Determination of lemon and carbonate effects on caffeine content of various teas and investigation of daily caffeine intakes

Abstract: Objective: Tea (Camellia sinensis), has been used for health field in thousands of years. Caffeine is one of the key component in tea and investigation of caffeine is a popular working subject among the researches. The novelty of this study is not only the determination of the caffeine contents of the teas, but also how addition of lemon and carbonate effects the caffeine contents. Another aim of the study is the investigation of the daily caffeine intakes from teas.

Methods: Tea infusions were prepared and caffeine contents were extracted by using chloroform and determined by UV-Vis Spectrophotometer. For lemon and carbonate addition experiments, lemon was added before the caffeine analysis and carbonate was added at the beginning.

Results: Maximum caffeine contents from highest to lowest were seen in black, earl grey and green in classic teas; fennel, mint and sage in herbal teas; lemon, apple and rosehip in fruit teas. With lemon addition caffeine contents were increased except green tea and with carbonate addition caffeine contents were decreased except black and fennel tea. Daily caffeine intakes are found between 32.10% (green tea with carbonate) – 77.20% (black tea with lemon), 1.85% (sage tea with carbonate) – 4.05% (fennel tea with lemon) and 2.10% (rosehip with carbonate) – 4.00% (lemon tea with lemon) in classic, herbal and fruit teas, respectively.

Conclusion: The significance of this study indicates that herbal and fruit teas contain caffeine, which is assumed zero in literature. The caffeine amount of herbal teas (20.79±0.36 – 30.68±0.63 ppm) were found barely higher than the fruit teas (22.87±0.54 – 28.54±0.75 ppm) but daily maximum caffeine intakes were found less than 5%. The daily maximum caffeine intakes were found in the teas as 525.36±2.84 – 20.79±0.36 ppm, where lemon addition increased to 617.90±3.54 – 22.97±0.58 ppm and carbonate addition decreased to 488.54±2.05 – 16.84±0.28 ppm.

Keywords: Caffeine content, Caffeine intake, Carbonate, Fruit tea, Herbal tea, Lemon

Özet: Amaç: Çay (Camellia sinensis) binlerce yıldır sağlık alanında kullanılmaktadır. Kafein, çay içerisindeki önemli bileşenlerden biri olup araştırmacılar arasında popüler bir çalışma konusudur. Bu çalışmanın yenilikçi yönü sadece çayların içerdikleri kafein miktarlarının belirlenmesi değil aynı zamanda çayın içeriğine limon vearbonatın nasıl etki ettiği incelenmesidir. Ayrıca bu çalışmanın diğer bir amacı da çaydan alınan günlük kafein alınan miktarlarının hesaplanmasıdır.

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Method: Caylar demlenip kafein miktarları kloroformla ekstrakte edilmiş ve UV/Vis spektrofotometresiyle belirlenmiştir. Limon ve karbonat eklemeli deneylerde limon, kafein analizinden önce, karbonat ise başlangıçta eklenmiştir.

Bulgular: Maksimum kafein içeriği çoktan aza doğru klasik çaylardan siyah, bergamut ve yeşil çayda; bitki çaylarından reze, nane ve ada çayında; meyve çaylarından limon, elma ve kuşburnu çayında belirlenmiştir. Limon eklemesi yeşil çay hariç kafein miktarını artırılmış ve karbonat eklemesi siyah ve reze çay hariç kafein miktarlarını azaltmıştır. Günümüzde %32.10 (karbonatlı yeşil çay) – %77.20 (limonlu siyah çay), %1.85 (karbonatlı ada çay) – %6.05 (limonlu reze çay) ve %2.10 (karbonatlı kuşburnu çay) – %4.00 (limonlu limon çay) olarak sırasıyla, klasik, bitki ve meyve çaylarında bulunmaktadır.

Sonuç: Bu çalışmada, literatürde sıfır olarak kabul edilen kafein içeriğinin bitki ve meyve çaylarında bulunduğu gösterilmiştir. Bitki çaylarının kafein miktarları (20.79±0.36–30.68±0.63 ppm), meyve çaylarını (22.87±0.54–28.54±0.75 ppm) kıyaslarken daha düşük olarak bulunmuş ama günlük maksimum alımların %5’ten düşük olduğu belirlenmiştir. Günümüzde maksimum kafein alımları klasik çaylarda ve meyve çaylarında bulunmaktadır (525.36±2.84–20.79±0.36 ppm) olup limon eklemesi tüm çayların kafein miktarını yükseltken (6179±3.54–22.97±0.58 ppm), karbonat eklemesi tüm çaylarda kafein miktarını azaltmıştır (488.54±2.05–16.84±0.28 ppm).

Anahtar Kelimeler: Bitki çay, Kafein miktarı, Kafein alımı, Karbonat, Limon, Meyve çay

1 Introduction

Tea is the most consumed beverage that comes after water, which consumed nearly 20 billion of cups in a day, is a leaf extract from Camellia sinensis plant [1]. Leaves and leaf buds of Camellia sinensis plant are used to produce different types of teas, depending on the method of preparing [2]. Fresh leaves of Camellia sinensis plant are used to made black and green teas but leave processing makes differences between these two types of tea [3]. According to tea manufacturing process there are three major types of teas, which are known as non-fermented green tea, semi-fermented oolong tea and fermented black tea [4]. In addition to these three types of tea, there are also lots of flavoured teas with various aroma. Earl Grey tea is an example of this kind of specific tea. Bergamot is a citrus fruit, which is used in earl grey tea and this kind of tea relate more to the bergamot oil that is used to flavour the tea then the tea base itself. Herbal and fruit teas are preferred to Camellia sinensis because of their positive effect on health and diseases prevention. Flowers, leaves, fruits, seeds, stems or roots of plant species are used in the brewing process of this kind of teas [5].

Tea leaf contains many chemical compounds such as a very large amount of polyphenols, which is the most specific feature of tea [6]. Catechins and methylated xanthine, caffeine and theobromine, which are known for their antioxidant activity and antimutagenic and anticarcinogenic properties, are the major groups of polyphenols. Beside the positive advantage of polyphenols on health, high caffeine intakes from tea can be cause adverse effects [7]. On the other hand, most herbal teas contain no caffeine, though they include polyphenols [8].

Most of the drinks mostly tea and coffee contain Caffeine (3,7-dihydro-1,3,7-trimethyl-1H-purine-2,6 dione) [9]. It is found nearly 63 plants species in the world and it can also be synthesized in the laboratory [10, 11]. Since caffeine has central-nervous-system stimulant properties, in recent beverages, which are consumed frequently, contain added caffeine. Soft drinks are also contain caffeine due to its flavouring agent properties. Caffeine has many effects on the human health. Kidney, heart and central nervous system diseases are recognized as the effects of caffeine. It also increases locomotor activity, vigilance, alertness, and arousal as well as sleep disturbance [12, 13].

In today caffeine content determination of different teas became a popular issue because of its health effects. Some of these studies and their results are shown in Table 1. As seen in Table 1, the variability of the published results of the caffeine content of teas varies region to region. Tea type, brewing time, leaf-water ratio, leaf form, soil, region and serving size are the many factors affecting the caffeine content of a cup of tea. [26]. Tea can be consumed by different ways. As an example, lemon and milk added teas are the most preferred types and besides of them fruit flavoured teas and cream added teas are also consumed. On the other hand, lemon or carbonate addition is a cultural behaviour in Turkey due to their positive effects on flavour and appearance.

In literature despite the fact that there are lots of researches about the caffeine contents of teas, there was no study on the effect of lemon and carbonate addition on caffeine content of various types of teas. For this purpose, after the determination of the caffeine contents of classic (black, green and earl grey), herbal (sage, fennel, mint) and fruit (apple, roseship, lemon) teas caffeine contents, lemon and carbonate are added to find out how lemon and carbonate affect these concentrations and how these
changes affects the daily caffeine intake percentages. The caffeine contents are determined by the method of UV-Vis spectroscopy. According to recommended maximum daily caffeine intake and analysis results, daily intake percentages of caffeine for adults are investigated.

| Table 1: Literature studied on the caffeine contents of various teas. |
|-----------------------------|------------------|-----------------|---------|
| **Tea**                      | **Sample type/brand** | **Volume (ml)** | **Caffeine (mg)** | **Reference** |
| Black                        | Local             | 125             | 30–60             | [14]          |
|                             | Local             | 190             | 50                | [15]          |
|                             | Local             | 190             | 33                | [16]          |
|                             | Local             | 200             | 59                | [17]          |
|                             | Local             | 200             | 12–67             | [18]          |
|                             | Local             | 200             | 15–75             | [19]          |
|                             | Gazaltein         | 1000            | 473.0±0.26        | [20]          |
|                             | Lipton            | 1000            | 440.0±2.00        |               |
|                             | Mobile            | 1000            | 463.0±1.80        |               |
|                             | Sasini            | 1000            | 738.19±2.53       | [11]          |
|                             | Chai mara moja    | 1000            | 3196.46±11.01     |               |
|                             | Kericho gold      | 1000            | 768.43±2.53       |               |
|                             | Finlays premium   | 1000            | 2343.10±1.66      |               |
| Earl grey                   | Dogus             | 1000            | 212               | [21]          |
|                             | Stash             | 177 (6 oz)      | 47                | [22]          |
|                             | Tazo              | 177 (6 oz)      | 59                |               |
| Green                       | Ground            | 100             | 26.8±0.81         | [7]           |
|                             | Non-ground        | 100             | 22.3±5.55         |               |
|                             | Stash premium green| 177 (6 oz)     | 36                | [22]          |
|                             | Tazo China green tips| 177 (6 oz) | 41                |               |
|                             | Local             | 236 (8 oz)      | 30–50             | [23]          |
|                             | Local             | 1000            | 232               | [24]          |
| Herbal                      | Mint              | 1000            | <10^-4            | [12]          |
|                             | All varietes      | 250             | 0                 | [25]          |
|                             | All varietes      | 177 (6 oz)      | bdl*              | [22]          |
| Fruit                       | All varietes      | 1000            | <10^-4            | [12]          |

*bdl: below the detection limit.

2 Material and Methods

Materials andEquipments used in the experiments

- Blue ribbon filter paper (MACHEREY-NAGEL GmbH & Co. KG, Düren, Germany)
- Water purification system GFL 2004 brand (Gesellschaft für Labortechnik, Burgwedel, Germany)
- Carbonate (Sigma Aldrich ACS reagent (≥99.7% purity), Taufkirchen, Germany)
- Chloroform (Sigma Aldrich Emsure, Taufkirchen, Germany)
- Caffeine (Merck Emprove, KGaA, Darmstadt, Germany)
- UV-Vis Spectrophotometry PerkinElmer, Lambda 35 brand (PerkinElmer, Massachusetts, USA)
- pH/ORP/Temperature Benchtop Meter Hanna Instruments, HI 2211 brand (Hanna Instruments, MI, USA)
2.1 Preparation of tea samples

Classic (black, green and earl grey), herbal (sage, fennel, mint) and fruit (apple, rosehip, lemon) teas, lemon and carbonate were purchased from the local market in Istanbul, Turkey.

The tea infusions were prepared according to ISO-3103 standard [27]. Where each of samples were weighed as 2±0.0005 g from selected tea into different glass beakers and 100 ml distilled water (90–100°C) was added. The extraction was carried out for 5 min. After extraction, the infusions were filtered through blue ribbon filter paper into volumetric flasks and then filled to volume of 100 ml using distilled water. Distilled water (pH: 5.5 at 22±2°C) was obtained from water purification system. For experiments of tea with lemon addition, lemon was squeezed and added to tea at a 1:6 ratio (v/v) 15 minutes before the caffeine analysis. For analysis of tea with carbonate addition, carbonate was weighted as 0.125±0.0005 g and added to weighted tea before the infusion step. After the infusion step, pH values of all of the parallel prepared teas were analysed and the average of these pH values were given. All pH measurements were conducted at the temperatures between 26–27°C.

2.2 Statistical methods

Minimum three samples (infusions) were prepared and analyzed from each kind of tea also for lemon and carbonate addition. All values were given in the tables are calculated using the equations of arithmetic mean and standard deviation, which are given in (1) and (2).

\[
\bar{X} = \frac{1}{n} \sum_{i=0}^{n} \left( \frac{X_i}{n} \right) \quad (1)
\]

\[
s = \sqrt{ \frac{\sum_{i=0}^{n} (X_i - \bar{X})^2}{n-1} } \quad (2)
\]

where \( \bar{X} \), \( X_i \), n and s, are the average value of the sample, the value at the parallel i, number of parallels and the standard deviation, respectively. The caffeine results and the pH values were given in the confidence levels (P) of >90 and >97, respectively.

2.3 Extraction of caffeine from tea

Caffeine can be dissolved in organic solvents such as ethyl acetate, chloroform, ethanol, carbon tetrachloride, methanol and dichloromethane. According to the literature studies, solubility of caffeine in chloroform shows higher value than the other solvents. Therefore, chloroform is a better solvent to separate and purify caffeine from solutions [28]. For this reason, chloroform was used in the extraction of caffeine from tea. According to the method 5 ml of prepared tea samples was poured into a separation funnel and rinsed by adding chloroform solution (20 ml). After the separation of two phases the bottom phase of caffeine content was taken to the UV-VIS spectroscopic analysis.

2.4 Determination of caffeine in tea samples by UV/Vis spectrophotometry

Caffeine stock solution (100 ppm) was prepared by dissolving 10.00 mg of pure caffeine in 100 ml chloroform then stock solution was diluted to the concentrations of 5, 10, 20, 30 and 40 ppm caffeine solutions for the preparation of calibration curve.

The wavelength range of caffeine was reported in the literature as between 270 and 280 nm [11,29]. For this purpose, several measurements were conducted for the determination of the wavelength and 272 nm was found as optimum. Chloroform was used as the blank solution. Coefficient of determination (R^2) was found as 0.997 from the calibration curve.

3 Results

3.1 pH results

According to pH results, all studied tea infusions are found as acidic. Fruit teas (rosehip, apple and lemon teas) are the most acidic teas among the others and followed by classic teas (black, earl grey and green teas) and herbal teas (mint, fennel and sage teas) respectively. pH values of the samples which were used during the caffeine analysis are also determined as 6.05±0.08 in pure water, 2.88±0.04 in lemon added pure water and 8.10±0.13 in carbonate added pure water.

pH results of the classic teas showed that the maximum pH value is seen in the green tea, and followed by earl grey and black tea. Sage tea has the highest pH value of 5.98±0.08 among herbal teas. On the other hand, lemon tea has the highest pH value of 5.31±0.08 among fruit teas. All pH values of infusion, lemon and carbonate added teas are given in Table 2. Since lemon added pure water has a pH value (2.88) lower than the tea infusions; the decrease in the pH values of infusions after the lemon
addition is an expected situation. On the contrary the pH value 8.10±0.13 is seen in the carbonate added pure water so this high pH value leads to increase the pH of the infusions after the addition of carbonate.

### 3.2 Caffeine contents

The caffeine concentrations of classic (black, green and earl grey), herbal (sage, fennel, mint) and fruit (apple, rosehip, lemon) tea infusions and infusions after lemon and carbonate addition are given in Figure 1.

Analysis results of the classic teas showed that maximum caffeine content is seen in the black tea, and followed by earl grey and green tea. The average caffeine content in black, earl grey and green tea are determined as 525.36±2.84, 467.54±3.68 and 299.40±3.87 ppm, respectively. With lemon addition to these 3 types of teas, the caffeine concentrations are increased in black, earl grey and green tea to 617.90±3.54, 522.35±2.21 and 331.58±2.50 ppm on the other hand the carbonate addition decreased the caffeine content to 488.54±2.05, 439.70±2.69 and 289.15±1.69 ppm respectively. For the comparison with the literature black teas caffeine content of 525 ppm, is in mutual agreement with the studies of Ali et al. (2012) [20] with the caffeine content between 440–473 mgL⁻¹ and Papadopoulos (1993) [14], with the caffeine content between 30–60 mg (in 125 mL), which is approximately equal to 240 – 480 mgL⁻¹. Green teas caffeine content was found between 22.3–26.8 mg (in 100 mL), which is approximately equal to 233–268 mgL⁻¹ by Suteerapataranon et al. (2008) [7], and 232 mgL⁻¹ by Aoshima et al. (2007) [24] are in mutual agreement with the found caffeine content of green tea (299 ppm). The earl grey teas caffeine content (212 ppm) given in literature was lower than the measured values (467.54±3.68 ppm). As aforesaid the caffeine amount of a cup of tea depends on many different factors such as; brewing time, tea type, leaf form, region, soil, the leaf to water ratio, and the size of the serving [26].

The caffeine content of herbal teas is generally accepted zero or below the detection limit in the literature on the contrary they contain barely caffeine [12, 25, 22]. As it is seen from the caffeine contents of the herbal teas, fennel tea has the highest caffeine content of 30.68±0.63 ppm then followed by mint (21.59±0.64 ppm) and sage (20.79±0.36 ppm) tea respectively. With lemon addition to all herbal teas, the caffeine concentrations are increased to 32.47±0.32, 23.67±0.22, and 22.97±0.58 ppm, in fennel, mint, and sage tea, respectively. After carbonate addition,

![Figure 1: The caffeine concentrations of 1000 ml classic, herbal and fruit tea infusions and infusions after lemon and carbonate addition.](image-url)
According to caffeine analysis results of fruit teas, lemon tea, has the highest caffeine content. The average caffeine content in lemon, apple and rosehip teas is determined as 28.54±0.75, 25.40±0.64 and 22.87±0.54 ppm respectively. The caffeine contents of all fruit teas increased after the lemon addition and decreased after the carbonate addition. The caffeine contents after lemon addition are determined as 32.13±0.64 ppm in lemon tea, 28.23±0.71 ppm in apple tea and 24.72±0.62 ppm in rosehip tea. On the other hand, after carbonate addition caffeine concentrations of lemon, apple and rosehip teas are decreased to 23.97±0.58, 23.23±0.37 and 19.17±0.42 ppm, respectively.

From the results, it is seen that the lemon addition increased and carbonate addition decreased the caffeine contents of all types of teas. From the literature, one can see that the solubility of caffeine in water can be increased by adding dilute acid (e.g., HCl or citric acid) on the contrary, bases decomposes the caffeine [30]. Since lemon contains citric acid and carbonate is a weak base, the increase in the caffeine contents after lemon addition and the decrease in the caffeine contents after carbonate addition are the expected results.

The contents of the caffeine in all types of teas generally followed from higher to lower as black > earl grey > green > fennel > lemon > apple > rosehip > mint > sage.

### 3.3 Health effects

Caffeine is one of the most comprehensively studied ingredients in the food products. The per capita consumption level of caffeine for all consumers (of all ages) is approximately 120 mg per day, or a mean intake of 1.73 mg/kg body weight/day [7]. Children consume significantly less caffeine than adults. The average daily intake of caffeine by young children ages 1–5 and 6–9 years from all caffeinated beverages was 14 and 22 mg/day, or 0.82 and 0.85 mg/kg body weight/day, respectively [31].

For maximum, adults can tolerate 400–450 mg of daily caffeine intake. Similarly, women of childbearing age, 10–12 years, 7–9 years and 4–6 years old humans can tolerate 300, 85, 60 and 45 mg of daily caffeine intakes, respectively [32].

In this study the amount of caffeine in a cup of coffee is calculated by using caffeine concentration-cup volume ratio (assuming a cup of tea is equal to 100 mL). Amounts of caffeine (mg) in 1, 3 and 5 cups of tea, is calculated and divided with 400–450 mg which is the maximum daily caffeine intake (MDI) amount for adults and daily intake

| Table 3: Maximum caffeine intake (%) from teas. |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Tea type        | 1 cup           | 3 cups          | 5 cups          | 1 cup           | 3 cups          | 5 cups          | 1 cup           | 3 cups          | 5 cups          |
| Infusions       | Lemon add.      | Carbonate add.  | Lemon add.      | Carbonate add.  | Lemon add.      | Carbonate add.  | Lemon add.      | Carbonate add.  | Lemon add.      |
| Infusions       | Infusions       | Infusions       | Infusions       | Infusions       | Infusions       | Infusions       | Infusions       | Infusions       | Infusions       |
| Black           | 10.58–12.21    | 13.73–15.44    | 10.58–12.21    | 13.73–15.44    | 10.58–12.21    | 13.73–15.44    | 10.58–12.21    | 13.73–15.44    | 10.58–12.21    |
| Green           | 6.65–7.22      | 7.36–8.28      | 6.65–7.22      | 7.36–8.28      | 6.65–7.22      | 7.36–8.28      | 6.65–7.22      | 7.36–8.28      | 6.65–7.22      |
| Earl grey       | 10.38–11.68    | 11.60–13.05    | 10.38–11.68    | 11.60–13.05    | 10.38–11.68    | 11.60–13.05    | 10.38–11.68    | 11.60–13.05    | 10.38–11.68    |
| Sage            | 0.68–0.76      | 0.72–0.81      | 0.68–0.76      | 0.72–0.81      | 0.68–0.76      | 0.72–0.81      | 0.68–0.76      | 0.72–0.81      | 0.68–0.76      |
| Fennel          | 0.47–0.53      | 0.50–0.57      | 0.47–0.53      | 0.50–0.57      | 0.47–0.53      | 0.50–0.57      | 0.47–0.53      | 0.50–0.57      | 0.47–0.53      |
| Mint            | 0.68–0.76      | 0.72–0.81      | 0.68–0.76      | 0.72–0.81      | 0.68–0.76      | 0.72–0.81      | 0.68–0.76      | 0.72–0.81      | 0.68–0.76      |
| Apple           | 0.50–0.57      | 0.54–0.61      | 0.50–0.57      | 0.54–0.61      | 0.50–0.57      | 0.54–0.61      | 0.50–0.57      | 0.54–0.61      | 0.50–0.57      |
| Rosehip         | 0.63–0.71      | 0.71–0.80      | 0.63–0.71      | 0.71–0.80      | 0.63–0.71      | 0.71–0.80      | 0.63–0.71      | 0.71–0.80      | 0.63–0.71      |
| Lemon           | 0.63–0.71      | 0.71–0.80      | 0.63–0.71      | 0.71–0.80      | 0.63–0.71      | 0.71–0.80      | 0.63–0.71      | 0.71–0.80      | 0.63–0.71      |

Caffeine content decreased to 25.32±0.66 ppm in fennel tea, 17.93±0.43 in mint tea, 16.84±0.28 ppm in sage tea.
percentages (DIP) (%) is calculated. At the selection of 3 cups a person whom drinks tea after the meals is assumed and at the selection of 5 cups the tea addicted person is assumed.

Daily intake percentages (DIP) (%) of caffeine is also calculated for lemon and carbonate added teas and these values are given in Table 3. From the results of Table 3, it can be said that all types of teas caffeine content in 1, 3 and 5 cups are lower than daily maximum tolerated caffeine intake for adults.

Analysis results of the classic teas showed that maximum caffeine intake percentages are calculated between 32.10–77.20%. From the classic teas, black, green and earl grey teas maximum caffeine intake percentages are calculated between 58.35 (carbonate add.) – 77.20% (lemon add.), 32.10 (carbonate add.)–41.40% (lemon add.) and 48.85 (carbonate add.) – 65.25% (lemon add.), respectively. The results of the herbal teas showed that maximum caffeine intake percentages are calculated between 1.85–4.05%. From the herbal teas, sage, fennel and mint teas maximum caffeine intake percentages are calculated between 1.85 (carbonate add.) – 2.85% (lemon add.), 2.80 (carbonate add.) – 4.05% (lemon add.) and 1.95 (carbonate add.) – 2.95% (lemon add.), respectively. Fruit teas analysis results showed that maximum caffeine intake percentages are calculated between 2.10–4.00%. From the fruit teas, apple, rosehip and lemon teas maximum caffeine intake percentages are calculated between 2.55 (carbonate add.) – 3.50% (lemon add.), 2.10 (carbonate add.) – 3.05% (lemon add.) and 2.65 (carbonate add.) – 4.00% (lemon add.), respectively. As a summary even a person who drinks 5 cups of tea daily, will not exceed the maximum tolerated amount of caffeine daily.

4 Discussion

This study presents two new results. First, concentrations of caffeine in herbal and fruit teas, which were assumed zero in the literature, are determined. Since lemon and carbonate addition is a cultural behaviour in many parts of the world, the effect of lemon or carbonate addition on caffeine concentrations is important for many tea consumers. So the effect of the lemon and carbonate addition to caffeine content of 3 main types of teas of classic (black, green and earl grey), herbal (sage, fennel, mint) and fruit (apple, rosehip, lemon) teas are determined. The daily maximum caffeine intakes in the classic types of teas are found in the black teas then followed by earl grey and green tea. Fruit teas (lemon, apple and rosehip) caffeine contents are barely higher than the herbal tea (mint and sage) contents except fennel tea. But both herbal and fruit teas daily maximum caffeine intakes are found less than 5%. Lemon contains citric acid in its structure so caffeine contents of all teas are increased with lemon addition due to caffeine’s high solubility in dilute acids. On the other hand, depending on the decomposition of caffeine in the bases, carbonate addition decreased the caffeine contents of all teas.

Maximum caffeine intake for 1, 3 and 5 cups of tea is also investigated. For 5 cups of tea consumption, daily caffeine intakes from classic, herbal and fruit teas are found between 32.10% (green tea with carbonate) – 77.20% (black tea with lemon), 1.85% (sage tea with carbonate) – 4.05% (fennel tea with lemon) and 2.10% (rosehip with carbonate) – 4.00% (lemon tea with lemon), respectively.

Conflict of interest: None declared.

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