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VARIATIONS IN MICRONUTRIENT CONTENT IN TUBERS OF INDIAN POTATO VARIETIES

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ABSTRACT: The objective of the present study was to determine genotypic variations in mineral content of the Indian potato varieties and thereby defines the way forward for breeding nutrient rich potato varieties. Considerable variations were observed in metal (Fe, Zn, Mn, Cu) concentrations in the 48 potato varieties under uniform management practices and non nutrient limited conditions with average yield levels ranging from 22.15 to 43.23 t/ha. Iron concentration in tuber flesh varied from 19.96 to 49.51 mg/kg, zinc from 12.59 to 22.85 mg/kg, manganese from 14.19-29.86 mg/kg, and copper from 5.13 to 21.06 mg/kg. The accumulation pattern of the metal on the basis of total content in tuber flesh and peel was in the order Fe> Mn> Zn> Cu. Average proportion of mineral content in tuber flesh was in the order of Zn (87.14%) > Cu (84.64%) > Mn (78.29%) > Fe (60.13%). Losses due to peeling are highest for Fe (39.87%) ranging from 24.10 to 53.83% in different varieties. The tuber yield did not show any significant correlation with tuber mineral content. Keeping in view large seasonal variations in mineral content in peel and significant loss of minerals like Fe during peeling process, strategies to increase the mineral content (micronutrient rich) potatoes should focus on improving their content in tuber flesh.

KEY WORDS: Micronutrients, *Solanum tuberosum* L., potato, varieties

INTRODUCTION

Micronutrient malnutrition in human beings is a serious problem worldwide and mineral deficiencies, particularly of Zn and Fe, are common in both developing and developed nations. The occurrence of mineral deficiencies is linked to the consumption of produce grown on soils with low mineral phytoavailability and inherently low tissue mineral concentrations in edible portions due to restricted phloem mobility (White and Broadley, 2009). Potato (*Solanum tuberosum* L.) one of world's most important food crops is a staple food in many countries. Potato tubers are important from micronutrient mineral nutrition point of view because of high mineral bio-availability (Burlingame *et al*., 2009; White *et al*., 2009) and low phytate content. The World Health Organization (2011) reported 50% of pregnant women and 40% of preschool age children in developing countries are anemic. Iron deficiency has negative effects on immune system, cognitive development, temperature regulation, energy metabolism and work performance.

Recommended daily allowance (mg Fe/ day) is 10 for children (4-8 years), 8 for adult males and 18 for adult females (USFNB, 2001). Zinc is needed for growth, normal development, DNA synthesis, immunity, neurosensory function and plays a functional role in many zinc containing proteins and a large number of zinc dependent enzymes. The extent of deaths among children under five years in developing countries due to zinc deficiency is 4.4% (Walker *et al*., 2009). The recommended daily allowance for Zn is 5 mg/ day for children (4-8 years), 11 mg/day for adult males and 8 mg/day for adult females (USFNB, 2001). Copper acts as an antioxidant and is required by the central nervous system. It plays a role in heme synthesis and

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promotes wound healing and its deficiency is characterized by loss of appetite, anemia, infection, edema, and arthritis. Manganese is a key component of several enzymes and its deficiencies result in skeletal deformation and inhibit the production of collagen in wound healing. Metal concentrations of plants depend not only in their content in soils but their contents also differ at species or genotypic level.

Plant breeding earlier mainly focused on increasing yield potential and resistance level of plants. However, now emphasis is being on breeding nutrient/mineral rich varieties with high yield potential. Increasing yields has been related to decreased concentrations of mineral elements due to dilution effect caused by plant growth rates exceeding the ability of plants to acquire these elements. Metal concentrations of plants depend not only in their content in soils but their contents also differ at species or genotypic level. Thus understanding the processes and patterns of the accumulation of minerals in different tuber parts is an important prerequisite to more targeted strategies to enhance the levels of desirable minerals through agronomy or breeding. To date, only sparse information is available on the genetic variations in content of minerals like Fe, Zn, Mn and Cu in field grown Indian potatoes varieties with varied yield potential. The present study was undertaken with an objective to examine the variation in micronutrients content and their partitioning in the tuber flesh and peel to assess the losses of important micronutrients as a result of peeling in 48 Indian varieties having wide range of yield.

MATERIALS AND METHODS

Forty-eight Indian potato varieties were grown for the study at the ICAR-Central Potato Research Institute Campus, Modipuram, India during the years 2014-2015 and 2015-16 under uniform management practices and non nutrient limited conditions. Ten unblemished representative potato tubers of each variety selected for this study. Each potato was hand-rinsed under a stream of tap water and the dirt was removed by gently rubbing by hand under the water stream followed by washing with high purity 0.1 N HCL and finally with distilled water to remove the surface contaminations. After rinsing with distilled water, the potatoes were shaken to remove any excess water, gently blotted with a paper towel and placed in a laboratory dark place to air dry prior to processing. After air drying about 0.5 mm peel was removed with the help of acid washed stainless steel vegetable peeler. Each potato tuber was cut into 4 equal slices longitudinally and opposite slices from each tuber was taken for mineral analysis. Samples were oven dried at 70 ^{o}C in glass petri dishes to study the mineral composition. All the plastic ware and glassware were cleaned by soaking in dilute HNO_3 and were rinsed with distilled water prior to use. Double glass distilled water was use for all analytical purposes. The tuber samples ground digested with HNO_3 (65%) and perchloric acid (70%). Metals (Fe, Zn, Mn and Cu) concentrations in the acid digest were determined with an atomic absorption spectrometer after making required dilutions with double distilled water. Surface soil samples (0-15 cm) of the experimental farm were analysed for determining soil fertility status. The soil was sandy loam in texture, neutral in reaction (pH 6.8), non saline (EC 0.31 dS/m), low in organic carbon (3.9 g/kg) and available nitrogen (80 mg NH_4-N/ kg), high in available P (32 mg/kg) and low in available K (90 mg/kg). The soil was high in respect of available micronutrient status. The available (DPTA extractable) Fe, Zn, Mn and Cu were 9.09, 2.04, 8.55 and 3.56 mg/kg soil, respectively. Correlation coefficients were worked out to study the inter-relationship amongst the metals in whole tuber as well as tuber flesh and tuber peel.

RESULTS AND DISCUSSION

Micronutrient concentration in tuber flesh and peel and their content in whole tuber

Iron

Iron concentration in flesh varied from 19.96 mg/kg in Kufri Garima to 49.51 mg/kg in Kufri Girdhari with an average concentration of 28.49 mg/kg and significant differences amongst the varieties (**Table 1**). In majority of varieties (34 in number) the concentration ranged from 20-30 mg/kg dry flesh weight and was >30 mg/kg in 13 varieties. Three varieties namely Kufri Red (37.23), Kufri Bahar (37.56) and in Kufri Arun (38.7) contained >35 mg/kg Fe . A wider range in Fe content in the peeled tubers has been reported by Brown *et al.*, 2010 (17 to 62 mg/kg) and Andean landraces (30 to 158 mg/kg of dry weight) (Andre *et al.*, 2007) in whole tubers.

In comparison to tuber flesh larger and significant variations in iron concentration were observed in tuber peel. The concentration ranged from 112.11 mg/kg in Kufri Surya to 346.72 mg/kg in Kufri Jyoti with an average value of 227.00. In 22 varieties the concentration ranged from 200-300 mg/kg and in seven varieties viz. Kufri Jyoti, Kufri Shailja, Kufri Khyati, Kufri Neela, Kufri Lalit, Kufri Badshah and Kufri Jawahar it was >300 mg/kg. The Fe content in whole potato tuber (flesh+peel) ranged from 27.15 to 64.21 mg/kg (**Table 2**).

Zinc

The average concentration of zinc in flesh varied from from 12.59 in Kufri Arun to 22.85 mg/kg in Kufri Anand with an average content of 17.64 mg/kg (**Table 1**). In more than 80% varieties average zinc concentration was > 15 mg/kg. In nine varieties *viz*. Kufri Ashoka, Kufri Naveen, Kufri Jawahar, Kufri Pukhraj, Kufri Girdhari, Kufri Pushkar, Kufri Himalini, Kufri Anand and Kufri Red average zinc concentration ranged from > 20 mg/kg (20.05 to 22.85). Zinc concentration in peel ranged from 19.65 in Kufri Giriraj to 40.65 in Kufri Badshah with an average content of 30.49 mg/kg. All the varieties accumulated between 20 to 40 mg/kg Zn in tuber peel except Kufri Giriraj, Kufri Neela and Kufri

Table 1. Concentration of minerals (mg/kg) in potato flesh and potato peel (dry weight basis)

	Flesh				Peel			
	Fe	Zn	Mn	Cu	Fe	Zn	Mn	Cu
Kufri Alankar	28.82±2.3	17.35±4.1	14.19±3.1	7.01±2.9	241.88±14	30.63±10.1	64.82±2.1	21.69±0.5
Kufri Anand	33.05±4.6	22.85±3.0	21.88±11.9	15.74±10.0	147.66±48.3	24.90±1.1	71.16±23.8	15.31±3.7
Kufri Arun	38.71±15.0	12.59±2.0	14.81±1.8	7.18±1.4	208.09±133.7	22.91±3.8	44.28±21.4	11.34±1.7
Kufri Ashoka	29.02±0.2	20.56±3.8	28.20±2.3	18.16±12.5	175.19±51.4	27.10±1.2	65.23±18.2	19.70±4.3
Kufri Badshah	24.07±2.3	18.15±7.5	22.24±12.1	12.46±8.9	306.96±120.1	40.65±13.4	73.43±8.5	38.79±12.8
Kufri Bahar	37.56±4.1	14.09±2.1	18.14±6.2	9.45±1.2	176.98±107.5	24.47±1.5	70.35±14.8	16.37±5.8
Kufri Chamatkar	32.86±7.0	14.13±4.8	15.05±0.6	9.26±6.3	191.31±92.4	31.58±9.7	58.55±25.9.1	30.47±11.3
Kufri Chandermukhi	23.05±3.2	19.44±1.7	27.11±2.5	12.84±8.4	241.01±54.0	28.52±5.8	63.87±10.1	28.18±5.2
Kufri Chipsona-1	28.62±4.0	17.66±2.1	26.10±9.0	17.48±15.6	269.72±82.6	32.82±5.4	39.51±9.8	26.94±3.7
Kufri Chipsona-2	20.75±3.8	16.44±2.3	25.08±7.0	15.44±13.5	165.13±38.9	28.88±12.2	43.12±8.0	19.39±2.7
Kufri Chipsona-3	22.78±5.9	14.70±7.3	26.81±6.8	17.40±15.1	251.68±66.2	34.66±9.3	47.8±4.2	26.95±4.1
Kufri Chipsona-4	23.94±2.3	16.48±1.8	24.56±17.5	8.87±1.1	234.71±110.8	28.52±4.9	72.56±5.6	22.84±0.9
Kufri Deva	22.34±6.5	14.52±6.8	25.42±11.4	11.81±10.2	261±178.964	32.89±8.3	81.60±43.7	30.23±7.0

	Flesh				Peel			
	Fe	Zn	Mn	Cu	Fe	Zn	Mn	Cu
Kufri Frysona	26.95±3.5	13.52±2.7	19.61±2.8	13.19±0.3	143.83±40.1	30.18±4.4	49.54±8.8	31.19±0.2
Kufri Garima	19.96±2.3	16.28±2.6	17.62±5.6	15.81±12.8	118.52±53.9	21.27±0.6	79±56.6	14.51±3.1
Kufri Gaurav	29.44±5.3	18.51±2.5	16.57±2.5	15.06±14.7	197.36±106.7	26.02±6.1	63.73±5.3	20.08±2.4
Kufri Girdhari	49.51±6.7	21.71±5.9	17.23±1.0	10.13±6.1	260.11±86.2	29.09±8.9	68.52±26.7	29.90±19.2
Kufri Giriraj	28.62±6.7	16.55±1.8	25.91±1.8	15.74±4.4	141.77±35.9	19.65±1.0	73.42±36.8	19.03±8.3
Kufri Himalini	23.56±3.3	22.48±6.8	23.93±8.4	12.26±7.6	267.21±213.3	32.22±14.6	74.16±23.0	33.44±17.5
Kufri Himsona	30.48±2.9	15.24±3.9	16.91±2.2	10.66±6.6	245.39±101.9	35.66±15.1	66.60±11.1	39.46±8.6
Kufri Jawahar	24.98±0.	20.98±0.1	20.08±5.2	15.36±14.9	300.94±41.4	30.59±7.1	69.03±22.5	17.68±5.6
Kufri Jeevan	30.61±1.6	17.77±2.9	16.45±1.5	10.86±6.8	132.39±8.4	24.30±4.2	86.24±12.0	30.21±23.5
Kufri Jyoti	23.95±1.8	15.85±2.2	21.97±13.2	5.13±0.6	346.72±29.5	35.89±0.8	87.94±3.9	14.70±1.7
Kufri Kanchan	29.42±6.8	15.08±5.3	27.15±7.5	7.58±1.6	256.30±92.8	34.37±11.7	86.16±16.9	19.09±3.2
Kufri Khasigaro	31.33±4.1	18.30±3.9	17.58±1.2	6.56±1.5	157.1±45.9	33.22±10.3	47.09±16.7	28.80±4.1
Kufri Khyati	31.13±6.2	16.31±0.3	20.06±0.3	11.88±5.1	330.46±31.2	35.20±4.3	54.43±5.8	17.47±2.3
Kufri Kuber	24.52±0.2	19.59±4.9	18.74±6.5	14.08±10.0	170.58±126.1	31.31±12.1	73.27±24.9	37.53±13.1
Kufri Kumar	30.06±4.7	17.03±4.1	19.93±5.4	16.88±13.9	265.35±120.4	27.65±9.6	46.80±8.1	21.97±3.2
Kufri Kundan	24.90±3.5	13.97±3.4	22.02±1.1	16.72±14.1	139.88±26.3	22.51±8.7	66.72±16.5	23.50±2.8
Kufri Lalima	27.91±7	18.84±6.6	23.99±12.0	14.96±11.1	239.94±83.8	38.20±11.8	79.06±30.0	30.38±5.5
Kufri Lalit	26.10±0.1	15.20±5.2	29.86±7.6	18±14.1	313.15±32.1	36.40±10.5	81.42±7.6	26.70±1.8
Kufri Lauvkar	27.57±4.8	19.89±0.9	24.88±5.8	16.05±0.8	168.77±36.9	28.15±12.8	56.83±21.1	19.01±2.2
Kufri Megha	28.45±0.4	19.22±4.4	19.87±0.5	21.06±17.1	292.91±116.1	34.98±15.7	107.48±19.5	30.01±0.1
Kufri Muthu	26.81±3.2	19.10±4.2	22.97±5.9	12.78±10.5	254.76±110.3	29.84±11.2	91.68±18.0	17.57±0.8
Kufri Naveen	28.66±1.1	20.72±7.0	20.74±4.5	12.07±8.650	195.53±121.9	34.12±12.8	96.48±26.0	28.69±11.2
Kufri Neela	27.23±3.6	18.17±1.1	17.73±4.5	15.19±8.6	316.21±204.6	40.07±19.0	99.23±34.0	25.92±11.6
Kufri Pukhraj	27.67±3.7	20.19±3.3	14.68±1.9	7.29±2.8	259.72±39.9	35.04±7.7	46.07±22.5	22.40±10.4
Kufri Pushkar	29.57±9.0	21.72±1.0	18.32±4.891	11.02±3.1	263.98±245.3	35.36±13.2	93.65±3.6	20.07±1.6
Kufri Red	37.23±10.7	20.05±0.8	15.65±6.994	10.50±8.9	205.08±86.9	28.18±8.3	70.03±16.6	38.41±8.1
Kufri Sadabahar	26.91±3.3	19.84±0.6	26.61±10.2	12.91±7.4	184.52±73.4	30.83±6.8	38.25±3.4	21.34±5.1
Kufri Safed	30.43±8.8	15.61±8.5	17.91±3.5	11.31±9.7	140.9±21.1	26.70±2.7	37.84±2.6	31.67±22.1
Kufri Shailja	28.03±1.8	17.50±2.4	26.06±8.3	14.06±1.1	337.34±168.2	31.35±1.0	79.81±28.0	30.10±18.5
Kufri Sheetman	29.06±10.5	14.59±5.1	18.16±2.0	8.79±4.6	274.06±145.4	34.91±13.9	44.03±8.0	23.40±6.3
Kufri Sherpa	28.68±2.5	18.91±1.3	15.05±1. 5	9.09±1.8	278.99±58.1	33.56±13.7	76.37±29.3	34.01±1.4
Kufri Sindhuri	25.67±2.5	18.30±0.9	18.82±1.8	11.74±10.3	167.60±61.1	32.47±14.4	66.58±11.1	25.09±13.4
Kufri Surya	33.44±10.3	18.41±6.1	23.56±9.9	16.19±10.7	112.11±4.3	22.36±3.7	65.61±18.0	15.59±1.8
Kufri Sutlej	26.38±1.8	17.20±3.6	23.76±9.6	11.47±8.3	224.19±14.0	24.64±1.2	66.22±11.0	30.61±17.6
Kufri Swarna	26.61±2.2	15.11±3.9	24.19±6.1	9.09±5.5	226.57±17.4	28.53±13.3	95.96±4.8	33.70±9.3
Mean	28.49	17.64	21.13	12.59	225.03	30.49	67.74	25.24
Minimum	19.96	12.59	14.19	5.13	112.11	19.65	37.84	11.34
Maximum	49.51	22.85	29.86	21.06	346.72	40.65	107.48	39.46
SD±	5.04	2.53	4.22	3.61	62.83	4.94	17.29	7.15

Badshah. Total zinc content (flesh+peel) in different varieties ranged from 13.51 to 23.35 mg/kg (**Table 2**). Zn content of potatoes has been reported to range from 2 to 37 mg kg^{-1} (True *et al.* 1978; Rivero *et al.* 2003 ; Burgos *et al.*, 2007 ; Brown *et al*,. 2011) and from 13 to 29 mg kg^{-1} of dry weight in whole potato tuber of Andean landraces (Andre *et al*., 2007). The zinc content of Indian cultivars was comparable to that reported in Atlantic and tetraploid clones

Table 2. Average yield (experimental plot basis) and mineral content (mg/kg) in whole potato tubers (flesh+peel) on dry weight basis

Varieties	Yield t/ha (fresh weight)	Fe	Zn	Mn	Cu
Kufri Alankar	26.33	45.41±10.4	18.34±3.1	18.40±3.6	8.23±3.0
Kufri Anand	40.64	43.40±1.6	23.02±2.8	26.25±13.6	15.66±9.4
Kufri Arun	38.78	54.71±0.8	13.51±2.3	17.21±3.0	7.55±1.5
Kufri Ashoka	37.54	41.41±6.3	21.06±3.4	31.40±0.1	18.23±11.8
Kufri Badshah	38.79	47.56±3.1	19.91±6.0	26.89±9.4	14.79±9.7
Kufri Bahar	35.70	49.87±14.9	14.94±2.2	22.50±7.8	10.06±1.7
Kufri Chamatkar	29.42	43.43±11.9	15.28±4.0	18.46±3.3	10.65±5.4
Kufri Chandermukhi	28.20	40.04±2.1	20.11±1.2	30.15±0.9	14.05±8.4
Kufri Chipsona-1	33.47	44.89±5.7	18.66±1.8	27.18±7.4	18.05±14.9
Kufri Chipsona-2	28.09	32.01±4.1	17.31±1.4	26.65±5.5	15.67±12.8
Kufri Chipsona-3	32.89	42.57± 3.7	16.51±5.6	28.49±6.2	18.36±13.3
Kufri Chipsona-4	29.13	38.97±6.7	17.37±1.8	28.43±14.8	9.93±1.3
Kufri Deva	29.33	41.53±5.6	15.99±5.8	29.29±7. 8	13.39±10.3
Kufri Frysona	31.46	35.16±1.4	14.70±1.9	21.71±1.5	14.41±1.00
Kufri Garima	38.35	27.15±4.7	16.69±2.3	21.04±6.4	15.79±12.1
Kufri Gaurav	38.63	41.73±5.3	18.94±2.7	19.66±2.9	15.29±14.0
Kufri Girdhari	30.81	64.21±8.9	22.13±4.9	21.21±1.9	11.68±7.4
Kufri Giriraj	29.50	37.28±5.4	16.80±1.1	29.39±3.8	16.06±13.8
Kufri Himalini	33.07	42.74±22.2	23.35±5.1	27.44±8.6	13.71±8.0
Kufri Himsona	30.15	47.84±8.5	16.96±2.2	20.84±0.4	12.87±6.3
Kufri Jawahar	34.75	46.16±1.8	21.67±0.2	24.05±7.4	15.46±14.2
Kufri Jeevan	26.36	38.83±0.7	18.24±2.43	22.12±3.4	12.54±8.5
Kufri Jyoti	34.54	45.32±2.2	17.23±1.6	26.31±13.8	6.03±0.6
Kufri Kanchan	28.81	45.36±3.2	16.36±4.4	31.72±4.7	8.45±1.9
Kufri Khasigaro	23.27	40.06±5.1	19.27±3.1	19.57±0.4	8.19±2.1
Kufri Khyati	43.23	53.50±13.1	17.67±0.3	22.56±0.1	12.23±5.0
Kufri Kuber	30.73	37.48±12.4	20.69±3.3	23.07±7.2	15.98±9.9
Kufri Kumar	28.30	48.77±17.7	17.96±2.8	22.07±3.924	17.36±13.0
Kufri Kundan	33.38	33.83±7.2	14.52±2.6	25.55±3.1	17.14±13.4
Kufri Lalima	35.65	44.95±3.0	20.31±5.4	28.77±14.4	16.12±10.0
Kufri Lalit	35.85	46.52±2.0	16.60±4.4	33.57±8.4	18.71±13.1
Kufri Lauvkar	30.39	38.29±4.7	20.43±1.8	27.52±7. 6	16.27±0.9

Table 2. contd...

Varieties	Yield t/ha (fresh weight)	Fe	Zn	Mn	Cu
Kufri Megha	22.15	47.83±4.8	20.26±3.1	26.79±2.5	21.61±15.9
Kufri Muthu	31.02	45.18±9.6	20.06±2.8	27.98±5.4	13.25±9.5
Kufri Naveen	30.58	42.30±10.8	21.90±5.3	26.33±5.0	13.32±8.5
Kufri Neela	32.65	51.33±23.8	20.04±0.8	23.86±5.5	16.18±6.9
Kufri Pukhraj	40.48	48.84±10.6	21.44±2.5	17.34±3.2	8.55±1.8
Kufri Pushkar	40.81	51.90±33.6	23.03±0.4	24.81±3.3	11.81±2.8
Kufri Red	31.00	50.48±0.6	20.73±0.0	19.59±6.7	12.58±8.3
Kufri Sadabahar	36.00	37.30±5.3	20.55±0.3	27.55±9.0	13.39±6.7
Kufri Safed	33.02	39.81±11.5	16.63±7.4	19.64±2.7	12.93±10.4
Kufri Shailja	38.75	52.87±15.9	18.58±2.0	29.86±6.3	15.15±2.1
Kufri Sheetman	27.83	47.09±2.3	16.04±4.0	20.26±2.9	9.96±5.0
Kufri Sherpa	29.25	49.98±21.4	20.15±0.1	20.02±1.9	11.03±1.2
Kufri Sindhuri	33.02	36.77±4.7	19.34±1.7	22.62±1.6	12.87±10.8
Kufri Surya	30.8	40.15±11.1	18.77±5.9	27.11±9.9	16.21±10.0
Kufri Sutlej	37.6	42.50±0.6	17.79±3. 6	27.42±7.2	13.12±9.4
Kufri Swarna	31.9	43.86±3.6	16.14±2.7	30.52±4.0	11.12±4.6
Mean	32.76	43.94	18.62	24.82	13.58
Minimum	22.15	27.15	13.51	17.21	6.03
Maximum	43.23	64.21	23.35	33.57	21.61
SD±	4.72	6.54	2.43	4.23	3.33

ranging from 18 to 26 mg kg^{-1} (Hayens *et al.*, 2012) in peeled potatoes.

Manganese

Variation in manganese content in the varieties was less compared to Fe and its concentration in tuber flesh ranged from 14.19 in Kufri Alankar to 29.86 mg/kg in Kufri Lalit with an average content of 21.13 mg/kg (**Table 1**). In twenty two varieties manganese concentration was less than 20 mg/kg and in remaining 26 varieties it ranged from 20.06 to 29.86 mg/kg. Kufri Lalit contained highest concentration which was comparable with Kufri Ashoka, Kufri Kanchan and Kufri Chandermukhi. Average Mn content in the present study was higher than 8 to 13 mg/kg reported by (Hayens *et al.*, 2012) but is comparable to that reported by Trehan *et al.*, 1996. Manganese concentration in peel also varied widely in different cultivars ranging from 37.84 to 107.48 mg/kg with an average concentration of 67.74. Total Mn content (flesh+peel) in different varieties ranged from 17.21 to 33.57 mg/kg (**Table 2**). Fourteen varieties accumulated <60 mg/kg Mn whereas 33 varieties accumulated 60-100 mg/kg in peel.

Copper

There were large differences among the varieties for tuber Cu concentration. Average copper concentration in tuber flesh ranged from 5.13 in Kufri Jyoti to 21.06 mg/kg in Kufri Megha (**Table 1**). Copper concentration in majority of the varieties (35 number) ranged between 10-20 mg/kg. Only one variety Kufri Megha had >20 mg/kg and remaining 12 varieties had <10 mg/kg. Total Cu content in different varieties ranged from 6.03 to 21.61 mg/kg (**Table 2**). The mean copper content of the Indian varieties in the present study was higher than the highest content of 12 mg/kg dry weight recorded by Haynes *et al*. (2012). Copper concentration in peel ranged from 11.34 in Kufri Arun to 39.46 mg/kg in Kufri Himsona with an average content of 25.24 mg/kg. Copper concentration in sixteen varieties is more than 30 mg/kg in peel.

The higher concentrations of minerals in tuber peel than tuber flesh may be due to direct uptake of minerals by periderm, soil contamination although due care was undertaken to clean the samples), differences in their mobility in phloem or binding of minerals by the periderm. Trehan and Sharma, (1996) and Wszelaki *et al*., 2005) also observed better nutritional value in potato peel/skin.

Partitioning of total micronutrient content in tuber flesh and peel

The mineral accumulation (peel+flesh) pattern in potato varieties was in the order of Fe> Mn> Zn > Cu (**Table 2**). Averaged across the genotypes, Trehan and Sharma (1996) reported accumulation in order of Fe> Mn> Zn >Cu whereas Ozturk *et al*., (2011) reported that potato accumulated the four elements in order of Fe > Zn > Mn >Cu. The variations in mineral accumulation pattern may be due to genotypic differences as reported in earlier studies of White *et al*., (2009), Rivero *et al*., (2003), Trehan and Sharma (1996). Further tuber mineral concentration also depend on their contents in soils. Although peel contain higher concentration of minerals on dry weight basis, given the relatively small mass and ranged from 6.5 to 8.8% on dry weight basis (data not given) in different varieties in the present study, and its overall contribution to the total mineral content of the tuber was highest in case of Fe (39.87%) (**Figure 1**). This may be due to the reason that Fe is tightly bound to the proteins in the periderm.

Higher proportion of Fe in peel than flesh was observed in some of the varieties due to large concentrations of Fe in the peel. The average contribution of tuber flesh to total Fe content of tuber was 60.13% and it ranged from

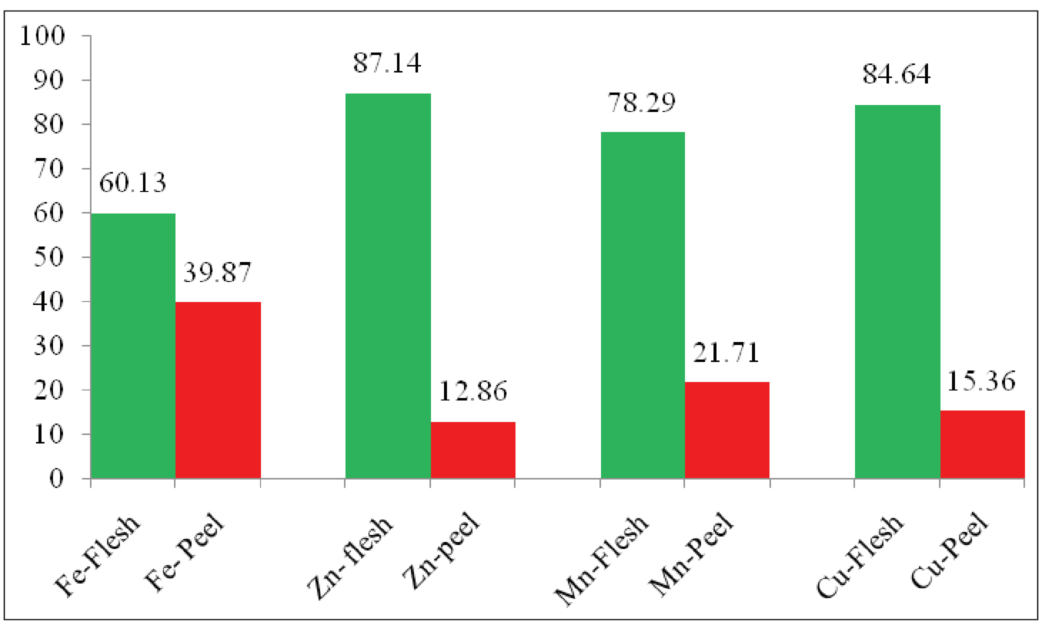

Fig. 1 Percent distribution of micronutrient content in tuber flesh and peel (mean of all varieties)

Table 3. Correlation (r) between tuber yield and mineral concentration in tuber flesh and peel and whole tuber (flesh+peel) mineral content.

	Yield	Fe-flesh	Fe-peel	Zn-flesh	Zn-peel	Mn-flesh	Mn- peel	Cu -flesh
Fe-peel	0.005	-0.085						
Fe - whole tuber	0.196	0.649*	0.703*					
Zn-flesh	0.152	0.102	0.092					
Zn-peel	0.108	-0.215	0.712*	0.137				
Zn- whole tuber	0.080	0.061	0.213	0.985*	0.308			
Mn-flesh	0.118	-0.422*	0.033	0.005	-0.057			
Mn- peel	0.056	-0.064	0.326*	0.234	0.325*	0.056		
Mn- whole tuber	-0.039	-0.412*	0.140	0.083	0.056	0.943*	0.387*	
Cu -flesh	0.039	-0.256	-0.115	0.1956	-0.135	0.456*	0.0460	
Cu -peel	0.065	-0.067	0.199	0.047	0.466*	-0.092	0.254	-0.072
Cu- whole tuber	-0.238	-0.267	-0.080	0.203	-0.053	0.438*	0.090	0.985*

*significant at p=0.05

46.17% in Kufri Badshah to 75.90% in Kufri Surya. Most of zinc was present in potato tuber flesh ranging from 81.93 % in Kufri Chipsona to 91.09% in Kufri Gaurav. Contribution of tuber flesh to total manganese content ranged from 67.68 in Kufri Pushkar to 90.17% in Kufri Sadabahar. Copper in potato tuber flesh ranged from 74.28 in Kufri Khasigaro to 93.08% in Kufri Garima. Averaged across the varieties the proportion of Zn was highest in tuber flesh (87.14%) followed by Cu (84.64%), Mn (78.29%), and Fe (60.13%).Thus peeling of potato tubers will cause higher losses of Fe. Although the proportion of the tuber peel (on dry weight basis) was less than 10% of the total tuber weight, peeling can cause substantial losses of some of the nutrients particularly that of Fe and Mn. Averaged across the varieties tuber peel contained 39.87% of the total Fe followed by Mn (21.71%), Cu (15.36%) and Zn (12.86%). Subramanian *et al*., (2011) reported about 55 % and 17% contribution of tuber skin to total Fe and Zn content in potato tuber, respectively. The findings of the present study are useful both for understanding distribtion minerals in tuber parts and for the dietary implications and nutrient losses due to peeling process. Dietary contributions of important minerals particularly iron, zinc in India appear to be very small keeping in view the present per capita potato consumption of about 23 kg (fresh weight basis), however, potatoes should be considered as part of a balanced and varied dietary regime since different foods contain different nutrients and other healthful substances and no single food can supply all the dietary nutrients requirements.

Correlation between tuber yield, and mineral content

Although there is some evidence in the literature to suggest that high yielding potato genotypes have lower concentrations of mineral elements in their tubers than low yielding genotypes when grown in the same environment, tuber yield did not show any significant association with any of the minerals in the present study. Similar insignificant correlation between tuber yield and iron, zinc and manganese content was also observed by (White *et al*., 2009). Varieties having high content of both Fe and Zn are preferred. Weaker correlation between Zn, Fe, Cu and Mn concentrations in the tuber flesh and peel may be because of differential mobility of these elements in the tuber parts.

CONCLUSIONS

Keeping in view the large seasonal variations in mineral concentrations in tuber peel compared to flesh and substantial proportion of minerals like Fe in peel, the future breeding strategies and agronomic practices should aim for increasing the accumulation of both zinc and iron in tuber flesh. Insignificant and very poor correlation between tuber yield and mineral content in present study does not support the hypothesis that high yielding varieties have lower concentrations of mineral elements in their tubers than low yielding varieties. Based on the present per capita potato consumption of about 23 kg (fresh weight basis) in India, dietary contributions of important minerals such as iron, zinc appear to be small, however, potatoes should be considered as part of a balanced and dietary regime since different foods contain different nutrients and healthful substances and no single food crop alone can meet the human dietary nutrients requirement.

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