Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2017; SP1: 974-979

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Iodine content of vegetables of Varanasi and its correlation with physico-chemical properties of soils

Triyugi Nath, Priyankar Raha, OP Singh and Prabhat Tiwari

Abstract
Iodine, one of the most important essential nutrient elements for human health and is an essential component of the thyroid hormones (thyroxin and triiodothyronin). Human body cannot synthesize iodine itself. Thus, the people depend on food materials for their iodine requirement. The present work was under taken to study the amount of iodine present in the most common consuming food vegetables, generally grown in district Varanasi and distributed form certain randomly selected vegetable markets of Varanasi. In addition, correlation of coefficient between iodine content of soil with vegetables were analyzed. The mean iodine concentration in the vegetables of Varanasi was 4.25 mg kg^{-1}. The iodine content in leafy vegetable spinach was found highest and lowest in fruit vegetable, brinjal. The iodine content in tested vegetables was in order, spinach > radish > cabbage > carrot > brinjal. Its content in Ramnagar vegetables was highest followed by Kashividyapith, Pandeypur, Lanka and Sunderpr vegetables, respectively. The coefficient of correlation between iodine content of soils and vegetables was significant for spinach and cabbage and its content in remaining vegetables was higher with higher iodine in soil solution but statistically not riched up to the level of significance.

Keywords: iodine, vegetables, human nutrition

Introduction
Iodine, one of the most important essential nutrient elements for human health and at presently, is of much interest in nutritional research. It is an essential component of the thyroid hormones; thyroxin and triiodothyronin are iodinated molecules of the amino acid tyrosine. The thyroid hormone regulate a variety of important physiological process in human body *viz.* promotes protein synthesis, regulates energy conversion, preserves the composition of central nervous system, and maintains normal metabolism. Deficiency of iodine in human diet leads to visible and invisible spectrum of health consequences collectively called iodine deficiency disorders (IDD) (Liao, 1992) [19]. Its major manifestations are goiter (enlargement of thyroid gland), mental defects, deaf mutism, stillbirth and miscarriages, weakness and paralysis of muscles as well as lesser degree of physical and mental dysfunction (Hetzel, 1983, Hetzel, 1987 and Hetzel, 1997) [15, 13, 14]. To prevent its negative manifestations iodine either have to be incorporated in the daily intake of individual (50-200 µg I day^{-1}) or to be fortified in agricultural crops specially vegetables and leafy vegetables (Dai *et al.* 2004, Dai *et al.* 2006; Hong *et al.* 2009; Huanxin *et al.* 2003) [17, 8, 7, 16]. To prevent and control IDD, iodized salt has been commonly used most economically practical method for supplementing iodine to human needs. Salt is iodized by the addition of fixed amounts of potassium iodide or iodate, as either dry solid or an aqueous solution. However, iodized salt as a daily supplement have some problems. The inorganic iodine is too volatile to be measured and thus difficult to evaluate its validity to the diet (Longvah and Deosthale 1998) [20]. Loss of iodine from iodized salt is mainly due to exposure to humidity and sunlight and also upon short term heating (dry and in solution) as may be encountered in cooking and during this the losses can be account 30-98% (Diosady *et al.* 1998; Biber *et al.* 2002; Wang *et al.* 1999 and Das Gupta *et al.* 2008) [10, 3, 25, 9].
Iodine requirement of human and animals largely depend on food crops and water commonly consumed by people in general because, human body cannot synthesize iodine itself and requirement only can completed its supply through food materials. Food crops and water derive their iodine from soils. Iodine present in the soil solution can be taken up by plants in the both form of negatively charged ions of iodide and iodate. Among the food crops, vegetables are important, as essential building blocks of any diet. Not only are they loaded with vitamins and minerals which are essential for healthy living, but they also help fill up as part of a balanced diet. Vegetables as a group are useful sources of a number of nutrients including vitamin C, vitamin K, folate, thiamin, carotenes, several minerals, dietary fiber and trace elements, and iodine is one of them. About 75 – 80% of iodine requirement of human

and animals comes from vegetable sources (Hetzel and Stanbury 1980; Liao 1992) [19, 12]. The concentration of iodine in vegetables is mainly determined by two factors: background content of iodine in soil and their biological assimilation. The background content of iodine in soil largely depends on the parent material, texture and geographic distribution of soil. The content of iodine in soil is relatively lower in interior and mountainous areas due to precipitation eluviations, which results in the deficiency of iodine in vegetables and the prevalence of IDD. Human population and livestock that only depend on the food grown in iodine deficient soil cannot obtain sufficient iodine for their body requirement (Hetzel 1997) [15]. Thus, IDD in human and animals are predominant in the areas where vegetation is poor in iodine.

Iodine Deficiency Disorders constitutes a major nutrition deficiency disorder in world. There are about 1.6 billion people living in iodine deficient area in 118 countries. The total numbers of sufferers are estimated to be more than 63 million in India and about 740 million people in the world (Benoist & Delonge, 2002) [2]. In India, a nationwide goitre survey revealed that out of 283 studied districts of 29 states and 4 union territories, 235 districts have prevalence of endemic goitre (National Iodine Deficiency Disorders Control Program, 2003) [22]. In addition, endemicity of goitre has also been reported from many new regions of India, including Manipur (Chandra *et al*. 2006), Tripura (Chandra and Ray 2001) [5] and Delhi (Pandav *et al*. 1996) [24]. In Uttar Pradesh, IDD is a serious nutritional problem and out of 83 districts, 34 districts have been surveyed for IDD and 29 districts have been found to be endemic. The severe occurrence of goitre, hypothyroidism, women pre and post pregnancy problems have been found in endemic in the eastern part of Uttar Pradesh particularly in Deoria, Gorakhpur and Gonda districts (Kapil and Singh, 2003) [18].

Iodine deficiency is still a significant public health problem. A continued effort is needed to control iodine deficiency. However, characterization of the iodine containing crops commonly consuming by people of Indo-genetic plane zone was not so for done until. Thus, to assessment of the quantity of iodine supply through food vegetables, the present work was planned to study the amount of iodine present in the most common consuming food vegetables, generally grown in district Varanasi and distributed form certain randomly selected vegetable markets of Varanasi. In addition, correlation of coefficient between iodine content of soil with vegetables were also analyzed.

Materials & Methods

Study area

Geographically the district Varanasi is situated at 25^0 18' of Northern latitude, 83^0 03' of Eastern longitude and at an altitude of 83.85 m above the mean sea level in the Indo-Gangatic plain of Eastern Uttar Pradesh. The district Varanasi having alluvial soil in the semi arid region to sub humid belt of Northern India. It is often subject to extreme of weather condition. The mean annual precipitation was 1100 mm. The area occasionally experiences to winter cyclonic rain during December to February. In term of percentage of total rainfall, about 84% is received from June to September, 0.7% from October to December, 6% from January to February and 9.3% from March to May as pre monsoonal rain. The mean relative humidity of this area is about 68% with maximum 82% and minimum 30% during July to September and April to early June, respectively. The minimum and maximum average temperature of the area ranged from 4.4^0 to 28.2 - 45^0 C, respectively. The temperature begins to rise from February onwards until the summer often exceeding 40^0 C in the month of May and June. During these extremely hot months, desiccating winds blow from west to east and dust storm frequently occurs.

Collection of vegetable samples

A market basket sample survey technique was adopted for collecting the vegetable samples. Edible portion of vegetables *viz.* spinach, carrot, radish, brinjal, and cabbage was sampled from five different vegetable markets *viz.* Sunderpur, Lanka, Kashividyapith, Pandeypur and Ramnagar during month of December, 2005 at one weak intervals. These markets lying at the centre of the adjoining vegetable growing areas, supply vegetables to the inhabitant of Varanasi.

Collection of soil samples

Surface soils of the vegetable cultivated land of Varanasi districts was sampled randomly from different blocks to a depth of 0-15 cm representing different vegetable markets. The soils samples were mixed thoroughly and a half of kilogram of composite samples from each site was drawn. Soil samples collected from different locations was air dried at room temperature under shade and grinded manually by wooden grinder and ground to pass a 2 mm sieve.

Analysis of iodine

To determine the iodine content in plant samples, the collected edible parts of vegetable samples were dried at 65 ^{0}C in hot air oven, ground in to powder by grinder and the concentration of iodine was analyzed by the colorimetric technique. This method is sensitive at lower level of iodine content and the detection limit is 0.04 µg /g (Bedi, 1999) [1]. A 0.5 g of powdered dry plant samples were taken in nickel crucible. The material was moistened with 1.0 mL distilled water, there after about 30 minutes, 1.0 mL of 2N Na_2CO_3 solution was added and dried in oven at 100^0C. The oven dried plant materials were placed in muffle furnace at 600^0C ± 10^0C for 90 minutes. The ashed material in the crucible was dissolved with 5 mL 0.7 N HCl and then after 15 minutes diluted with 5 mL distilled water and centrifuged at 8000 rpm for 5 minutes. The colourless supernatant fluid was transferred exactly 3.0 mL in a 25 mL clean graduated test tube. Solutions of ceric ammonium sulphate (i.e. 0.815% dissolved in water and 8.0 mL concentrated H_2SO_4 / 100 mL) and arsenious acid (i.e. 0.315% arsenious oxide + 0.165% NaOH + 7.0 mL concentrated H_2SO_4 / 100 mL) were taken in separate test tubes on water both at 37^0C for 10 minutes. Then 1.0 mL arsenious acid was added in each test sample tube and again all the tubes were left on water bath for another 30 minutes. There after 11 mL ceric ammonium sulphate was added and optical density was measured at 415 nm in spectrophotometer. The iodides have catalytic effect on the reduction of ceric sulphate by arsenious acid in the presence of sulphuric acid solution. The graded progress of the reaction can be followed by the steady disappearance of the yellow colour of the ceric ions which is measured in the spectrophotometer using PC Based Double Beam UV-VIS spectrophotometer (Systronic, India Model Number 2202). The concentration of iodine was directly calculated from the standard graph.

Hot water extractable iodine was extracted from well processed soil method adopting by Whitehead, 1973. For this 2 g of processed soil was boiled under reflux of water for 45 minutes, then filtered through Whatman no. 42 filter paper and centrifuged for 5 minutes at 8000 rpm and estimated by colorimetric technique (Bedi, 1999) [1] as above mentioned procedure.

Regents and standards

Analytical grade chemicals were used throughout the study without any further purification. To prepare all the reagents and calibration standards double distilled water was used.

Statistical analysis

Iodine content obtained from vegetables grown in the district Varanasi was statistically analyzed by Fisher "T" test to find the differences in iodine content between different vegetables and vegetable markets. The test of significance was carried out at 5% level of significance by referring to "T" table value. Correlation matrix between iodine content in soil and vegetables were carried out using SPSS (Version 17) software package. All the parameters were carried out in triplicate to minimize the error within ± 3.0.

Result and Discussions

Samples of important vegetables such as spinach, carrot, radish, cabbage and brinjal were collected from different markets (Sunderpur, Lanka, Kashividyapith, Pandeypur and Ramnagar) of Varanasi at different intervals and determined their iodine content. Investigation of the data showed that the highest iodine content in the spinach was 11.20±1.90 mg kg^{-1} in Ramnagar market (Table 2 and Fig. 1) followed by 8.31±3.73, 5.37±4.53, 5.07±3.19, and 4.40±1.67 mg kg^{-1} in the Kashividyapith, Pandeypur, Sunderpur and Lanka, respectively. Similarly, iodine content in the carrot was obtained 3.67±1.12 mg kg^{-1} highest in Ramnagar (Fig. 2) followed by 3.62±1.39, 3.12±0.60, 2.44±1.58 and 1.13±0.61 mg kg^{-1} in the Kashividyapith, Lanka, Pandeypur and Sunderpur markets, respectively. Its concentration in the radish was recorded 7.64±1.41 mg kg^{-1} maximum in the Ramnagar (Fig. 3) followed by 5.36±1.40, 4.57±2.64, 3.92±1.02 and 2.17±0.73 mg kg^{-1} in the Lanka, Pandeypur, Kashividyapith and Sunderpur markets, respectively. Similarly, iodine content in the cabbage was also found maximum 5.35±1.30 mg kg^{-1} in Ramnagar (Fig. 4) followed by 4.81±1.58, 4.27±1.30, 3.75±1.75 and 2.73±0.16 mg kg^{-1} in the markets of Kashividyapith, Pandeypur, Sunderpur and Lanka, respectively, while its content in the brinjal was found 3.50±0.78 mg kg^{-1} in Ramnagar (Fig. 5) which was superior over 3.08±0.70, 2.87±1.34, 2.02±1.15 and 1.76±0.52 mg kg^{-1} in the Sunderpur, Kashividyapith, Lanka and Pendeypur, respectively.

Further, data were surmised in the Table 2 indicated that the mean iodine content in the vegetables of Varanasi ranged from 2.65±0.73 - 6.87±2.85 mg kg^{-1} with mean value of 4.25±1.38 mg I kg^{-1}. The highest iodine value was recorded 6.87±2.85 mg kg^{-1} in the spinach followed by 4.73±2.01, 4.18±1.01, 2.80±1.05 and 2.65±0.73 mg kg^{-1} in the radish, cabbage, carrot and brinjal, respectively. The iodine content in leafy vegetable, spinach was found highest, followed by cabbage (modified leaf). The iodine was lowest in fruit vegetable, brinjal. Thus, iodine was accumulated maximum in leafy part of the vegetable, then root/ modified root and comparatively low amount in fruit part of the vegetables (*i.e.* brinjal). Moreover, coefficient of correlation (r) was significant for spinach, cabbage and mean iodine present in the different vegetables from its content present in respective soils (Table 1).

The scanning of the data presented in the Table 2 revealed that the Ramnagar market has highest iodine content in the vegetables followed by Kashividyapith, Pandeypur, Lanka and Sunderpur. Highest value of iodine obtained in Ramnagar vegetable was due to highest content of iodine in the Ramnagar soil (Table 1) and a significant correlation coefficient was calculated between iodine content in soil solution with represented vegetable. Geographical location contributes significant impact on iodine enrichment in plants (Moiseyev *et al.* 1984) [21]. Ramnagar and its adjoining areas were located near the Ganga River and having rich alluvial (sandy loam) soil which have highest capacity of iodine uptake. Furthermore, results of several researchers showed that enrichment of iodine in soils can enhanced its uptake in plants and particularly leafy vegetables (Dai *et al.* 2004, 06; Hong *et al.* 2009; Huanxin *et al.* 2003) [17, 8, 7, 16]. Thus, soil having higher iodine content in soil solution, produce plants will richer in iodine.

The result showed that wide variations in the iodine concentration in vegetables. This variability might be due to capacity of vegetables to iodine uptake, climatic and seasonal conditions and or due to soil type and fertilizers treatment received; interaction between these factors are also important. Groppel and Anke (1986) [11] were reported that soils high in iodine generally produce plants richer in the element than iodine low soils. Plant species also differ widely in their ability to absorb and retain iodine from the soil (Butler and Glenday, 1962) [4] and the botanical composition of pastures can greatly influenced its uptake. The uptake of iodine also varied in the various organs of crops (Moiseyev *et.al.,* 1984) [21].

The vegetables collected from different markets of Varanasi, spinach accumulated highest amount of iodine than other vegetables *viz.* Radish, cabbage, carrot and brinjal. In fact that uptake of element (iodine) depends upon type and nature of vegetation and the total uptake of iodine by plants can occur either by root from soil or other aerial parts of the plants from the atmosphere (Newton and Toth, 1952) [23]. The plant can take up gaseous iodine mainly by the stomata means that the weather conditions affect the uptake. When the stomata are open, the uptake of iodine is higher than when the stomata are closed. Calculations have shown that 60% of the uptake of elementary iodine is dependent on the stomata and the rest 40% by sorption from the other part of the plants. Other gaseous iodine compounds like methyl iodide are taken up in lesser amount. Spinach is a broad leaf vegetable which has higher numbers of stomata than other tested vegetables. Thus, spinach received much higher iodine than other vegetables.

The data pertaining to statistical differences of iodine content at 5% level of significance analyzed by Fisher "t" test and the statistical "t" value presented and standard deviation in the Table 3 revealed that iodine content of spinach was significantly higher in Ramnagar market as compared with its content in Lanka. However, its content in others remain markets were not reach the level of significance. Its concentration in the carrot was found significantly higher in Ramnagar and Lanka as compared with Sunderpur market. Although in case of radish it was found significant difference in the Kashividyapith in comparison to Sunderpur and Ramnagar in comparison to Sunderpur and Kashividyapith market. Similarly, iodine content in the cabbage was recorded significantly higher in Ramnagar and Kashividyapith over iodine content in the cabbage of Lanka. However in case of brinjal its content was significantly higher in the Ramnagar as compared with iodine content of Pandeypur market, while remaining other markets do not have significant difference of iodine content in comparison to each others in all the vegetable crops *viz.* spinach, carrot, radish, cabbage and brinjal, respectively. Thus, iodine content in different vegetable growing areas greatly influenced the iodine content in vegetables.

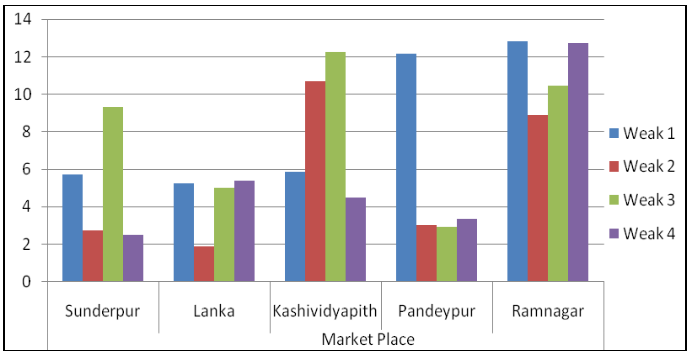

Fig 1: Iodine content (mg kg^{-1}) in the market basket samples of spinach grown in Varanasi

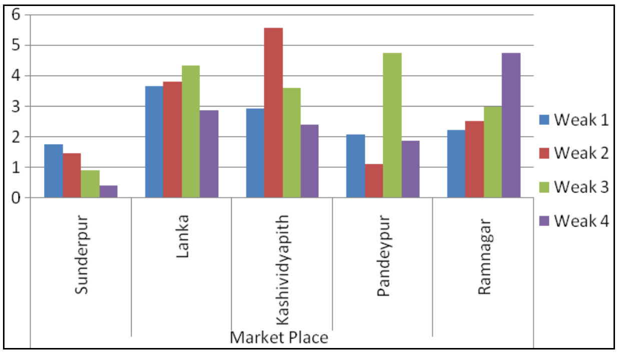

Fig 2: Iodine content (mg kg^{-1}) in the market basket samples of carrot grown in Varanasi

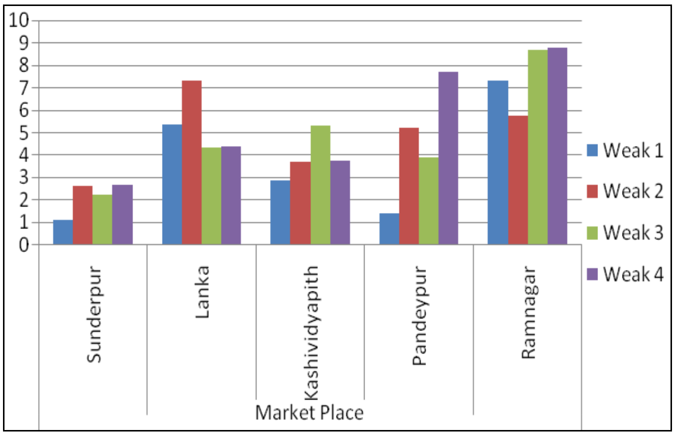

Fig 3: Iodine content (mg kg^{-1}) in the market basket samples of radish grown in Varanasi

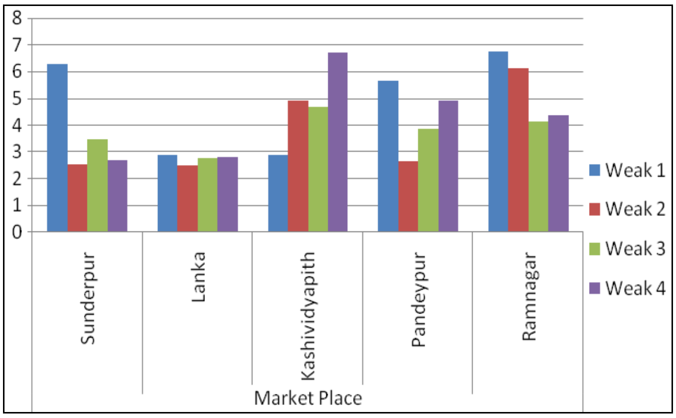

Fig 4: Iodine content (mg kg^{-1}) in the market basket samples of cabbage grown in Varanasi

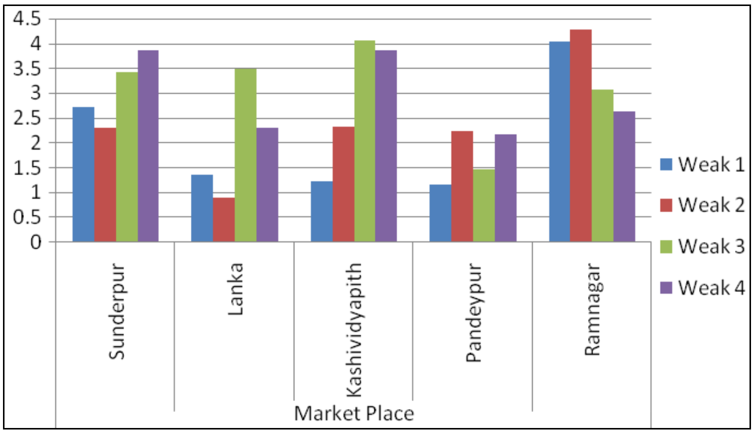

Fig 5: Iodine content (mg kg^{-1}) in the market basket samples of brinjal grown in Varanas

Table 1: Mean iodine content in the soil and their correlation with physic-chemical properties of soil with standard deviation and coefficient of correlation.

Location (number of soil samples analysed)	Hot water soluble iodine in soil	BD (Mg m^{-1})	PD (Mg m^{-1})	WHC (%)	pH	EC (dS m^{-1})	CEC (C mol P^{+} kg^{-1})	OM (g kg^{-1})	$CaCO_3$ (%)	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
Sunderpur (6)	1.28±0.15	1.38±0.08	2.44±0.08	39.05±1.64	7.50±0.15	0.08±0.05	13.87±4.48	7.16±2.13	1.67±0.82	292.1±67.5	35.4±5.85	228.7±18.4
Lanka (5)	1.08±0.17	1.31±0.07	2.46±0.11	39.66±4.07	7.46±0.22	0.08±0.05	10.59±4.88	6.98±2.21	1.63±1.02	284.3±65.4	37.9±5.65	226.9±12.7
Kashividyapith (6)	2.09±0.19	1.35±0.06	2.40±0.06	40.15±4.03	7.43±0.28	0.09±0.07	14.26±5.19	8.32±1.82	1.83±0.98	312.1±46.6	39.5±3.76	238.1±15.8
Pandeypur (8)	1.86±0.28	1.36±0.06	2.41±0.12	41.25±3.52	7.40±0.30	0.07±0.03	14.42±3.39	7.26±2.17	2.00±0.89	296.5±67.3	36.3±6.08	241.2±18.6
Ramnagar (6)	2.41±0.11	1.35±0.07	2.40±0.06	43.20±3.88	7.23±0.38	0.36±0.25	11.91±2.71	9.16±1.79	3.25±2.04	324.6±90.7	39.0±6.75	250.8±20.9
Mean	1.74±0.56	1.35±0.03	2.42±0.03	40.66±1.63	7.40±0.10	0.14±0.13	13.01±1.68	7.78±0.93	2.08±0.67	301.9±16.2	37.6±1.77	237.1±9.8
Correlation coefficient (r)	1.000	0.224	-0.961**	0.862	-0.818	0.678	0.286	0.899*	0.785	0.950*	0.575	0.953*

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 2: Mean iodine content (mg kg^{-1}) in the market basket sample of vegetables in different markets of Varanasi and correlation coefficient (r) between iodine content soil and vegetables.

Location of the markets (notation)	Spinach	Carrot	Radish	Cabbage	Brinjal	Mean
Sunderpur (S)	5.07 ± 3.19	1.13 ± 0.61	2.17 ± 0.73	3.75 ± 1.75	3.08 ± 0.70	3.04±1.50
Lanka (L)	4.40 ± 1.67	3.12 ± 0.60	5.36 ± 1.40	2.73 ± 0.16	2.02 ± 1.15	3.53±1.34
Kashividyapith (K)	8.31 ± 3.73	3.62 ± 1.39	3.92 ± 1.02	4.81 ± 1.58	2.87 ± 1.34	4.71±2.13
Pandeypur (P)	5.37 ± 4.53	2.44 ± 1.58	4.57 ± 2.64	4.27 ± 1.30	1.76 ± 0.52	3.68±1.52
Ramnagar (R)	11.20 ± 1.90	3.67 ± 1.12	7.64 ± 1.41	5.35 ± 1.30	3.50 ± 0.78	6.27±3.22
Mean	6.87 ± 2.85	2.80 ± 1.05	4.73 ± 2.01	4.18 ± 1.01	2.65 ± 0.73	4.25±1.38
Correlation coefficient (r)	0.887*	0.599	0.540	0.964**	0.439	0.861*

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 3: Fisher "t" test values of mean iodine content in the market basket sample of vegetables in different markets of Varanasi

Comparative iodine content (location)	Fisher's "t" test value				
	Spinach	Carrot	Radish	Cabbage	Brinjal
S vs. L**	0.370	5.908*	4.042*	1.158	1.587
S vs. K**	1.320	3.297*	2.785*	0.898	0.275
S vs. P	0.111	1.543	1.746	0.482	3.027*
S vs. R**	3.299*	3.132*	6.880*	1.469	0.797
L vs. K**	1.913	0.055	1.652	2.611*	0.973
L vs. P	0.404	1.445	0.530	2.351	0.409
L vs. R**	5.370*	0.852	2.296	3.996*	2.141
K vs. P	1.000	1.125	0.453	0.521	1.551
K vs. R**	1.382	0.562	4.252*	0.529	0.807
P vs. R**	2.371	0.705	2.052	0.764	3.714*

* = Significant at t 5% at 6 df (2.447).
** = Significantly higher
S = Sunderpur, L = Lanka, P = Pandeypur, K = Kashividhyapith and R = Ramnagar

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