UV-Vis and HPLC Analysis of the Content of Commercially Available Paracetamol and Aspirin

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Abstract. The objective of this study was to determine the actual active pharmaceutical ingredient (API) content in commercial aspirin and paracetamol tablets using ultraviolet-visible (UV-Vis) spectrophotometry and High-Performance Liquid Chromatography (HPLC) and to assess whether the measured values comply with pharmacopeial standards. The experiment involved preparing a series of standard solutions, generating calibration curves, and analyzing triplicate samples of each tablet type to evaluate methods' linearity and precision. Standard solutions of 4-acetamidophenol were prepared and analyzed to establish a calibration curve at 242 nm. Samples from two brands of paracetamol tablets (A: Shanxi Fen he Pharmaceutical Co. and B: Sichuan Tong yuan Pharmaceutical Group Co.) were accurately weighed, diluted, and analyzed under identical spectrophotometric conditions. Results demonstrated a strong linear relationship between absorbance and API concentration. However, significant deviations in the measured API content were observed in Brand A, attributed primarily to undissolved particulate matter and possible volumetric dilution errors during sample preparation. Conversely, Brand B exhibited relatively consistent API content, with only minor deviations slightly exceeding the Paracetamol limit (±5%), but still within the safe therapeutic dosage range; The HPLC method showed excellent performance, with both aspirin (Kunming Yunjian Pharmaceutical Co.) and paracetamol (Sichuan Tong yuan Pharmaceutical Group Co.) displaying strong linear relationships across replicate measurements. Although the measured API contents were approximately 5.7–6% lower than the labeled values, they remained within the ±10% range permitted by the Chinese Pharmacopoeia.

Keywords: UV-Vis, HPLC, Aspirin, Paracetamol.

1. Introduction

Ensuring the accuracy and consistency of active pharmaceutical ingredient (API) concentrations in medicinal tablets is crucial for patient safety and therapeutic efficacy. Aspirin (acetylsalicylic acid) and paracetamol (acetaminophen) are two of the most used over-the-counter drugs for pain relief and fever reduction. however, deviations in dosage can lead to reduced efficacy or increased risk of toxicity, particularly hepatotoxicity at higher doses. Thus, precise quantification methods are necessary for quality control and regulatory compliance. According to the Chinese Pharmacopoeia (2020 edition), oral solid dosage forms, such as tablets, with single doses below 100mg must maintain API concentrations within ±10% of the labeled amount; exceeding 100 mg must maintain API concentrations within ±5% of the labeled amount [1].

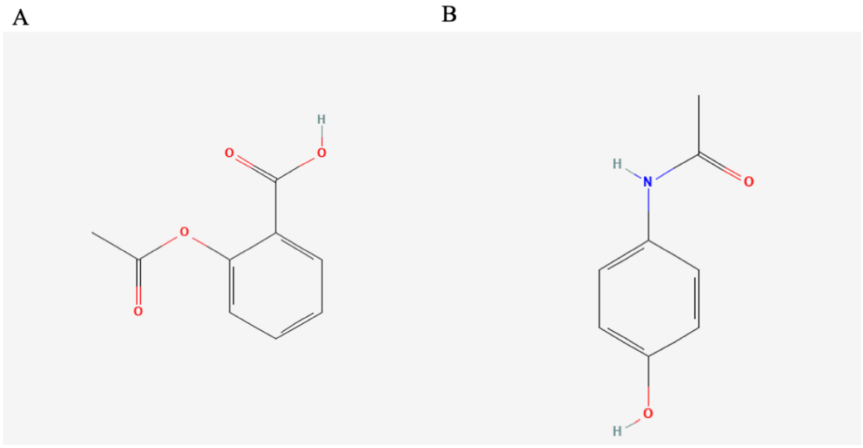

Figure 1. Chemical structural formula. A) aspirin. [2] B) paracetamol. [3]

Ultraviolet-visible (UV-Vis) spectrophotometry, governed by Lambert-Beer's Law, is frequently utilized for quantitative pharmaceutical analyses because of its simplicity, rapidity, and cost-effectiveness. However, the reliability of this analytical method can be compromised by procedural inaccuracies such as volumetric dilution errors, impurities, or physical interferences like undissolved particles causing light scattering. Such errors may significantly affect absorbance measurements and thus the calculated API content [4]. The High-Performance Liquid Chromatography (HPLC) method is widely recognized for its high sensitivity, reproducibility, and ability to simultaneously detect multiple compounds within complex matrices, making it an ideal technique for API quantification in tablet formulations. [5]

The aim of this experiment is to determine the content of APIs in two commercially available brands of acetaminophen tablets by UV-visible spectrophotometry and to analyze the content of active ingredients in commercially available acetaminophen and aspirin tablets using high performance liquid chromatography. The results will be compared with the contents stated in the respective product labels to assess the quality consistency and degree of compliance. Specifically, standard solutions of paracetamol and aspirin at defined concentrations were prepared and analyzed to construct calibration curves. Subsequently, preparative procedures including careful weighing, dilution, UV-Vis's absorbance analysis and HPLC were performed on commercial tablet samples to assess consistency and accuracy. The central question in this experiment was whether the measured API content was consistent with the values labeled on the package and whether the results were within the acceptable range specified in the pharmacopeial standard. [6] We hypothesize that the active pharmaceutical ingredient (API) content in tablets from three commercial brands of the two compounds meets the standards specified in the Chinese Pharmacopoeia when tested by UV-Vis spectrophotometry and HPLC, indicating their safety and reliability.

2. Method

2.1. Preparation of paracetamol standards for UV-Vis

According to Equation 1, a 5 mL pipette was used to transfer 2.857 mL of 17.5 M acetic acid into a 1 L volumetric flask. A small volume of distilled water was added, and the solution was shaken simultaneously to ensure homogeneity. The solution was then diluted to the calibration mark with distilled water to prepare 1 L of 0.05 M acetic acid. Following this, in accordance with Equation 2, 99.7 mg of 4-acetamidophenol was accurately weighed and transferred into a 100 mL volumetric flask. Approximately 50 mL of 0.05 M acetic acid was added to dissolve the powder. Any residual powder adhering to the neck of the flask was rinsed into the flask with additional 0.05 M acetic acid. However, insoluble substances were observed at the bottom of the flask; thus, the flask was placed in an ultrasonic bath for 11 minutes to achieve complete dissolution and obtain a homogeneous solution. Care was taken not to overfill the flask before ultrasonication to avoid volume expansion that could

surpass the calibration mark. After cooling to room temperature, the solution was diluted to the calibration mark with 0.05 M acetic acid, yielding a 100 mL solution of 4-acetaminophen at a concentration of approximately 997ppm. To further dilute the 997-ppm 4-acetaminophen solution to 49.85 ppm, a 5 mL pipette was used to transfer 5 mL of the 997ppm solution into another 100 mL volumetric flask, which was then filled up to the mark with 0.05 M acetic acid. Subsequently, five standard solutions were prepared by transferring 0.5, 1.0, 2.5, 4.0 and 5.0mL aliquots of the 49.85 ppm solution into five separate 25 mL volumetric flasks, each filled to the calibration mark with 0.05 M acetic acid. As a result, a series of standard solutions with concentrations of 0.997, 1.954, 4.885, 7.976, and 9.970 ppm were obtained, as calculated by Equation 3.

After preparation of the standard solutions, an ultraviolet spectrophotometer was used to measure absorbance at 242 nm. Prior to measurement, each cuvette was rinsed twice with ethanol. Initially, the frosted sides of the cuvettes were held, and ethanol was added to approximately two-thirds of the cuvette volume. The cuvettes were shaken gently to ensure the internal surfaces were thoroughly rinsed. Ethanol was then discarded into a waste container, and the rinsing procedure was repeated once more with fresh ethanol. Subsequently, the cuvettes were rinsed twice with 0.05 M acetic acid in the same manner. Following preparation, the cuvettes were filled to approximately two-thirds volume with the blank (0.05 M acetic acid) and the five standard solutions (0.997, 1.954, 4.885, 7.976, and 9.970 ppm of 4-acetamidophenol). The cuvettes were placed into the ultraviolet spectrophotometer sequentially in order of increasing concentration. Prior to insertion, all cuvette surfaces in contact with the spectrophotometer holder were carefully wiped with lint-free tissue to prevent solution corrosion of the instrument. Additionally, care was taken to avoid direct contact with the transparent optical surfaces of the cuvettes to prevent measurement errors. Finally, software analysis was employed to record the absorbance values of the standard solutions.

$$C^1V^1 = C^2V^2 \tag{1}$$

$$The\ material\ weight\ =\ (Paper\ weight\ +\ Material\ weight)\ -\ Paper\ weight \tag{2}$$

$$Weight(mg)/Volume(L) = Concentration(ppm) \tag{3}$$

$$25mg/(Packageweight/Tabletsweight) = Theoreticalweightofpowder \tag{4}$$

$$APIcontent = Actualpowderweight \times APIPercentage \tag{5}$$

$$Weight(mg) \times molecularweight(mol/mg)/Volume(L) = Concentration(mM) \tag{6}$$

$$LOD = 3.3 \times \sigma_blank/Slope \tag{7}$$

$$LOQ = 10 \times \sigma_blank/Slope \tag{8}$$

2.2. Paracetamol tablets UV-Vis analysis

Three tablets from each brand of paracetamol (brands A and B) were weighed individually. According to the label information, brand A tablets contained 0.3 g of API each, while brand B tablets contained 0.5 g each. Using Equation 1, the measured weights of the tablets from brand A were found to be 352.2 mg, 351.1 mg, and 348.9 mg, respectively, while those from brand B weighed 662.1 mg, 661.8 mg, and 660.0 mg, respectively. Each tablet was individually ground into a fine powder. Since a theoretical API content of 25 mg per sample was required, and following calculations based on package information and Equation 4, powder samples weighing 34.3 mg, 30.0 mg, and 29.7 mg were prepared from the three tablets of brand A, respectively. For brand B, the powder samples weighed 31.8 mg, 32.5 mg, and 33.6 mg, respectively.

Each powder sample was transferred into separate 50 mL volumetric flasks, and approximately 30 mL of 0.05 M acetic acid was added to each flask. Residual powder adhering to the neck of the flask was rinsed down with additional 0.05 M acetic acid. Insoluble substances were observed at the bottom of each flask; thus, the solutions were ultrasonicated for 8 minutes to promote complete dissolution. Following ultrasonication, the solutions appeared generally clear, though slightly whitish with suspended particles. After cooling to room temperature, each flask was filled to the calibration mark

with 0.05 M acetic acid. Subsequently, 400 μL aliquots from each of these solutions were transferred into six separate volumetric flasks and again diluted to the calibration mark with 0.05 M acetic acid.

The cuvettes were prepared by rinsing twice with ethanol, followed by two rinses with the corresponding test solutions. Each cuvette was then filled to approximately two-thirds of its capacity with the respective test solution. Before placing each cuvette into the ultraviolet spectrophotometer, the external surfaces were carefully wiped clean. Absorbance measurements at 242 nm were taken sequentially, beginning with the blank solution (0.05 M acetic acid) and followed by the samples in the order: A1, A2, A3, B1, B2, and B3. A significant visual discrepancy was noted among the group A samples. Therefore, the final dilution and preparation steps for solutions A1 through A3 were repeated, and absorbance measurements were conducted again under the same spectrophotometric conditions.

2.3. Peek identification and assignment-HPLC

According to Equation 2, 21.1 mg of standard aspirin and 20.1 mg of paracetamol were weighed, and each powder was transferred into two 25 mL volumetric flasks, respectively. Approximately 10 mL of acetonitrile (ACN) was added into the two flasks. The flasks were shaken until the solids dissolved, and a homogeneous colorless liquid was obtained. The solution was diluted to the calibration mark with ACN. In this way, 4.69 mM aspirin solution and 5.32 mM paracetamol solution were obtained (calculated by Equation 6). Two 1 mL syringes were used to draw the solutions, which were then filtered through different 0.22 μm filters into injection sample vials. The membrane was pre-wetted with a small amount of the same solvent prior to the specific operation to improve filtration efficiency. Before initiating the filtration process, all air was expelled from the syringe to prevent gas from entering the membrane and causing structural damage. During operation, a secure and tight connection between the syringe and the filter was ensured to prevent leakage or detachment. Consistent and moderate pressure was applied during filtration; excessive or sudden force was avoided as it could compromise the integrity of the membrane. The optimal outflow was in the form of slow, single droplets rather than a continuous stream, as high flow rates could significantly reduce filtration efficiency and increase the risk of membrane rupture. If noticeable resistance or clogging occurred during the process, the filter was replaced immediately. After filtration, drawing back on the syringe plunger was avoided, as this could introduce air back into the membrane and adversely affect subsequent filtration performance and sample quality.

2.4. Preparation standard solution of aspirin and paracetamol

According to Equation 2, 41.3 mg of standard aspirin and 20.2 mg of standard paracetamol were weighed and transferred into the same 100 mL volumetric flask. Approximately 50 mL of ACN was added into the flask. The flask was shaken until the solids dissolved, and a homogeneous colorless liquid was obtained. ACN was added up to the calibration mark to achieve the final volume, and a mixed solution was obtained containing 2.29 mM aspirin and 1.34 mM paracetamol (Equation 6).

To prepare calibration solutions, 1, 2, 4, 8, and 16 mL of a stock solution containing 2.29 mM aspirin and 1.34 mM paracetamol were accurately pipetted into five separate 25 mL volumetric flasks. Each flask was then diluted to the mark with acetonitrile (ACN). This procedure yielded five mixed standard solutions with final concentrations of 0.0916 mM aspirin and 0.0536 mM paracetamol; 0.1832 mM aspirin and 0.1072 mM paracetamol; 0.3664 mM aspirin and 0.2144 mM paracetamol; 0.7328 mM aspirin and 0.4288 mM paracetamol; and 1.4656 mM aspirin and 0.8576 mM paracetamol, respectively (calculated by Equation 1). After dilution, each flask was sealed with a stopper and gently inverted ten times to ensure complete mixing. A 1 mL aliquot of each solution was then drawn using a syringe and passed through a 0.22 μm membrane filter into individual HPLC injection vials for subsequent analysis.

2.5. Preparation of test sample of aspirin and paracetamol tablets

According to the drug insert, each aspirin tablet contained 25 mg API, and each paracetamol tablet contained 500 mg API. According to Equation 5, to obtain accurately 40 mg of aspirin and 20 mg of paracetamol from tablets, it was necessary to weigh 150.9 mg of aspirin powder and 26.5 mg of paracetamol powder. The tablets were ground separately with a mortar and pestle. 150.8 mg of aspirin and 26.5 mg of paracetamol were weighed. The samples were transferred into two different 25 mL volumetric flasks as described in Section 5.2, and approximately 10 mL of ACN was added. Insoluble substances were observed at the bottom of each flask; thus, the solutions were ultrasonicated for 20 minutes to promote complete dissolution. Following ultrasonication, the solutions appeared generally clear, though slightly whitish with suspended particles. ACN was added up to the calibration mark. At this point, an 8.88 mM aspirin solution and a 5.28 mM paracetamol solution were obtained (Equation 6). 5 mL of each stock solution was pipetted into new 25 mL flasks and diluted to the calibration mark with ACN, respectively. Each sample produced three filtered solutions to be tested, using the same filter membrane and syringe. Resistance was not felt during use, and the requirements of Section 5.1 were strictly followed.

3. Result

3.1. Calibration curve for two paracetamol tablets in two tests

Based on the coefficient of determination (R^2 = 0.9881), the regression equation demonstrates a strong fit, indicating that the model explains approximately 98.81% of the variation in absorbance. Although R^2 is slightly below 0.99, this does not suggest a poor fit. Visual inspection of the 95% confidence interval shows that the absorbance measurement at 4.885 ppm lies near the edge of the confidence band, as do several other points. While this distribution may raise mild concerns about experimental variation, all data points still lie within the confidence range. One potential explanation for the slight deviation could be background signal interference from the spectrophotometer, which might have contributed to small shifts in absorbance values. (Fig. 2A)

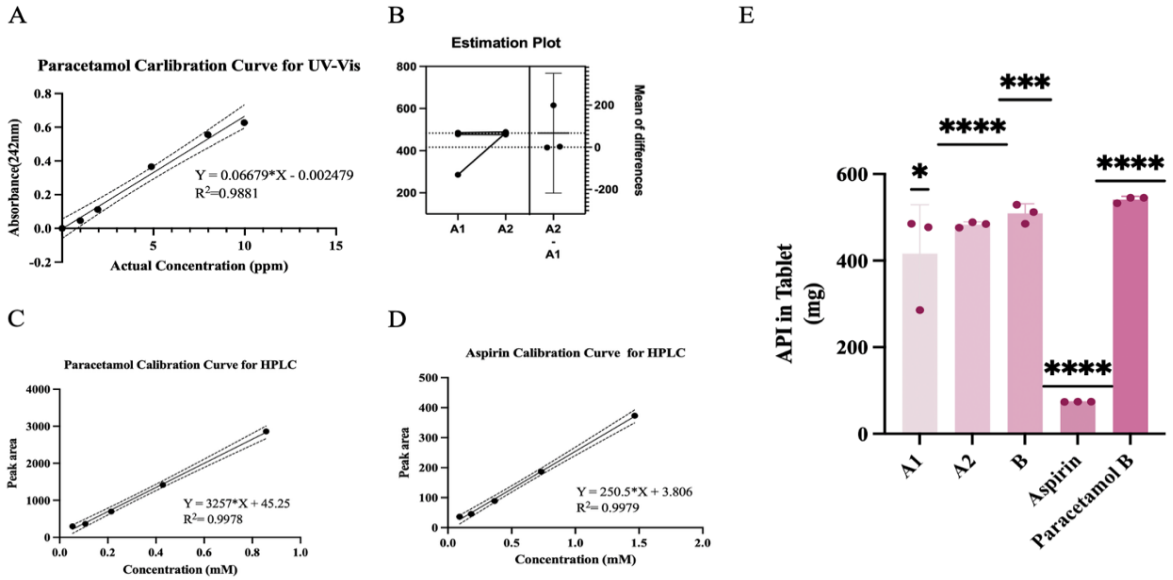

Figure 2. A) Linear regression equations relating actual concentration of standard 4-Acetamidophenol and absorbance at 242nm. where the equation is y = 0.06679x - 0.002479 and the variance is R^2 = 0.9881. The slope of 0.06679 indicates that for every 1 ppm increase in concentration, the absorbance increases by about 0.0668. B) An estimation plot for the A1 and A2 analyses. The midpoint of the graph is the mean difference of A2 relative to A1, and the vertical line is the 95% confidence interval, which crosses 0, indicating that the difference between the groups may be due to chance. C) Linear correlation images of aspirin peak area and concentration.

Where the linear regression function is Y = 250.5*X + 3.806, and the R-square is 0.9979. D) Linear correlation images of aspirin peak area and concentration. Where the linear regression function is Y = 3257*X + 45.25, and the R-square is 0.9978. E) This bar graph illustrates the average amount of active pharmaceutical ingredient (API) in aspirin and paracetamol tablets across five groups. Each bar represents the mean API content, with individual data points and error bars indicating variability across replicates. Group A1 shows noticeably larger variability compared to the other groups. Aspirin exhibits significantly lower API content than all paracetamol groups, while Paracetamol B shows the highest API level. Several pairwise comparisons are statistically significant (****, $p < 0.0001$), indicating meaningful differences between brands or drug types. The overall consistency among replicates suggests high precision of the quantification method

Figure 2C, 2D demonstrates that both aspirin and paracetamol calibration curves exhibit excellent linearity. The data points align closely with the regression line, and the narrow 95% confidence intervals indicate high precision of the fitted models. Additionally, the R^2 values are very close to 1 for both curves, confirming a strong linear relationship between concentration and peak area. These results validate the reliability of the calibration models for accurate quantitative analysis.

3.2. Data analysis after absorbance measurements

Table 1. Subsequent analysis of A1n, A2n and B1 with respect to absorbance

Number	API concentration from curve(ppm)	API (mg)	API in tablets (mg)	Percentage of API	Average	SD	t value
A1-1	13.63	42.59	485.44	137.83%			
A1-2	7.733	24.17	285.51	81.35%	416.13	113.2	1.775
A1-3	12.48	39.00	477.44	136.84%			
A2-1	13.72	42.88	488.75	138.77%			
A2-2	12.69	39.66	484.90	138.18%	483.33	6.352	49.94
A2-3	12.45	38.91	476.34	136.52%			
B1	8.137	25.43	529.47	79.97%			
B2	7.628	23.84	485.38	73.41%	509.04	22.22	0.704
B3	8.347	26.08	512.28	77.62%			

To measure the difference between the concentration of a drug product obtained by absorbance testing and the concentration indicated on the actual package, it was analyzed by calculating the mean, standard deviation, t-value, and percentage of active ingredient. The details are shown in Table 1.

By looking at the data in the table, in the group of A1-n, A1-2 deviates greatly from the other two in the same group and can be considered an outlier. Although A1-2 best matches the predicted value of the brand name drug. the mean value of A1-n is 416.13 with a standard deviation of 113.2, indicating a very large fluctuation. A1-2 can be reasonably suspected as a measurement error or sample anomaly. the API percentages for the A2-n group are highly consistent with minimal error. The mean value is 483.33, and the standard deviation is only 6.352. The data have credibility and excellent consistency. However, the t-value reached 49.94, indicating a huge difference between the measured and expected values. Measurement accuracy is high, but the API content is systematically high, and there may be “overdose”, so it is reasonable to suspect that there is a systematic error in group A2-n. The API percentages in group B are highly consistent, with very small error. The mean value is 509.04 and the t-value is only 0.704, which indicates that the test results are very close to the expected results. However, the standard deviation is 22.22, which indicates a large fluctuation and is suspected to be caused by operational errors during measurement. (Table. 1)

According to Figure 2, even though there is an error in the A1-2 data, there is strong consistency between the rest of the data, which shows that there is a systematic error along with a measurement error in the experimental process regarding brand A. In summary, because of the existence of errors in the A1-n group, the group is no longer used as reference data in the subsequent analysis, and the data of the A2-n group are used to represent the test results of the A brand. (Fig. 2B)

3.3. Data from curve

Based on the blank signal, the calculated LOD for aspirin was $4.3*10^{-5}$ mM and the LOQ was $1.2*10^{-5}$ mM; LOD for paracetamol was $3.4*10^{-6}$ mM and the LOQ was $9.2*10^{-6}$mM. These values are well below the lowest concentration used in the calibration curve, indicating that all measured concentrations fall within the reliable quantification range. This demonstrates that the method has high sensitivity and is well-suited for trace-level analysis.

The actual drug content (API) of aspirin and paracetamol tablets was quantified and compared. As shown in Table 8, the average API content for aspirin was 31.45 mg with a low standard deviation (SD = 0.14), while paracetamol showed a significantly lower average of 16.31 mg (SD = 0.23). The high t-values (393.1 for aspirin and 125.5 for paracetamol) reflect the consistency within replicate measurements. (Table. 2)

Table 2. Actual drug concentration and API content

Drugs	Calculated Conc. (mM)	Average Conc. (mM)	API (mg)	Average API (mg)	SD	t-value	LOD (mM) (7)	LOQ (mM) (8)
			Aspirin					
A1	1.39		31.29					
A2	1.4	1.397	31.53	31.45	0.14	393.1	$4.3*10^{-5}$	$1.2*10^{-5}$
A3	1.4		31.53					
			Paracetamol					
P1	0.85		16.05					
P2	0.87	0.863	16.44	16.31	0.23	125.5	$3.4*10^{-6}$	$9.2*10^{-6}$
P3	0.87		16.44					

The bar graph further illustrates this difference, with asterisks indicating a highly significant difference ($p < 0.0001$) between the two groups. These results confirm that the HPLC method used is precise and sensitive, and it successfully distinguishes between varying drug concentrations in tablet formulations. (Fig. 2E)

4. Discussion

4.1. Brand A Results Analysis

Due to the significant deviation between the measured results of Group A and the expected theoretical values, a systematic analysis of the entire experimental process was conducted. First, as shown in Figure 1, although the regression fit was slightly below ideal ($R^2 < 0.99$), all data points fell within the 95% confidence interval, and the absorbance values of the blank control remained at zero across four measurements [7]. This effectively ruled out systematic errors caused by poor fitting or impurities in the blank solution. Next, the possibility of procedural errors during dilution or contamination and scratches on the cuvette surface was examined [8]. A comparison between Group A1 and Group A2 (excluding the outlier A1-2) revealed relatively consistent results, suggesting that repeated measurements after dilution did not significantly differ from the initial readings. Therefore, these sources were unlikely to be the main contributors to the observed error. Additionally, as the three measurements were conducted on three different UV-Vis's spectrophotometers, the possibility of instrument aging or malfunction was also excluded. Based on a comprehensive analysis, the significantly higher-than-expected absorbance values in Group A (approximately 1.6 times the theoretical value) could be attributed to two main factors: (1) the presence of undissolved particles in the solution, which increased light scattering and thus absorbance, and (2) potential errors during the volumetric dilution step in solution preparation [4]. According to the experimental record (Section 5.2), the original solution appeared "whitish and with some suspended particles," confirming the presence of insoluble material. Since the weighing and transfer processes were conducted within acceptable error margins, the most likely source of deviation was inaccurate volume adjustment.

However, due to the lack of a repeated experiment for the original solution preparation, this inference cannot be definitively confirmed. To reduce such measurement errors in future experiments, it is recommended to filter the solution to remove suspended particles and to document the preparation process in greater detail to minimize manual errors. Given that the results of Group A were significantly affected by potential procedural mistakes, they will not be used for comparison against the standards outlined in the Chinese Pharmacopoeia.

4.2. Brand B Results Analysis

According to the "Chinese Pharmacopoeia (2020 edition)", the limit of active ingredient content in general oral solid preparations (e.g., tablets) is ±5% of the labeled amount when a single dose is greater than 100 mg. The tablets measured for Brand B were labeled at 500 mg (i.e., 0.5 g), so the active ingredient should be in the range of 475-525 mg [9].

Of the three sets of data measured, B1 was below the lower limit of 4.47 mg of active ingredient, slightly outside the acetaminophen margin of error, while the remaining two tablets (B2 and B3) were within the allowable range. Although the B1 sample deviated from the acetaminophen standard, the actual content was within the recommended single dose range for acetaminophen (325-500 mg, up to 1000 mg), and was therefore acceptable in terms of safety. However, the consistency deviation of this tablet is a cause for concern, and it is recommended that quality control be strengthened during the production process to ensure product stability and consistency of efficacy. The conclusions of the experiment are consistent with the hypothesis.

4.3. Aspirin and paracetamol HPLC Result Analysis

In summary, both the standard calibration curves and the replicate tablet measurements demonstrated strong linearity and high repeatability, respectively. These results indicate that the experimental procedures were conducted in accordance with analytical protocols, without significant systematic or random errors, and that the HPLC instrumentation operated reliably throughout the study.

Although the measured API contents were slightly lower than the theoretical values, the deviation (~5.7–6%) is within the acceptable range specified by the Chinese Pharmacopoeia, which permits a ±10% variation from the labeled amount for conventional tablets. Therefore, the observed reductions in API are likely attributable to factors inherent in the tablet manufacturing process, rather than analytical or procedural issues. [1] Overall, both aspirin and paracetamol tablets meet the regulatory standards for API content and can be considered compliant with quality specifications.

5. Summary

In this This experiment evaluated the accuracy of active pharmaceutical ingredient (API) measurement in paracetamol tablets using ultraviolet-visible (UV-Vis) spectrophotometry and High-Performance Liquid Chromatography (HPLC). UV-Vis analysis of acetaminophen standard solutions at 242 nm yielded a linear relationship ($R^2 = 0.9881$), with absorbance values falling within a 95% confidence interval, though Group A exhibited significant deviations due to undissolved particles and volumetric dilution errors. These findings underscored the need for improved filtration and meticulous solution preparation. Meanwhile, HPLC quantification of APIs in aspirin and paracetamol tablets demonstrated excellent linearity ($R^2 > 0.997$) and precision (RSDs < 2%), confirming the method's reliability. While measured API contents were slightly lower (5.7–6%) than labeled values, they complied with pharmacopeial limits (±10%), suggesting manufacturing-related variations rather than analytical errors. Overall, both methods proved effective for pharmaceutical analysis, with HPLC offering superior consistency, while UV-Vis results highlighted procedural refinements for enhanced accuracy. The study affirms that the tested products meet regulatory standards, validating both techniques for routine quality control.

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