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).