Sources and References

- Research Articles
  - Effect of Microbial Fermentation on Caffeine Content of Tea Leaves
  - Caffeine content of beverages as consumed
  - Spectrophotometric Analysis of Caffeine
  - Factors Affecting the Levels of Tea Polyphenols and Caffeine in Tea Leaves
  - Distribution of Catechins, Theaflavins, Caffeine, and Theobromine in 77 Teas Consumed in the United States
  - A rapid and simple determination of caffeine in teas, coffees and eight beverages
  - Caffeine in tea Camellia sinensis — Content, absorption, benefits and risks of consumption
  - Determination of Caffeine in Coffee Products According to DIN 20481
  - Optimization of Caffeine Extraction from Various Tea Types Using Dichloromethane as an Organic Solvent
  - Characterization of Effects of Different Tea Harvesting Seasons on Quality Components, Color and Sensory Quality of “Yinghong 9” and “Huangyu” Large-Leaf-Variety Black Tea
  - Chemical constituents analysis of white tea of different qualities and different storage times
  - Analysis of differences in the accumulation of tea compounds under various processing techniques, geographical origins, and harvesting seasons

- Video Sources
  - I Did Caffeine Analysis: The Unexpected Truth!
  - How to extract Caffeine from Tea (Classic DCM Method)

Research Articles

This section includes articles that have been peer-reviewed. Other content may include review or technical articles written in an academic context.

Effect of Microbial Fermentation on Caffeine Content of Tea Leaves

Source of Article Wang et al. - 2005 - Effect of Microbial Fermentation on Caffeine Content.pdf

Research Articles

Caffeine content of beverages as consumed

Source: Gilbert et al. - Caffeine content of beverages as consumed.pdf

Spectrophotometric Analysis of Caffeine

Source: Ahmad Bhawani et al. - 2015 - Spectrophotometric Analysis of Caffeine.pdf

Research Articles

Factors Affecting the Levels of Tea Polyphenols and Caffeine in Tea Leaves

Source: Lin et al. - 2003 - Factors Affecting the Levels of Tea Polyphenols an.pdf

Research Articles

Distribution of Catechins, Theaflavins, Caffeine, and Theobromine in 77 Teas Consumed in the United States

Source: Friedman et al. - 2006 - Distribution of Catechins, Theaflavins, Caffeine, .pdf

Research Articles

A rapid and simple determination of caffeine in teas, coffees and eight beverages

Source: Sereshti and Samadi - 2014 - A rapid and simple determination of caffeine in te.pdf

Research Articles

Caffeine in tea Camellia sinensis — Content, absorption, benefits and risks of consumption

Source: Gramza-Michałowska - 2014 - Caffeine in tea Camellia sinensis — Content, absor.pdf

Research Articles

Determination of Caffeine in Coffee Products According to DIN 20481

Source: Naegele and Technologies - Determination of Caffeine in Coffee Products Accor.pdf

Research Articles

Optimization of Caffeine Extraction from Various Tea Types Using Dichloromethane as an Organic Solvent

Source: Memon and Idress - 2024 - Optimization of Caffeine Extraction from Various T.pdf

Research Articles

Characterization of Effects of Different Tea Harvesting Seasons on Quality Components, Color and Sensory Quality of “Yinghong 9” and “Huangyu” Large-Leaf-Variety Black Tea

Source: Ye et al. - 2022 - Characterization of Effects of Different Tea Harve.pdf

Research Articles

Chemical constituents analysis of white tea of different qualities and different storage times

Source: Chemical_constituents_analysis.pdf

Research Articles

Analysis of differences in the accumulation of tea compounds under various processing techniques, geographical origins, and harvesting seasons

Source: 1-s2.0-S0308814623016187-main.pdf

Video Sources

Video Sources

I Did Caffeine Analysis: The Unexpected Truth!

Source: https://www.youtube.com/watch?v=etnMr8oUSDo&ab_channel=JamesHoffmann

Note: Probably the closest thing to a caffeine analysis done with some test comparisons, but for coffee. It is relatively simple in the sense that you don't need a lot of setup other the equipment itself.

Video Sources

How to extract Caffeine from Tea (Classic DCM Method)

Source: https://www.youtube.com/watch?v=RIbff5iD0GQ&ab_channel=NileRed

Note: Uses dichloromethane method (DCM) to extract caffeine. The setup is a bit more involved and requires attention to equipment use. The video shows the process step by step, but it uses 6 tea bags which is not something you would normally use for consumption. In addition, the yield extracted might be small. But disposal is of concern since DMC is carcinogenic.

Video Sources

The Extraction of Caffeine from Tea Leaves All Parts

Source: https://www.youtube.com/watch?v=8Z_Ei1ITJpA&ab_channel=BristolChemLabS

Note: Goes over each process and gives an overview of the equipment needed.

Blog Sources

Blog Sources

How can I measure the caffeine content in drinks?

Source: https://www.camlab.co.uk/blog/how-can-i-measure-the-caffeine-content-in-drinks

Caffeine Source Reference

Source: https://www.caffeineinformer.com/caffeine-source-reference

Caffeine

Summary

Tea, *camellia sinensis*, includes a number of bioactive chemicals including caffeine.

The precise amount of caffeine extracted from tea depends on a combination of factors that include 1) the location or region; 2) the material of the tea leaves; 3) the processing itself; and 4) brewing parameters. The aging of tea is a potential factor, but requires more research.

First, the location or region of the tea matters because of the varietals used when producing tea. In one study, the differences in biochemical indicators, such as caffeine, were examined among green tea because of its wide distribution and processing green tea can vary depending on the region (Fu et al. 2024). They found that the Southwest region (Yunnan, Guizhou, Sichuan, and Chongqing) typically had higher caffeine levels compared to the Jiangnan region (Zhejiang, Hunan, Anhui, Jiangxi, Jiangsu, and Hubei), South region (Guangxi, Fuijan, and Hainan), and Jiangbei region (Shanxi and Shandong). The authors speculate that the Southwest region tend to use large-leaf varieties when producing tea which have a higher caffeine content than small-leaf tea varieties.

Second, the material of tea leaves can impact the level of caffeine. White Tea is known for having a grading system of silver needle (only uses buds), White Peony or BaiMudan (uses two or more larger leaves and one bud), Gong Mei (has a blend of buds and leaves) and Shou Mei (Mostly leaves). One study compared the caffeine content of the different grading levels of White Tea for the same year (Ning et al., 2016). They found that Silver Needle had the highest amount of caffeine concentration followed by Bai Mudan, Gong Mei, and Shou Mei. Thus, the highest grade has the most caffeine and the lowest grade has the lowest levels of caffeine. The grading system for White tea reflects the amount of buds and leaves used when producing tea. Buds and young leaves are likely to have a higher caffeine concentration compared to mature and older leaves.

Third, the processing itself can impact caffeine, specifically roasting and microbial fermentation. Roasting the tea leaves sublimates the caffeine which results in a lower caffeine content (Fu et al., 2024). Several articles have found that oolong teas tend to have lower caffeine levels compared to other types of teas (Hicks et al., 1996; Fu et al., 2024; Zuo et al., 2002). Fermentation, specifically pile-fermentation was found to increase the level of caffeine content in green tea and black and that the effects are more pronounced in green tea (Wang et al., 2005). This seems supported by another where shu pu'er and young raw pu'er were found to have similar caffeine levels (Pedan et al., 2018).

Finally, brewing parameters will ultimately influence how much tea an individual extracts. These parameters include the amount of leaf used during the brewing session, the length of the steeping time, the amount of infusions made, and the temperature of the water (Astill et al., 2001). The more leafs used and longer steeping times, the more caffeine will be extracted. More infusions

means an individual will consume more caffeine. Boiling water temperature agitates the tea leaves more compared to using cooler water temperatures. As a result, using boiling water means extracting more caffeine.

Side Note: The effects of aging tea seem to suggest that as one stores tea for a long period of time, the level of caffeine can increase. When comparing the different ages of Shou Mei from 2013, 2012, 2010, and 1993, caffeine levels did not differ between 2013, 2012, and 2010 (Ning et al., 2016). However, the 1993 Shou Mei had the highest levels of caffeine content compared to the 2013, 2012, and 2010 Shou Mei (Ning et al., 2016). When comparing the different ages of Ya'an Tibetan tea, they found that caffeine levels did not differ much from 1 to 5 years, but that 10 year aging had more caffeine levels compared to 1 year and 5 year aging. For pu'er teas, one study suggests that caffeine levels did not change much from the length of storage for raw pu'er teas (Zhou et al., 2020). These suggests suggest a certain threshold in aging is needed before the caffeine content is increased.

It is unclear whether one should recommend a hard and fast rule for the general amount of caffeine in the type of tea. For example, google searching "which tea has the lowest (or highest) caffeine" will produce results that suggest black/red tea has the highest caffeine content and white tea has the lowest caffeine content. But the material used or the processing production are important factors to consider as well. For example, white tea is claimed to have low caffeine, but this depends on whether young buds or mature leaves are being used (Ning et al., 2016).

Caffeine Extraction

Measuring caffeine would not be easy. The existing methods to measure tea range from requiring laboratory equipment to a DIY approach. In reviewing their approaches, the way they extract caffeine differs from how one normally brews tea such as the amount of grams used and steeping time. While these studies are not perfect, the amount of caffeine typically extracted from tea is low.

Below I summarize three different approaches to measuring caffeine:

Precise measurement of caffeine requires laboratory grade equipment such as a UV spectroscopy or a High Performance Liquid Chromatography (HPLC). An example of UV spectroscopy can be found here (Spectrophotometric Analysis of Caffeine) stating that this type of procedure is often used in universities and research institutes. An example of a HPLC can be found here regarding the type of equipment needed.

An alternative would be to measure coffee with more of a DIY approach, but it is less precise and requires careful attention to detail. The most popular method would be to use Dichloromethane to extract caffeine. Several sources exist that provide a breakdown of the equipment needed and procedures to follow such as this article and this video. The goal is to extract caffeine in its pure form which would appear as needle-like crystals. The amount of setup; however, is costly compared the end result of extracting a low yield amount of caffeine. This article provides a frame of reference where they used Dichloromethane and extracted .089g caffeine from black tea and .08g from green tea — less than .1 grams.

From a commercial standpoint, measuring caffeine with the Lighttells CA-700 coffee caffeine analyzer would be straightforward. The cost is steep (more than $2500), but requires less setup or access to a laboratory space. The product was intended to measure caffeine from coffee, but contacting them would suffice to double check whether it can measure caffeine from tea.

An observation I noticed is that each process differs in the amount of grams used when measuring tea or coffee. Precise measurement methods seem to use less than 1 gram, whereas less precise measurements require using more grams. In this context, the amount of grams used when measuring caffeine content from tea differs from the amount of grams one might use when casually brewing tea (e.g., gōngfū chá).

Tea and Human Health

Physiological Effects of Tea - Jitters

[Please note that the footnotes appear inline].

This report will answer two questions:

1) What do most people mean when they say "jitters"?
2) What causes "jitters?

Sometimes people experience “jitters” when drinking tea. This type of “jitters” is different from “coffee jitters” where people report experiencing shaky hands, increased heartbeat, bursts of energy. The experience of “jitters” from tea is somewhat different from “coffee jitters” as people tend to ask why they get jitters from tea (examples here, here, and here). Other times, you might hear people feeling “tea drunk”, a “buzz”, or a kind of “high” when drinking tea.

Some broad distinctions can be offered to better explain what we mean when people talk about physiological or sensory experiences with tea.

Sometimes the sensation of feeling jitters is more directly related to a caffeine rush. Some people have reported feeling shakes, dizziness, cold sweats, and heart palpitations. These kinds of sensations can happen when one is drinking tea on an empty stomach or from excessive amounts of drinking tea. In addition, people often mention caffeine and L-theanine in discussions about tea and physiological responses.

L-theanine is a non-protein amino acid that is found naturally in tea plants that contributes to the taste profile of tea (Vuong, 2011). The amount of L-theanine can vary depending on the type of the tea and brewing time (Keenan et al., 2011). The effects of L-theanine are associated health and cognitive benefits, and is often cited as a factor for feeling relaxed, but alert (Vuong, 2011). L-theanine has also been found to counteract the negative effects of caffeine (Vuong, 2011) which may explain why individuals do not often report feeling negative effects when drinking tea.

The reason for why some might experience jitters could be physiological imbalances between caffeine and L-theanine. The dosage amount of L-theanine needed to counter effects of caffeine is unclear. High amounts of L-theanine is not easy to achieve. For example, 150 - 250 mg of L-theanine would require drinking nine and 15 cups of tea per day (Vuong, 2011). Also, caffeine levels of a tea may depend on the geographic region and whether roasting processing was involved (Fu et al., 2024).

In other instances, people might be talking more about how the tea makes them feel or the “energy” of tea. This sensation may sometimes be described as feeling “heavy”, “drugged, “euphoria”, “body feel”, “a high”, “blood flowing through the veins” or “getting smacked by a tea that’s too strong”. In a more poetic sense, the sensation can be described as an unspeakable sense of openness (Ma, 2023). This can be referred to as chaqi[pinyin: chá qì simplified:].

What is chaqi?[The idea of “Chaqi” sounds less scientific and more mystical in the way the concept is sometimes described. The idea of “chaqi” being mystical or scientific is a separate issue for the time being. From a western perspective, it’s easy to overthink the word having more connotations than it should.] No single definition can probably capture this concept, but some balance must be maintained. Too strict a definition means loss of information that contribute to experiences of understanding chaqi. Too loose a definition does not help either because anything can be considered chaqi. Language matters too because of the limitations in being able to translate descriptions of sensations across languages (e.g., Chinese to English).[I do not discuss further, but Traditional Chinese Medicine (TCM) cannot be ignored because the idea of is rooted in TCM. TCM also influences how tea is discussed as some might say green teat is “cold” and fermented/oxidized tea is considered “hot”.]

Discussions about what is and what is not chaqi are not always clear. The experience of chaqi can be somewhat subjective because individuals will have different responses to the same tea. Two points of consideration can help clarify what people mean when saying statements like “this has good chaqi”.

The first point of consideration is that chaqi can refer to the strength or power of the tea. These kind of descriptions are more directly related about the tea whether it is talking about the aroma, taste, liquor, and mouthfeel. They talk more about the quality of the tea itself. For example, an experienced tea drinker would probably understand the statement “a fresh Bulang is more aggressive than a Yiwu” or “Yiwu is more relaxing than a Bulang.” Both example statements are more commonly overhead in China in which chaqi is meant to refer to the body feel of the tea.

The second point of consideration is that chaqi can refer to the effects of tea consumption. This can refer to a change in mental state, such as feeling perceptive, mediative, or alert. This can also refer to changes in one’s physical state, such as sweating, blood rush, or increased heart rate. These effects are more dependent on the individual and can sometimes seem more subjective.
What are factors that contribute to why some people report difference sensation experiences?

The first is that certain types of teas seem to provide more chaqi than others. Sheng pu’er, shu pu’er, yancha, and dancong are types of teas often discussed in relation to chaqi. For example, it’s more common to hear about the chaqi from a pu’er tea than from a green tea. For example, a good aged sheng pu’er is sometimes described as being heavy, relaxing, and in a state of sedation. In contrast, a young sheng pu’er can be considered more “wirey” or “jittery” likely because these teas are fresh off production and have not had sufficient time to undergo years of fermentation. Some research also suggest chemical differences between sheng and shu pu’er due to processing differences and changes in bioactivity from the aging process (see Wang et al., 2022).

Second is whether the material is sourced from older or younger tea trees. Ancient tea trees[No clear standard definition, but generally refers to tea trees 100+ years.] then to have more chaqi than terrace teas[Generally refers to teas planted at terraced or leveled land on mountain sides. These are cultivated tea bushes and typically planted neatly.]. One reason for the difference is because ancient tea trees have developed roots deep in the ground that have access and can absorb minerals and nutrients that contribute to the complex taste reported in tea (Hung, 2016). The same ancient tea trees are rarely disturbed by humans unlike terrace teas that require more intervention from humans. The age of the tree seems to explain why teas that use younger material don't provide as much body feel compared to teas that use older material.

In one study, experts could identify which pu'er samples were from ecological forests or terrace production stating the former has more of a bitter taste (Ahmed et al., 2010). When analyzing the phytochemicals of pu'er, the levels of Total Catechin Contents (TCC) and Total Methylxanthine Contents (TMC) were different depending on source material. In general, pu'er samples from ecological forests had higher mean TCC levels than pu'er samples from terrace plantations (Ahmed et al., 2010). Pu'er samples from terrace plantations had higher mean TMC levels than pu'er samples from ecological forests (Ahmed et al., 2010). Overall, these results demonstrate differences in chemical composition between teas from ecological forests of tea plantations.

The difference in chemical composition probably explain why people have different experiences when drinking pu'er tea. The sensation of only experiencing jitters or feeling caffeinated might stem from drinking pu'er made from terrace plantations that usually have low levels of total catechin and high levels of total methylxanthine which include caffeine. If one experiences a sort of "high" or chaqi, this might stem from pu'er made from ecological forests that usually have high levels of total catechin (Ahmet et al., 2010).

Summary

Defining people's physiological or sensory experiences with tea can be tricky for a number of reasons.

First, people may not have the sufficient vocabulary or experience to delineate differences, especially when much of the tea culture is built around training and defining taste and sensory experiences. The notion of articulating these experiences with specific terminology can be seen as too abstract or pretentious (Ma, 2023). In addition, concepts may not be easily translated or understood across languages which can create difficulties in describing these experiences.

Second, what is "jitters" can depend on what physiological or sensory experiences we are referring. At a basic level, one might define it as something more akin to a "caffeine rush" in which they are overstimulated. In another sense, one might be referring to the "high" or "buzz" that can be more abstract but often has more positive sensory associations. Still, in other cases, one might be talking more directly about the tea itself in terms of its strength. These descriptions are not always in isolation and can sometimes overlap in trying to describe the sensation.

Third, what factors affect these sensory experiences? Drinking tea on an empty stomach or drinking too much tea can contribute to negative sensory experiences. The type of tea can matter

as certain teas like sheng pu’er, shu pu’er, yancha, and dancong lend to sensory experiences. In the case of pu’er tea, the source material from ancient trees of terrace plantations have different chemical constituents which may explain why these teas lead to different physiological and sensory experiences. The aging process also matters as bioactivity levels change over time as part of the fermentation process.

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Effects of Pesticides and Fertilizers

This report will answer the following question:

What are known negative effects to humans (if any) when pesticides and fertilizers are used for tea?

I discuss fertilizers and pesticides separately and then discuss both in relation to tea farmers.

Fertilizers

Fertilizers play an important role in the cultivation of tea as they are highly-nutrient intensive. Tea plants are often picked for young leaves and shoots and constant harvesting of young leaves can deplete soil nutrients. Tea plantations have been adopting the use of chemical fertilizers, especially nitrogen fertilizers as results support that it can be effective in yield and quality production (Han et al., 2008; Kang et al., 2019). The use of fertilizers to increase yield production is reasonable to meet global demands for tea as natural gardens do not produce high yields. However, excessive fertilization can lead to environmental problems such as land degradation, soil acidification, and greenhouse gas emissions (see Kang et al., 2019). In fact, an overview of tea gardens in China found that overuse of chemical fertilizers was a common problem with over 30% of tea plantations suffering from excessive use (Kang et al., 2019).

To my knowledge, no research can be found on the effects of fertilizers in relation to human health. Most research focuses on the effects of fertilizer on the environment, crop yield, and quality of the tea (Kang et al., 2019; Raza et al., 2025). In this case, fertilizer use is likely to have an indirect effect towards human health as existing research supports that overuse of poor management can affect the production of tea (Kang et al., 2019; Raza et al., 2025).

Pesticides

Pesticides are often used to control for insects and pests, but pesticides usage can introduce toxicity and pollutants into the environment. Food safety standards have set maximum residue limits (MRLs) regarding the maximum amount of pesticide residues for various crops. MRLs are the maximum concentration of a pesticide residue expressed in milligrams per kilo (mg/kg) (FAO and WHO, 2025, p. 19). Countries and organizations can have different standards for what MRL values are considered acceptable.

In the case of tea, pesticides can be problematic without proper care. Unlike other fresh leaves, tea leaves are not typically washed of chemicals as tea leaves are manufactured directly after

harvest (Fernandes et al., 2023). Pesticide residues can be left on tea leaves over time as certain types teas are valued for their aging process.

The research on the effects of pesticide residue on human health is mixed. Some research suggests that the risk of pesticide residues to human health are negligible (Feng et al., 2022; Yang et al., 2020). However, others call for more careful research of using pesticides in tea (Lu et al., 2020; Fernandes et al., 2023). Taiwanese researchers have found that pesticide residues from triazophos, carbofuran, and endosulfan pose significant risk to human health as these pesticides are known to be highly toxic and soluble (Lu et al., 2020). A review of existing papers found that the among the different types of Chinese teas, scented tea had the most heavy metal contamination that exceeded safety standards (Hu et al., 2023). Scented teas are often sprayed with chemical pesticides which explain the high amounts of heavy metals present in detection (Hu et al., 2023). In addition, the types and concentrations of pesticide use can vary which call for more studies regarding long term effects (Fernandes et al., 2023).

Tea Farmers and Fertilizer/Pesticide Use

In general, tea farmers may opt to avoid using pesticides and fertilizers.[1] In Kūnmíng, informants state that tea forests tend to grow well without the use of fertilizers and pesticides (Ma, 2018). In Jǐngmài, farmers report that they do not use fertilizers and pesticides as part of their management system (Li et al., 2023). In Fènghuáng, some farmers opt to use natural methods for deterring insects and producing their own fertilizers (Lin et al., 2022). The skepticism of using commercial pesticides and fertilizers is because of concerns that using chemicals will damage the biotic and abiotic parts of the ecosystem that are beneficial for the growth and quality of tea (Lin et al., 2022). As one farmer states:

"*I do not use those market-bought fertilizers because I am not sure what has been added to them. I compost and fertilize with soybean residue and the tea trees grow very well.*" (page 11, Lin et al., 2022)

Informants and farmers claim that using pesticides and fertilizers can have negative affects on the ecological system (Lin et al., 2022; Ma, 2018). In extreme cases, the abuse of chemical fertilizers and pesticides have lead to the death of tea tress in Fènghuáng (Lin et al., 2022). Evidence from tea plantations support that intensive management can lead to crops being more susceptible to pests and diseases, which in turn can ultimately harm the environment and human health (Yan et al., 2020).

Pesticides and fertilizers are often used in modern farming conventions and some evidence suggests these applications can affect the quality of tea. One recent paper examined the quality of five varieties of oolong tea under two different management systems (He et al., 2024). The first management system was an artificial tea garden that was naturally grown for 35 years without any artificial management, deep soil ploughing, or use of pesticides and fertilizers. The second was a conventional management system that involved cutting plantings, pruning management, conventional herbicide weeding, conventional pesticide use, and standard deep ploughing. They

found that oolong varieties produced through conventional management system had higher aesthetic appeal and higher catechines compared to naturally grown varieties. However, naturally grown varieties were found to have better taste and aroma compared to varieties that were conventionally managed.

Conclusion

Both fertilizers and pesticides are important in manging tea production as they have effects in the growth of tea and deterring unwanted pests. Fertilizers are not known to have negative effects on health health, and some evidence suggest that the effect of pesticide residue on human health is negligible. However, research has called for further investigation into investigated certain types of pesticides and long-term effects. Moreover, the overuse of fertilizers and pesticides can have negative effects on the surrounding ecosystem which thereby affect the quality of the tea.

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Footnote

[1]One consideration is the use of pesticides from the perspective of the tea industry. Generally, discussion of pesticides are often considered taboo. The reason is because admitting pesticide use can lead to negative stigmas of not buying your tea. The more pressing concern is farmers using pesticides and the lack of personal protective equipment (PPE). Will from Farmerleaf provides a thoughtful discussion here: https://www.youtube.com/watch?v=DNWZJTOBeDc

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