*International Research Journal of Biology and Biotechnology*
Volume 11 Issue 4, October-December 2023
ISSN: 2995-4487
Impact Factor: 8.06
http://kloverjournals.org/journals/index.php/bb

# FORTIFYING THE HARVEST: IDENTIFYING NUTRIENT-RICH POTATOES THROUGH HIGH ASCORBIC ACID, IRON, AND ZINC GERMPLASM

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**Abstract**
Potatoes are a vital source of essential minerals, and their bioavailability is regulated by various factors, including the presence of promoters and inhibitors. Here, we present a study on the mineral content of eleven coloured skinned potato genotypes and advanced hybrids. The mineral composition of both the whole potato and tuber flesh was evaluated, and significant variation was observed depending on the genotype and tissue. Contrary to popular belief, potato peels were found to contain significant minerals. We identified four potential nutrient-rich genotypes that could serve as genetic stocks or be released as new varieties. Moreover, we found that bioavailability of minerals is crucial for their absorption, which is regulated by various factors. Our analysis revealed significant positive correlations between Fe-Zn, Cu-Zn, Ca-Zn, Cu-Fe, Ca-Fe, and Ca-Mn contents. Thus, biofortification of potatoes with essential minerals could address the food and nutritional security concerns of countries like India, which has seen a rise in the per capita consumption of fresh potatoes. Current breeding objectives for potato yield, resistance, and processing properties have limited variations in nutritional attributes. Consequently, identifying nutrient-rich germplasm accessions and high-yielding biofortified potato varieties could help in the development of nutrient-rich potatoes for food and nutritional security.

**Keywords:** bioavailability, biofortification, coloured potatoes, essential minerals, germplasm accessions, nutritional security, potato genotypes, tuber flesh, whole potato.

## Introduction

Hidden hunger affects more than 2 billion individuals in the developed and developing nations (FAO, 2013). The socio-economic constraints involved in success of conventional fortification, dietary diversification and supplementation has led to rethink of interventions into the nutritional biodiversity of crop germplasm *per se* for biofortification. Potato (*Solanum tuberosum* L.) holds the position of third most important food crop globally. The ability of the crop to yield high and nutritious food per unit area, time and water has interested the agricultural researchers and policy makers. China, the world's largest potato producer and consumer targets its half of the increased food production demand in next 20 years to be met from this crop (https://cipotato.org/crops/potato).

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Potatoes are the excellent, low fat source of carbohydrates, proteins, ascorbic acid, minerals like potassium, phosphorus and magnesium, vitamins like B1, B3 and B6 and bioactive compounds. Bioavailability of minerals depends on its absorption percent. The absorption percent of potato iron and zinc is 10 and 25 percent respectively. Presence of promoter and inhibitors affects mineral bioavailability. Potato has low phytates and oxalates content and high ascorbate, b-carotene, cysteine rich polypeptides, organic acids render it ideal for mineral biofortifcation.

Worldwide researchers have reported significant genotypic-by-environment (GxE) interaction for iron and zinc content but this does not affects the relative ranking of genotypes with moderately high heritability of both the traits. Genetic associations between iron and zinc are significantly positive with negative association with tuber dry matter. Increasing micronutrient concentration has no negative impact on resistances also.

India, being is the second largest potato producer and increased per capita consumption of fresh potatoes at an Annual Compound Growth Rate of 2.34 (1991 to 2010; CPRI, Vision 2050) and demand of 125 million tonnes by 2050, there is need of high yielding biofortified potato varieties to harvest the dual benefit of food and nutritional security. The nutritional analysis of released varieties depicted narrow variations as till now the main breeding focus was for yield, resistance and processing attributes. The germplasm accessions including advanced hybrids with high ascorbic acid, iron and/or zinc is to be identified that may serve as potential parental lines for introgression of nutrient genes in adapted genetic background or to be released as nutrient rich potatoes.

## Material and Methods

Eleven coloured skinned potato varieties and advanced hybrids (Table 1) *viz*., Kufri Kesar, PS/11-47, PS/11-86, PT/14-16-1, 14KP-39-1, 14KP-14-1, 14KP-14-2, 14KP-21, P-12, 14KP-39-3 and 14KP-14-3 were grown during Rabi season of 2017-2018 at the experimental farm of the ICAR- Central Potato Research Station, Patna. Recommended dosage of fertilizers and inter cultural operations were followed. Dehaulmimg was done at 90 days after planting followed by harvesting after 15-20- days. Freshly harvested unblemished 10 tubers were used for analysis. Samples were oven dried at 80°c for 72 hours, grinded and acid digest in di-acid mixture ($HNO_3$: $HClO_4$ = 2:1). Triplicate samples were used in atomic absorption spectrometer for estimation of micro and macronutrients. Statistical analyses were performed by using Complete Randomized Design (CRD) in TNAUSTAT software (Manivannan, 2014).

Table 1. Coloured skinned potato genotypes and their parentage



| Genotype | Parentage | Genotype | Parentage |
|---|---|---|---|
| Kufri Kesar | CP 2376 × JP 100 | 14KP-14-2 | CP 2366 × CP 3770 |
| PS/11-47 | Kufri Arun × CP 3192 | 14KP-21 | 2005 P 75 × CP 3770 |
| PS/11-86 | PS 8/97-1 × PRT- 19 | P-12 | Kufri Arun × Desiree |

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| | | | |
|---|---|---|---|
| PT/14-16-1 | PS 5/51-1 × D 150 | 14KP-39-3 | Kufri Pushkar × CP 2340 |
| 14KP-39-1 | Kufri Pushkar × CP 2340 | 14KP-14-3 | CP 2366 × CP 2340 |
| 14KP-14-1 | CP 2366 × CP 2340 | | |

**Results and Discussion Variations in micro nutrient content**

Among the micro nutrients of dietary importance in tuber flesh (without peel), the mean zinc content of the eleven genotypes was 21.83 ppm or mg/kg dry weight basis (Table 2). This average zinc content was higher than those reported in tuber flesh of Indian potato varieties (17.64 ppm, Sharma *et al*., 2017). The highest zinc content in tuber flesh was in PS/11-47 and 14KP-14-3 (26.20 ppm each) which was statistically equivalent to second highest containing genotype PT/14-16-1 (25.81 ppm). The maximum zinc content in tuber flesh was reported up to 22.85 ppm in Indian potato varieties (Sharma *et al*., 2017). Least performing genotypes were PS/11-86 and P-12 (18.70 ppm) that were statistically similar to 14KP-39-1 (20.42 ppm), 14KP-14-2 (18.90 ppm) and 14KP-21 (19.20 ppm). However, mean zinc content in whole potato (tuber flesh with peel) was 23.96 ppm higher than those of mean content in potato flesh (21.83 ppm) depicting that potato peels do affect the zinc content of potato tuber (Fig. 1).

Average iron content in tuber flesh of eleven accessions was 45.65 ppm (Table 2) much higher compared to 28.49 ppm in Indian potato varieties (Sharma *et al*., 2017). Best performing genotypes 14KP-14-3 (58.29 ppm) and 14KP-14-1 (57.35 ppm) had higher tuber flesh iron content than those reported in Indian potato varieties (49.51 ppm, Sharma *et al*., 2017). 14KP-39-1 has lowest iron content (37.85 ppm) two times to that that lowest iron containing cultivated potato variety (19.96 ppm, Sharma *et al*., 2017). Mean iron content of whole potato (51.22 pm) was higher than those in tuber flesh only (Fig. 1) again signifying the nutritional value of potato peel.

Highest copper containing genotypes were 14KP-14-1 (9.50 ppm), 14KP-39-3 & 14KP-14-3 (9.30 ppm each) and14KP-39-1 (9.10 ppm) with lowest content up to 5.90 ppm (Kufri Kesar) (Table 2). However, these highest copper containing genotypes have much lower copper content than those in Indian potato varieties (21 ppm). The average cooper content in tuber flesh was 7.76 ppm as compared to 12.59 ppm in Indian potato varieties. The mean copper content of whole potato (8.93 ppm) was higher than those of tuber flesh (Fig. 1).

Manganese content in tuber flesh was highest in PS/11-47 (21.60 ppm) (Table 2) which was much lesser than the highest containing red skinned potato variety Kufri Lalit (30 ppm, Sharma *et al*., 2017). The average manganese content of tuber flesh (12.61 ppm) was also lower than the average content of Indian potato varieties (21.13 ppm; Sharma *et al*., 2017) and also to that of manganese content of whole potato (14.53 ppm, Fig. 1)

**Variations in macro nutrient content**

Macro nutrient, *viz*., calcium in tuber flesh ranged from 320.50 ppm (14KP-39-1) to 486.50 ppm (14KP-14-1) (Table 2). The average calcium content of tuber flesh was 409 ppm which was quite low than that in Andean potato cultivars (1092.93 ppm; Andre *et al*., 2007). The calcium content of whole potato (509.42 ppm) was higher than in potato flesh only (Fig. 1). Magnesium ranged between 900.40 ppm

(PS/11-47) to 1084.90 ppm (PT/14-16-1) in tuber flesh (Table 2) with average content of 989.58 ppm lower than that in whole tuber (1095.45 ppm) (Fig. 1).

**Table 2.** Micro and macronutrient composition of coloured skinned potato genotypes

| Genotypes | Micronutrient | | | | Macronutrient | |
|---|---|---|---|---|---|---|
| | Zn (ppm) | Fe (ppm) | Cu (ppm) | Mn (ppm) | Ca (ppm) | Mg (ppm) |
| K. Kesar | 21.00bc | 39.46cd | 5.90$^{c}$ | 14.50$^{b}$ | 470.10$^{ab}$ | 967.10$^{e}$ |
| PS/11-47 | 26.20$^{a}$ | 43.85bcd | 7.30bc | 21.60$^{a}$ | 448.60$^{ab}$ | 900.40$^{f}$ |
| PT/14-16-1 | 25.81$^{a}$ | 47.20$^{b}$ | 8.50ab | 11.30bc | 427.70bcd | 1084.90$^{a}$ |
| 14KP-39-1 | 20.42$^{c}$ | 37.85$^{d}$ | 9.10$^{a}$ | 11.10$^{c}$ | 320.50$^{f}$ | 1055.80$^{ab}$ |
| 14KP-14-1 | 23.95ab | 57.35$^{a}$ | 9.50$^{a}$ | 11.70bc | 486.50$^{a}$ | 948.30$^{ef}$ |
| PS/11-86 | 18.70$^{c}$ | 41.77bcd | 6.80$^{c}$ | 12.70bc | 360.70$^{ef}$ | 992.60cde |
| 14KP-14-2 | 18.90 $^{c}$ | 42.70bcd | 6.80$^{c}$ | 13.10bc | 433.30abc | 937.60$^{ef}$ |
| 14KP-21 | 19.20 $^{c}$ | 46.39bc | 6.80$^{c}$ | 10.30$^{c}$ | 337.20$^{ef}$ | 953.30$^{ef}$ |
| P-12 | 18.70 $^{c}$ | 46.05bc | 6.10$^{c}$ | 10.60$^{c}$ | 374.10def | 1045.70abc |
| 14KP-39-3 | 21.10bc | 41.20bcd | 9.30$^{a}$ | 11.20bc | 380.20cde | 1026.20bcd |
| 14KP-14-3 | 26.20$^{a}$ | 58.29$^{a}$ | 9.30$^{a}$ | 10.60$^{c}$ | 459.60$^{ab}$ | 973.50$^{de}$ |
| **Mean** | **21.83** | **45.65** | **7.76** | **12.61** | **408.95** | **989.58** |
| Range | 18.70-26.20 | 37.85-58.29 | 5.90-9.50 | 10.30-21.60 | 320.50-486.50 | 900.40-1084.90 |
| SE(±) | 0.94 | 2.01 | 0.42 | 0.98 | 17.10 | 17.16 |
| CV % | 14.25 | 14.63 | 17.90 | 25.68 | 13.87 | 5.75 |

Characterization of Coloured Skinned Potato Genotypes ...

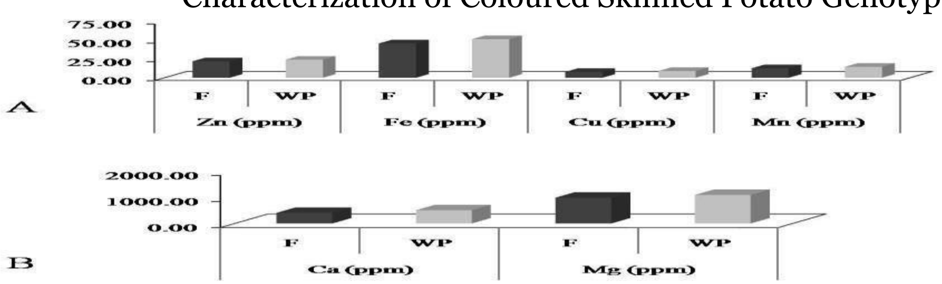


**Fig. 1:** Comparison of mean micronutrient (A) and macronutrient (B) content in flesh and whole potato (including flesh) of 11 potato genotypes

## Correlations among different mineral nutrients

Correlations among Fe, Zn, Cu, Ca, Mn (Fe-Zn, Cu- Zn, Ca-Zn, Cu-Fe, Ca-Fe and Ca-Mn) contents in potato flesh tuber indicate significant positive correlation at 5% level of probability with each other (Table 3). The value of correlation of coefficient (r) was 0.55, 0.54, 0.62, 0.44, 0.52 and 0.37, respectively. On the other hand significant negative relationship was observed among Mg-Mn and Ca-Mg contents at 5% level of probability with each other. The value of correlation of coefficient (r) was -0.59 and -0.45, respectively.

Correlation analysis was presented in Table 3.

**Table 3:** Correlation coefficients among micro and macro nutrients

| | Zinc | Iron | Copper | Manganese | Calcium | Magnesium |
|---|---|---|---|---|---|---|
| Zinc | 1.00 | | | | | |
| Iron | 0.55* | 1.00 | | | | |
| Copper | 0.54* | 0.44* | 1.00 | | | |
| Manganese | 0.35 | -0.24 | -0.27 | 1.00 | | |
| Calcium | 0.62* | 0.52* | 0.10 | 0.37* | 1.00 | |
| Magnesium | -0.11 | -0.20 | 0.24 | -0.59* | -0.45* | 1.00 |

* Significant at $p<0.05$

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