Original Article

Oxalate content and calcium binding capacity of tea and herbal teas

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Thirty-two commercially available teas consisting of green, oolong and black teas were bought from supermarkets in Christchurch, New Zealand in June 2001. Fifteen herbal teas were also purchased at the same time. The soluble oxalate content of the infusate made from each of the teas was determined using high pressure liquid chromatography. The mean soluble oxalate contents of black tea in tea bags and loose tea leaves were 4.68 and 5.11 mg/g tea, respectively, while green teas and oolong tea had lower oxalate contents, ranging from 0.23 to 1.15 mg/g tea. The soluble oxalate content of the herbal teas ranged from not detected to 3.00 mg/g tea. A regular tea drinker consuming six cups of tea/day would have an intake of between 26.46 and 98.58 mg soluble oxalate/day from loose black tea, 17.88 and 93.66 mg soluble oxalate/day from black tea in tea bags and a maximum of 18.0 mg/day from herbal teas. The oxalate intake from the regular daily consumption of black teas is modest when compared to the amounts of soluble oxalate that can be found in common foods. However, oxalate in black teas has the potential to bind to a significant proportion of calcium in the milk, which is commonly consumed with the black teas.

Key words: black tea, calcium binding capacity, green tea, oolong tea, soluble oxalate.

Introduction

Tea is consumed in many countries around the world; oolong tea is widely consumed in China and Taiwan while green tea is preferred in many Asian and North African countries. Black tea is more often consumed in Western countries.

Tea is made from brewing the leaves of the evergreen tropical bush *Camellia sinensis* in hot water. Only the top two leaves and the buds are plucked from the sprigs that emerge from the plucking plateau that forms on the top of the plant following pruning. Green tea is obtained from steaming and drying the fresh tea leaves directly after plucking, without fermentation. Oolong tea is obtained when the fresh leaves are subjected to a partial oxidation stage before steaming and drying. Black tea undergoes a full oxidation stage for several hours before steaming and drying. Colour and flavour are generated by enzymic oxidation of the flavan-3-ols and by subsequent reactions, including coupled chemical oxidations of the active intermediates generated. Drying is essential to stabilise the product before storage.

A number of foods, such as spinach, rhubarb, beets, nuts, chocolate, wheat bran and strawberries, are known to contain high oxalate levels.[1] It has been suggested that tea is a significant source of oxalate intake in English diets.[2] Noonan and Savage, in their survey of oxalate-containing foods, placed tea in Group 2.[1] Group 2 contained food with an oxalate/calcium mEq ratio of between 1.0 and 2.0. These were foodstuffs that had a low ratio and were not thought to have a big effect on calcium availability. Although tea is reported to contain between 300 and 2000 mg oxalate/100 g fresh weight, it is not consumed in the same quantities or in the same way as other foods. In many cases it is consumed with milk, which reduces its oxalate/calcium ratio. In some publications it is not clear whether the oxalate content has been measured in tea leaves or in brewed tea. Insoluble oxalate which is principally oxalate bound to calcium will be retained in the tea leaves and is of no consequence in human nutrition, while soluble oxalate will be extracted in the brewing process.

Tea without milk is known to have a high oxalate content and has been shown to increase urinary oxalate concentrations when taken regularly.[3,4] These findings have prompted a recommendation to eliminate black tea from the diets of those people who form oxalate stones.[5] Herbal teas have been recommended as an alternative to black tea as they contain much lower levels of oxalates.[5] However, while herbal teas rarely contain leaves from *Camellia sinensis* they do contain plant materials such as citrus peels, berries, flowers and leaves, all of which may contain soluble oxalates. This study was carried out to measure the soluble oxalate content of the most popular teas and herbal teas

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currently available in New Zealand and to determine whether herbal teas would be acceptable as an alternative drink for people who tend to form calcium oxalate stones.

Materials and methods

Sampling and extraction

Samples of herbal, green, oolong and black teas were bought from different supermarkets in Christchurch, New Zealand, during June 2001. Each sample of tea in a teabag was infused in 245 mL of hot (90°C) nanopure water for 5 min (a standard cup in New Zealand contains 250 mL). Each tea was stirred twice. After 5 min of infusion, the tea bag was removed and squeezed twice. Two loosely heaped teaspoons of tea leaves were extracted in the same way except that the tea leaves were removed by filtering the solution through a tea strainer.

Each tea infusion was cooled to room temperature and 20 mL of the tea solution was pipetted into a 100 mL volumetric flask and made up to volume with nanopure water.

Soluble oxalic acid determination

Each sample of tea was filtered through a 0.45-mm cellulose acetate membrane syringe filter (Sartorius, Goettingen, Germany) and analysed in triplicate using the method outlined in detail by Savage *et al.*,[6] based on an earlier method.[7] A 5 μL aliquot of the filtered sample was injected onto a Waters high pressure liquid chromatograph (HPLC) with a UV detector set at 210 nm (San Jose, California, USA). The chromatographic separation was carried out on a 300 × 7.8 mm Biorad Aminex Ion exclusion column (HPX-87H; Hercules, California, USA) attached to an Aminex cation guard column using an isocratic elution at 0.5 mL/min with 0.0125 mol/L sulphuric acid (Analar, BDH, Dorset, UK) as the mobile phase. The analytical column was held 50°C. The oxalic acid peak was identified by comparison of the retention time to a range of common plant organic acid standards. The amount of oxalic acid in each sample was determined by using external standards. The data are presented as the mean of three determinations.

Calcium binding potential

Once the soluble oxalate concentration of the extracted tea had been determined the amount of calcium that could bind to this soluble oxalate was calculated. Assuming that only black teas are consumed with milk, the percentage of calcium in the milk added to the tea drink that could be bound to soluble oxalate was calculated. The calculation was based on the assumption that 25 mL non-fat milk containing 160 mg calcium/100 mL would be added to the drink.

Results

The total amount of soluble oxalates extracted from black tea was 5.11 ± 0.51 mg/g for loose-packed black teas and 4.68 ± 0.38 mg/g for black teas in teabags (Table 1). The amount of soluble oxalates extracted from green teas was 0.68 ± 0.19 g/g, while 0.23 mg/g was obtained from oolong teas.

As teabags contain between 1.95 and 2.5 g of tea, a cup of black tea would contain a mean value of 9.54 mg of oxalate (range 3.0–15.6 mg). A cup of tea made from 2.4 g loose-packed black tea leaves would contain a mean value of 12.21 mg oxalate (range 5.1–16.4 mg oxalate) per cup of tea. Green tea and oolong tea would supply much lower levels of oxalate ranging from 0.3 to 1.7 mg oxalate per cup of tea.

Herbal teas contained very low levels of soluble oxalate ranging from not detectable to 3.00 mg/g tea (Table 2). A cup of tea made from these herbal teas would contain a maximum of 5.9 mg oxalate per cup of tea.

Discussion

The soluble oxalate content of black tea sold loose or in teabags ranges from 1.5 to 6.9 mg/g tea, while overall the mean oxalate content of tea sold in teabags is marginally lower than black tea sold loose (4.68 compared with 5.11 g/g tea). These values are comparable to the mean oxalate content of Japanese black tea (5.3 mg/g tea) reported by Kamiya *et al.*[8] Twinings Jasmine Tea, which contained the lowest levels of soluble oxalate (1.5 mg/g tea), and Twinings Earl Grey (2.2 mg/g tea) are two black teas that are advertised to contain additives that improve taste (jasmine flowers and bergamot, respectively). The levels of oxalate in black tea are significantly higher than those found in green (mean 0.68 mg/g tea) or oolong teas (0.23 mg/g tea). This suggests that the levels of oxalate in the original sprigs are low and that an increase in oxalate occurs in the tissue as a result of the fermentation process used to make black tea. This confirms the suggestion that oxalates are the end product of metabolism in many plant tissues and act as a 'dump system' in the metabolism of the leaf tissue.[1]

The level of oxalates found in the green teas consumed in New Zealand are comparable with the values reported for a similar green tea consumed in the USA.[9] The levels of oxalate reported in Japanese green tea[8] are significantly higher (mean 1.48 mg oxalate/g tea).

These results show that consumption of six cups of tea (a moderate daily consumption for a tea drinker) made from either loose black tea or black tea in tea bags would result in an intake of between 17.9 and 98.6 mg soluble oxalate/day. While this intake of oxalate would occur on a daily basis for a regular tea drinker, the levels are modest when compared to the amounts of soluble oxalate found in common foods.[1,6] However, these results confirm the observation made by Zarembski and Hodgkinson that 'tea is a significant source of oxalate intake in English diets.'[2]

Steeping tea for different times and stirring the tea have been shown to have a significant effect on the oxalate content of the final extraction.[9] From their data a regular tea drinker consuming six cups of tea/day would consume between 65 and 124 mg soluble oxalate/day, which is comparable to the results obtained in the present study.

The soluble oxalate content of hot drinks made from herbal teas available in New Zealand ranges from not detected to 1.6 mg soluble oxalate/cup. These values are comparable to the soluble oxalate content of herbal teas

Table 1. Mean soluble oxalate content and calcium binding capacity of green, oolong and black teas

	Weight of loose tea or tea bag	mg oxalate/g tea	mg oxalate/cup tea	Ca binding capacity (%)†
Green tea				
Twinings Green Tea	1.97	1.15	2.27	–‡
Healtheries Green Tea	1.34	0.24	0.32	–
Dilmah Green Tea	2.12	0.79	1.67	–
Lipton Green Tea Jasmine	2.14	0.54	1.16	–
Mean (±SE)	1.89 (0.19)	0.68 (0.19)	1.36 (0.41)	–
Oolong tea				
Lipton Oolong Tea	2.56	0.23	0.58	–‡
Black tea in tea bags				
Twinings English Breakfast	2.05	3.72	7.63	84.9
Twinings Lady Grey	2.06	3.90	8.03	89.4
Twinings Lemon Scented	2.07	4.93	10.21	113.6
Twinings Ceylon and Orange Pekoe	2.11	2.38	5.02	55.9
Twinings Lapsang	2.10	4.18	8.78	97.7
Twinings Darjeeling	2.06	4.29	8.84	98.4
Twinings Prince of Wales	2.27	3.17	7.20	80.1
Twinings Jasmine	2.00	1.49	2.98	33.2
Choysa	2.36	5.30	12.51	139.2
Twinings Earl Grey	1.95	2.24	4.37	48.5
Dilmah	2.11	5.35	11.29	125.6
Lipton	2.08	2.99	6.22	69.3
Bell	2.49	6.07	15.11	168.1
Coffeetime English Breakfast	1.95	6.51	12.69	141.2
Edglets	2.51	6.22	15.61	173.7
Jones Tea	1.96	6.65	13.03	145.0
Clipper	2.12	4.32	9.16	101.9
Rosemount	2.20	5.90	12.98	144.4
Mean (±SE)	2.14 (0.04)	4.68 (0.38)	9.54 (0.86)	107.23 (9.44)
Black tea, loose				
Twinings Earl Grey	1.95	2.26	4.41	49.1
Choysa	2.36	2.16	5.10	56.8
Bell	2.49	5.91	14.72	163.8
Tiger	2.40	5.26	12.62	140.4
PG tips Brook Bond	2.40	6.12	14.69	163.5
Bushells Blue Label	2.40	4.89	11.74	130.6
Edglets	2.40	6.85	16.43	182.8
Choysa Supreme	2.40	6.58	15.79	175.7
Amber Tips	2.40	6.01	14.42	160.5
Mean (±SE)	2.36 (0.05)	5.11 (0.51)	12.21 (1.49)	135.90 (16.57)

†Calculated from the addition of 25 mL non-fat milk (160 mg Ca/100 mL). ‡Green and oolong teas are not usually consumed with milk.

available in the USA, which range from 0.6 to 1.7 mg soluble oxalate/cup.[9] If six cups, each containing 1.6 mg soluble oxalate, were consumed/day then a maximum of 9.6 mg soluble oxalate would be consumed each day. This would contribute substantially less to a person's oxalate load when compared to the consumption of black teas without milk.

If black tea is consumed with added milk or is consumed with calcium-containing meals then less oxalate will be absorbed, as soluble oxalate will bind to the calcium and continue down the digestive tract without being absorbed.[5] Oxalate absorption from tea could elevate urinary oxalate levels leading to an increased risk of kidney stone formation. However, two prospective studies show that the consumption of tea (two or three cups/day) actually leads to a reduced risk of kidney stone formation by 8% in women[10] and 14% in men.[11] Two positive benefits of moderate tea consumption are its antioxidant content and the resulting increase in urinary volume because of tea drinking,[5] thereby reducing the risk of stone formation in high oxalate-containing urine.

The potential of the soluble oxalate extracted from each tea to combine with calcium is shown in Table 1. If the tea is consumed with 25 mL non-fat milk (containing 160 mg Ca/100 mL) then, for a large majority of the teas, there is an excess capacity to bind the calcium in the milk. These results suggest that the consumption of milk with black tea could result in a large amount of the calcium becoming unavailable after binding to the soluble oxalate in the tea. A recalculation of the total daily calcium intake may be required to take account of this.

Table 2. Mean soluble oxalate content of herbal teas

	Weight of tea in bag (g)	mg oxalate/g tea	mg oxalate/cup tea
Healtheries St Johns Wort and Blended Berries	2.14	0.73	1.56
Healtheries Apricot and Mango	2.00	–	–
Healtheries Ginseng Blackcurrant and Vanilla	2.00	0.19	0.38
Lipton Ginseng and Lemon Grass	2.00	0.20	0.40
Red Seal Ginseng with Mate Tea	2.00	0.02	0.04
Red Seal Ginseng and Lemon	2.00	0.20	0.40
Red Seal Ruby Zest	1.76	0.25	0.44
Red Seal Camomile	0.91	0.74	0.67
Red Seal Blackcurrant	2.13	0.15	0.32
Twinings Camomile and Spiced Apple	1.20	0.34	0.41
Twinings Blackcurrant	1.95	3.00	5.86
Twinings Lemon twist	1.51	0.17	0.25
Twinings Rosehip and Hibiscus	2.22	0.12	0.27
Twinings Camomile	0.93	0.43	0.40
Twinings Peppermint	1.93	0.21	0.41
Organic Tea Ginseng	2.00	–	–
Mean (± SE)	1.79 (0.11)	0.42 (0.20)	0.84 (0.40)

–, Not detected.

Conclusions

The results from this experiment show that while a regular tea drinker would be consuming oxalate every day, the levels are modest when compared to the amounts of oxalate that can be found in other common foods. It would be very difficult to consume an excessive amount of soluble oxalate from the regular consumption of black tea without milk. The consumption of black tea with milk would mean that small amounts of oxalate would be absorbed on a daily basis and would place black tea in the low risk group of foods, as defined by Noonan and Savage.[1]

The results also show that the consumption of milk with black tea could result in a large amount of the calcium in the milk becoming unavailable after binding to the soluble oxalate in the tea. A recalculation of the total daily calcium intake may be required to take account of this.

For calcium stone formers, especially those with elevated urinary oxalate levels, the consumption of green, oolong or herbal teas, or the consumption of black teas with milk, would be a wise recommendation.

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