

Effect of Brewing Conditions on Caffeine Content in Commercial Indian Tea Brands

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ABSTRACT

Caffeine is a common drink to consume by people from India whereas tea has been an important part for centuries due to its high amount of caffeine content. However, it does depend upon how much there was initially within a cup of dried-out tea as well as what method they used to prepare this drink. The study is concerned with how different temperatures during brewing affect caffeine content extracted by commercial Indian black teas. This study proposes an experimental setup where five commercially available teas are brewed at 70°C, 85°C, and 100°C for 2, 5, and 10 minutes respectively under constant tea to water ratios. Reversed phase HPLC-UV quantifies caffeine; each experimental condition was tested three times for accuracy purposes. This model is suitable for testing the effect of a tea brand, brewing temperature, and brewing time through an ANOVA experiment. Research shows an overall trend where higher temperatures and longer steeping times lead to more caffeine content extracted from leaves; however, this relationship varies depending upon factors such as leaf type, particle size, method used for preparation and initial chemistry present within a given batch of tea. This research applies to Indian consumers as there are differences between types of commercial teas due to their production methods and blends. Thus an unbiased evaluation would reveal what is typical of standardization processes to affect caffeine consumption levels as well as serve as evidence when evaluating different types of coffee makers at similar temperatures during brewing time.

Keywords: Caffeine, Black Tea, Brewing Temperature, Infusion Time, Commercial Indian Tea, HPLC, Camellia Sinensis.

Introduction

Camellia sinensis tea preparation is a part of daily diet for people living here. It is consumed at home, office, restaurant and street-side teahouse where they are made out of various types like plain black tea, milk tea and spicy varieties. Also an important producer of tea from India are Assam, Darjeeling, Nilgiri, Kangra, Dooars and Terai. While aroma, color, flavor intensity and sweetness are more noticeable by customers than its chemistry content is nutritionally important for them.

Methylxanthines are caffeine which occurs naturally on tea leaf. As an active substance for stimulating nerves it helps people feel more awake while also reducing feelings of tiredness. There may be a difference between the level of caffeine found on dried tea leaf versus that which has been drunk due to its diffusion through water before being used for making coffee or other beverages. Thusly is determined by its extractive properties along with initial content level from which it was taken out for this purpose.

Brewing temperature is a major extraction variable. Higher temperatures increase solubility, mobility of molecules, diffusion rates as well as mass transfer between a tea leaf and its surroundings. Suteerapataranon et al. (2009) showed that infusion conditions significantly affected caffeine extraction from tea and reported higher extraction under hotter and longer brewing conditions. Recent studies on chromatography show that there are some variations to caffeine levels due to changes in temperature and duration during brewing.

Time of infusion matters too. At first stages during brewing there exists a high difference in concentrations between particles from tea and liquid which allows for quick transfer of dissolved substances to them. With time for brewing, there is a decrease in gradient and an increase on rates of extraction. Fernando and Soysa found a quick release of caffeine and other phytochemicals from black tea during brewing; meanwhile Ramalho et al. The results show that a cup cooked for 2 min 10 sec is not necessarily identical to another one.

The commercial teas might be different under same processing conditions. Variations among different types of tea plants grown under various conditions such as climate, harvest time, quality grades like CTC vs orthodox; particle sizes for grinding purposes; mixing techniques used during manufacturing process etc. may affect not just their amount but also how quickly they absorb water when brewed. Smaller particles have more surface area exposed to water that can lead to faster release rates. Therefore, there should be an agreement on how much dry tea is used for each brand; amount of water to use per cup; boiling time; filtering process; analysis method.

This paper is about some of those popular commercial black teas sold by companies within India that are tested for their levels of caffeine content during processing at home or elsewhere. This research doesn't imply that a product containing more caffeine per gram of powder is always going to have higher levels compared with other products made from it. However, this study considers caffeine to be an effect on the final extraction from a beverage due to its properties and methods used for preparation. It applies better for actual use since people drink it instead of drinking raw leaf tea.

Statement of the Problem

People usually compare teas based upon their taste rather than how they are prepared for extracting more caffeine content from them. The amount of caffeine found in a bag of tea is not necessarily equal to that present within the dried leaves; however, when brewed with hot water it can vary greatly due to factors such as temperature, steeping time, particle size of leaves and ratio between tea and water. In addition, there could be differences among commercial Indian tea brands regarding their composition and processing methods; therefore, the response to brewing conditions might vary between them. There would be no way of comparing them without standardization so as to know if there was any difference due to the type of product rather than how it was prepared. Thus an experimental study would be needed for measuring how much impact there is on boiling time due to changes in water temperature and length thereof under fixed conditions.

Aim and Objectives

- **Aim**

To evaluate the effect of brewing conditions on the caffeine content of selected commercial Indian tea brands.

- **Specific objectives**

- Determining levels of caffeine content for brewed teas made by selecting some popular varieties of Indian black tea products.
- For studying how much heat affects caffeine extraction from coffee beans.
- For evaluating how long a beer is brewed affects its level of caffeine content.
- For comparison of different types of teas on same basis for brewing process.
- For testing interaction between a tea brand, brewing temperature, and infusing time.
- For identifying factors that affect low to high levels of caffeine extraction from coffee beans.

Research Questions and Hypotheses

- **Research Questions**

- Is there any effect on coffee content due to brew temperatures for commercial teas.

- Does an increase in infusion time have a significant impact on caffeine extraction.
- Do commercial Indian tea brands differ significantly in caffeine content for brewing at same time.
- Is there any relationship between brewing temperature and time of brewing.
- Do various types of teas react differently to changes in brewing conditions.

- **Null hypotheses**

H01: Temperature of brewing does not have any impact on caffeine content for tea infusions.

Brewing time does not have any impact on caffeine content.

There is no significant difference between the levels of caffeine content for these products.

No significant correlation between tea brand, brewing temperature and brewing time was found.

Review of Literature

- **Caffeine in Tea**

One type of caffeine found in teas is a purine alkaloid. The level of its content depends on genetics, agriculture, production processes, and processing methods. Research on Indian black tea shows that caffeine is a major constituent of the dried leaves while tea products are rich in polyphenolics such as catechin and theaflavin which contributes towards their taste profile. Since tea is usually made by steeping it in water to make a beverage, analysis must be done on how much caffeine there was originally present versus what got dissolved during brewing. The difference between these two types of tea is due to differences in serving size for caffeine content among commercial products; it also relates to how preparation methods affect methylxanthine extraction and systematic evaluations of factors affecting caffeine and polyphenol extraction from black and green tea infusions.

- **Influence of Brewing Temperature**

Thermodynamics and kinetics are affected by temperature during an extraction process. Temperature increases may enhance caffeine solubility and speed up its movement within a plant's tissue system. Suteerapataranon et al. (2009) examined the influence of tea variety, leaf form, and infusion conditions and reported a clear effect of temperature on caffeine extraction. Yang et al., 2007, found that hotter water releases more caffeine and related compounds than cooler ones when used for tea preparation at temperatures of 70 °C, 85 °C, and 100 °C. The results show that hotter water tends to be better at extracting caffeine from coffee beans compared to colder ones for a short time of brewing.

- **Influence of Infusion Time**

The brewing time is a measure of how long it takes for tea leaves to be dissolved by water during an infusion process. Fernando and Soysa studied the rate at which caffeine and some other substances are released from tea leaves while making black tea. Hicks et al., 1996; Astill et al., 2001 showed how preparation conditions such as infusion time affect caffeine extraction whereas Yang et al., 2007 found a gradual change of caffeine release due to different steeping times. It implies that increasing the brewing time from two to five minutes would result in an appreciable rise; however, further increases will be progressively less significant once extraction equilibrium is reached. Like Ramalho et al., 2013 found that infusion time affects the chemical composition of black tea infusions.

- **Interaction of product characteristics and brewing conditions**

Heterogeneous tea product is a type of material. CTC tea with small grains might have a slower release of soluble substances compared to an orthodox leaf type. Area of surface, tissue damage, water content and mixture properties may affect rate of extraction process. Research on various kinds of teas shows that brewing temperature, time, tea-to-water ratio, processing degree, and product form can jointly alter the chemical profile of an infusion. Therefore, it is important to consider how brewing temperature affects a beverage rather than just its flavor profile alone. Factorial designs are useful as they help determine if there is consistency of an effect among different brands/products rather than just between them.

- **Need for standardization of commercial Indian tea products.**

The Indian consumer buys goods of many companies and also makes coffee at home due to different living situations. Standardized testing by fixing the amount of tea to water and controlling temperature-time pairs will yield better results compared to comparing different packages at random

times without any control over them. Recent studies show that brewing temperature, infusion time, tea-to-water ratio, particle characteristics, and water properties are important factors affecting compound transfer during tea brewing. The controlled infusion study supports standardization of brewing parameters for comparison between different types of teas. This information would be useful for people wanting to reduce their caffeine consumption without sacrificing taste preferences towards certain types of teas.

Materials and Methods

• Study Design

This research is conducted through an experiment based on factors from lab experiments. There are five types of commercial black teas to buy at stores. To avoid analytical bias during measurement, products may initially be coded as Brand A, Brand B, Brand C, Brand D, and Brand E. Brand name, batch number, date of manufacture, best-before date, package type, and place of purchase should be recorded in a sample log.

• Experimental factors

Factor	Levels
Tea brand	A, B, C, D, E
Brewing temperature	70°C, 85°C, 100°C
Brewing time	2, 5, 10 minutes

The design therefore includes $5 \times 3 \times 3 = 45$ treatment combinations. Each treatment will be prepared independently in triplicate, giving a total of 135 infusions.

• Standardized Tea-to-Water Ratio

Two grams of tea are weighed on an analytical balance for each treatment and then boiled in 200 ml of purified water. Tea mass and water volume are constant during an experiment. Standardizing this process matters since altering a tea-to-water proportion could affect caffeine levels without regard for boiling time or length of steeping period.

• Brewing Procedure

The purified water is then heated at a specified temperature of 70°C, 85°C, or 100°C. The temperature should be checked right away for an accurate measurement during injection by means of a calibrated thermometer. Weigh out some amount of tea and add it to 200 ml of water then boil it for 2, 5, or 10 minutes. After a certain time frame has passed for this purpose, it would then be filtered out so as not to continue any more extraction process. The samples are chilled at room temperature for storage before being analyzed by chromatography. All treatments are made fresh by tripling them for each patient.

• Determination of Caffeine by HPLC-UV

The amount of caffeine can be measured by reverse phase HPLC-UV analysis. The pure caffeine reference standard is needed for preparing an analytical method of multi point calibration curves. A practical calibration range may include 2.5, 5, 10, 15, 20, and 25 µg/mL, provided that validation confirms linearity over this interval. Fernando and Soysa described a simple HPLC-UV method to simultaneously determine caffeine and catechins from tea products with good calibration linearity. If needed, tea infusions must be diluted to ensure their peak area falls within an acceptable value as per validation criteria.

A suitable reversed phase C18 analytical column for chromatography with UV detection at around 280 nm would be used by this experiment (subject to laboratory method validation). The final method should document mobile phase composition, flow rate, injection volume, column temperature, retention time, system suitability, linearity, precision, limit of detection, and limit of quantification. The quantification of this data would follow a linear model $y=mx+c$ where y represents chromatography results, x denotes caffeine levels, m stands for slope while c signifies an offset value.

• Expression of Caffeine Content

The effect of caffeine should be reported mainly by mg of caffeine per 200 ml infusion since it is an approximate measure for standard serving size. Also, results can be given in terms of milligrams of caffeine extracted per gram of dry tea. Both unit reporting allows for comparison between actual caffeine content per cup and extraction rate based on quantity of tea consumed.

- **Quality Assurance**

- Calibration standard freshness test blank testing.
- Triple independent trials per experimentation group.
- The calibration for an analytical scale and a thermometer.
- Uniformity of tea mass and amount of water per sample.
- Filtration immediately after reaching its destination point.
- Identical dilution method and injection technique used here.
- Mean value, standard deviation and coefficient of variability from repeated trials.

- **Statistical Analysis**

Mean value of data is given by its average plus standard deviation. Three way ANOVA is used to analyze factors such as brand, temperature and brewing time along with their interaction effects on product quality. If there is an important statistical effect found by means of analysis, Tukey's Honestly Significant Difference Test can be applied to make further comparisons between groups. The statistical significance is to be tested for $p < 0.05$. Also effect size is important to report as it shows how much an effect actually matters instead of just being statistically significant.

Results Presentation Framework

Table 7 is a simulated data set (mean $\pm$ standard deviation, $n = 3$) that shows how much caffeine is extracted from coffee beans under different brewing methods. Values are determined by research showing that there is an increased rate of caffeine extraction at higher temperatures and longer times between brewing and infusing different brands. These are not HPLC-UV data; they should be replaced with lab findings prior to submitting this paper for publication as a research article.

Table 7: caffeine content of five commercial Indian tea brands under different brewing conditions (mg/200 mL; simulated mean $\pm$ SD, $n = 3$)

Tea Brand	70°C/2 min	70°C/5 min	70°C/10 min	85°C/2 min	85°C/5 min	85°C/10 min	100°C/2 min	100°C/5 min	100°C/10 min
Brand A	22.4 $\pm$ 0.7	27.8 $\pm$ 0.9	31.2 $\pm$ 1.0	28.9 $\pm$ 0.8	34.8 $\pm$ 1.1	38.1 $\pm$ 1.2	34.7 $\pm$ 1.0	40.9 $\pm$ 1.2	44.2 $\pm$ 1.3
Brand B	25.1 $\pm$ 0.8	30.3 $\pm$ 0.9	34.2 $\pm$ 1.1	31.4 $\pm$ 0.9	37.6 $\pm$ 1.1	41.0 $\pm$ 1.2	37.6 $\pm$ 1.1	44.1 $\pm$ 1.3	47.0 $\pm$ 1.4
Brand C	19.8 $\pm$ 0.6	24.9 $\pm$ 0.8	28.4 $\pm$ 0.9	25.5 $\pm$ 0.7	31.3 $\pm$ 0.9	34.6 $\pm$ 1.0	30.9 $\pm$ 0.9	36.9 $\pm$ 1.1	40.1 $\pm$ 1.2
Brand D	27.0 $\pm$ 0.8	32.8 $\pm$ 1.0	36.1 $\pm$ 1.1	33.5 $\pm$ 0.9	39.9 $\pm$ 1.2	43.2 $\pm$ 1.3	40.3 $\pm$ 1.1	46.8 $\pm$ 1.3	50.1 $\pm$ 1.4
Brand E	23.4 $\pm$ 0.7	28.6 $\pm$ 0.9	32.5 $\pm$ 1.0	29.6 $\pm$ 0.8	35.7 $\pm$ 1.0	39.0 $\pm$ 1.1	35.8 $\pm$ 1.0	42.0 $\pm$ 1.2	45.3 $\pm$ 1.3

Note: These values may be used for layout, statistical-workflow, or proposal demonstration only. Replace all 45 values with measured mean $\pm$ SD data from the three independent HPLC-UV replicates before reporting experimental findings.

- **Expected Analytical Trends**

According to research papers, there is an increase in caffeine content due to higher temperatures during boiling and extended steeping times. For context only, Chin et al. (2008) reported approximately 14-61 mg caffeine per serving across brewed white, green, and black teas; these published values are not substitutes for the present study's measurements. Therefore, precise measurements of brands A to E should be obtained through experiments. One important finding would be that there is a greater difference between the effects of increasing temperature from 70 °C to 100 °C on beer aging process. This suggests that high temperatures result in faster initial extraction while low temperatures take longer for comparable levels of extraction.

- **Brand-to-Brand Comparison**

Firstly compare these five companies on an equal basis for comparison purposes. Significant effects on brands are due to specific characteristics of products such as caffeine content. If a brand consistently has higher caffeine levels for all nine types of coffee, then this could be due to their starting amount of caffeine or because they have properties which allow quick extraction rates. On the other hand, a high level of temperature-based vs time based interaction between products indicates changing rankings due to different brewing methods.

Discussion

This study aims at separating out of products' effect on results due to their preparation process. The difference matters since you can't just choose any kind of coffee drink to get more caffeine content out of it. Brewing process affects amount of caffeine from leaves that goes into drinking water prior to consumption. Thus, research which reports just caffeine on dry tea is inadequate for measuring intake of beverages made with it.

In case there is an important impact on temperatures then it will be compatible to our understanding about how much heat affects extraction process. Increased temperatures lead to higher levels of molecular movement which may speed up solute transport within injured or permeable plant cells. There might be a greater difference between finely processed commercial black tea products due to their manufacturing processes that have increased accessibility of surface area.

The length of time for making coffee is also consistent with an extract kinetic study. First minute of injection will be significant due to high concentration difference at that time between leaves and water. As more soluble caffeine is removed by easy access to it, its extraction rate will decrease while there are higher concentrations of caffeine around that area. Thus, a ten minute cup of coffee might have more caffeine than an eight minute cup without being five times as strong.

Commercial Brand Effect needs to be taken carefully. The product isn't identical to another at any given time or batch of manufacturing process. Seasonal tea blend variations are available from different sources. Thus this paper is concerned to find out which batch was analyzed here instead of assuming that any particular batch represents an eternal standard among manufacturers' products. Cross-batch replication will improve subsequent studies.

Practical importance is found to be about consumers' knowledge. People trying to reduce their intake of caffeine might think that changing brands is all they have to do. This study will determine if there is any difference between short-term vs coolness of an extract for less amount of caffeine from that same source material. However these suggestions would be more accurate if they were grounded by actual measures of impact instead of just saying "less time spent brewing equals lower levels of caffeine.". The sensory qualities should also be taken into account as they are affected by variations to temperature and time which affect flavor, aroma, color, bitterness, and extractability of polyphenols.

Also shows that analysis is important for standards setting purposes. Variations of small size like amount of tea used, quantity of water added at each step for measuring time until completion may appear as results independent from those variables being tested on them. Therefore replication of preparation and validation by HPLC is needed to ensure accurate results. The factorial ANOVA is suitable for this purpose as it assesses both independent variables and their interaction effects on each other.

Conclusion

Temperature for brewing and duration of infusing is an essential factor affecting how much caffeine gets extracted out of a cup of tea. This paper proposes an experimental design to compare five types of Indian black teas grown under different temperature conditions (three) and time intervals between brewing sessions (3). There is some research showing that higher temperatures and longer times during extraction lead to more caffeine being transferred into beverages; however, this effect varies due to differences among commercial products such as leaf type, particle size, processing methods, blending ratios, and starting levels of caffeine concentration. To isolate genuine brand effect vs difference due to preparation method through keeping same amount of tea per cup analyzed three times via HPLC-UV analysis for this purpose. The final conclusion regarding which type of product has more caffeine than another would come solely from experimental results obtained through testing at a lab setting using proper statistics methods.

Limitations and Recommendations

One major problem is that analyzing a single package or production run does not reflect sales from other packages/production runs within the same brand. Also, this study is concerned with temperature and time whereas factors like particle size, agitation, water chemistry, repeated infusion, addition of milk, and household boiling practices might affect caffeine extraction rates. Future research will involve several samples from each brand; also a study on physical properties like leaf particle sizes for both CTC and orthodox tea varieties as well as an evaluation of traditional Indian milk-tea making techniques. The measurement of polyphenol content along with taste characteristics is needed for better knowledge about how much more caffeine can be extracted from tea without affecting its flavor profile.

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