



Potato biofortification: game changer for micronutrient upliftment

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ABSTRACT

Biofortification is an integrated approach to improve food's nutritional value, address common nutrient deficiencies, and support global food security. It was found through biofortification that the micronutrient concentrations were greatly enhanced by the application of zinc fertilizer. Long-term micronutrient availability may be possible with this sustainable, dependable, and reasonably priced method.

The potato, also known as *Solanum tuberosum*, is highly prized for its great nutritional content and potential output. One of the best sources of micronutrients is potatoes, particularly when eaten with their skin. Being the most widely used non-grain staple crop in the world and having a huge commercial command, it appears to be a great aspirant for the process of biofortification. Consequently, raising the concentrations of micronutrients in affordable staple crops appears to be an excellent strategy to address the challenge.

Zinc is found in around 1.08 milligrams per large normal potato, which is 9.8% of the daily value (DV) for males and 13.5% of the DV for women. Thus, biofortifying it with zinc may be the best way to address micronutrient deficiencies. The recommended dietary allowance of zinc for men during adulthood is suggested upto 11mg a day while for adult women it is prescribed to 8mg a day, where as in pregnant or lactating women the recommended dietary allowance of zinc is upto 12 mg.

Compared to the statistical data of non biofortified potatoes from United States Department of Agriculture 2019, biofortification of potatoes with zinc increased overall zinc percentage, moisture, calories, carbohydrate, and total fibre. According to the current study, biofortifying potatoes with zinc may be a sustainable way to enhance their overall nutritional content. It may also be a tool to combat different nutritional deficiencies and reduce the proportion of micronutrient malnutrition among population.

Keywords: *Biofortification, Potato, Zinc, RDA, Micronutrient deficiencies.*



INTRODUCTION

Biofortification is the process to accumulate nutrients and its synthesis or by plants at source, as opposed to traditional fortification, which calls for artificial chemicals. Enhancing the micronutrient content of crops, especially staples that support human populations in underdeveloped nations, can be accomplished effectively and affordably through biofortification. Comparing biofortification to conventional fortification, the former may increase bioavailability and nutrients are synthesized or accumulated. The efficacy of micro nutrient biofortification of potatoes employing the soil with foliar treatments with micronutrient elements have been investigated and analyzed in this research.

In order to assess the potential relevance of tested methods for the production of biofortified crops, the investigation describes the effects of various biofortification technologies on yields as well as important nutritional quality characteristics of potato tubers. Numerous approaches can be employed to eradicate deficiency of several micronutrients like by enhancing the intake of various micronutrients through dietary sources. These consist of crop biofortification, food fortification, pharmacological supplements, and diet diversification. Crop biofortification is the most acceptable and sustainable approach to addressing the universal issue of micronutrient starvation.

The aim of biofortification is to grow staple crop that is high in minerals by utilizing the most advanced biotechnology and the most successful conventional breeding methods. This approach offers numerous advantages because of the high degree of sustainability of the biofortified agricultural system. The nutritional content of crops can be raised via a number of biofortification techniques, such as nutritional genetic alteration, plant variety development through conventional breeding, and agronomic biofortification.

Potato is extremely valued in agricultural production systems due to its high nutritional content and potential yield. It is estimated globally that approx 366 billion pounds of potato is grown on farmland sized upto 20 million acres. The temperate zone of northern hemisphere's has the highest concentrations, grow the crops in summer season, when slight frost get started. As per the nutritional profiling of potatoes various vital nutrients like, Iron and folate, Vitamin K, C, B6 are found in abundance. Potatoes cooked along with its peel can increase its nutritional value and dietary fibre content. Nonetheless, there may be a small variation in nutritional value between varieties. Antioxidants including flavonoids, carotenoids beta carotene, anthocyanins, and phenolic compounds for instance, are present in plenty amount in coloured tubers. Few of these elements, like anthocyanin, continue to exist in considerable quantities even after boiling.

According to the data gathered thus far, a number of factors influence how well agricultural plants are biofortified, considering the type and species of plant, natural environment, micro nutrient application method, and its chemical form. Many studies in the subject have focused on producing a variety of plant species in greenhouses, such as tomatoes, lettuce, pepper and spinach. Certain research suggests that increasing the iodine content of potato production may be possible through fertilisation or the application of iodine-enriched nutrient solutions in greenhouse cultivation.

As it is a very good source of energy, proteins, lipids, vitamins, and minerals, Potato is a versatile crop, as it contains good amount of the antioxidant such as vitamin C, its biofortification can significantly reduce micronutrient deficiencies. Being an electrolyte, potassium is a great source of energy and supports the health of our heart, muscles, and neurological system, is another essential ingredient in potatoes. It is often prepared by a culinary process (e.g., boiling, frying, baking) before consumption. As per the research by (Yang et.al; 2016) cooking



procedures substantially change the physical and chemical characteristics of potatoes and also impact the bioavailability and concentration of bioactive compounds. The potato germplasm varies greatly in reference to size, shape, colour of pulp and peel, pigmentation, peel type, nutritional quality along with resistance to abiotic or biotic stressors. Therefore, certain undiscovered gene which can be employed in the biofortification scheme must be present in a diverse potato gene pool.

Micronutrients are already abundant in potatoes, particularly when eaten with the peel. Those with micronutrient deficits may benefit from its fortification. Potatoes appear to be an excellent candidate for biofortification due to their significant industrial demand and position as the most consumed grainless staple crop globally. During a trial of an ultrasonic pretreatment combined with vacuum impregnation was implemented to fortify whole potato with iron. The physicochemical characteristics of fortified potatoes were assessed with the different parameters of cooking.

On other hand, eating the peel can enhance utilization in general. Fiber content is found in abundance in the peel and flesh of the potato. Baked potato along with its peel contain approx 2.6gm of fiber in per 100gm compared to 1.8 g for those without peel. The recommended daily intake of fibre for men and women is 30 to 38 grams and 21 to 25 grams, respectively. Potatoes contain high value of potassium; a 100 gm of baked potatoes with the pulp have 652 milligram potassium, or 18 percent of the daily intake for individuals. It has been discovered that most of the soils in agricultural system persist reduced concentrations of zinc is available for the crops. It has a significant detrimental effect on the productivity and public health.

Priming potato tubers in solutions containing zinc is an effective method of fortifying them. Priming of potato with 0mg, 10mg, 20mg and 30mg zinc solution for the time of 8hrs, 12hrs, 16hrs and 24hrs was performed to assess and analyze the impact of Zn fortification and its bioavailability. The amount of phytic acid (PA), Zn concentration, and dry matter in potato was tested to calculate the Zn:PA ratio. As extended duration for priming, higher the content of Zn is observed in the cortex of tubers'. It was demonstrated that the bioavailability of zinc increased with a larger concentration of zinc in the solution.

A three-year field experiment examined the foliar treatment of KIO₃ and the soil application of KI at up to 2.0 kg I ha was conducted by Smolen, L. et al., 2020. We looked at the dried matter, starch, biomass, iodine production, and sugar content of potato. The examined iodine application techniques showed no negative effects on dry matter content or potato production. Both topically administered and soil-applied iodine increased the concentration of the element in potato and does not affect their sugar or starch content. An iodine biofortification efficiency of 2Kilogram Iodine ha⁻¹ was highest when KIO₃ was sprayed foliarly. Iodine content in 100g of potatoes can be estimated to 25% of the RDA. Iodine-fortified potatoes can be added to a regular diet as an additional source of I, according to the study's findings.

A recent study conducted by Jongstra (2020) it was found that, potatoes have a significantly better iron availability, in contrast to grains. Andre et al. (2015) observed more than 70% of the iron liberated from the potatoes is still available at the intestinal level, according to an in vitro gastrointestinal digestion and a model of the human gut based on CaCO₂ lines. Furthermore, zinc content absorbed by individuals through their gastrointestinal tract from different agricultural foods is very small. Potato tubers have a high zinc bioavailability due to the high levels of organic molecules that promote zinc absorption and the low levels of compounds that prevent the absorption of zinc. Hence, we can say that a relevant amount of RDA for zinc and iron can be acquired from potatoes.

The folate biofortification of potatoes could dramatically reduce the prevalence of anaemia and NTDs while increasing the intake of natural folates. (Goyer and Navarre, 2007), given the narrow range of folate levels in contemporary potato cultivars—roughly three to four times—it appears to have little ability to produce the necessary



folate enhancement. Biofortification of micronutrients offers a viable alternative to alleviate various deficiencies and enhance quality of life., and it appears to be well received by underserved areas. Zinc (Zn) and Iron (Fe) deficiencies are the most common of all the micronutrients. About 17% of people worldwide suffer from zinc deficiency (Hefferon 2019; Wessells and Brown 2012). The problem is exacerbated in developing nations such as India. (Harding et al. 2018;Talsma et al. 2017). India is home to more than half of the world's micronutrient-deficient population. (Ritchie 2018). Over the past decade, numerous initiatives, including biofortification, food fortification and dietary supplements has proven to be a successful strategy for reducing this secret hunger. (Allen and de Brauw 2018; FAO 2017; Oersteiner et al. 2016).

The additional technique known as biofortification has been successful in eliminating micronutrient deficiencies. The production of biofortified potatoes treated with zinc may offer a long-term remedy for the issue of micronutrient scarcity. Top crop biofortification solutions include agronomical practices, transgenic methods and breeding of plants. Nonetheless, potatoes are perfect crop for genetic approaches of biofortification because of their high genetic variability for micronutrient content. Therefore, genotypes with high iron content could be used as parental lines in potato breeding programs. The development of iron-biofortified potatoes by transgenic methods, rapid breeding, and marker-assisted selection may benefit from the screening of the genes or QTLs causing the high iron content in these genotypes.

OBJECTIVES OF THE STUDY

- Unveil the micronutrient attainability of zinc biofortified *Solanum tuberosum*.
- Nutritional Comparison between *Solanum tuberosum* and Zinc rich bio-fortified *Solanum tuberosum*

METHODOLOGY

The present study was performed in departmental laboratory at Era University, Lucknow. A stratified, multiple-parameter design with three replications was used for the experiment, which compared biofortified and non-biofortified potatoes to see how the nutritional content of the former changed following zinc biofortification.

Moisture Content

A sample weighing 5.0 grammes was oven-dried for 4 to 5 hours at 110°C. Reweighing the oven-dried sample after it had cooled in a desiccator. They kept doing this until the weight didn't change. A percentage of the moisture content will be used to represent the weight loss that occurs. (A.O.A.C., 2005).

$$\text{Moisture content (\%)} = \frac{\text{loss in weight}}{\text{Weight of Sample}} \times 100$$

Total Fat Content

Five grams of the sample were taken and defatted using n-hexane (boiling point 68-78°) in the Soxhlet apparatus for eight hours. The resultant extract was then evaporated to dry, and the crude fat content was calculated using the A.O.A.C. 2005 technique.

$$\text{Total Fat (\%)} = \frac{w_2 - w_1}{\text{Weight of Sample}} \times 100$$



Crude Protein Content

The Micro Kjeldhal technique was used to determine the sample's protein content. In concentrated sulphuric acid, at 130–140°C, 5.0 grams of a deflated, moisture-free sample were digested. Following distillation with 40% boric acid, it was titrated with 0.1N hydrochloric acid to measure the nitrogen percentage. To determine the protein concentration the nitrogen percentage of the sample was multiplied by a factor of 6.25 (A.O.A.C, 2005).

$$\text{Nitrogen (\%)} = \frac{V1 \times N1 \times F1 \times \text{Molecular weight of Sample}}{\text{Weight of Sample} \times 10}$$

Total Ash

The sample, weighing 5.0 grammes, will be burned in a dried crucible over a low flame until it is completely smoke-free. A muffle furnace will hold it at 600°C for 6.0 hours, then cooled in a desiccator and weighed. After the sample is put back into the muffle furnace until two consecutive weights are the same, the percentage of ash will be calculated. (A.O.A.C), 2005).

$$\text{Determination of Ash content (\%)} = \frac{w2 - w1}{\text{Weight of}} \times 100$$

Fiber Content

Crude fibre is the amount of dried residue that is lost when it is ignited under certain conditions following sample digestion with 1.25% NaOH and 1.25% H₂SO₄ solutions.

$$\text{Determination of fiber content (\%)} = \frac{w2 - w1}{\text{Weight of}} \times 100$$

Total Carbohydrate content

Using the following calculating technique, the sample's 5.0g total carbohydrate content was determined. (A.O.A.C. 1995)

$$\text{Total Carbohydrate \%} = 100 - (\text{Crude Protein \%} + \text{Crude Fiber \%} + \text{Ash \%} + \text{Crude Fat \%})$$

Zinc Content



An atomic absorption spectrophotometer (Varian, AA240, Victoria, Australia) was used to estimate the mineral, such as zinc, using the standard procedures outlined in AOAC (2005). 20 minutes after digestion, in 10 millilitres of nitric acid at 60 to 70 degrees Celsius, a 0.5-gram test sample was digested with HCL at 190 degrees Celsius. 20 minutes after digestion, 0.5 grams of the sample with HCL were digested at 190°C in 10 ml of nitric acid at 60-70°C, until the solution turned clear.

The digested sample was then placed in a 250 ml volumetric flask to increase the volume by adding distilled water and then kept in an atomic absorption spectrophotometer after filtration. Through an atomic absorption spectrophotometer, known strength samples were passed to make the standard curve. A corresponding standard curve was generated for each mineral to project the concentration of minerals in the unknown samples.

RESULT & DISCUSSION

Zinc concentrations doubled as a result of biofortifying *Solanum tuberosum* with zinc, and the potato crop's productivity improved as well. Applying zinc fertilizer had a significant impact on increasing the micronutrient concentrations through biofortification, according to the current study. It is a sustainable, dependable, and reasonably priced approach that may provide micronutrients in the long run. Instead of artificially adding nutrients to food crops during processing, this new method has the potential to significantly improve the nutritional content of food crops in the fields.

MOISTURE CONTENT

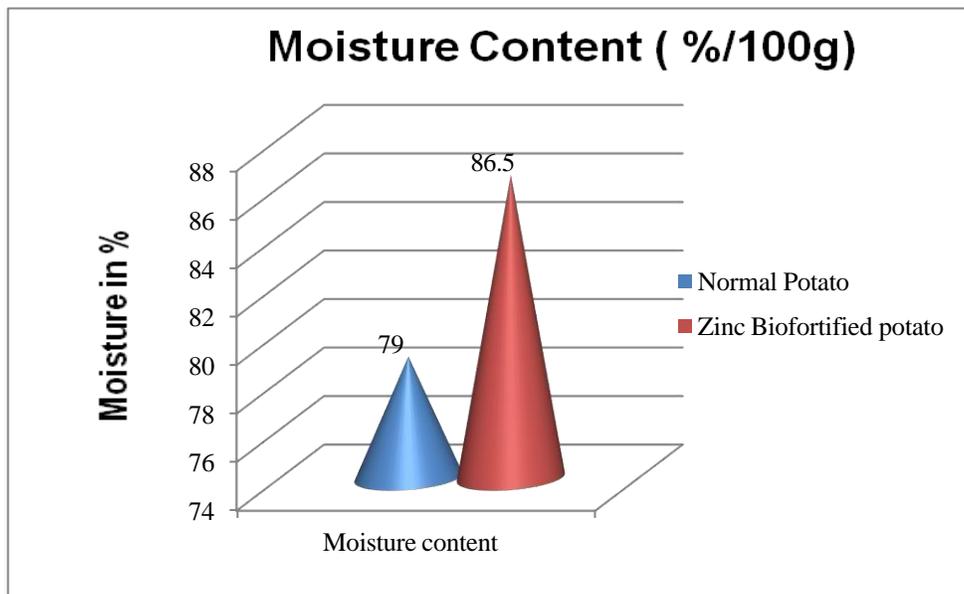


Fig1. Availability of total moisture content

Following oven drying at 110°C for four to five hours and reweighing, the moisture content of the bio-fortified potato was determined to be 86.5%, whereas that of the standard type was 79%. (USDA 2019).



TOTAL FAT PERCENTAGE

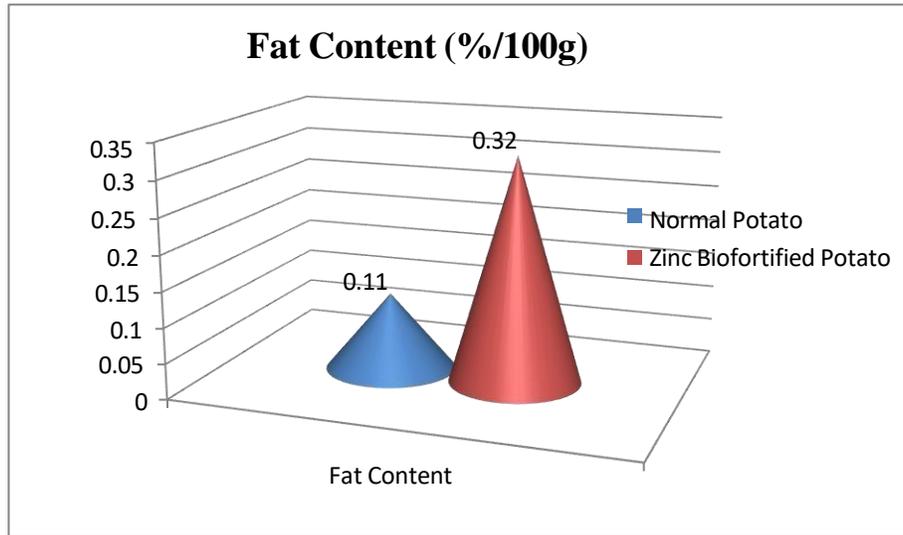


Fig2. Availability of total fat content

In order to determine the amount of fat in the biofortified potato, the sample was repeatedly washed (percolated) with petroleum ether, an organic solvent, while being refluxed in a Soxhlet unit thimble. The results show that the amount of non-biofortified potatoes was 0.11% (USDA 2019) per 100 gm, however the amount in the biofortified potato sample was 0.32% per 100 gm.

TOTAL PROTEIN CONTENT

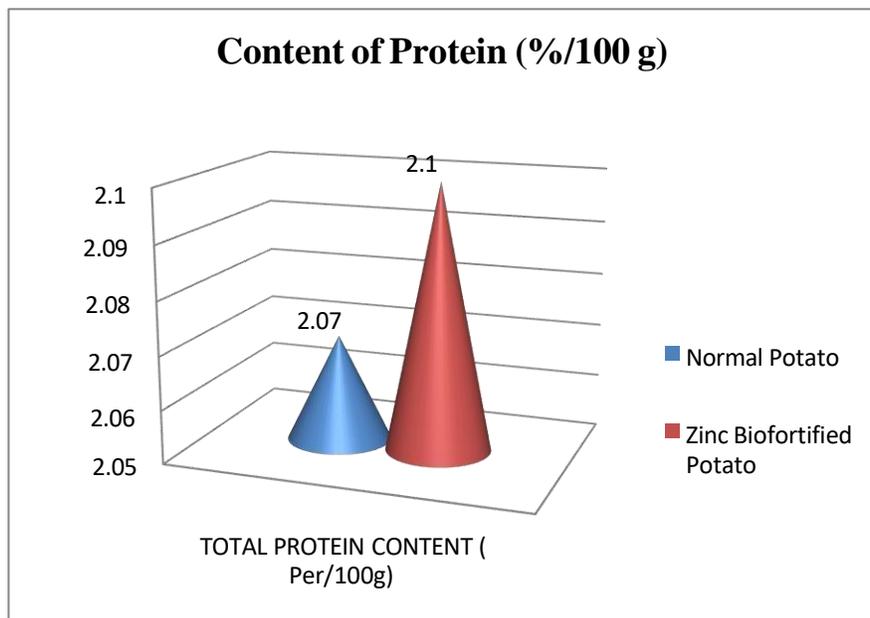


Fig3. Availability of total protein content



There is no discernible difference in the protein level of biofortified and non-biofortified potatoes; the former has a protein content of 2.1% per 100g, while the latter has a protein value of 2.07 percent as per United States Department of Agriculture 2019.

ASH CONTENT

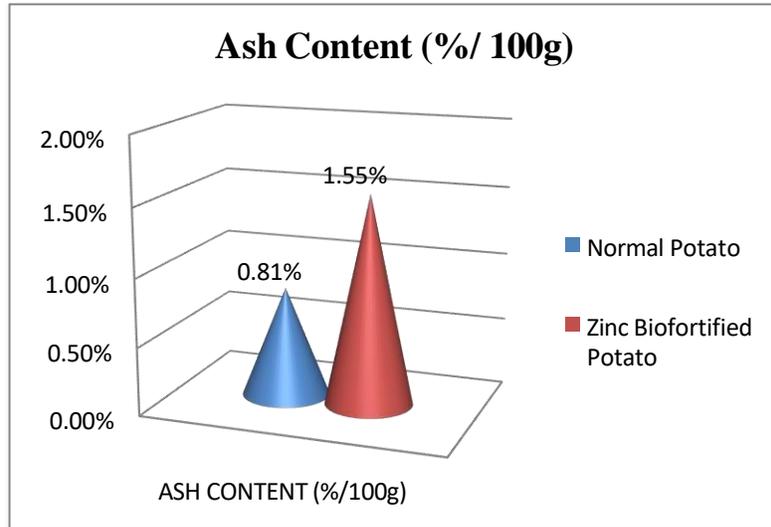


Fig4. Availability of ash content

Following an ash content examination using a muffle furnace, it was discovered that the biofortified potato had a higher ash percentage to 1.55% than the normal potato, which showed 0.81% (USDA 2019) of ash content.

TOTAL FIBER CONTENT

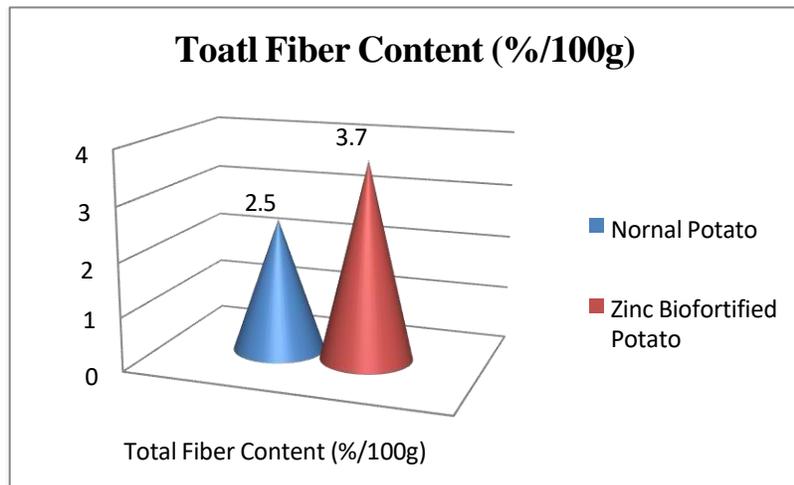


Fig 5. Availability of total fiber content



The fibre content of potatoes in the biofortified variety is significantly higher than that of the non-biofortified variety, which has a fibre content of up to 2.5% (USDA 2019) per 100g, but the biofortified variety has a fibre value of up to 3.7% per 100g sample.

CARBOHYDRATE CONTENT

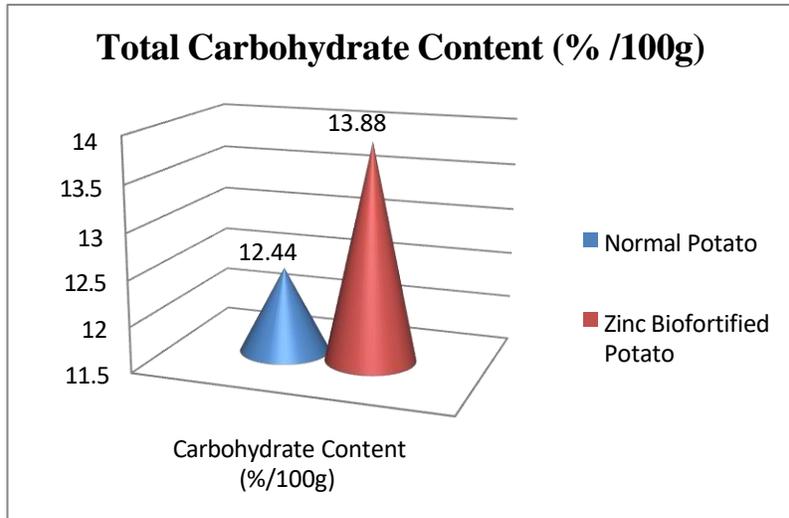


Fig6. Availability of carbohydrate content

When compared to standard potatoes, the biofortified potato's total carbohydrate content slightly increased. The zinc biofortified potato had a carbohydrate level of 13.88% per 100 grammes, whereas the non-biofortified potato had a carbohydrate content of 12.44% per 100 grammes (USDA 2019).

TOTAL ENERGY CONTENT

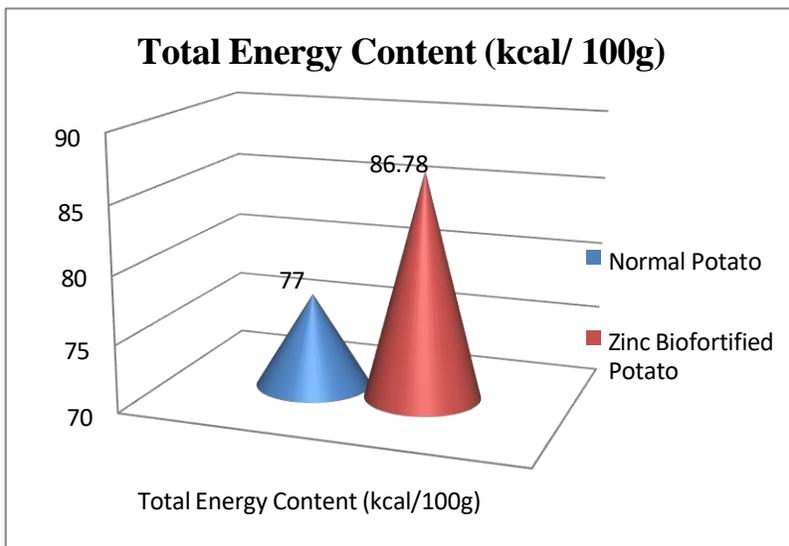


Fig7. Availability of total energy



Energy content of biofortified potatoes with zinc is higher than that of non-biofortified potatoes. The energy content of a non-biofortified potato was 77 kcal (USDA 2019), whereas the energy content of a biofortified potato was 86.78

ZINC CONTENT

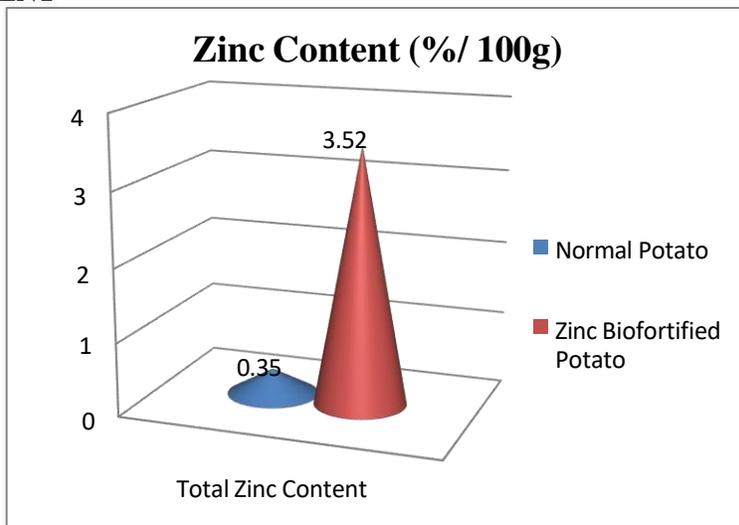


Fig8. Availability of zinc content

Biofortification with zinc has beneficial effect on boosting the zinc content of potatoes. Zn concentration in non-biofortified potatoes is 0.35% (USDA 2019), however it rises to 3.52% after biofortification.

STATISTICAL ANALYSIS

Table1- Statistical data presentation

S.No.	Nutritional Content	MEAN		STANDARD DEVIATION		Value of t-test
		ZBP	NP	ZBP	NP	
1	Moisture	86.6	79.6	1.27	1.15	0.002304
2	Fat	0.33	0.10	0.02	0.015	0.000277
3	Fiber	3.8	2.6	0.010	0.1	0.000125
4	Ash	1.60	0.82	0.03	0.03	1.65005
5	Protein	2.06	2.08	0.11	0.12	0.870889
6	Carbohydrate	14.01	12.50	0.15	0.61	0.044117
7	Energy	86.61	77.33	0.53	2.08	0.012258
8	Zinc	3.58	0.33	0.13	0.02	0.000334

To determine the level of significance, all data were compared using qualitative characteristics before being examined using paired-sample t tests. With the exception of protein, all parameters (moisture, fat, fibre, ash,



carbohydrate, total energy, and zinc) have p-values less than 0.05, indicating a statistically significant difference in mean test scores between biofortified (BP) and non-biofortified (NBP) potatoes. Therefore, biofortification with micronutrients has a major effect on the nutritional value of potatoes and has the potential to be a game-changer at the local level to fight micronutrient malnutrition and hidden hunger worldwide.

CONCLUSION

In contrast to normal potato type of *Solanum tuberosum*, this study assesses the nutritional composition of *Solanum tuberosum* biofortified with zinc that indicates a justifiable improvement in nutritional levels. On the basis of the results, it can be concluded that biofortifying the crop with zinc has proven to be a successful strategy for addressing hidden hunger & micronutrient deficiencies. When compared to non-biofortified potatoes, the nutritional quality of zinc-fortified potatoes has a greater influence on increasing the nutritional content, according to the assessment. The results show an increase in total fibre moisture, carbohydrate overall zinc percentage & energy, however the levels of protein and fat do not change as a result of biofortification.

Zinc is mandatory for many bodily systems and roles, including the thyroid gland, blood coagulation, flavour and odor perception, and immunity. Zinc also supports normal expansion and advancement during pregnancy, puberty, & childhood. It is advised that women over the age of 19 take 8 mg of this daily dose, while men should take 11 mg. A little more is needed during pregnancy and nursing (11 mg and 12 mg, respectively).

Because of its affordability and accessibility, as well as the fact that it is one of the most popular non grain staple crops eaten by the maximum population of people, potatoes are a perfect crop for biofortification. Therefore, it is demonstrated by this study that biofortifying potatoes with various micronutrients can enhance their overall nutritional quality in a sustainable manner. It can also be used to reduce the ratio of concealed hunger and fight against different nutritional deficiencies.

References

1. Al-mentafji HN. Official methods of analysis of AOAC International. AOAC: Washington, DC, USA. 2005.
2. Campos H, Ortiz O. The potato crop: its agricultural, nutritional and social contribution to humankind. Springer Nature; 2020.
3. Friedman M. Potato glycoalkaloids and metabolites: roles in the plant and in the diet. *Journal of agricultural and food chemistry*. 2006 Nov 15;54(23):8655-81.
4. Jaiswal, D.K., Krishna, R., Chouhan, G.K., de Araujo Pereira, A.P., Ade, A.B., Prakash, S., Verma, S.K., Prasad, R., Yadav, J. and Verma, J.P., 2022. Bio-fortification of minerals in crops: current scenario and future prospects for sustainable agriculture and human health. *Plant Growth Regulation*, 98(1), pp.5-22.
5. Jongstra R, Mwangi MN, Burgos G, Zeder C, Low JW, Mzembe G, Liria R, Penny M, Andrade MI, Fairweather-Tait S, ZumFelde T. Iron absorption from iron-biofortified sweetpotato is higher than regular sweetpotato in Malawian women while iron absorption from regular and iron-biofortified potatoes is high in Peruvian women. *The Journal of nutrition*. 2020 Dec;150(12):3094-102.
6. Kumar P. STRATEGIES FOR AGRONOMIC BIOFORTIFICATION OF POTATO TUBERS WITH
7. ZINC. *Potato Journal*. 2022 Aug 18;49(1).
8. Laurie S, Faber M, Adebola P, Belete A. Biofortification of sweet potato for food and nutrition security in South Africa. *Food Research International*. 2015 Oct 1;76:962-70.
9. Lo Dico GM, Cammilleri G, Macaluso A, Vella A, Giangrosso G, Vazzana M. Simultaneous determination of As, Cu, Cr, Se, Sn, Cd, Sb and Pb levels in infant formulas by ICP-MS after microwave-assisted digestion: Method validation. *J. Environ. Anal. Toxicol*. 2015 Jan 1;5(328):2161-0525.
10. Mishra T, Raigond P, Thakur N, Dutt S, Singh B. Recent updates on healthy phytoconstituents in potato: a nutritional depository. *Potato Research*. 2020 Sep;63:323-43.
11. Singh B, Goutam U, Kukreja S, Siddappa S, Sood S, Sharma J, Bhardwaj V. Biofortification strategies to improve iron concentrations in potato tubers: lessons and future opportunities. *Potato Research*. 2022



Mar;65(1):51- 64

12. Thakur V, Sharma A, Sharma P, Kumar P, Shilpa. Biofortification of vegetable crops for vitamins, mineral and other quality traits. *The Journal of Horticultural Science and Biotechnology*. 2022 Jul 4;97(4):417-28.
13. White PJ, Thompson JA, Wright G, Rasmussen SK. Biofortifying Scottish potatoes with zinc. *Plant and soil*. 2017 Feb;411:151-65.
14. Yang Y, Achaerandio I, Pujolà M. Influence of the frying process and potato cultivar on acrylamide formation in French fries. *Food control*. 2016 Apr 1;62:216-23.
15. Vergara Carmona VM, CecílioFilho AB, Almeida HJ, Gratão PL. Fortification and bioavailability of zinc in potato. *Journal of the Science of Food and Agriculture*. 2019 May;99(7):3525-9.
16. Zhang, R., Zhang, W., Kang, Y. *et al.* Application of different foliar iron fertilizers for improving the photosynthesis and tuber quality of potato (*Solanumtuberosum* L.) and enhancing iron biofortification. *Chem. Biol. Technol. Agric.* 9, 79 (2022). <https://doi.org/10.1186/s40538-022-00346-8>