations. Ultraviolet detection plays an essential role in maintaining both precise and consistent analysis results. We aim to create a state-of-the-art analytical method which performs precise pharmaceutical examinations that both match regulatory requirements and deliver reliable substance assessments.

Experimenting

Tools

The LC-100 S-HPLC includes both a fast computer processor together with user-friendly controls collaborated with straightforward maintenance requirements. This cutting-edge instrument maintains outstanding stability combined with reliability through its electronic signal organization and internal electrical circuit and structural system while also featuring process optimization capabilities together with cinematic workspace requirements. The HPLC-UV system, featuring a laser diode type, comprises two essential components: a laser diode manufactured by Angstrom Advanced Inc., USA, and a quartz cell from the UV-100 PC series. The system package includes a versatile computer interface compatible with IBM platforms.The system utilized Matlab R2003b and PLS Toolbox along with VP pumps and variable frequency programmable UV indicators. The system featured PLS as one of its components alongside R2003b software while including R2003b PLS Toolbox for chemometric structures and a UV indicator operated through variable frequency programming. Peak regions within the system start exchanging information at this stage of development. This research employed the LC solution programming instruments from Angstrom Advanced Inc. as its main software system. Presentation of findings required the implementation of an Agilent Ion Pac zorbax 300-SCX column for both chromatographic

separation and estimation purposes. An Agilent Ion Pac zorbax 300-SCX column served both analytical functions during estimation procedures. The analytical column's operational performance remained unaffected when temperature changes occurred. Credential systems operated at the portable stage before HPLC integration used this process for handling drug standard approaches and verifying pharmaceutical tablets [17-19].

Reagents and Chemical

Medical instruments together with pharmaceutical applications utilize Lot number 097H3685 and CAS number 22204-53-1 which holds authorized use by Sigma-Aldrich Industries. This authorization confirms adherence to rigorous industry requirements which assures superior product quality with peak safety and functional outcomes for medical instrument and pharmaceutical manufacturing.

Market Sample

Naproxen tablets used for analysis in this research came from Wockhardt UK Ltd and delivered 500 mg of Naproxen medicine under their Wockhardt UK Ltd® brand. This pharmaceutical preparation meets all pharmaceutical requirements for maintaining consistency, potency and therapeutic effect.

Sample Preparation for Analysis

This study obtained all HPLC-grade solvents from Sigma-Aldrich® because this company provides precise measurement-grade solutions with high purity. Naproxen solutions were meticulously prepared at concentrations of 5, 10, 15, 20, and 25 µg/mL, using a carefully optimized solvent composition consisting of methanol, water, and acetonitrile in a volumetric ratio of 60:20:20 (v/v). A solution environment of precise accuracy was established by controlling the pH at 3.0 using perchloric acid and 7 mM Docusate sodium which ensured stability with reproducible performance. A standard naproxen solution was similarly formulated using the identical solvent system—methanol, water, and acetonitrile (60:A solution of naproxen containing mestozoate sodium (7 mM) and perchloric acid at 60:20:20 v/v was formulated to maintain a pH of 3.0. Standard solutions containing precise concentrations ranging from 5 µg/mL to 25 µg/mL were used to develop a precise calibration curve for method accuracy testing and regulatory quality standard compliance verification.

Sample Modernization

Analysis of additional aspects of Naproxen-Wockhardt UK Ltd® tablets led to improvements in the PLS (Partial Least Squares) configuration that expanded upon preliminary results from the basic Wockhardt UK Ltd® Naproxen-500 mg tablets. An informative methodological model was created due to require more detailed analysis and manage potential test category inconsistencies. The modification served to optimize basic analysis so the testing methodology could create structured evaluation procedures for examining patterns used to purchase different segments of medications. End-to-end validation support through condensed testing worked as an essential aspect to measure the prediction precision of the recently improved analytical model. The developed RP-HPLC method allowed core modifications to be finalized during test segment efficiency assessments across categories. The method evaluation included three supplementary free-form naproxen concentrations to test robustness and minimize measurement variation. The expanded analytical structure established an accurate method framework to uphold quality control as well as regulatory compliance across assessed product sections [20].

Preparation of Solutions

Preparation of the Mobile Phase

A controlled mixture of methanol, water and acetonitrile obtained the correct ratio followed by the addition of 7 mM Docusate sodium and 3 mM perchloric acid to optimize HPLC performance. The water bath ultrasonic treatment applied for five minutes ensured a thorough combination of all solution components while achieving optimal solution homogeneity. A high purity solution ready for HPLC analysis was obtained as the mobile phase went through vacuum filtration using a 0.45 µm membrane filter for consolidating contaminant removal [21].

Preparation of Naproxen Standard Solution

A 1000 mL volumetric flask received 500 mg of naproxen after which the volume was adjusted using mobile phase solvent to create the homogenous stock solution. Precision in measurement allowed a 5-milliliter stock aliquot to be transferred from the stock solution into a 100-milliliter volumetric flask before mobile phase addition completed the dilution process. This carefully prepared standard solution functioned as an essential reference standard which enabled precise calibration methods and validated the accuracy needed for subsequent analytics work [22].

Preparation of Naproxen Sample Solution

An analytical solution of naproxen required crushing twenty professional naproxen tablets with a 500 mg active ingredient into uniform microparticles. The well-powdered sample obtained equal amounts by volume before addition of mobile phase up to the final solution strength at 25 mg/mL capacity in a 1000-mL volumetric flask. A 30-minute incubation followed by solution preparation served to completely dissolve both naproxen API and excipients to maximize analytical results. Under precise conditions about 5 milliliters of solution were accurately obtained from the prepared solution before diluting it to a final volume of 100 mL by using mobile phase solvent. The extensive preparation procedures generate solutions that combine precision and accuracy with reproducibility for efficient high-precision chromatographic applications [23].

Wavelength Selection for Method Development

The research team meticulously performed multiple investigations to determine which detection wavelength would deliver the most precise naproxen measuring results. Various quantities of naproxen were methodically produced using a methanol:Multiple data points collected by spectral analysis covered 190–300 nm wavelength to identify the most absorbent naproxen spectrum usingcedures that included methanol:acetonitrile solvent solution. A spectral scan of naproxen confirmed its peak absorption at 254 nm which determined 254 nm as the best wavelength for improved sensitivity and measurement precision during RP-HPLC analysis. The detection wavelength of 254 nm was selected for excellent analytical performance and reliable quantification in upcoming investigations (refer to Figure 2) [24].

Method Development

The RP-HPLC method underwent thorough development and optimization procedures to achieve conformance with the specifications defined by United States Pharmacopeia (USP). The method development process achieved optimized chromatographic performance by adjusting solvent proportions and using proper column materials together with flow rate controls for peak resolution enhancement. The method development process carefully controlled variables such as:

- Detection wavelength: 254 nm
- Flow rate: Maintained at 1.0 mL/min
- Column temperature: Set at 25°C

Studies to validate method reliability and precision and reproducibility have been conducted using the chromatographic conditions that appear in Figure 2 and Table 1. The optimal method conditions ensure both precise quantification while maintaining reliable analytical functionality needed for pharmaceutical quality control surveillance [25].

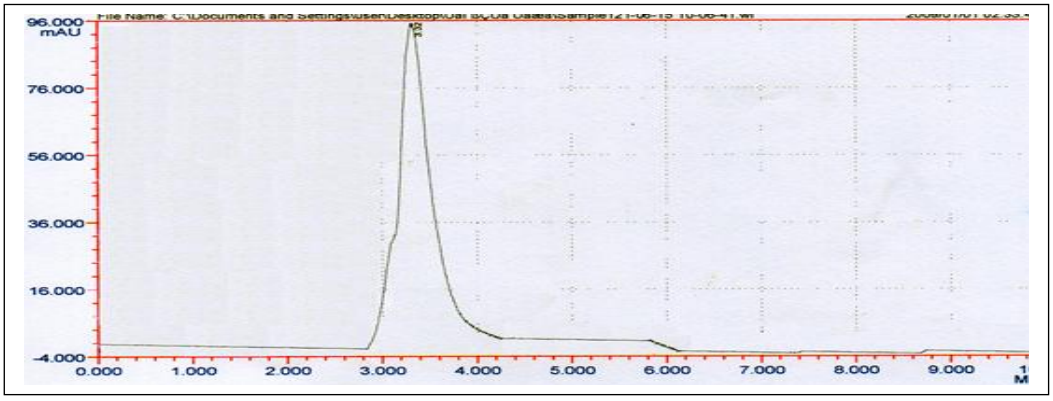


Figure 2: UV spectra of Naproxen

3.5. Conditions of Chromatography

Table 1: exhibits the obtained basic parameter values utilizing RP-HPLC.

Mobile phase	Methanol: water: acetonitrile in a (60:20:20) v/v ratio, with 7 mM Docusate sodium and perchloric acid at pH 3
Run time	10 min
Column temperature	25 ^{o}C
Detection wavelength	254 nm
Flow rate	1.0 ml/minute
Injection volume	20 µL

Construction of Calibration Curve

The research team established naproxen solutions at different concentrations from 5 µg/mL up to 25 µg/mL for experimental purposes. The experimental solutions used mobile phase as diluent to obtain calibration data via generated curves. Developing this procedural method enabled personnel to produce precise solutions from known amounts. Reliable and consistent data acquisition required precise experimental conditions as an essential component of chromatographic analysis. Total peak surface areas were measured post-chromatographic analysis to establish concentration levels. The standard solutions at each concentration level received their average value through computation to produce one uniform calibration curve. Peak area measurements integrated into concentration levels created a dependable quantitative method for RP-HPLC analysis during the curve development stage. The reliability of measurement methods stayed uniform throughout the course of research.

RESULTS

The Exertion Degeneration Studies

1- These efforts were carried out in accordance with the recommendations made by the International Council for Harmonisation (ICH), which included oxidative and photochemical testing [26-28].

1. Acid Degeneration

A researcher used 100 milliliters of powdered formulation to dissolve 60 milligrams of Naproxen drug. The experimentation involved addition of 5 milliliters 0.1N hydrochloric acid (HCl) to the sample at a temperature control point between 70–80°C. The chemical degradation of the solution needed 2 to 3 hours of reflux exposure. A portable stage served to verify complete reaction completion by performing NaOH neutralization after reaching targeted degradation objectives. Naproxen standards could produce HCl when exposed to aqueous solutions. The cleavage of chemical bonds through water addition represents a fundamental hydrolysis reaction which liquid systems consistently demonstrate. Energetic conditions combined with specific parameters allow amine hydrogenation to occur without needing acid-based or base-catalysts (Figure 3).

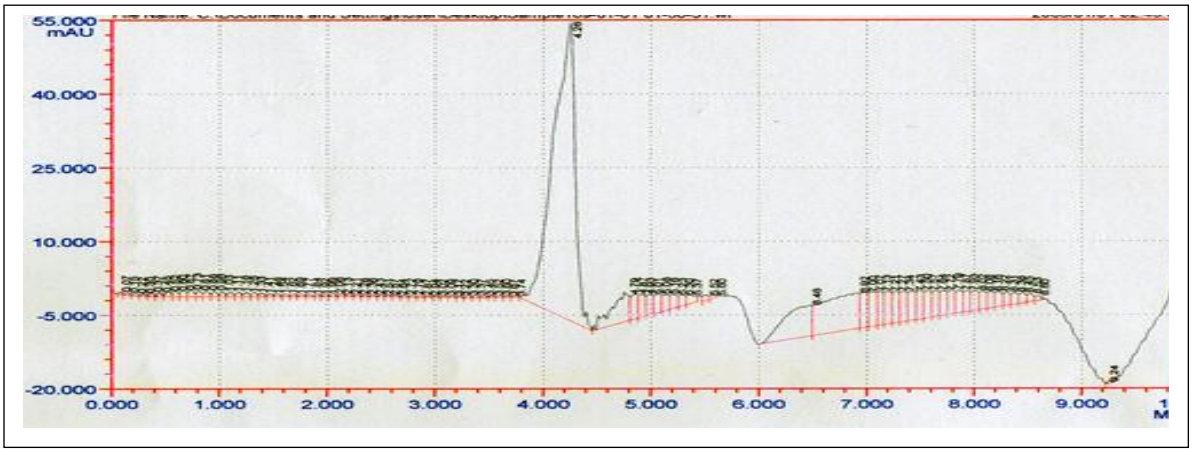


Figure 3. Acid degeneration

2. Base Degeneration

Mixing 100 millilitres of Naproxen solution required sodium hydroxide (NaOH) to regulate amine salt formation. The container received two liters of hydrochloric acid solution (0.1N concentration) under continuous reflux conditions at an elevated thermal setting for two to three hours. The HCl solution creation began by pouring salt into water leading to solution reactiveness optimization through additional water addition as pictured in [Figure 4].

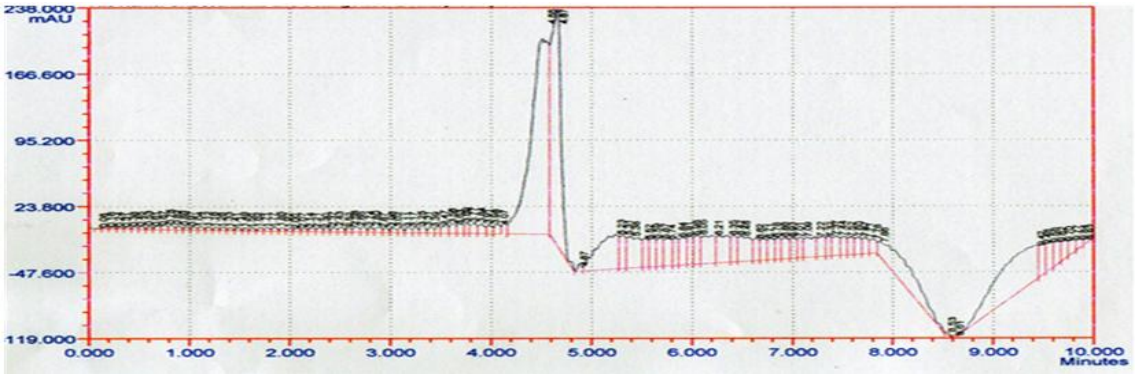


Figure 4. Base degeneration

3. Oxidative Degeneration

The sterilization process combined 60 milligrams of Naproxen with 5 milliliters of 20% Hydrogen peroxide solution and took place inside a 100 milliliter flask. The solution at reflux conditions maintained itself at a stable state for 2 to 3 hours before completing the process. The final preparation stage included container processing illustrated in Figure 5 which led to its readiness for crushing.

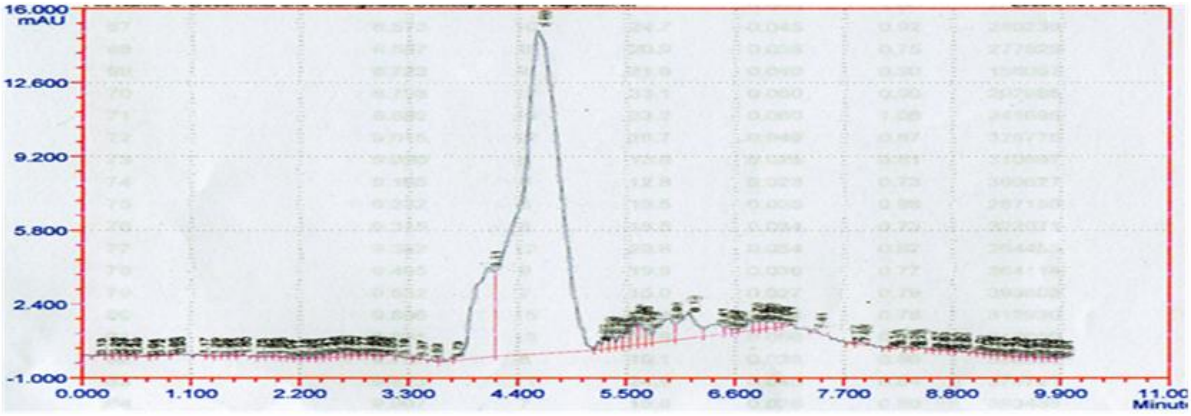


Figure 5. Oxidative degeneration

4. Photolytic Degeneration

Damage caused by oxidation is illustrated in Figure 6.

An exposed Petri dish containing Naproxen remained outside under direct sunlight for 2 to 3 hours to determine photodegradation potential. A milliliter volumetric device prepared the diluted solution before the pressure cooking procedure ran to establish a uniform sample for analysis. The tablet received exposure. Partial Naproxen breakdown under photolytic conditions allows detection of pharmaceutical preservatives and supplies crucial data about compound stability.

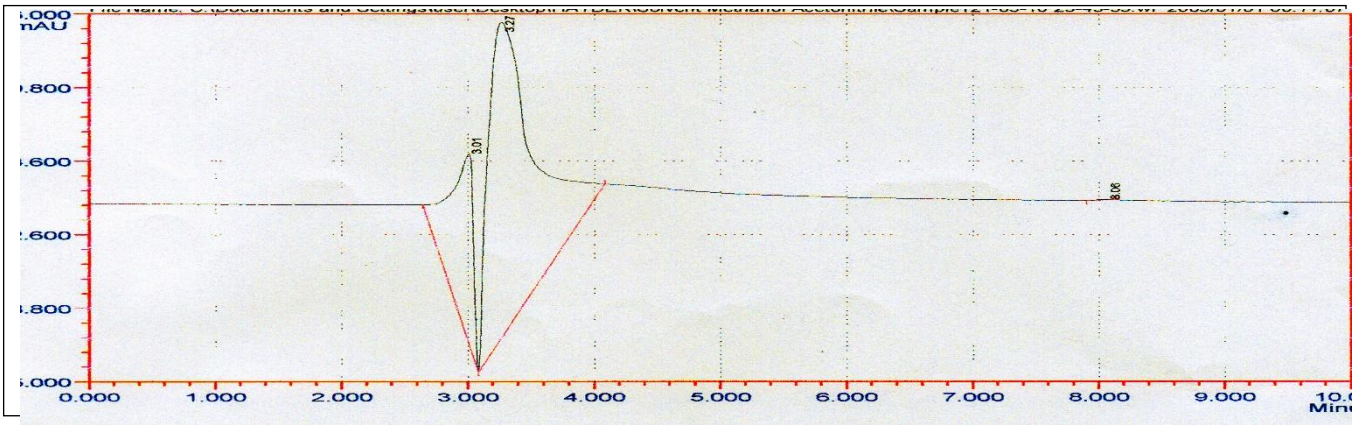


Figure 6. Photolytic degeneration

Thermal Degeneration

Sodium Naproxen was subjected to thermal treatment by baking on a glass plate at a temperature of 105°C for a period of 2 to 3 hours. Following the heating process, the substance was dissolved in 100 milliliters of water, and the resulting solution was subsequently discarded.The thermal degradation of the Naproxen molecule becomes evident when the solvent temperature exceeds 100°C, as illustrated in Figure 7. This experiment provides valuable insights into the stability and breakdown characteristics of the compound under elevated thermal conditions.

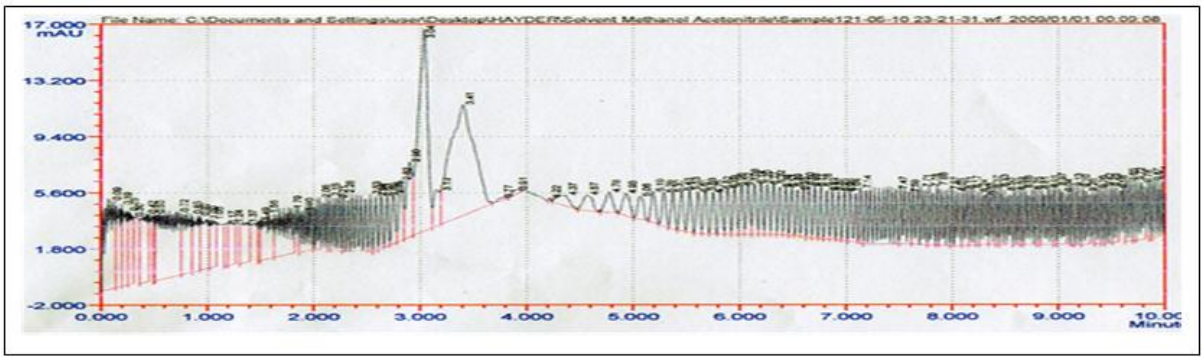


Figure 7. Thermal degeneration

Infrared Spectrophotometer of Naproxen

To record infrared spectra at room temperature using KBr discs, the University of Basrah for Science, Technology, and Education utilized an FT-IR-84005582 SHIMZU handset. This equipment was employed to effectively accomplish the analysis.

For Naproxen -Standard

Standard [Figure 8] shows the Naproxen structural framework. The O-H peak at 3200–3600 cm^{-1} shows excessive intensity which points to probable hydrogen bonding patterns in the structure. UV light scanning shows steady absorption and stretching and hydrogen bond-associated frequency patterns throughout the analysis of the given sample that reaches its highest point at 1487 cm^{-1}. The specific band regions for C-H stretching and bending occur from 3010–3100 cm^{-1} to 675–1000 cm^{-1}. The stretching and bending frequencies for aromatic C=C bonds exist between 2850–2900 cm^{-1} as well as between 3300–2100 cm^{-1}.

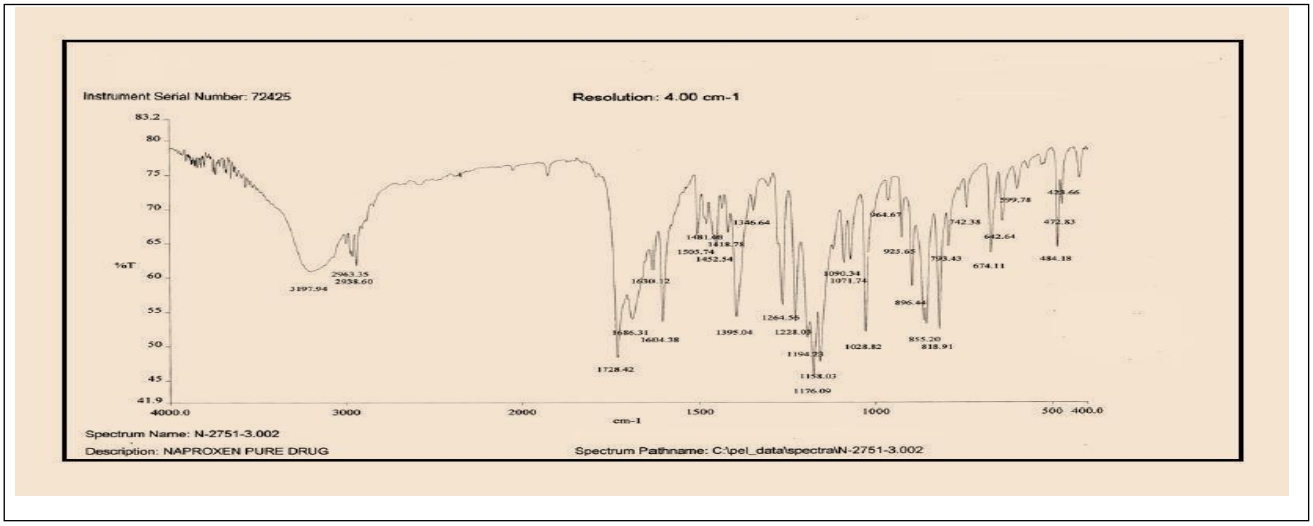


Figure 8. FT-IR Spectrum of Standard Naproxen.

A sample of Naproxen is required.

Naproxen's infrared (IR) spectrum shows that it is used to, strong and distinct absorption peaks are observed within the range of 3160–1662 cm^{-1}, while weaker yet noticeable absorbances are also present within the same spectral region. The Fourier-transform infrared (FT-IR) spectrum of Naproxen reveals characteristic peaks corresponding to the stretching vibrations of carbonyl (C=O) and carbon-oxygen (C-O) bonds, appearing within the ranges of 1670–1820 cm^{-1}, respectively.A significant absorption band detected at 1487 cm^{-1} is associated with the aromatic C=C bond, which has been linked to the phenomenon referred to as "bending the curve" or

frequency bending in this context. Additionally, the stretching and bending vibrations of the hydroxyl (O-H) functional group are observed within the range of 3200–3600 cm^{-1}, further confirming the molecular interactions and structural characteristics of Naproxen.

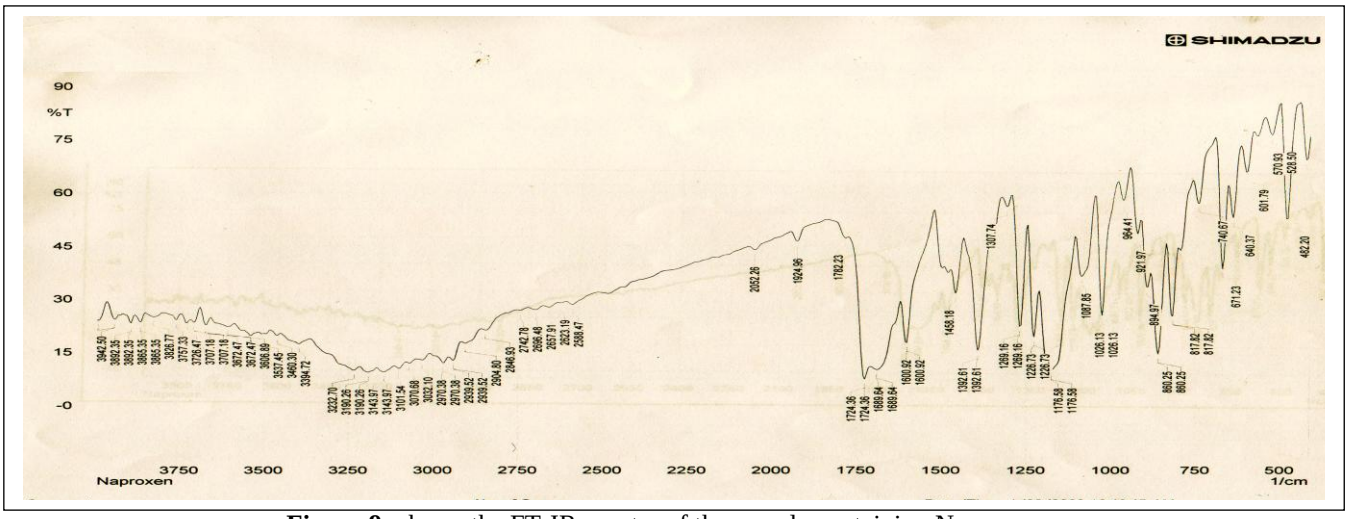


Figure 9: shows the FT-IR spectra of the sample containing Naproxen.

FINDINGS DISCUSSION

The Optimisation of Reaction Conditions for HPLC

It is necessary to optimise the chromatographic parameters that have been provided. successfully eliminate naproxen byproducts from the analytical system. The optimized organic phase formulation combines methanol with water and acetonitrile at ratios between 60% to 100%.Through a flow rate of 1 millilitre per minute, the Figled G perlite system was used to apply a 20:The researchers passed organic mixtures acidified to pH 3 with chloric acid through a 20:2 ratio to the column. More than several experimental runs required these procedures. The Ion Pac C18 column performed successful separation of targeted substances with dimensions 4.5 mm x 254 mm and 5 μm particle size. Naproxen data from laboratories showed its half-life spans 3.40 hours. As shown in Figure 10 peak analysis demonstrates the separation conditions' operational efficiency from a one minute run period.

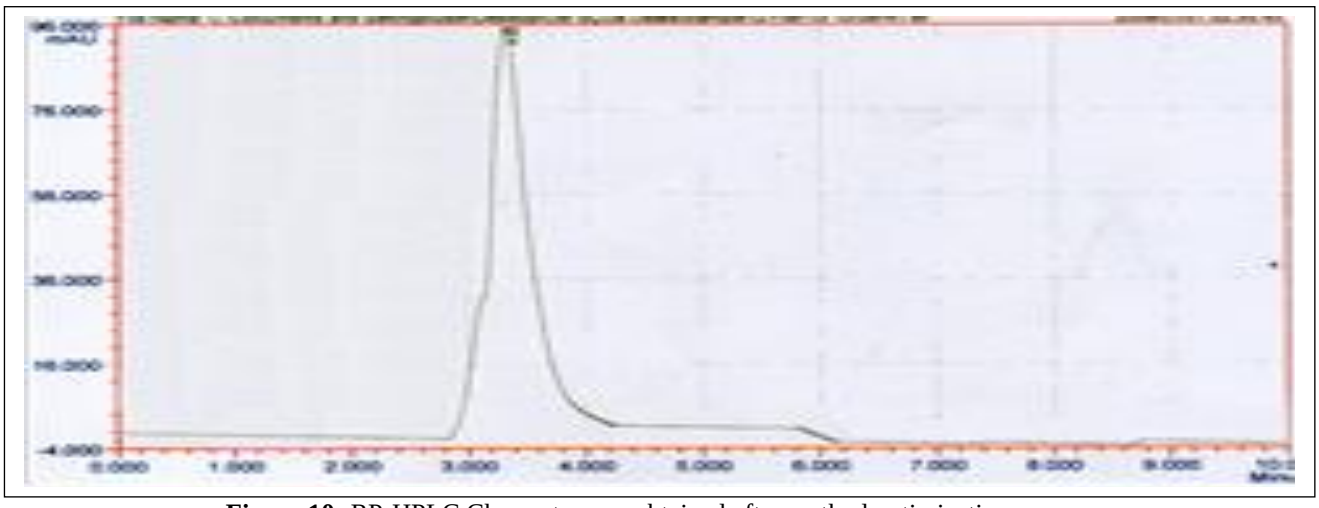


Figure 10: RP-HPLC Chromatogram obtained after method optimization

System Suitability

The accumulation of Naproxen provides evidence that the direction and help that were offered during idea analyses were shown to be successful. It has been found that the relative standard deviation (RSD) for the peak height area and residence duration was 2.0%. This conclusion was reached on the basis of the audit experience that is shown in Table 2.

Table 2. System suitability analysis of Naproxen

Recommended Limits	Value of Naproxen	Parameters
≥ 2000-2500	350	USP plate count
≥ 1.0-2.0	2.84	USP tailing factor
RSD ≤ 1	65418.9	Peak area (%RSD 0.110)
RSD ≈ 0.500	3.4 ± 0.1	Retention time (%RSD 0.130)
≥ 5 min	5.2 min	Resolution

The Verification of Procedure and Measurement

An HPLC-UV system that has been verified analytical method followed International Council for Harmonisation (ICH) guidelines [29] to assess sensitivity alongside specific test features and linearity and accuracy and robustness parameters. The method exhibited effective performance at 15 µg/mL Naproxen concentration through the thorough analytical peak region examination for method reliability assessment. Table 3 presents a full summary of validation data which outlines consolidated results from testing. The experiment revealed consistent peak regions across compounds while the research team adjusted flow rates and detector wavelength and thermal settings - showing method endurance. The validated HPLC-UV method meets both accuracy standards and operational suitability for routine analytical needs.

Table 3: Robustness of the developed method for Naproxen

Parameter	Naproxen		
	Discovered	Recovery	RSD
System	15 µg/ml	100 %	0.110 %
Analyst	15 µg/ml	100 %	0.111 %

Specificity

A study investigating forced degradation tested the proposed analytical technique's specificity by evaluating its capacity to differentiate Naproxen from its solvent-generated byproducts under stress testing circumstances. The method's reliability for Naproxen identification was tested against various potential degradation byproducts potentially encountered during stability testing by measuring 15 µg/mL Naproxen containing tablets under stress conditions. The summary of Naproxen degradation data from forced experimentation appears in Table 4 and Figures 2–7 illustrate chromatographic results from experimental runs under different parameters. Research shows Naproxen breaks down most rapidly in basic solutions indicating its decreased stability in alkaline media. Experiments showed Naproxen demonstrated maximum resistance towards degradation when subjected to heat exposure and exposure to light but displayed diminished stability when applied to alkaline solutions alone. The single peak observed during decomposition indicated that breakdown followed an established uniform pathway.

Table 4: Results of forced degradation studies

Degradation Condition	Naproxen Concentration (60 µg/ml)	% Recovery	% Degradation
Control (Undegraded)	100.000	98.89	1.110
Acidic Degradation	95.412	99.047	0.953
Basic Degradation	93.215	99.167	0.833
Oxidative Degradation	87.506	99.223	0.777
Photolytic Degradation	85.003	99.689	0.311
Thermal Degradation	75.710	99.394	0.606

Linearity and Range

Researchers carried out spectral analysis on solutions with concentrations ranging from 5 µg/mL to 25 µg/mL. The chromatographic peak heights from the recorded chromatograms were meticulously analyzed and integrated to generate a precise linearity plot.The correlation coefficient (R^2) achieved a value of 1.0, indicating an almost perfect linear relationship between the concentration and the corresponding peak response, demonstrating the method's high precision and reliability.Figure 11 provides a visual representation of the linearity assessment, confirming the robustness and accuracy of the analytical approach for quantifying Naproxen.

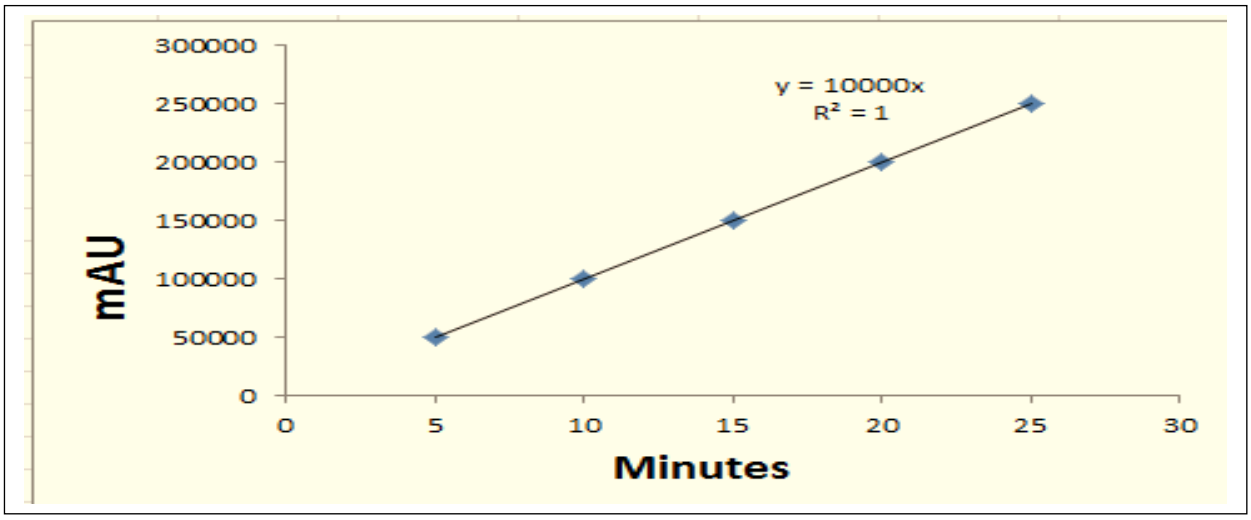


Figure 11. Calibration plot of Naproxen

The Regression

The evaluation of analytical method sensitivity required calculations to establish the lower limit of quantification (LLOQ) and the limit of detection (LOD). Experimental findings verified that the established analytic procedure functions correctly through application of standard calculation methods employing a baseline standard deviation of 10 and precision standard deviation of 3.3. Analysis of the selected drug revealed an LOD measure at 0.01 µg/mL and an LLOQ measure at 0.11 µg/mL. These findings emerged from the combination of the standard deviation (SD) values for drug response and the calibration curve slope (S). This analytical method demonstrates adequate sensitivity to perform quantitative measurements on the examined drug. The regression statistics fully demonstrate method precision and reliability as shown below.

Table 5: Regression Analysis of the Proposed Method

Parameter	Value
Coefficient of Determination (R^2)	1.000
Standard Error	~0.00
Standard Error of Estimate	~0.00
Intercept	~0.00
Slope	10,000
Lower Limit of Detection (LLOD) (µg/ml)	0.01
Lower Limit of Quantification (LLOQ) (µg/ml)	0.11

Accuracy

The precision of a forecast depends heavily on matching the expected return with the final actual value during comparison. Tests determine recoverability through calculation of R which indicates the measurement of analyte recovery effectiveness. Different techniques enable such an operation. Before using the calibration curves created for varying Naproxen amounts it needed independent testing through three different participants in three separate runs. The obtained data underwent percent Recovery calculation [(Recovered concentration/ Injected concentration) X 100] for evaluating the validity of proposed methodology. The experimental findings appear in Table 6. Laboratory data reaches an acceptable level only when it has deviated from the target value by more than ten percent [31].

Table 6: The compiled findings of precision

Claimed Concentration (µg/ml)	Found Concentration (µg/ml)	Recovery ± RSD
5	5.0	100 ± 0.100
10	10	100 ± 0.092
15	15	100 ± 0.0977
15 µg/ml for drugs (Naproxen, Wockhardt UK Ltd., 500 mg)	15	100 ± 0.122

Precision

In order to determine the percentage of RSD, six measurements were carried out using the model that was stated, and the amount of Naproxen that was administered was 100 mg/mL. According to the information shown

in Table 7 [31], the United States Pharmacopeial Convention (USPC) determined that the RSD's accuracy was unsatisfactory, with a value of less than 2%.

Table 7: Experiment findings on precision

Claimed Concentration (µg/ml)	Intraday Analysis (Found ± RSD%)	Interday Analysis (Found ± RSD%)
5	5.00 ± 0.100	5.00 ± 0.092
10	10.00 ± 0.092	10.00 ± 0.109
15	15.00 ± 0.0977	15.00 ± 0.901
20	20.00 ± 0.170	20.00 ± 0.089
25	25.00 ± 0.122	25.00 ± 0.899
15 µg/ml (Naproxen, Wockhardt UK Ltd., 500 mg)	15.00 ± 0.192	15.00 ± 0.099

The Applications of Method

The Naproxen 500 mg dosage was established through assessment of commercially available Wockhardt UK Ltd. produced tablets which officially state Naproxen content at 500 mg per tablet. The standard Naproxen material contained 0.111% concentration by mass but the Wockhardt UK Ltd. formulation had 0.11% concentration by mass. Together these results validate the proposed analytical method as an effective instrument to examine Naproxen formulations. Additional evidence demonstrating profile precision for dosage determination appears in Table 8 of this experiment.

Table 8: Analysis of Naproxen in tablet form

Analyte	**Labeled Content (mg)**	**Detected (mg)**	**Average (mg)**	**Percentage of Recovery**	**Percent Relative Standard Deviation**
Naproxen Standard	15	15	15	100	±0.110
Naproxen-Wockhardt UK Ltd.-500mg	15	15	15	100	±0.192

CONCLUSION

The advanced RP-HPLC method shows rigorous validation results for Naproxen analysis which proves accurate while demonstrating reliable precision. The method operates at a high analytical consistency level because standard deviation estimates fall under 2%. A determined theoretical elimination half-life of 3.40 ± 0.1 minutes demonstrates the robustness and accuracy of this validation technique. Moreover these findings showcase how the method functions as a reliable tool for pharmaceutical assessment due to its 100% extraction recovery rate. These superior sensitivity parameters indicate the RP-HPLC method delivers remarkable LOD and LOQ values that improve measurement accuracy when separating drug components from measurement background noise.

Conflict Over Disclaimers of Interest

Although reviewed by multiple individuals the authors maintain they have no adverse interests in the research project. Researchers have taken steps to ensure the study cannot be misused for legal purposes. The research investigators developed their work to increase public understanding of pharmaceutical products. The authors used their personal funds to pay all expenses throughout their research project.

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