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RESEARCH ARTICLE

BIOFORTIFICATION OF SOLANUM TUBEROSUM: A RATIONAL APPROACH FOR NUTRITIONAL SECURITY

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Abstract

Potato also known as (Solanum tuberosum L.) is very desirable since it has a high yield potential as well as a high nutritional value. Potato is one of the richest source of micronutrients especially when consumed along with skin. With its enormous industrial demand and status as the most utilized non-grain staple crop globally, it seems to be a prime choice for biofortification. Biofortification can aid people with micronutrient deficiencies. Through biofortification, it was discovered that applying zinc fertilizer significantly improved the micronutrient concentrations.It is an affordable, reliable, and sustainable technique that has the potential to provide long-term micronutrient availability. Recommended daily allowance (RDA) of zinc for men and women over the age group of 19 yrs is 11 mg and 8 mg, respectively; while during pregnancy and breastfeeding, the RDA is higher at 11 mg and 12 mg. In contrast to data given by USDA 2019 for non biofortifiedpotato, Biofortification of potato with zinc resulted an increase in moisture, energy, carbohydrate, total fiber, and zinc % overall. The current study suggest that biofortification of potato with different micronutrients can be a sustainable approach to improve its overall nutritional quality as well as it can be a weapon to fight against various micronutrient deficiencies and decrease the ratio of hidden hunger.

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Introduction:-

In agricultural production systems, the potato (Solanumtuberosum L.) is very desirable since it has a high yield potential as well as a high nutritional value. Roughly 20 million hectares of cropland are used to raise 366 million tonnes of potatoes that are produced globally each year. The concentrations are maximum in the temperate zone of Northern Hemisphere, where the crop is grown in the summer, during the frost-free season.

Energy, vitamins, minerals, proteins, and lipids are all found in good amounts in potatoes. This versatile crop's biofortification can significantly reduce micronutrient deficiency because it contains a lot of the antioxidants like vitamin C. Another important component found in potatoes is potassium, an electrolyte that is a fantastic source of energy and helps keep our heart, muscles, and nervous system functioning. Before eating, it is frequently put

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through a culinary procedure (such as boiling, frying, and baking). The physicochemical properties of potatoes are significantly altered by the cooking processes, which also have an impact on the bioavailability and concentration of bioactive substances (Yang et al., 2016).

Though, consuming potato with peel may improve the gross intake as it is a high fiber food and majority of fiber content is present in the flesh. A potato after baking with the peel contains 2.6 mg of fiber per 100 gm serving, but one without the skin has 1.8 gm. For men and women, respectively, the daily fiber requirements are 30 to 38 gm and 21 to 25 gm of fiber, respectively. Potassium is found in abundance in potatoes; a 100 gm portion of baked potatoes containing the tuber has 0.65gm, or 18% of the recommended daily allowance for humans. Mineral potassium supports the electrolyte and fluid balance. It might also lower blood pressure. The vitamin content of potatoes is high; 11.8 mg of vitamin C and 0.25 mg of vitamin B6 in a 100 g portion of oven-baked potatoes with peels cover 20 and 10 percent of the daily requirements for humans, respectively.These micronutrients act as vital antioxidants, preventing oxidative damage to cells and reducing the risk of cancer and heart disease.

Increasing the dietary absorption of vital micronutrients through a variety of approaches could help in decreasing micronutrient shortages. These encompass crop biofortification, food fortification, medicinal supplementation, and diet diversification. Of all the strategies, crop biofortification is the most acceptable and sustainable way of combating the worldwide epidemic of hidden hunger. When potatoes are eaten with their skin on, they become much more nutritious and its fortification may be beneficial to those with deficiencies in certain micronutrients.

Potatoes appear to be an excellent option for biofortification because of its substantial industrial demand and position as the world's most consumed non-grain staple crop.In a study, vacuum impregnation (VI) with ultrasound pretreatment (US) was used to fortify entire potatoes with iron. After a cooking treatment, the physicochemical characteristics of the fortified potatoes were assessed, and the US parameters were optimized. According to the obtained results, the iron content was greatly increased by VI and US-VI treatments, by roughly 137.5 and 210%, respectively. SunActive Fe's relative bioavailability for cooked fortified potatoes was less than that of ferrous sulphate, but it had no unfavorable effects on the fortified potatoes' texture, color or sensory assessment.

Potatoes include a considerable amount of vitamin C, vitamin B6, K, Fe, and folate, according the nutritional characteristics. Potatoes that are cooked without being peeled can have more minerals and dietary fiber. Although from variety to variety, the nutritional content could differ a little. For instance, antioxidants such as polyphenols, b-carotene, carotenoids, anthocyanins, and flavonoids, are abundant in colored potatoes. Anthocyanin is one of these substances that persist in considerable quantities even after cooking.

According to a study by Jongstra et al. (2020), potatoes have far higher iron bioavailability than grains. Andre et al. (2015) demonstrated that using an in vitro gastrointestinal digestion and a CaCO2 lines-based model of the human gut, more than 70% of the iron released from the potatoes remains available at the intestinal level. Additionally, the quantity of Zn that is gastro intestinally accessible to humans from various agricultural meals is quite tiny. Because there are large amounts of organic molecules that encourage Zn absorption in potatoes and low concentrations of chemicals that inhibit the absorption of Zn, potato tubers have high Zn bioavailability. So, potatoes can provide a sizable portion for zinc and iron as per RDA.

The size, shape, color of the flesh and skin, the distribution of pigments, the type of skin, the concentration of nutrients, and biotic and abiotic stresses tolerance are all highly variable in the potato germ plasm. As a result, a diversified pool of potato gene must contain few unknown hereditary elements which could be used in biofortification programme of Solanum tuberosum. The findings collected so far show that a variety of variables, including plant type and species, environmental circumstances, iodine application technique, and iodine's chemical form, affect how effectively agricultural plants are biofortified. Studies in the field have concentrated a lot on growing several plant species in greenhouses, including lettuce, pepper, spinach and tomatoes. According to certain findings, applying iodine-enriched nutrient solution or using fertilization in greenhouse growing may be able to boost the iodine content of potato production. However, no comprehensive field study has examined the efficacy of iodine biofortification of potato tubers.

The effects of biofortification with iodine in potatoes using foliar and soil applications of iodine compounds has been evaluated and compared in a study. The study included a description of the impact of several biofortification procedures on yields and important nutritional quality aspects of potato tubers in order to evaluate the possible relevance of tested methods for the production of biofortified crop. Using the most effective conventional breeding techniques and cutting-edge biotechnology, biofortification aims to create staple crops that are rich in micronutrients. Due to the biofortified agricultural system's high level of sustainability, this strategy provides many benefits. Various biofortification methods, including agronomic biofortification, plant variety development through genetic modification and traditional breeding can increase the crop's nutritional content.

Of all micronutrients, irons (Fe) as well as zinc (Zn) deficits are extremely common. Zinc deficiency affects roughly 17% of people on Earth (Hefferon 2019; Wessells et al,. 2012). Underdeveloped nations like India experience an even worsening of this problem (Harding et al. 2018; Talsma et al. 2017). India is home to over half (50%) of the world's population for micronutrient deficiencies (Ritchie et al. 2018). Many efforts, including diet supplementation, fortification of food, and biofortification have been successful in reducing this hidden hunger during the past ten years (Allen and de Brauw 2018; Obersteiner et al. 2016; FAO 2017).

Micronutrient deficiencies have been effectively eradicated with the help of the supplementary method known as biofortification. Unfortunately, combination of two-gene model ADCS (GA-engineering)and GTPCHI, which had earlier shown promise in grain (Blancquaert et al., 2015) and tomato (Garza et al., 2007), did not work well for potatoes (Blancquaert et al., 2013). In order to increase the consumption of folates naturally and significantly lower the prevalence of anemia and NTDs, potatoes could be folate biofortified. Given the minimal range for the levels folate in contemporary cultivars of potato (3- to 4-fold approximately; Goyer and Navarre, 2007), it seems to have less ability to produce necessary improvement in folate levels. In order to combat various deficiencies and boost quality of life, micronutrient augmentation by biofortification offers an efficient alternative and seems to be well accepted by communities in need.

Objectives:-

1. To assess the nutritional content present in biofortified (Zinc) variety of Solanumtuberosum.
2. Comparison of nutrient availability between Solanumtuberosum and Zinc rich bio-fortified Solanumtuberosum.

Literature Review:-

A study's findings showed that applying iron fertilizers to the soil boosted the Iron content, quality and output of the tubers.The plants' increased levels of gas exchange parameters, chlorophyll fluorescence, and photosynthetic pigment content may have led to the rise in production, quality, and Fe content. We discovered that throughout two years of cultivation, potatoes treated with five iron fertilizer sprays produced more potato tubers and had a higher Fe content.The T5 and T3 treatments increased tuber yield more than the CK treatment, despite the T5 treatment having a substantially higher Fe concentration than the CK and other treatments. In 2020, T5 and T3 treatments increased tuber output by 33.28% and 18.85%, and in 2021, 50.74% and 54.48%, respectively, when compared to CK. T5 therapy increased Fe content by 112.64% and 54.98%, respectively, in 2020 and 2021 as compared to CK (Zhang et al., 2022).

A study explored that by applying Zn fertilizers to the leaves, seed tubers, and soil, increases the possibilities of raising the zinc (Zn) content in potato tubers. Initially zinc content was increased by around 30%after applying zinc sulfate (ZnSO4) at a rate of 5 kg Zn ha-1, split applications of ZnSO4 (19.6%), along with the application of one kilogram of zinc as zinc EDTA (17.6%) to whole tubers. Zinc sulphate (5 kg ha-1) and zinc-EDTA (1.0 kg ha-1) can be applied to the soil in single or split applications, foliar applications, and seed tubers can be soaked in zinc sulphate solution prior to planting to dramatically enhance the concentration of zinc in the tuber peels. Zinc sulphate (5 to 10 kg Zn ha-1) and Zn-EDTA (1 to 2 kilograms Zn ha-1) considerably raised the concentration of zinc in both peeled (tuber flesh) and unpeeled entire tubers during the second year of study.(Kumar P,. 2022)

The production of iron-biofortified potatoes might offer a long-term solution to the problem of micronutrient shortage. Agronomic practices, plant breeding, and transgenic methods are the top crop biofortification options. However, due to its high genetic variability for iron content, potatoes are a perfect crop for genetic methods of iron biofortification. So, in potato breeding programmes, genotypes with increased iron concentration may be employed as parental lines. Through marker-assisted selection, rapid breeding, and transgenic methods, the development of iron-biofortified potatoes could be facilitated by the screening of the genes or QTLs responsible for the high iron content in these genotypes. (Singh, B. et al,. 2022)

Eating crop plants that have higher iodine content can assist supplement a daily diet with more iodine. Evaluating the effectiveness of potato tuber biofortification with iodinewas the work's goal. A three-year field experiment was conducted to investigate the soil application of KI and the foliar application of KIO3 at concentrations up to 2.0 kg I ha1. The dry matter, iodine, biomass, yield, starch, and soluble sugar content of potato tubers were all measured. Regarding the potato yield or dry matter content, the investigated iodine application methods had no detrimental effects. Iodine applied topically and in the soil both raised the amount of that element in potato tubers without lowering their starch or sugar content. When KIO3 was sprayed foliar at a dose of 2.0 kg I ha−1, the greatest iodine biofortification efficiency was observed. 100gms of potatoes may contain enough iodine to meet up to twenty-five percent of theelement's Recommended Daily Allowance. According to the study's findings, iodine-fortified potatoes can be used as an extra Iodine source in a normal diet. (Smolen, L. et al,.2020)

It has been found that the majority of agricultural soils have low zinc (Zn) concentration that is accessible to crops, which has a considerable negative impact on productivity and public health issues. To fortify potato tubers, an efficient technique is to prime them in Zn-containing solutions. Potato tubers were primed for 12, 16, and 24 hours, respectively, at concentrations of 0, 10, 20, and 30 mg mL1 Zn to evaluate how Zn concentrations and the duration of the tuber priming period affect Zn fortification and bioavailability. To ascertain the molar ratio of PA:Zn, the dry matter, Zn content, and amount of phytic acid (PA) in tubers were all measured. The Zn concentration of the cortex of the tubers rose with a longer priming period. The solution's greater Zn content was shown to enhance the bioavailability of Zinc. (Carmona,V. et al,.2019)

Due to the progressive emergence of a widespread micronutrient shortage, it has drawn more attention in crop development. In India, potatoes are one of the most extensively produced vegetable crops. When certain micronutrients (zinc/Zn, boron/B, etc.) are applied to potato crops during the early stages of growth, the foliage significantly increases. However, as the crop grows, assimilate translocation increases, which eventually results in a higher yield. To raise both the quantity and quality of potato tubers, zinc is crucial. Zinc concentration in potato tubers can be increased up to 3–4 times by zinc loading through both soil and foliar application, which is significantly higher than that of other widely recognized crops. Ascorbic acid concentration has been shown to rise with zinc fertilization, whereas tubers' tyrosine and total phenol contents have been found to decrease, improving the quality of processing. Lastly, a viable solution to reduce widespread zinc-driven malnutrition in Asian nations may be zinc-fortified potatoes. (Sarkar, S.et al,.2019)

Materials and Method:-

Proximate Analysis

The setup for the experiment was a stratified, multiple-parameterdesign with three replications, to compare biofortified potatoes with non-biofortified to observe the changes in the nutritional content of potatoes after introducing biofortification with zinc.

Moisture Content

5.0 grams of the sample wasoven-dried at 110°C for 4 to 5hrs. After cooling indesiccators, the oven-dried sample was reweighed. This process was repeated until the weight remained constant. The loss in weight that results will be measured as a percentage of moisture content (A.O.A.C)., 2005).

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

Fat Content

5.0 grams of the sample were obtained and defatted in the Soxhlet apparatus for 8 hours using n-hexane (boiling point 68–78˚). The final extract was dried by evaporation, and the amount of crude fat was determined using the A.O.A.C. 2005 procedure.

$$\text{Fat (\%)} = \frac{\mathrm{w2-w1}}{\text{Weight of Sample}} \times 100$$

Crude Protein Content

The Micro Kejeldhal technique estimates the sample's protein content. 0.5gram of a deflated, moisture-free sample was digested at 130–140°C in concentrated sulfuric acid. Following distillation with 40% boric acid, it was titrated with 0.1N hydrochloric acid to estimate nitrogen percent. The percent nitrogen in the sample was multiplied by a factor of 6.25(A.O.A.C), 2005, to determine the protein content of the sample.

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

Total Ash

A dried crucible containing 5.0 grams of the sample will be burned on a low flame until all of the material is smokeless. It will be held at 600°C for 6.0 hours in a muffle furnace, after which it will be cooled in a desiccator and weighed. The sample will be placed in the muffle furnace once more until two successive weights are constant, at which point the % of ash will be computed. (AOAC 2005).

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

Crude Fiber Content

Crude fiber is lost upon burning the dried residue left over after the sample is digested in a solution containing 1.25% $H2SO4$ and 1.25% NaOH under particular conditions.

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

Total Carbohydrate content

The total carbohydrate content in 5.0gm of the sample calculated with help of the following calculation method (AOAC 1995)

Total CHO%= 100-(Protein%+Fiber%+ Fat%+ Ash%)

Mineral Content

The mineral, zinc, was measured using an atomic absorption spectrophotometer (Varian, AA240, Victoria, Australia) following the standard procedures as stated in AOAC (2005). A 0.5-gram food sample will first be broken down by 10 milliliters of nitric acid at 60 to 70 degrees Celsius for 20 minutes. After that, it will be broken down by HCL at 190 degrees Celsius until the solution is clear. After moving the digested sample into a 250 ml volumetric flask and adding distilled water to enhance the volume, the flask was filtered and put into an atomic absorption spectrophotometer. Samples of known strength were passed through an atomic absorption spectrophotometer to create the standard curve. Each mineral's corresponding standard curve is used to estimate the mineral concentration of an unknown sample.

Result and Discussion:-

Biofortification of Solanumtuberosum with Zinc increased Zn concentrations as well as it has shown a positive result on the productivity of the potato crop.The current study's findings indicate that applying zinc fertilizer significantly improved the micronutrient concentrations through biofortification. It is an affordable, dependable, and sustainable technique that has the potential to provide long-term micronutrient supplies. Instead of artificially boosting the nutritional content of food crops during processing, this is a new method that has enormous amounts of potential to improve their nutritional worth in the fields.

Moisture Content

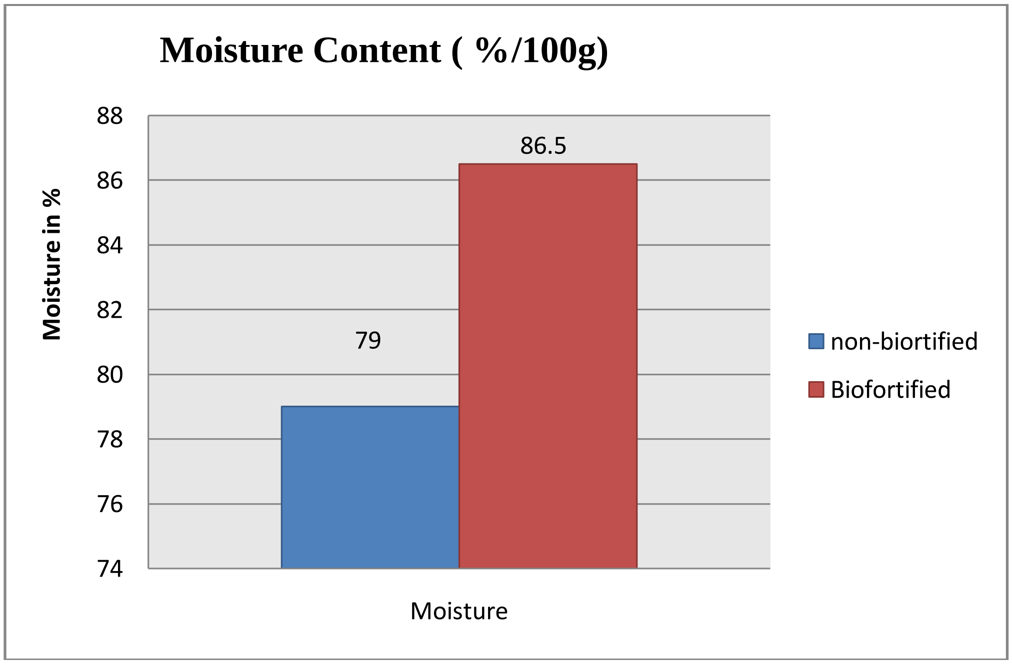

Fig 1:- Comparison of moisture content.

After comparing the moisture content of the bio-fortified potato with the normal variety, it was discovered that after the sample was oven dried at 110°C for four to five hours and reweighed, the moisture content of the bio-fortified potato was 86.5%while the normal variety's moisture content was found to 79% (USDA 2019).

Fat Content

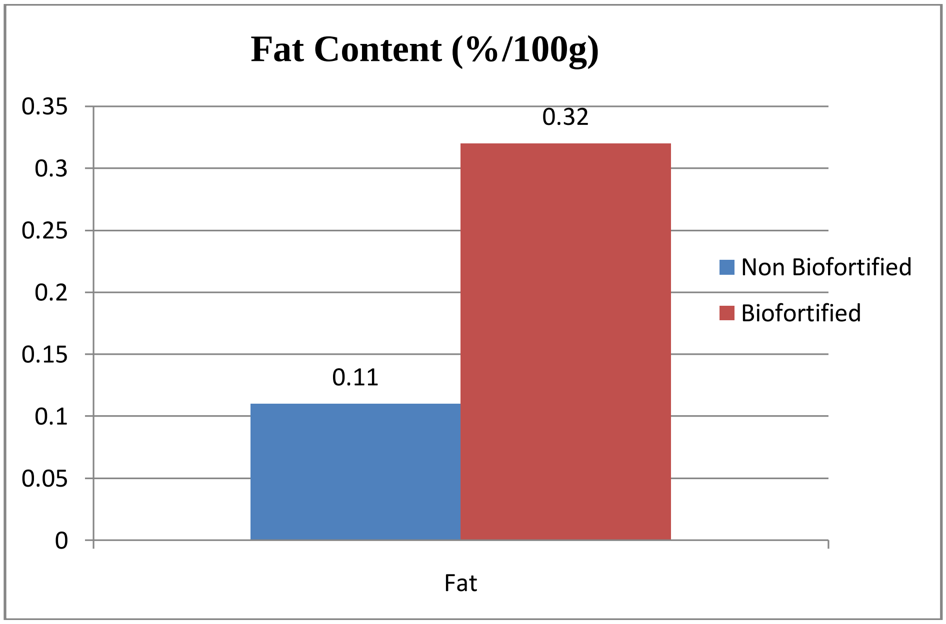

Fig 2:- Comparison of fat content.

For analyzing the fat contentof the biofortified potato,a petroleum ether organic solvent and reflux in a Soxhlet unit thimble were used, and fat was extracted from the sample by repeatedly washing (percolating) it. The results signifies that, non biofortified potato contain 0.11% (USDA 2019) in per 100 gm where as it was found to be 0.32% in per 100gm in the biofortified potato sample.

Protein Content

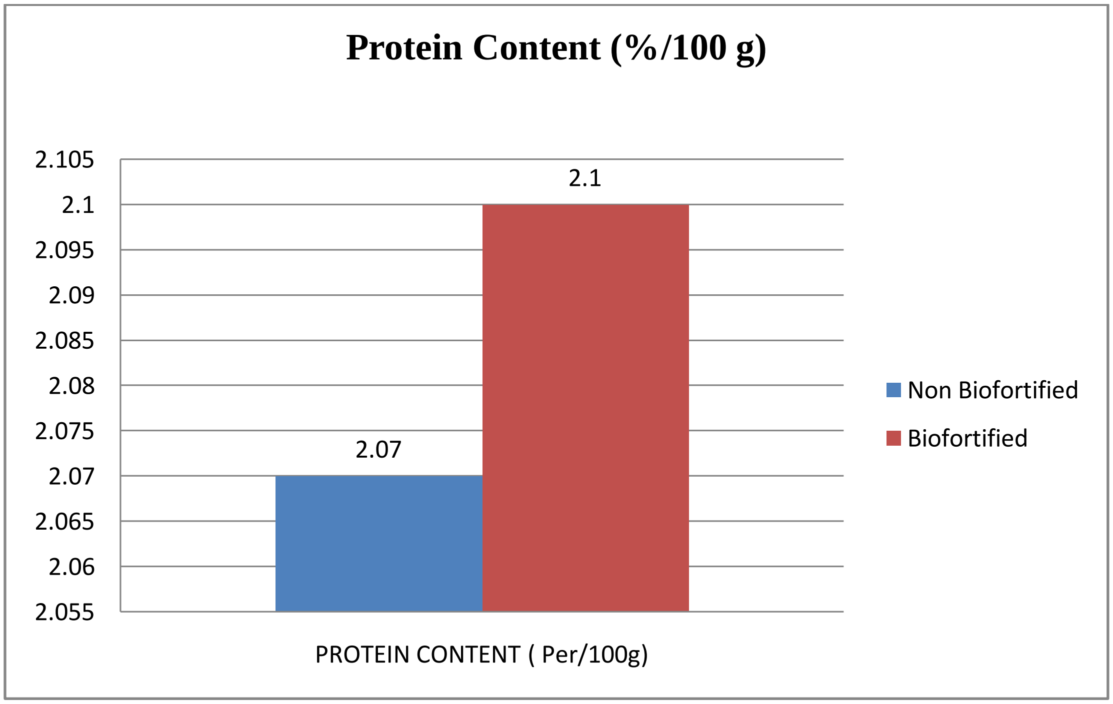

Fig 3:- Comparison of protein content.

While comparing protein content of biofortified potato it was observed no such difference as the protein content is 2.1% in biofortified variety where as on non biofortified variety it was found to be 2.07% (USDA 2019) in per 100g.

Total Ash

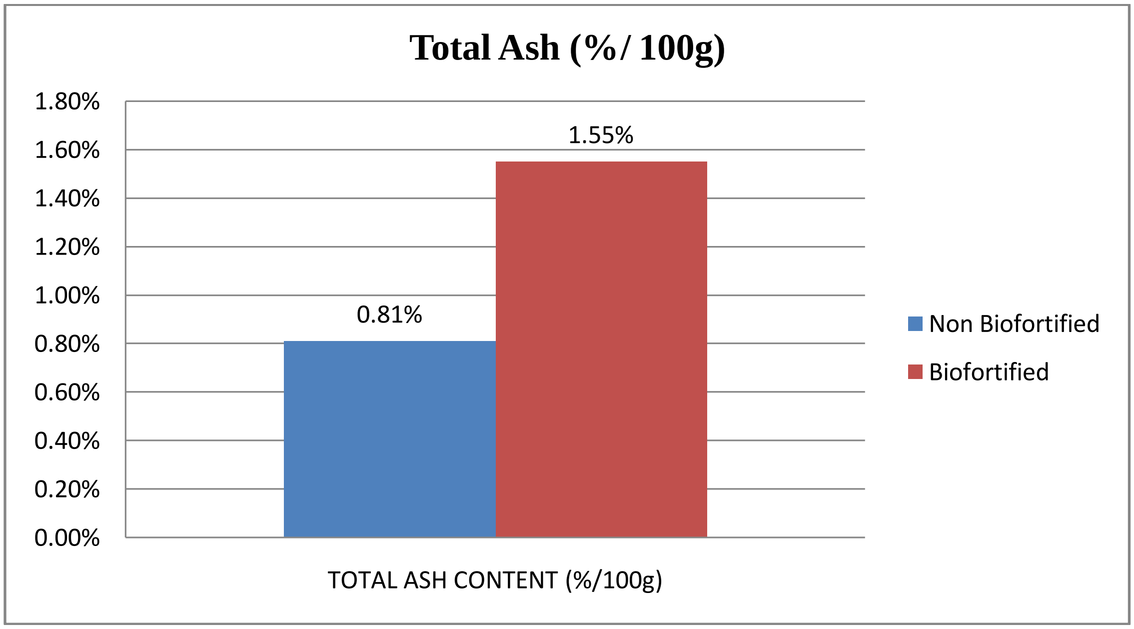

Fig 4:- Comparison of ash content.

After treating the potato with heat in muffle furnace to perform ash content analysis, it was found that the biofortified potato contains more ash percentage i.e. 1.55% where as the non biofortified potato contain 0.81%(USDA 2019) of ash content was found.

Crude Fiber Content

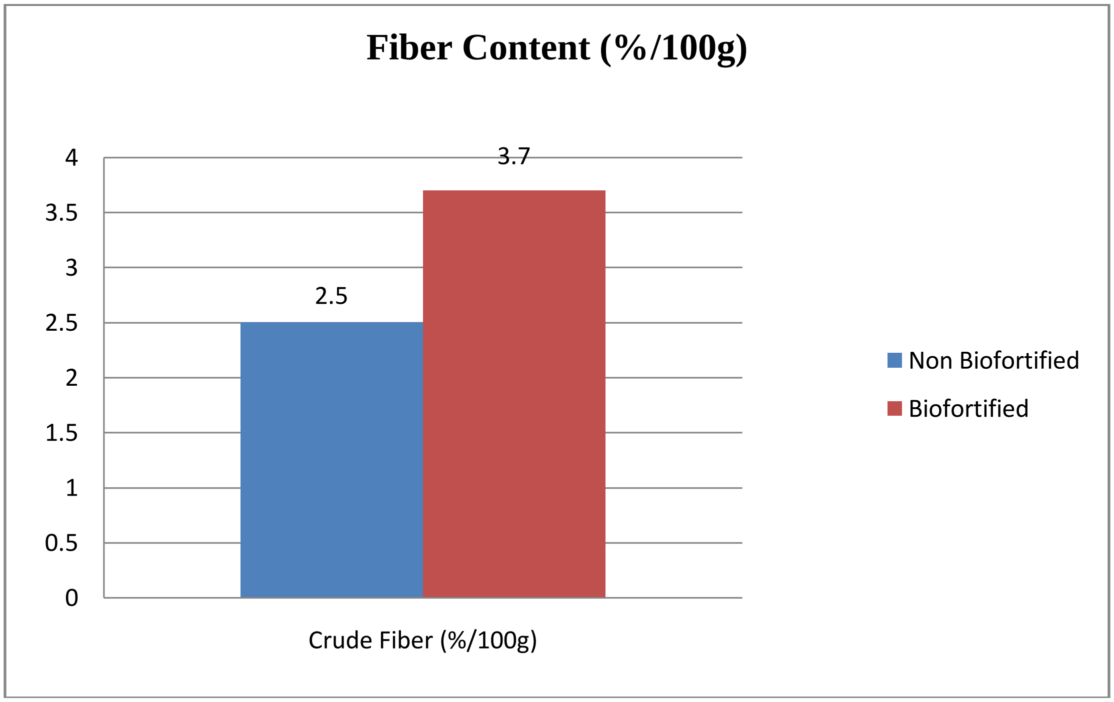

Fig 5:- Comparison of fiber content.

Biofortified variety shows a significant increase in the fiber content of potato as in non biofortified potato the fiber content range upto 2.5% (USDA 2019) in per 100g, where as in biofortified potato have the fiber content upto 3.7% in per 100g sample.

Total Carbohydrate

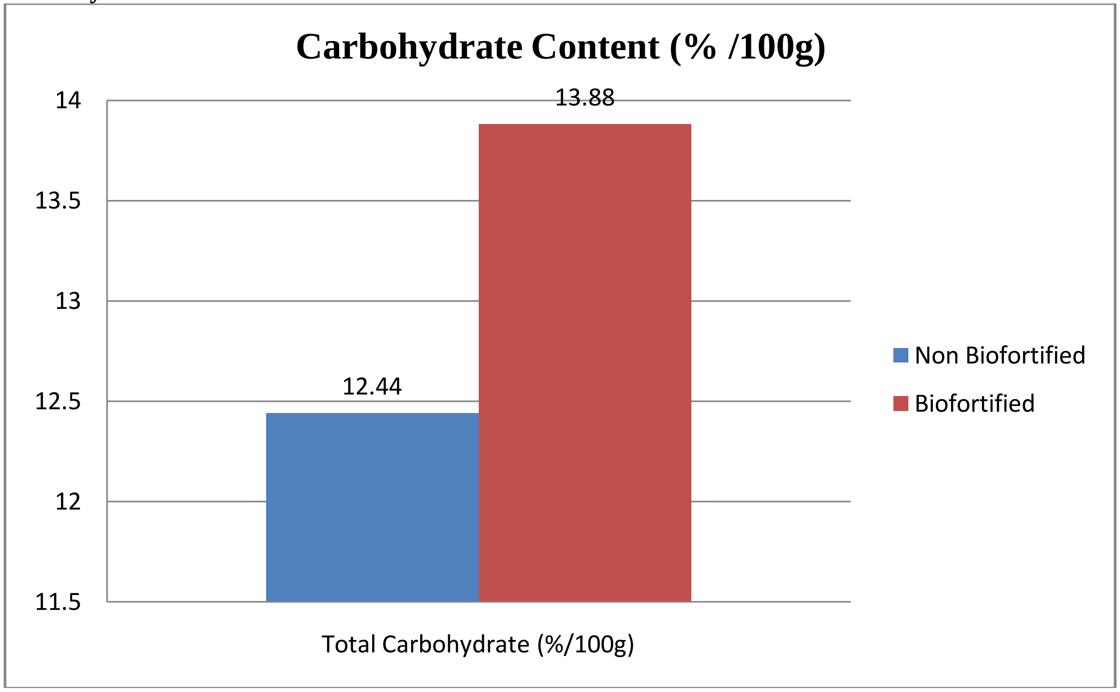

Fig 6:- Comparison of carbohydrate content.

Total carbohydrate content in biofortified potato showed slight increase in comparison to normal potato. It was found to be 13.88% per 100gram in zinc biofortified potato where as in non biofortifiedpotato, carbohydrate content is 12.44% (USDA 2019) per 100gram.

Total Energy Content

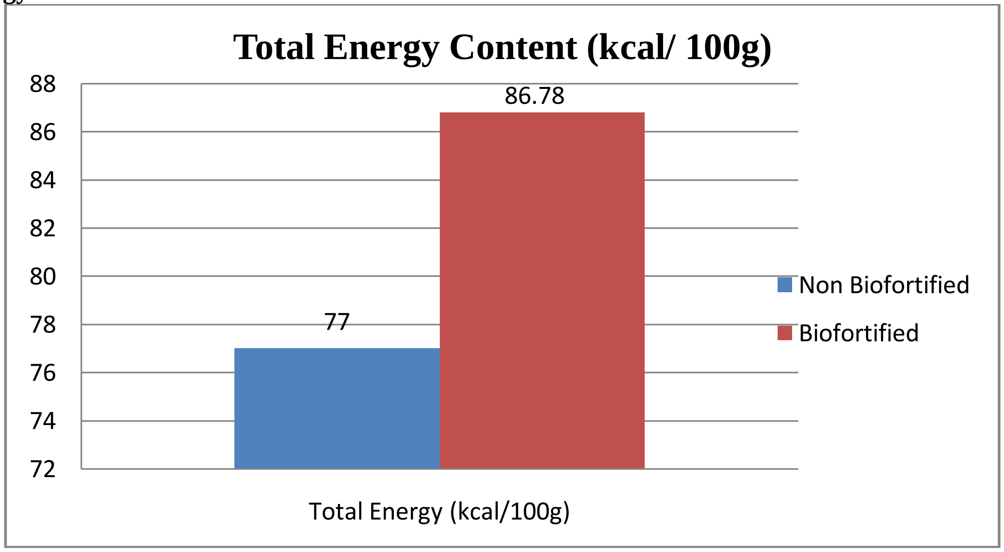

Fig 7:- Comparison of total energy content.

The potato biofortified with zinc have higher energy content in comparison to non biofortified potato. There was 77kcal (USDA 2019) energy in non biofortified potato where as in biofortified potato it was observed 86.78kcal.

Zinc Content

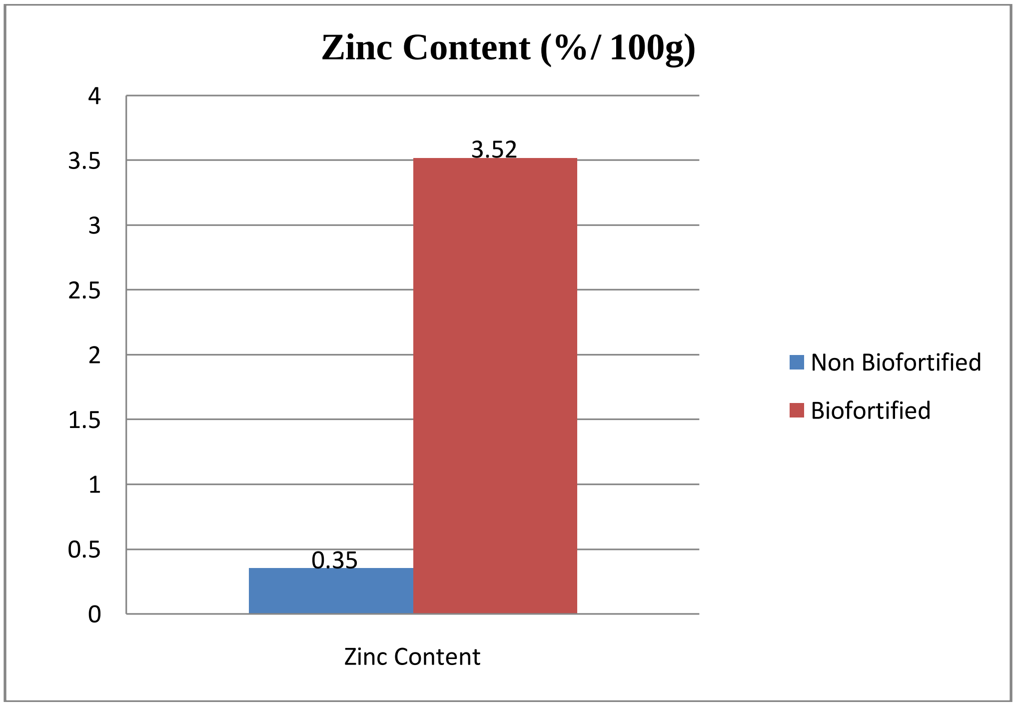

Fig 8:- Comparison of zinc content.

Biofortificationwith zinc reflects a positive impact for enhancing the Zinc content of potato. In non biofortified potato the Zn content is 0.35% (USDA 2019) whereas after biofortification with Zn it has increased upto 3.52%.

Statistical Analysis

All data were subjected to compare qualitative parameters for level of significance and then analyzed by paired-sample t tests. Since the p-value is less than 0.05 for all the parameters (moisture,fat, fiber, ash, carbohydrate, total energy and zinc) except protein, it is concluded that there is a statistically significant difference in the mean test scores between biofortified potato and non biofortified potato.

Hence, Biofortification with micronutrient shows significant impact on the nutritional aspects of potato and it can be revolutionary factor at grass root level to combat hidden hunger and micronutrient malnutrition in the world.

Table 1:-

S.No.	Parameter	Mean		SD		t-test value
		BP	NBP	BP	NBP	
1	Moisture	86.5	79	1.44	2	0.008068
2	Fat	0.32	0.11	0.02	0.01	0.001075
3	Fiber	3.7	2.5	0.01	0.2	0.02854
4	Ash	1.55	0.81	0.09	0.04	0.003204
5	Protein	2.1	2.07	0.1	0.14	0.780316
6	Carbohydrate	13.99	12.44	0.15	0.49	0.023932
7	Energy	86.78	77	0.50	2.6	0.020458
8	Zinc	3.52	0.35	0.17	0.01	0.001014

Conclusion:-

The current study evaluates the nutritional composition of zinc biofortifiedSolanumtuberosum and signifies a sustainable enhancement of nutrient content in comparison to non biofortified variety of Solanumtuberosum. Based on the obtained results it can be said that bio fortification of the crop with zinc proved to be an effective way to fight with micronutrient malnutrition and combat hidden hunger.

Many of the body's regular processes and systems depend on the mineral zinc, including thyroid gland, blood coagulation, taste and smell perception, and the immunological system. Additionally, zinc promotes healthy growth and development in childhood, adolescence, and pregnancy. Men and women over the age of 19 are recommended to consume 11 mg and 8 mg of this daily intake, respectively. Pregnancy and lactation requires slightly more at 11 mg and 12 mg, respectively.

It has been found during the assessment; the nutritional quality of Zinc biofortified potato has better impact in improving the nutritional content in comparison to non biofortified potato. Results reflect an increase in moisture, energy, carbohydrate, total fiber and over all zinc percentage where as protein, fat content does have any effect of biofortification on its values.

Potato is an ideal crop for biofortification due to its accessibility, cost effectiveness and it is one of the most consumed non grain staple crop consumed by majority of the population. So with the help of this study it is proved that biofortification of potato with different micronutrients can be a sustainable approach to improve its overall nutritional quality as well as it can be a weapon to fight against various micronutrient deficiencies and decrease the ratio of hidden hunger.

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