IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 10, March 2025
Impact Factor: 7.67

Tea Leaves to Titration: Simplifying Caffeine Extraction and Analysis

Sakshi Sunil Padge, Karbari Sana Abdul Sami, Khan Shoyeab Mutalib
Department of Chemistry
Anjuman Islam Janjira Degree College of Science Murud, Raigad

Abstract: *This research paper focuses on the extraction and analysis of caffeine from tea leaves using a simple titration method. The primary objective was to evaluate the caffeine content in various tea types, while employing a straightforward and accessible analytical technique. The caffeine was extracted from the tea leaves through a solvent extraction process, followed by quantification through titration, which allowed for the precise determination of caffeine concentrations. The study assessed the efficiency of the extraction process and analyzed the impact of factors caffeine yield. Results showed variations in caffeine content across different samples, highlighting the influence of specific extraction conditions. This research not only demonstrates the effectiveness of simple titration as an analytical method for caffeine determination but also provides insights into the caffeine composition of common teas. The findings are valuable for both consumers and manufacturers interested in understanding caffeine levels in tea products.*

Keywords: Caffeine extraction, tea leaves, Soxhlet, ultrasonic extraction, analytical methods, sustainability, tea types, nutritional analysis

I. INTRODUCTION

Remote Caffeine ($C_8H_{10}N_4O_2$) is a naturally occurring alkaloid found in more than 60 plant species, most notably in tea, coffee, cocoa, and kola nuts. It is widely consumed globally in various forms, particularly through beverages such as coffee, tea, and energy drinks. Caffeine acts as a stimulant of the central nervous system and is known to improve alertness, concentration, and reduce fatigue. It is one of the most consumed psychoactive substances in the world. Tea, in particular, has become a staple beverage in various cultures, valued not only for its stimulating effects but also for its purported health benefits. Tea is rich in bioactive compounds such as polyphenols, flavonoids, and tannins, which are believed to contribute to its antioxidant, anti-inflammatory, and anticancer properties.

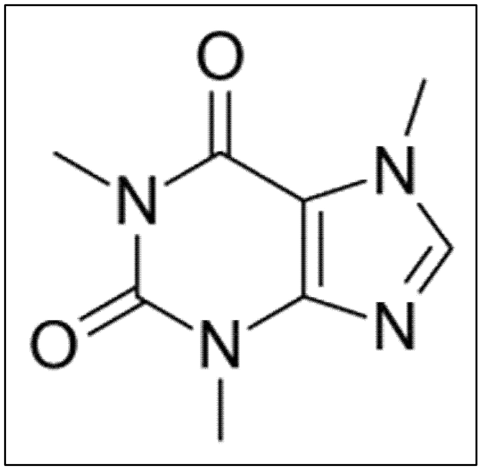
The extraction of caffeine from plant sources, particularly from tea leaves, has been an area of significant scientific interest due to its wide range of industrial applications. These include the production of caffeinated beverages, pharmaceuticals, food additives, and even cosmetics. The process of extracting caffeine from tea leaves is not only of commercial importance but also holds potential for optimizing the utilization of plant materials, which would otherwise be discarded after processing. This project aims to explore different extraction methods for caffeine from tea leaves, focusing on their efficiency, the factors influencing caffeine yield, and the subsequent analysis of the extracted caffeine using high-precision techniques.

Caffeine in Tea: Chemical Structure and Physiological Effects:

Caffeine is classified as a methylxanthine alkaloid, a group of naturally occurring compounds that include theobromine and theophylline. It is an odorless, bitter-tasting compound that is water-soluble, which allows it to easily dissolve in hot water when tea leaves are brewed. The chemical structure of caffeine consists of a purine base, which is closely related to adenine and guanine, components of DNA. The molecule contains three methyl groups ($-CH_3$) attached to nitrogen atoms, which makes it a highly bioactive compound.[1]

DOI: 10.48175/IJARSCT-24723

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 10, March 2025
Impact Factor: 7.67



1.1. Skeletal formula of caffeine

The physiological effects of caffeine are well-documented and can vary depending on the dose consumed. At lower doses, caffeine primarily functions as a stimulant for the central nervous system by blocking adenosine receptors in the brain. Adenosine is a neurotransmitter responsible for promoting relaxation and sleep, and when its activity is inhibited by caffeine, it leads to increased alertness and reduced fatigue. In higher doses, caffeine can increase heart rate and blood pressure, stimulate diuresis (increased urination), and may even have adverse effects such as jitteriness or insomnia.

Friedrich Ferdinand Runge etal. Isolated relatively pure caffeine for the first time. In 1827, Oudry isolated "theine" from tea, but it was later proved by Mulder and Jobat that theine was the same as caffeine. The structure of caffeine was elucidated near the end of the 19th century by Hermann Emil Fischer, who was also the first to achieve its total synthesis. This was part of the work for which Fischer was awarded the Nobel Prize in 1902. [1]

Clementz and Dailey (1988) etal. determined Pure caffeine occurs as odourless, white, fleecy masses, glistening needles of powder. Its molecular weight is 194.19 g/gmol, melting point is 236, point at which caffeine sublimes is 178, at atmospheric pressure, pH is 6.9 (1% solution), specific gravity is 1.2, volatility is 0.5 %, vapour pressure is 760 mm Hg at 178, solubility in water is 2.17 g per 100 mL water at 25, and vapour density is 6.7. [2]

Gebely, Mumin (2006) etal. reported that; Every time we drink tea, coffee, cocoa, chocolate or cola, we are giving our body a hit of caffeine. Alcohol and nicotine, along with caffeine are the three most widely used mood-affecting drugs in the world. The effects of caffeine on human being depend on concentrations. Consuming high dosage of this compound causes various physiological and psychological effects which include stimulation of the central nervous system. [3]

RESEARCH METHODOLOGY

In this experiment, you will perform a liquid-liquid extraction of the tea solution with an organic solvent, dichloromethane, to separate the caffeine from the basic tea solution and away from the tannins, gallic acid and the remainder of the tea components. Since caffeine is more soluble in the organic solvent dichloromethane (CH2Cl2) than in water, it partitions primarily into the dichloromethane. The tannins and gallic acid, being acidic compounds, are converted to water soluble salts by the sodium carbonate and remain in the aqueous layer during the extraction. The other components of tea are not very soluble in dichloromethane. Therefore, the extraction of tea solution with dichloromethane removes virtually no other compound but caffeine. The solid caffeine can then be isolated by evaporation of the low- boiling dichloromethane and identified by its melting point and mass spectrum.

Preparation of Sample

7 grams of tea (or) coffee were taken in 150 ml of distilled water and 5g of sodium carbonate is added. The solution was then heated and was kept at 100□C for 15 min. Then, the solution was cooled and filtered using Whatman filter paper.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 10, March 2025
Impact Factor: 7.67

Sample is heated

Caffeine Extraction Procedure

This sample was placed into a separating funnel and 6 ml of dichloromethane (DCM) was added. The caffeine was extracted by inverting the funnel at least three times, venting the funnel after each inversion. Vigorous shaking will produce an intractable emulsion, while extremely gentle mixing will fail to extract the caffeine.

Bottom layer containing dichloromethane

The bottom layer containing dichloromethane (DCM) was removed to a clean flask, leaving behind the layer of water and the extraction procedure was repeated twice more and the solvent layers combined.

Separation of Caffeine

The dichloromethane was evaporated from the extract by heating the flask on mantle or by covering with perforated aluminium foil and leave it for some time and allow it to get evaporated and it was recovered in the other beaker using Heat Reflux Extraction method.

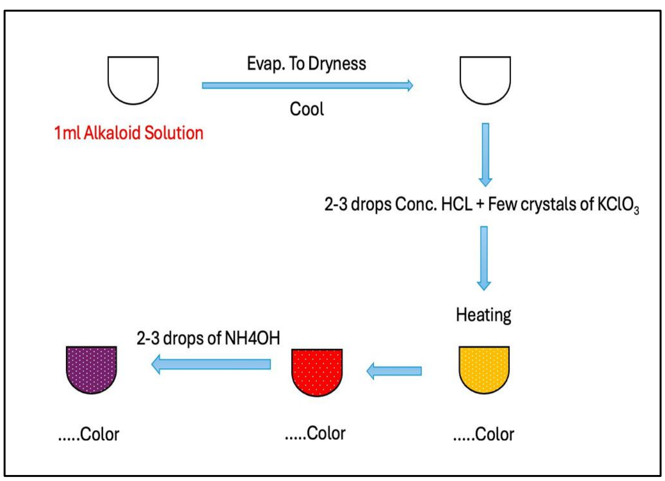
IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 10, March 2025
Impact Factor: 7.67

Caffeine

The residue obtained was whitish powder which was considered to be pure caffeine. The mass of flask with residue was measured on electronic scale.

Murexide test

Confirmative Test for Caffeine Detection Murexide test can be carried out for caffeine detection as follows: In a watch glass, small amount of a sample with 2-3 drops of concentrated hydrochloric acid is mixed. Use a glass rod for mixing. Then we add a few small crystals of potassium chlorate and mix well.
Heat the watch glass until the sample is dry.
Allow to cool.
Add a drop of ammonium hydroxide solution. The sample should turn purple.



Murexide test

Results:

Extraction of caffeine from tea and coffee was achieved by using Dichloromethane as an extracting solvent.

Sr. No	Sample	Amount of Sample (g)	Caffeine Extracted (g)	Caffeine Yield (%)
1	Tea	7	0.226	3.23%
2	Coffee	7	0.345	4.93%

Leave the test tube in the warm water bath. Add 2-propanol a drop at a time until the solid dissolves. Use the minimum amount required. This should be no more than 2 millilitres.

Now you can remove the test tube from the water bath and allow it to cool to room temperature.

Add 1 ml of hexane to the test tube. This will cause the caffeine to crystallize out of solution.

Carefully remove the liquid using a pipette, leaving the purified caffeine.

Wash the caffeine with 1 ml of a 1:1 mix of hexane and diethyl ether. Use a pipette to remove the liquid. Allow the solid to dry before weighing it to determine your yield.

With any purification, it's a good idea to check the melting point of the sample. This will give you an idea of how pure it is. The melting point of caffeine is 234 °C.

II. CONCLUSION

A method has been developed for the extraction and purification of caffeine from tea and coffee. The caffeine was obtained through liquid-liquid extraction followed by recrystallization, ensuring a purified final product. The study highlights the importance of selecting optimal extraction conditions to maximize yield. Caffeine is known to act as a central nervous system stimulant, and its consumption must be monitored, particularly in individuals with high blood pressure or heart conditions. Excessive intake can lead to adverse health effects, making awareness essential for consumers. Research studies indicate that caffeine, though widely consumed, should be treated as a bioactive compound rather than a regular dietary component. Moderate consumption is generally considered safe, but overuse can lead to negative physiological effects. The findings from this study provide useful insights into caffeine extraction techniques and their practical applications. Understanding caffeine levels in beverages helps in making informed choices regarding daily intake. This research contributes to the broader discussion on caffeine's role in human health, ensuring that both consumers and healthcare professionals remain aware of its potential effects. Future studies could explore alternative extraction techniques and their efficiency in different caffeine-containing beverages.

REFERENCES

[1]. Barone, J. J., & Roberts, H. R. (1996). Caffeine consumption. *Food Chemistry and Toxicology*, **34**, 119. McGraw-Hill, New York.

[2]. Fredholm, B. B., Battig, K., Holmen, J., et al. (1999). Actions of caffeine in the brain with special reference to factors that contribute to its widespread use. *Pharmacological Reviews*, **51**, 83-133.

[3]. Rogers, P. J., & Dernoncourt, C. (1998). Regular caffeine consumption: A balance of adverse and beneficial effects for mood and psychomotor performance. *Pharmacology Biochemistry and Behavior*, **59**(4), 1039-1045.

[4]. Caffeine, body fluid-electrolyte balance, and exercise performance. (2002). *International Journal of Sport Nutrition and Exercise Metabolism*, **12**, 189-206.

[5]. Shirlow, M. J., & Mathers, C. D. (1985). A study of caffeine consumption and symptoms: Indigestion, palpitations, tremor, headache, and insomnia. *International Journal of Epidemiology*, **14**(2), 239-248.

[6]. Peterson, J., Dwyer, J., Bhagwat, S., Haytowitz, D., Holden, J., Eldridge, A. L., Beecher, G., & Aladesanmi, J. (2005). Major flavonoids in dry tea. *Journal of Food Composition and Analysis*, **18**, 487-501.

[7]. Onami, A. T. (1996). A simple method for isolation of caffeine from black tea leaves: Use of a dichloromethane-alkaline water mixture as an extractant. *Journal of Chemical Education*, **73**(6), 556.

[8]. Song, G., Lin, J., Qu, F., & Huie, C. W. (2003). Extraction of catechins and caffeine from different tea leaves and comparison with micellar electro-kinetic chromatography. *Chinese Science Bulletin*, **48**(22), 2438-2443.

[9]. Khokhar, S., & Magnusdottir, S. G. (2002). Total phenol, catechin, and caffeine contents of teas commonly consumed in the United Kingdom. *Journal of Agricultural and Food Chemistry*, **50**(3), 565-570.

[10]. Dufresne, C. J., & Farnworth, E. R. (2001). A review of latest research findings on the health promotion properties of tea. *Journal of Nutritional Biochemistry*, **12**(7), 404-421.

[11]. Zuo, Y., Chen, H., & Deng, Y. (2002). Simultaneous determination of catechins, caffeine, and gallic acids in green, oolong, black, and puerh teas using HPLC with a photodiode array detector. *Talanta*, **57**(2), 307-316.

[12]. Louwrance, P. W., Mphangwe, N. I. K., Nyirenda, H. E., & Apostolides, Z. (2000). Analysis of caffeine and flavan-3-ol composition in the fresh leaf of *Camellia sinensis* for predicting the quality of black tea produced in Central and Southern Africa. *Journal of the Science of Food and Agriculture*, **80**(13), 1823-1830.

[13]. Peker, H., Srinivasan, M. P., Smith, J. M., & McCoy, B. J. (1992). Caffeine extraction rates from coffee beans with supercritical carbon dioxide. *AIChE Journal*, **38**(5), 761-777.

[14]. Silvarolla, M. B., Mazzafera, P., & Lima, M. M. A. (2000). Caffeine content of Ethiopian *Coffea arabica* beans. *Genetics and Molecular Biology*, **23**.

[15]. Pan, X., Liu, H., & Niu, G. G. (2003). Microwave-assisted extraction of tea polyphenols and tea caffeine from green tea leaves. *Chemical Engineering and Processing*, **42**(2), 129-133.

[16]. Tarka, M. S., & Hurst, W. J. (1998). Introduction to the chemistry, isolation, and biosynthesis of methylxanthines. In G. A. Spiller (Ed.), *Caffeine* (pp. 9-16). CRC Press, Boca Raton.

[17]. Arnaud, M. J. (1987). The pharmacology of caffeine. *Progress in Drug Research*, **31**, 273.

[18]. Islam, M. S., Rahman, M. M., & Abedin, M. Z. (2002). Isolation of caffeine from commercially available tea and tea waste. *Jahangirnagar University Journal of Science*, **25**, 9.

[19]. Jeanne, C. S. (1987). *Introductory Clinical Pharmacology*. J. B. Lippincott Company, **3**(19), 122-125.

[20]. Kaplan, E., Holmes, J. H., & Sapeika, N. (1974). Caffeine content of tea and coffee. *South African Medical Journal*, **48**, 510-511.

[21]. Debas, H. T., Cohen, M. M., Holubitsky, I. B., & Harrison, R. (1971). Caffeine-stimulated acid and pepsin secretion: Dose-response studies. *Scandinavian Journal of Gastroenterology*, **6**(5), 453-457.