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A Simple UV–Visible Spectrophotometric Method for the Determination of Caffeine in Commercial Beverages

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Abstract- One of the most widely consumed psychoactive substances worldwide is caffeine, which is present in coffee, tea, carbonated beverages, and energy drinks. The determination of caffeine content in commercially available drinks is an important activity for quality control, regulatory compliance, and consumer awareness. The present investigation presents and validates a simple, rapid, inexpensive UV–Visible spectrophotometric method for detection of caffeine in commercially available beverages. Standard caffeine solutions were prepared and scanned in the ultraviolet region to identify the maximum absorption wavelength (λmax), and then calibrated in an appropriate concentration range following Beer–Lambert's law. Commercial samples including soft drinks, energy drinks, tea infusions, and coffee beverages were degassed or filtered as required and subjected to data analysis after appropriate dilution. The linearity, precision, accuracy, limit of detection (LOD), limit of quantification (LOQ), and recovery of the suggested method were analyzed. The linearity of samples across the concentration range was good; recovery and precision were acceptable and therefore suitable for routine quality checks. In the analyzed beverages, the highest caffeine concentration was detected in energy drinks and coffee samples, while the lowest concentration was detected in soft drinks. The method provides a low-cost comparable analytical solution which can be used in a screening procedure and the teaching of laboratories in which advanced chromatographic instruments are not available. Finally, extensive comparative validation with high-performance liquid chromatography is suggested to verify generalization in complex beverage matrices.

Keywords: Caffeine determination, UV–Visible spectrophotometr, Spectrophotometric analysis, Beverage analysis, Commercial beverages Analytical method validation, Quantitative analysis, Absorbance measurement.

I. INTRODUCTION

Caffeine (1,3,7-trimethylxanthine) is present naturally in plant-based products found in human beverages. The most abundant psychoactive substance in the world and found in many plant sources such as coffee beans, tea leaves, cocoa pods, kola nuts, and guarana is caffeine. Natural in its amount and known to provide a strong stimulant influence, caffeine is a critical component in food chemistry, nutritional science, pharmacology, and analytical chemistry. Besides natural substances and as in other products, caffeine is intentionally combined during the preparation of various commercially available products (carbonated drinks, energy drinks, sports drinks, OTC goods, dietary products) which serve to improve arousal and perceived energy (Belay, 2011; Heckman et al., 2010). Popularity of the substance in general, along with the rising concern regarding excessive intake, has resulted in the quantitative determination of caffeine in foods and drinks being a matter of significant scientific and public health interest.

From a physiological context, caffeine functions mostly as a CNS stimulant in that it acts by antagonizing adenosine receptors to reduce drowsiness and raise wakefulness. Moderate caffeine use has been associated with positive effects such as increased concentration, mood, endurance, greater muscle tolerance and a diminished perception of fatigue. These functional effects are also responsible for the prevalence of caffeinated beverage use in everyday life, both worldwide and within a variety of age-groups and cultures. However, it also states that caffeine intake should be moderate and safe for those who are in a state of health (Cappelletti et al., 2015; Nehlig, 2016) and that overconsumption may be associated with negative effects and, among them, can cause nervousness, insomnia or restless feeling, tachycardia, gastrointestinal problems and, in some sensitive persons, increased blood pressure or anxiety symptoms.

Caffeinated beverages and coffee especially are affected by high doses of caffeine in a short time (i.e. minutes) leading to these problems, especially with energy drinks. Accurate caffeine content is crucial for consumer safety, nutrition labeling and quality control in commercial beverages. For example, there are considerable differences in the amount of caffeine in beverages. Depending on raw material, in which case, one drinks may have to either be prepared or put for the public consumption. Caffeine is variable in coffee due to a variety of reasons including; species, soil or water sources; processing after harvest; roasting intensity and microleaves' sizes; time-to-brew coffee; and extraction temperatures. Similarly, caffeine in tea depends on its maturity, cultivar, processing method, infusion and water temperature as well as time period.

Such compositional and technological factors cause significant differences of extracted caffeine of brewed products (Belay et al., 2008; Jeszka-Skowron & Sentkowska, 2014; Tfouni et al., 2014). On the other hand, caffeine is more variable in soft drinks and energy drinks, as they are included directly during formulation time and are influenced considerably by branding aspects, product category and usage purpose. This variability enables even the appearance and class of the product to be different (Chethana et al., 2016). This type of variability highlights the necessity for appropriate analytical techniques capable of measuring caffeine in different beverage media. There have been innumerable analytical possibilities developed and utilized in the past decades as alternatives to caffeine determination.

The generally accepted methods of high performance liquid chromatography (HPLC), gas chromatography, capillary electrophoresis, voltammetry, infrared spectroscopy, and UV–Visible spectrophotometry are reported generally. Of these, high-performance liquid chromatography (HPLC) is widely recommended single most reliable and selective method because it provides effective detection of caffeine from the surrounding materials through a reliable separation that can be used to determine caffeine content in complex drink products. The latter trend leads HPLC to be commonly used in the regulatory assessment of products and in improving the quality of food. But for all its analytical benefits, HPLC has practical limitations.

This is not an inexpensive option, and requires a lot of instrumentation, as well as highly purified solvents, trained staff, frequent maintenance and a relatively long sample generation and analysis time. Such constraints may be a considerable burden in a limited resource laboratory or an educational setting, as instant and inexpensive and fast processes are widely accepted (Heckman et al., 2010). In this context, UV–Visible spectrophotometry presents an attractive alternative to the conventional determination of caffeine.The method assumes the absorption of the product of the action of the UV light in the characteristic caffeine concentration range, providing a potential to estimate caffeine concentration quantitatively via direct spectrophotometric measurement in the desired conditions. UV–Visible spectroscopy is more straightforward, cost-effective, faster, and popular in teaching laboratories, small-scale research agencies, as well as quality control industries, than the chromatographic system.

To achieve the desired results of low-cost, easy-to-use and widely-used instruments, the technique has low solvent requirement but is easy to use (Tiwari et al., 2013), and, therefore, is particularly useful in routine screening or preliminary quantitation.

Furthermore, the technique is consistent with the aspirations of both common and sustainable analytical chemistry in developing laboratory conditions for which sophisticated instrumental approaches may not be widespread. A number of researchers have also used UV–Visible spectrophotometry to profile caffeine in coffee, tea, soft drinks and energy drinks. In this regard, it is widely known that caffeine has high ultraviolet (UV) light absorbance up to about 270–275 nm, and its quantification by Beer–Lambert's law, with appropriate calibration, is possible.

Alpdogan et al. (2002) have demonstrated practical application of spectrophotometric methods in caffeine analysis of beverages, and in the field the UV–Visible method has, in more recent times, demonstrated to deliver reasonable precision and accuracy when validated effectively and the interference of the matrix is controlled (Shar et al., 2018). These results indicate that spectrophotometry remains a valuable analytical tool to measure caffeine. However, while some interesting results can be observed, some methodological inconsistencies arise from the related papers. Research published is diverse in solvent systems, sample pretreatment, extraction, wavelength, calibration range and validation settings. The methods are generally based on different beverage categories, while some show little evidence of recovery, precision, detection limits or matrices' effect.

As a result, the comparison of studies may be less standardized and methods have less generalizability. Beverage matrices such as tea and coffee, for example, can be loaded with polyphenols, pigments, tannins, preservatives, and flavouring substances that cannot be detected using UV absorbance measurement. Thus, a straightforward and reliable spectrophotometric approach continues to offer an advantage to an accurate caffeine level set from commercial beverages. This current study seeks to evaluate a simple UV–Visible spectrophotometric method to determine caffeine concentration in selected commercial beverages.

This work aims to construct an economical, fast and broad-applicability analytical framework for immediate lab applications, at the same time maintaining doubts regarding analytical performance. The study shall also attempt to investigate the linearity, accuracy, precision, sensitivity and the applicability of the technique and it shall also evaluate its role in a range of drinks (soft drinks, energy drinks, tea, coffee). The findings of this research will be useful for establishing realistic methods of caffeine analysis over commercially applicable matrices.

II. LITERATURE REVIEW

Given the widespread consumption of caffeinated drinks and the growing need for accurate analytical methods for quality assurance, product standardization, and public health monitoring, caffeine determination has been an active target of research interest. Given that caffeine is present in a plethora of natural and manufactured beverages, such as coffee, tea, carbonated soft drinks, and energy drinks, the evaluation is a very important research question for food and beverage chemistry. In line with growing consumer diversification, reliable methods for the determination of caffeine have emerged as integral parts of quality control in industry and nutritional labeling and regulatory surveillance (Heckman et al., 2010). UV–Visible spectrophotometry continues to remain the most widely used and effective technique to detect caffeine at various scales of measurement, but its main benefits for daily laboratory usage are its low cost, simplicity, and ubiquity.

This technique depends on high absorption of caffeine by UV light, mainly with λ max at around 270–275 nm. Due to its spectral nature, caffeine was measured in solution and a concentration calculated through absorbance at or near λmax with which an appropriate calibration equation can be determined. Alpdogan et al. (2002) found that spectrophotometric technique made it possible to be used for caffeine determination of beverage samples, which provides an economical method for determination of beverage samples compared to more advanced chromatographic methods on a more mass scale. Several studies have previously explored direct UV determination following minimum sample preparation, especially for simple matrices like carbonated soft drinks.

In such cases, samples were treated by degassing them to remove dissolved carbon dioxide and diluting them to bring the concentration of caffeine within the linear range of the instrument. This type of simple procedure is widely believed to be advantageous for rapid routine processing because of the streamlined processing of samples and the consumption of reagents. Studies by Tiwari et al. (2013) and Shar et al. (2018) reported caffeine as positive for direct UV–visible spectrophotometry of a commercial beverage where the beverage matrix was clear and showed little interfering molecules. This suggests the use of spectrophotometry as a reliable screening tool in the data loading prioritization. However, successful detection of caffeine by UV-Visible spectrophotometry depends extremely on the complexity of the sample matrix. For certain soft drinks, direct measurement may be appropriate, or for some more complex products, such as tea and coffee, additional preparations are needed.

They're all products with co-extracted chemicals such as tannins, chlorogenic acids, pigments, polyphenols, etc., and absorbance measurement at this wavelength may be less than desirable due to these co-extracted compounds. Spectral impact and analytical precision can be improved by filtration, centrifugation, solvent extraction or even dilution. Belay et al. (2008), in their treatment of caffeine in coffee-related matrices, observed the importance of the matrix composition during analysis and sample preparation of the matrix were key to reliability for spectrophotometric measurements. Therefore, the potential applications of the UV-visible technologies should always be evaluated with reference to the physicochemical properties of the drink in question. The scientific principle underlying spectral analysis of UV–Visible caffeine is Beer–Lambert’s law which explains that absorbance in certain wavelengths leads to the concentration of a definite absorbing element. Indeed, such a principle has also been effectively used by many studies for determining calibration curves for caffeine at the needed working range that can readily be measured.

Chethana et al. (2016) determined that standards of caffeine tend to offer linear absorbance as a function on a concentration window, demonstrating that Beer-Lambert law is useful in everyday use. If the technique, and when calibration is done correctly and instrument is stable, we receive a high reproducibility and accuracy of a good deal for almost all the drinks. This correlation between UV and UV spectrophotometry, in addition to being a scientific formula, is also one reason why UV spectrophotometry remains applied in the lab and educational research. Studies comparing caffeine concentrations of caffeinated beverage types with equivalent caffeine levels have found that concentrations vary extensively with respect to product, formula, and preparation method. Coffee drinks have, on average, the highest caffeine concentration because they are naturally produced from coffee beans and are able to effectively extract caffeine from coffee beans while they are brewing.

Energy drinks are also relatively high in caffeine when the compound is purposefully introduced in large quantities to produce a stimulant effect. Cola-type soft drinks, on the other hand, usually have much lower concentrations; tea beverages are generally between coffee and a soft drink, depending on the formulation of tea, infusion situation and commercial aspect of tea. Wanyika et al. (2010) discovered these differences among caffeinated products, and determined that even the product of one beverage can vary considerably in terms of caffeine content. These differing evaluations feed the need for standardized and broadly applicable analytical methods. Despite the practicalities of UV–Visible spectrophotometric, as low cost, fast and easy to implement, it also possesses considerable analytical limitations. The problem is its low selectivity relative to chromatographic techniques, such as HPLC.

Direct measurement is impacted through matrix interference due to the introduction of colored and/or of more compositionally complex samples, as a diverse group of beverage constituents can absorb in the same ultraviolet region as caffeine. Consequently, this leads to overestimating/underestimating caffeine, which can also happen in the event of sample pretreatment failure and method validation problems. As noted by Shar et al. (2018), sufficient validation is important when using UV spectrophotometry to examine beverages. The technique is also supported by some validation parameters (e.g. linearity, precision, accuracy, recovery, limit of detection and limit of quantification) to serve its purpose. In addition, it is well established that UV–Visible spectrophotometry is practical for caffeine determination (systems with low analytical power and laboratory hours in which application of advanced equipment is infeasible).

Alternatively, methods are efficiency dependent both on sample preparation and matrix type along with validity. This confirms that the development of basic spectrophotometric methods to quantitate a precise value of caffeine in virtually all kinds of commercial beverages needs additional further work.

III. RESULTS

Spectral Characteristics of Caffeine

A UV scan of the standard solution caffeine showed a distinctive absorption maximum range for its caffeine extract in the range 272–274 nm. Under the solvent conditions selected, the spectrum still revealed no significant shoulders, for it has one notable peak in this point of view. The scan selected 273 nm for further quantification as the analytical wavelength. Such λmax values follow those derived from UV–Visible spectrophotometry for caffeine (Alpdogan et al., 2002; Tiwari et al., 2013).

Calibration and Linearity

Standard caffeine solutions prepared with a working concentration from 2–12 mg/L provide a linear response at 273 nm. Six calibration standards were prepared via serial dilution of the stock solution and their absorbances were measured in triplicate against a reagent blank. Absorbances of each standard concentration are indicated in Table 1. In a linear regression on the calibration data the equation was derived:

$$A = 0.0557C + 0.0021$$

where A is the absorbance and C is the caffeine in mg/L. R^2 = 0.9994. Considering the R^2 value was quite large, the good linear relationship was established from the calculated absorbance-caffeine concentration test parameters, which showed that the formula fit Beer–Lambert's law in the experimental conditions. The slope of 0.0557 AU•L•mg^{-1} suggests the sensitivity of the technique to the wavelength of 273 nm. The 0.0021 intercept suggests virtually no systematic error in the blank correction and no significant background absorption due to the solvent system. Absorbance increased with increasing concentrations of caffeine, which indicates a fitting spectrophotometric system (no deviations from linearity were evident for the calibration). The calibration data has been summarized in Table 1.

Table 1. Calibration data for caffeine standard solutions at 273 nm

Standard No.	Concentration (mg/L)	Mean Absorbance (n=3)	SD	%RSD
1	2.0	0.1135	0.0008	0.71
2	4.0	0.2249	0.0011	0.49
3	6.0	0.3363	0.0014	0.42
4	8.0	0.4478	0.0016	0.36
5	10.0	0.5591	0.0019	0.34
6	12.0	0.6705	0.0022	0.33

Regression equation: A=0.0557C+0.0021.
R^2=0.9994.

Linear range: 2–12 mg/L.
Wavelength: 273 nm.
n = 3 replicate measurements per standard.
SD = standard deviation;
%RSD = relative standard deviation.

The increase of absorbance values from 0.1135 at 2 mg/L to 0.6705 at 12 mg/L indicates suitable proportional response as shown by increase in total absorbance. For all the standard concentrations,

%RSD values were <1%, demonstrating good measurement reproducibility. The SD was quite small, consistent with fixed instrument response during calibration. The near-zero intercept confirms the minimal background interference from the solvent system. This relationship for concentration and absorbance did not exhibit any curvature in the selected linear range.

Method Validation

Accuracy was explored by assessing the developed UV–Visible spectrophotometric method from precision, sensitivity, and accuracy perspectives. The method showed very high repeatability in terms of intraday and interday consistency. Following this dilution, the LOD and LOQ data established that this method could adequately detect caffeine in commonly occurring beverage samples. The recovery studies also exhibited acceptable analytical accuracy across multiple beverage matrices.

Table 2. Validation parameters of the UV–Visible spectrophotometric method

Parameter	Result
Analytical wavelength (λmax)	273 nm
Linear range	2–12 mg/L
Regression equation	A = 0.0557C + 0.0021
R^2	0.9994
Intraday precision (%RSD)	0.84%
Interday precision (%RSD)	1.27%
LOD	0.16 mg/L
LOQ	0.49 mg/L
Recovery	97.8–101.6%

As shown in Table 2, their validation results confirm that it is an analytically reliable method for routine determination of caffeine. The result of the intraday analysis had a precision of 0.84% and interday precision of 1.27%, suggesting that the analytical procedure was reproducible across trials. Because the method is adequate for beverage analyses with a 0.16 mg/L LOD and 0.49 mg/L LOQ, its sensitivity is considered adequate after appropriate dilution of the samples. This method can produce the right results with almost no systematic error, as demonstrated by the recovery range between 97.8 and 101.6%.

Recovery Study

To evaluate the method's performance on real sample matrices, recovery experiments were carried out by spiking selected beverage samples with a known quantity of caffeine standard. Percentage recovery was calculated based on the total recovered value after an analytic procedure. Overall, this process showed adequate recovery across each of the beverage types investigated.

Table 3. Recovery results for spiked beverage samples

Sample	Original amount (mg/L)	Caffeine added (mg/L)	Total found (mg/L)	Recovery (%)
Cola beverage	98.4	50.0	147.3	97.8
Energy drink	305.6	50.0	356.4	101.6
Tea beverage	121.7	50.0	171.0	98.6
Coffee beverage	418.5	50.0	468.8	100.6

The recovery values ranged from 97.8% to 101.6%, indicating that the analytical method used for different drink matrices is satisfactory. The cola beverage obtained the least recovery and the energy drink sample had the maximum recovery. However, all these values were within reasonable limits of the analytical range, which means that matrix interference was minimal and the sample preparation procedure was adequately optimized for reliable caffeine determination.

Caffeine Content in Commercial Beverages

The validated technique was then used on commercial beverage samples. Absorbance values were converted to caffeine concentrations according to the calibration equation and corrected with dilution factors. The findings indicate that the caffeine content varied significantly according to beverage types.

Table 4. Caffeine content of commercial beverages

Beverage category	Sample code	Dilution factor	Absorbance	Measured concentration in diluted sample (mg/L)	Calculated caffeine in original sample (mg/L)
Cola	C1	10	0.5510	9.86	98.6
Cola	C2	10	0.5681	10.17	101.7
Energy drink	E1	20	0.8483	15.19	303.8
Energy drink	E2	20	0.8695	15.57	311.4
Tea beverage	T1	10	0.6807	12.18	121.8
Tea beverage	T2	10	0.6940	12.41	124.1
Coffee beverage	CF1	50	0.4682	8.37	418.5
Coffee beverage	CF2	50	0.4817	8.61	430.5

As can be seen in Table 4, caffeine content differed greatly between the beverages we found. Cola samples have the lowest amount (between 98.6 and 101.7 mg/L), tea beverages the moderate (121.8 to 124.1 mg/L), where energy drinks showed the higher concentration (303.8 to 311.4 mg/L). The caffeine was highest in coffee drinks (418.5 mg/L and 430.5 mg/L).

These results unequivocally demonstrate that the studied caffeinated beverage types can be distinguished based on the caffeine level.

Comparative Trend of Caffeine Content

For easier comparison, the mean caffeine concentration for each beverage category was calculated. The results are presented in Table 5.

Table 5. Mean caffeine concentration by beverage category

Beverage category	Mean caffeine concentration (mg/L)	SD
Cola	100.2	2.2
Tea beverage	123.0	1.6
Energy drink	307.6	5.4
Coffee beverage	424.5	8.5

The average level and distribution of caffeine concentrations are listed in Table 5. coffee > energy drinks > tea beverages > cola beverages.

Coffee beverages had the highest mean amount of caffeine content (424.5 mg/L), followed by energy drinks (307.6 mg/L). Moderate caffeine content in tea beverages (123.0 mg/L) and lowest average for cola beverages (100.2 mg/L) could be found. The low standard deviations in each category suggest that the replicate samples were fairly similar to each other, but coffee and energy drink samples varied slightly more than tea and cola, possibly due to the differences in formulations or dilutions.

IV. DISCUSSION

Spectral Characteristics and Analytical Wavelength

The UV absorption spectrum provided additional information confirming that caffeine has a precise absorption limit of about 273 nm, which is in line with the λmax reading reported by previous research that caffeine has λmax in aqueous systems between 272 and 275 nm (Alpdogan et al., 2002; Tiwari et al., 2013). The strong peak for absorption in this region supported 273 nm as the operational wavelength. As highest absorbance is achieved at λmax, the sensitivity of the test was enhanced, allowing more reliable quantification over the selected calibration range. The observed spectral signature proved that the prepared caffeine standard was stable and was free of significant spectral irregularities.

Linearity and Compliance with Beer–Lambert's Law

The calibration values were very linear in the 2–12 mg/L concentration range, as indicated by the regression equation A = 0.0557C + 0.0021 and the high coefficient of determination (R^2 = 0.9994). This provides strong evidence for Beer–Lambert's law compliance in the working range. The low intercept showed that the blank absorbance was minimal and that systematic baseline error was negligible. The very low %RSD values for calibration standards indicate that the instrument response was stable and highly reproducible. This linear performance is key to quantitative spectrophotometric determination and is consistent with other reports in which caffeine standards exhibited similar absorbance-concentration relationships (Chethana et al., 2016).

Validation Performance of the Method

The validation data show that the method developed has acceptable analytical reliability in routine caffeine estimation for use in commercial beverages. We found these intraday and interday precision values of 0.84% and 1.27%, respectively, to be acceptable in this simple UV-based assay. The low values suggest that this method can be replicated both within the same day and across different days of analysis. Likewise, the method attained a reasonable sensitivity, an LOD of 0.16 mg/L and an LOQ of 0.49 mg/L, indicating the method could detect and measure caffeine well below the concentrations generally seen in commercial beverages after dilution. The recovery figures, varying from 97.8% to 101.6%, demonstrated that reliable results of the method could be obtained for a range of beverage matrices. Of course, that is important since some components such as sugars, acids, preservatives, and colorants interfere with UV measurements. The acceptable recovery values indicated the fair control of these problems by reference to sample preparation conditions used.

Distribution of Caffeine in Beverage Samples

The coffee beverages contained the greatest amount of caffeine, more than 418 mg/L; energy drinks had about 304–311 mg/L; and tea drinks had only mild levels of caffeine, also recorded at 122–124 mg/L. In fact, cola drinks had the lowest concentrations of caffeine with about 99–102 mg/L. The findings are chemically reasonable and consistent with those of previous scientific research indicating that coffee and energy drinks have elevated caffeine levels compared to tea and soft drinks (Wanyika et al., 2010; Chethana et al., 2016). The relatively high coffee beverage caffeine content is due to the abundant caffeine in coffee beans and its high caffeine extraction from the beans. Energy drinks contain caffeine as an intentional additive, but they are usually in high doses to jolt the body. Tea is another cup that naturally contains caffeine, but the extraction of caffeine may be lower than in coffee due to differences in the composition and conditions under which the product is extracted from the tea plant. Cola has lower caffeine than its coffee counterpart, because in general caffeine is much lower in cola drinks.

Interpretation of Category-Wise Variation

The fact that the cola and tea varieties vary less clearly indicates that the product components of the tested samples are more closely homogeneous. The slightly larger comparisons between energy drink samples and coffee samples could, however, be attributed to variations in formulations, caffeine fortification, or sample handling, e.g. dilution. Since bean type, roasting habits, and preparation preferences are among the factors that affect caffeine levels in coffee drink products, its quantity still varies greatly. In a similar way, energy drinks will vary greatly based on the brand-specific formulation and whether they include caffeine-containing additives like guarana.

Practical Significance of the Findings

The generated spectrophotometric technique is shown to be able to distinguish high- and low-caffeine beverages with good analytical precision. This has an applied significance in quality control, educational laboratory exercises, and preliminary screening of commercial products. Ease of use, low cost, and the availability of instruments are reasons it is used in laboratories where sophisticated chromatographic equipment is not accessible.

Comparison with Earlier Studies

Convergence between these results is consistent with previous UV–Visible spectrophotometric investigations that have supported the simple and inexpensive detection of caffeine by absorbance in the UV (Shar et al., 2018; Tiwari et al., 2013). The calculated values of λmax, linearity, and trend of beverage concentrations have been verified. Similarly, this work strengthens the evidence for the analytical validity of the method using the method validation criteria; namely, precision, recovery, LOD, and LOQ. This is more scientific than studies that only measure concentrations without formal validation.

V. CONCLUSION

A simple and cheap UV–Visible spectrophotometric detection technique for caffeine in consumer drinks has been established. We found that an initial screening at 273 nm obviously indicated the maximum caffeine absorbance for this technique. The linearity of 2–12 mg/L calibration was high and determination coefficient was also high, demonstrating Beer–Lambert's law to be observed with the experimental scenario. It also gave the method satisfactory validation performance in terms of precision, sensitivity, and recovery as well, demonstrating the applicability on routine caffeine analysis in beverage samples. For each type of product category analyzed by the method there were noticeable differences in caffeine contents between them. Coffee beverages had the highest caffeine concentrations, followed by energy drinks, tea beverages had medium concentrations, and cola drinks had the lowest concentrations. But these results of an interesting phenomenon vs those of the composition and formulation practices of these drinks and agreement with previous studies. In addition, the experimental design proposed from the developed method can indeed be used for clearly separating beverage types by caffeine level, as confirmed by the data. An important advantage of the proposed framework is that it is user-friendly and approachable. The UV–Visible spectrophotometric method is low in instrumentation cost compared to common chromatographic methods (e.g., HPLC), simple sample preparation, and a short analysis time, which are suitable for traditional quality control and instruction laboratories or in resource-limited industries. But in this study validation and sample procedures should closely monitor and control matrix interference, especially in complex drinks (tea and coffee). Overall, the obtained UV–Visible spectrometric approach is a reliable and accurate method of caffeine determination for commercial beverages. Although more sophisticated methods have increased sensitivity and specificity, the present method is applicable for quick screening and routine analyses.

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