Himachal Journal of Agricultural Research Vol. 32(2) : 67-75, 2006

Sodium, potassium, calcium, copper and zinc in tea [*Camellia sinensis* L. (O.) Kuntze] of Himachal Pradesh

R. G. Sud and Kiran Koundal
Department of Chemistry and Biochemistry
College of Basic Sciences
CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur-176 062.

Abstract

Sodium, potassium, calcium, copper and zinc varied significantly in green tea shoots and made black orthodox tea (TGFOP-1 and GOF grades). The proportions of sodium, potassium, calcium, copper and zinc seeped into the tea liquors from orthodox tea during infusion varied in the order: potassium > calcium > sodium >>> copper > zinc. Very low transfer ratio of copper and zinc was attributed to their complex formation tendencies. The amounts of these nutrients ingested through tea drinking and the nutrients removed from tea gardens through plucking of green tea shoots were estimated.

Key words: Tea, orthodox, minerals, nutrients, liquor.

Introduction

The importance of soil and plant nutrients for growing a disease-free healthy tea bush with higher yields and quality is well understood (Tolhurst, 1962, Pethyagoda and Krishnapillai, 1970, 1971, Ranganathan and Natesan, 1985, Ruan *et al.*, 1999, Subbarao *et al.*, 2003). Apart from genetic characters, the geographical location, agrotechniques and method of manufacture were reported to contribute to the mineral composition of black tea (Kalita and Mahanta, 1993, Fernandez-Caceres *et al.*, 2001). Tea is no longer considered to be a simple non-alcoholic beverage. Tea leaves naturally contain many minerals which can transfer into infusion. However, the transfer ratio was reported to be dependent on both the temperature and strength of infusion (Tascioglu and Kok, 1998). Tea infusion prepared by seeping the made tea in near boiling water was reported to contain proteins, vitamins, carbohydrates and some essential dietary metals (Powell *et al.*, 1998). Calcium is vital for the bones and teeth; at the molecular level it is important for muscle contraction, blood clotting and nerve transmission activities. Potassium helps regulating fluid balance in cells and their proper functioning including nerves and muscles. Zinc is present in many enzymes and helps in tissue repair and growth. Ongoing research is discovering new health benefits offered by tea drinking (Wargovich, 1999, Wu and Wei, 2000, Basu, 2003, Higdon and Frei 2003, Atoui *et al.*, 2005).

In Himachal Pradesh, India the China type tea (Kangra local jat) bushes grows on the gentle slopes of the outer Himalayas (Latitude: 32°07' 15.68" N, Longitude: 76°31' 47.26" E, altitude: 1290m above mean sea level, soil pH 4.8-5.8) where the annual potential transpiratory demand of about 1,100mm is totally met by the annual mean rainfall of 2,500mm with hot and humid summers and cold winters. Owing to low temperatures during the winter months the tea bushes experience complete dormancy for about 120-150 days and plucking is done from April to October. The productivity of tea bush has been increased due to various improvements in agronomic and cultural practices (Anonymous, 2000, Annual Reports (IHBT), 1990-2005). Although nutrient status of tea gardens (Sharma *et al.*, 2001) and studies on micro and macro nutrients of green tea shoots (Sud *et al.*, 1990, 1995) have been reported, however, no systematic work seems to have been carried out on the mineral nutrition of Kangra tea. Present studies were conducted to evaluate sodium, potassium, calcium, copper and zinc in green tea shoots, made black tea, tea liquor and spent tea leaves and the amounts of nutrients ingested through drinking of Kangra orthodox tea were estimated. The amounts of these nutrients depleted from tea gardens through plucking of green tea shoots

were estimated to provide some information to replenish these.

Material and Methods

Samples of green tea shoots (two leaves and a bud) were collected from local tea gardens at seven day intervals. The samples were washed with double distilled water to free these from any adhering soil or dust, dried at 60±5°C in a hot air oven for 48 hours and crushed by hand before storing in sealed polythene bags (Chapman and Pratt, 1961). Weekly samples of commercial Kangra tea (orthodox) comprising two grades namely Tippy Golden Flowery Orange Pekoe (TGFOP-1) and Golden Orange Fannings (GOF) were collected from the Palampur Cooperative Tea Factory Ltd., Palampur. At the tea factory green tea leaves received from tea gardens were allowed to wither in withering troughs for a period of 18-20 hours depending on the weather conditions with respect to temperature and humidity. A wither per cent of more than 70 during the rainy season when the relative humidity was more than 90 per cent was achieved by circulating hot air through the withering troughs. The withered leaf was subjected to two rolling each of 45 minutes duration. The rolled leaf was then spread on the floor in 3-5cm thick beds and allowed to ferment for about 2 to 3 hours. The adequately fermented leaf was then dried in a hot air blast at an inlet temperature of 118-120°C and exhaust temperature 70°C within 25-30 minutes. The raw tea thus manufactured was subjected to vibrating sieves for grading. All samples in triplicate were stored in sealed polythene bags which were opened only at the time of analysis.

(a) Tea liquor

2g sample of made black tea was taken in a 500mL Erlenmeyer conical flask. 200mL of boiling double distilled water was poured in the flask containing tea sample. The flask was fitted with air condenser and placed in a hot water bath maintained at 90±0.5°C for 20 minutes with constant stirring. The hot content was filtered through cotton plug in a 500mL flask and allowed to cool to room temperature. Finally the tea liquor was stored in a pearl pet bottle at 4°C.

(b) Moisture content

2g tea sample was taken in a pre-weighed petri-dish and kept in a hot air oven at 95±0.5°C till constant weight. The difference of weights was recorded to estimate the per cent moisture content.

(c) Total soluble matter

200mL double distilled water was taken in a 500ml conical flask and heated to boil. The conical flask was removed from the hot plate, 2g made tea was immediately put into the flask and it was covered with a watch glass. The contents of the flask were allowed to brew for 5 minutes after which the hot liquor was filtered through Whatman No. 1 filter paper. The extracted tea leaves were collected carefully, dried at 95±0.5°C for 48 hours and finally weighed. The decrease in weight was taken to be the total soluble matter - the solid matter from the made tea that had seeped into water during brewing.

(d) Ash content

2g sample taken in a pre-weighed silica crucible was ignited in a muffle furnace at 500±10°C for 12 hour, cooled in a desiccator and weighed. The difference of weights was recorded to estimate per cent ash content.

(e) Elemental analysis

The elements sodium (Na), potassium (K), calcium (Ca), copper (Cu) and zinc (Zn) were estimated in 100mL solution prepared after digesting (i) 1g sample (green tea shoots, made black tea, extracted tea leaves) (ii) dried mass obtained after evaporating 50mL of tea liquor from *(a)* to dryness; in diacid (a mixture of concentrated HNO_3 sp gr 1.42 and $HClO_4$ 70% of "Analar" BDH chemicals at a ratio of 4:1). The elements Ca, Cu and Zn were estimated in an Atomic Absorption Spectrophotometer (Perkin Elmer 3100) at wavelengths 422.7nm, 324.8±0.7nm and 213.9nm, respectively. Na and K were estimated with the help of flame photometer (Systronic make Sr. No. 3491).

All analytical estimations were carried out in triplicate to minimize any source of error. The data were pooled and analysed statistically using a randomized block design (Snedecor and Cochran, 1994).

Results and Discussion

In Kangra valley of Himachal Pradesh the annual tea crop yield is distributed over four flush seasons between March end/April to October/ November. After having experienced winter dormancy from November to March the tea of first flush (March end /April - mid May) is valued for its superior liquor characteristics and a distinct flavour which decline gradually during the second flush season (mid May -

June) showing a minimum during main or rainy flush season (July - mid September) and slight improvement through the back end (mid September - October/ November) flush season (Gulati and Ravinderanath, 1996). Monthly crop distribution in Kangra valley showed that the main flush season accounts for about 50 to 60 per cent of the annual crop production. This could be due to the high rainfall, high humidity and warm weather conditions which favour longer internodes and faster growth. The results reported in the present studies correspond to the low yielding dry and hot second flush and high yielding humid and warm rainy flush seasons.

Table 1 represents the mean values of moisture content, total soluble matter and ash content along with CD at 5% and coefficient of variance (CV). A perusal of Table-1 indicated that the moisture content and the total soluble matter varied significantly throughout. Teas manufactured during second flush had higher moisture contents and soluble matter compared to the rainy season teas. Tea being hygroscopic in nature was reported to absorb moisture on accelerated storage with free access to air and moisture (Ekanayake *et al.*, 1987). The total soluble matter in GOF grade tea was invariably more compared to the total soluble matter in TGFOP-1. This

Table 1. Code number, date of collection, mean values of moisture content, total soluble matter in TGFOP-1 and GOF grades of made black orthodox tea and ash content in TGFOP-1 grade of made black orthodox tea and green tea shoots

Code No.	Date of collection	Mean moisture (%)	Mean total soluble matter (%)		Mean ash (%)	
		TGFOP-1	TGFOP-1	GOF	TGFOP-1	Green shoots
1.	May, 14	10.23	29.49	30.34	5.08	5.00
2.	May, 21	10.43	30.47	28.87	5.18	4.77
3.	May, 28	10.74	31.45	31.69	4.65	4.83
4.	Jun, 04	9.81	30.80	32.49	4.92	4.60
5.	Jun, 11	9.20	27.44	28.63	4.67	4.73
6.	Jun, 18	9.76	32.20	30.87	4.92	4.44
7.	Jun, 25	9.63	30.44	27.59	4.88	4.82
8.	Jul, 02	9.13	29.39	29.60	5.06	4.68
9.	Jul, 09	9.54	28.86	28.86	5.22	4.70
10.	Jul, 16	9.84	25.28	26.89	4.95	4.82
11.	Jul, 23	9.55	25.82	28.14	4.79	4.70
12.	Jul, 30	9.55	24.82	27.08	4.63	4.47
13.	Aug, 06	9.76	24.71	24.34	4.65	4.53
14.	Aug, 13	9.63	24.08	25.32	5.25	4.66
15.	Aug, 20	9.59	22.94	23.76	4.91	4.60
16.	Aug, 27	9.18	24.41	24.98	4.65	4.63
17.	Sep, 03	8.87	25.31	31.25	4.75	4.68
18.	Sep, 10	8.54	22.08	31.41	4.71	4.64
	Mean	9.61	27.22	28.45	4.82	4.74
	CD (P=0.05)					
	Replicates	NS	NS	0.08	NS	NS
	Treatments	0.19	0.20	0.20	0.17	0.18
	CV	1.21	0.44	0.42	2.09	2.27

NS = Non-significant

could be due to smaller particle size of the GOF grade tea leaves which rendered more number of particles per unit weight and enhanced surface area in contact with the extraction medium. High ash content of TGFOP-1 compared to green shoots could be due to adhering dust particles during floor fermentation, drying and sorting of tea manufacture.

The contents of sodium, potassium, calcium, copper and zinc in green tea shoots varied significantly throughout the plucking seasons (Table 2). Leaf nutrient content was strongly associated with changes in climate (Tolhurst, 1971, Ranganathan and Natesan, 1985, Sud *et al.*, 1995). Rainy season green tea shoots had higher sodium and potassium contents. This could be due to the solubility of these nutrients being a precondition for their availability and uptake by the tea bush. High calcium content in green tea shoots of dry and hot season and towards the end of rainy season compared to peak rainy season (Mid July – mid August) corroborated our earlier findings on Kangra tea. High temperature and high atmospheric demand was reported to assist calcium uptake by the tea bush (Sud *et al.*, 1990, 1995). Significantly the lowest copper content was recorded in green tea shoots during hot summer season, however, hot climate with little rains from onset of rainy season in the region (mid June to 1st week of July) seemed to assist the copper uptake by the tea bush. Copper content in green tea shoots decreased significantly during rest of the monsoon season. Significant seasonal variations in the levels of zinc observed in the present studies could be due to its interaction with other minerals. Iron and

Table 2. Mean sodium, potassium, calcium, copper and zinc in green tea shoots

Code No.	Sodium $x10^{-1}$ (g kg^{-1})	Potassium (g kg^{-1})	Calcium (g kg^{-1})	Copper $x10^{-3}$ (g kg^{-1})	Zinc $x10^{-2}$ (g kg^{-1})
1.	4.303	43.921	1.761	14.000	3.400
2.	4.783	37.246	2.078	17.670	4.400
3.	4.466	36.275	1.889	16.670	4.233
4.	4.304	42.040	1.963	15.670	4.433
5.	4.384	34.375	1.933	26.000	5.500
6.	5.181	36.269	1.865	24.330	5.000
7.	4.784	33.439	1.820	20.670	4.333
8.	5.102	39.165	1.813	30.330	6.633
9.	5.182	39.169	1.973	25.330	4.733
10.	5.261	41.079	1.632	12.670	4.833
11.	5.103	36.283	1.824	14.330	4.600
12.	5.146	43.438	1.652	15.330	4.233
13.	5.183	41.055	1.592	16.670	4.133
14.	4.662	40.126	1.561	19.330	3.633
15.	4.783	46.793	2.397	10.670	3.333
16.	4.863	45.814	2.081	13.670	4.467
17.	4.672	46.333	2.073	13.940	4.233
18.	4.744	45.809	2.062	14.140	4.333
Mean	4.826	40.479	1.887	18.410	4.470
CD (P=0.05)					
Replicates	$9.254x10^{-5}$	NS	NS	NS	NS
Treatments	$2.2667x10^{-4}$	0.055	0.022	0.0037	0.0033
C. V.	0.03	0.08	7.21	12.14	4.42

NS = Non-significant

manganese application in sand culture has been reported to suppress zinc uptake by young tea plants (Borpujari and Dey, 1982).

Sodium, potassium, calcium, copper and zinc varied significantly in made black orthodox tea (Table 3). It was of interest to note that their concentrations in green tea shoots and made black tea (TGFOP-1 and GOF grades) were not in agreement. No reason could be given for this observation. All the minerals except copper were invariably less in made black orthodox tea compared to their assays in green tea shoots (Table 2). Higher copper content in made black orthodox tea could be due to the wearing away of machinery during rolling process of tea manufacture. The mineral contents of green tea leaf were reported to change during tea manufacture due to wear and tear of machinery (Ravichandran and Parthiban, 1998).

In general the amounts of sodium, potassium, calcium, copper and zinc that seeped into tea liquor

Table 3. Mean sodium, potassium, calcium, copper and zinc in TGFOP-1 and GOF grades of orthodox tea

Code No.	Sodium $x10^{-1}$(g kg^{-1})		Potassium (g kg^{-1})		Calcium (g kg^{-1})	Copper $x10^{-3}$(g kg^{-1})		Zinc $x10^{-2}$(g kg^{-1})	
	TGFOP-1	GOF	TGFOP-1	GOF	TGFOP-1	TGFOP-1	GOF	TGFOP-1	GOF
1.	3.745	4.788	41.007	42.966	1.038	15.670	22.000	2.567	3.767
2.	4.225	4.384	35.710	36.276	1.638	15.330	19.330	3.033	3.567
3.	4.544	4.188	35.340	34.372	1.551	24.330	34.000	2.900	2.567
4.	4.066	3.825	33.310	29.318	1.606	29.330	13.000	2.967	3.400
5.	3.987	4.131	33.485	35.345	1.505	28.330	30.670	2.467	3.300
6.	4.066	4.095	36.283	32.737	1.705	14.000	22.000	2.833	1.267
7.	4.305	5.181	33.414	30.530	1.434	22.000	20.330	3.033	3.333
8.	4.306	5.103	36.290	39.144	1.371	21.000	21.330	2.267	2.400
9.	4.358	5.343	40.563	34.387	1.536	20.330	22.330	2.400	2.867
10.	4.073	4.944	37.222	36.279	1.282	19.670	20.330	2.233	2.667
11.	3.993	4.945	38.176	38.210	1.392	15.670	24.330	2.667	2.300
12.	3.906	4.703	42.283	31.502	1.272	19.670	15.330	3.033	2.433
13.	5.587	4.624	38.958	31.498	1.224	25.330	30.330	3.000	3.467
14.	4.465	4.384	39.135	35.335	0.874	23.000	41.000	2.533	4.467
15.	5.978	4.544	41.061	42.016	0.935	20.000	29.330	1.500	3.333
16.	5.024	5.023	46.796	32.457	0.927	14.670	31.670	1.467	3.167
17.	4.625	5.182	38.191	37.684	0.875	16.000	27.330	1.500	2.933
18.	5.506	6.856	46.295	29.597	0.956	15.670	29.000	1.267	2.867
Mean	4.487	4.791	38.529	34.981	1.285	20.000	25.200	2.426	3.006
CD(P=0.05)									
Replicates	NS	NS	NS	NS	NS	NS	NS	NS	NS
Treatments	$1.442x10^{-2}$	$6.504x10^{-3}$	1.027	0.441	0.024	$3.241x10^{-3}$	$4.173x10^{-3}$	$3.352x10^{-3}$	$3.389x10^{-3}$
C V	1.99	0.82	1.65	0.77	1.15	9.76	9.98	8.33	6.80

NS = Non-significant

were low (Table 4) compared to their amounts in made tea. Considerable amounts of potassium and calcium transferred into brew of TGFOP-1 grade of tea. Copper and zinc were either very low or not detected in the tea liquors. The concentrations in TGFOP-1 grade tea liquors were in the order potassium > calcium > sodium >>> zinc > copper. The observations agreed with the earlier results in Darjeeling orthodox tea (Kalita and Mahanta, 1993). The transfer of metal ions from tea leaves to liquor was reported to depend upon several parameters including brewing temperature and time (Tascioglu and Kok, 1998). Moreover, in tea leaves, minerals may not be present in free state and as such the nature of complexes could also be responsible for their transfer into water.

Table 4. Mean concentration of sodium, potassium, calcium, copper and zinc in one cup* of TGFOP-1 grade tea liquor

Code No.	Sodium $x10^{-4}$ (g)	Potassium $x10^{-2}$ (g)	Calcium $x10^{-3}$ (g)	Copper $x10^{-5}$ (g)		Zinc $x10^{-4}$ (g)	
			TGFOP-1	GOF	TGFOP-1	GOF	
1.	2.548	6.675	0.833	ND	0.592	ND	ND
2.	2.871	6.836	2.422	ND	0.472	0.200	ND
3.	3.032	7.875	1.973	ND	1.350	ND	ND
4.	1.594	5.361	2.036	1.200	1.168	ND	0.800
5.	2.236	6.611	2.055	1.000	3.200	ND	0.900
6.	3.506	5.728	2.174	ND	1.734	ND	ND
7.	3.351	5.464	1.996	0.200	ND	ND	ND
8.	3.195	5.346	1.728	ND	0.600	ND	ND
9.	3.774	4.508	1.880	ND	ND	ND	ND
10.	2.239	5.766	1.580	1.066	1.400	ND	ND
11.	1.449	5.728	1.307	0.934	ND	ND	ND
12.	1.118	6.909	1.241	0.800	ND	0.200	ND
13.	1.596	6.914	1.246	ND	ND	ND	ND
14.	4.149	6.071	0.983	ND	3.466	ND	ND
15.	6.212	6.305	1.240	ND	1.200	ND	ND
16.	4.303	7.600	1.052	ND	ND	ND	ND
17.	4.306	5.809	1.091	ND	0.734	ND	0.500
18.	3.835	7.350	1.294	ND	0.666	ND	0.800
Mean	3.073	6.270	1.613				
CD (P=0.05)							
Replicates	NS	NS	NS	NA	NA	NA	NA
Treatments.	$1.512x10^{-5}$	$1.193x10^{-3}$	$1.659x10^{-5}$	NA	NA	NA	NA
C. V	2.97	1.15	3.43				

ND = Not detected NS = Non-significant NA = Not assessed

*Prepared from 2g of tea leaves in 200mL hot double distilled water with infusion time of 20 minutes at 90±5°C

Considerable amounts of sodium, potassium, calcium, copper and zinc were estimated in extracted tea leaves (Table 5). It was of interest to note that whereas the sodium, potassium and calcium contents in extracted tea leaves were lower compared to their concentrations in made black orthodox tea; the copper and zinc contents were higher in extracted tea leaves. TGFOP-1 grade of made orthodox tea had soluble matter in the range of 23.76 to 32.49 per cent (Table 1) and rest 67.51 to 76.24 per cent of the total mass remained as extracted tea leaves. Decreased mass of the extracted tea leaves due to seepage of soluble matter into liquor coupled with a less proportions of copper and zinc that transferred into the infusion might result into higher concentrations of copper and zinc in extracted tea leaves compared to their concentration in the made black orthodox tea. Moreover polyphenols and their oxidation products might have formed stable coordinated complexes with copper and zinc ions through terminal hydroxyl groups that could prevent their transfer into the tea infusions. Organic compounds in tea, especially polyphenols have been reported of complexing copper and iron and reduced their transfer into the tea liquor (Brown *et al.*, 1998,

Table 5. Mean sodium, potassium, calcium, copper and zinc in extracted tea leaves of TGFOP-1 and GOF grades of tea

Code No.	Sodium $x10^{-1}$(g kg^{-1})	Potassium (g kg^{-1})	Calcium $x10^{-1}$ (g kg^{-1})	Copper $x10^{-3}$(g kg^{-1})	Zinc $x10^{-2}$(g kg^{-1})
1.	2.471	7.631	6.226	25.33	4.533
2.	2.789	6.866	4.273	19.67	3.233
3.	3.028	10.300	5.645	32.00	3.767
4.	3.269	6.506	5.881	25.67	3.333
5.	2.868	6.099	4.776	23.33	3.167
6.	2.313	7.641	6.181	21.00	4.300
7.	2.630	6.091	4.362	21.67	3.967
8.	2.709	9.559	5.070	28.33	3.233
9.	2.471	8.021	5.957	30.00	3.100
10.	2.953	8.393	4.918	14.33	2.967
11.	3.335	9.537	7.386	11.00	3.300
12.	3.347	8.404	6.513	25.00	3.200
13.	2.789	8.388	6.009	22.00	3.467
14.	2.390	8.782	3.827	38.00	2.833
15.	2.872	9.536	3.148	29.67	2.800
16.	2.872	8.795	3.982	22.33	3.167
17.	2.472	9.144	3.294	32.00	2.700
18.	3.588	9.545	3.092	23.33	2.467
Mean	2.843	8.291	5.030	24.70	3.307
CD (P=0.05)					
Replicates	NS	NS	8.506×10^{-2}	NS	NS
Treatments	1.148×10^{-2}	2.295×10^{-2}	2.083×10^{-3}	3.553×10^{-4}	3.883×10^{-3}
C. V	2.43	0.17	0.25	8.67	7.07