Effect of Quality attributes of Potato by using Biochar and NPK Fertilizers with Biozyme granules

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Abstract

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The present study, which took place at the central Research Farm of Naini Agricultural Institute, SHUATS, spanned across the years 2022-2023 and 2023-2024. Throughout this study, an experiment was meticulously conducted utilizing a variety of Kufri badhash under the Factorial Randomized Block Design (FRBD) framework. This experiment included three replications, each encompassing three levels (2.5, 5, 7.5 tha^{-1}) of Biochar and three levels (50%, 75%, 100%) of Inorganic fertilizers. Additionally, two levels (25 and 50 kg ha^{-1}) of Biozyme granules were also part of this comprehensive research design. The results obtained regarding various quality parameters in the years 2022-23 and 2023-24, such as moisture content (80 and 81 $100g^{-1}$), tuber dry matter content (20.98% and 21.96 %), starch content (13.54% and 14.12%), reducing sugar (0.28% and 0.30%), non-reducing sugar (0.35% and 0.37%), and total sugar (0.58% and 0.59%) were notably elevated with the application of T_{16}. Notably, the maximum protein content (2.07 and 2.31%), carbohydrate (14.58% and 14.85%), and total soluble solid (6.44% and 6.77%) were observed with the application of T_{18} in accordance with the recommended practices. Conversely, the minimum values were recorded for T_1, showcasing the significant impact of the application techniques on the various parameters studied.

Keywords: *Protein, Carbohydrate, Starch and Total sugars*

Introduction:

Potatoes, scientifically known as *Solanum tuberosum* L., rank among the crops with the highest consumption rates globally and hold great economic importance, acting as a fundamental dietary component for millions around the world. The critical factors determining the quality of potatoes, including but not limited to their physical characteristics, texture, flavor, nutritional content, and ability to be stored, significantly influence consumer satisfaction and market reception. As a result, the comprehension and enhancement of these quality aspects are of utmost importance for both producers and consumers. The role of potatoes in ensuring food security for the continuously growing global population has been well-documented in literature (Thiele *et al.* (2010); Scott and Sourez (2012). Noteworthy is the nutritional richness of potatoes, attributed to their substantial levels of protein, starch, fat and carbohydrates*Banu et al. (2007).* Despite its potential for high productivity, the potato plant's shallow root system often necessitates considerable nutrient input to uphold the productivity and quality of the tubers.

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Potato is indeed a highly nutritious vegetable with a composition of 16% carbohydrates, 2% proteins, 1% minerals, 0.6% dietary fiber, and minimal fat. It is wonderful to know that apart from being a great source of carbohydrates, potatoes also contain beneficial compounds like phenolic acids, ascorbic acid, and carotenoids~~.~~**(**Rai and Yadav, 2005) The versatility of potato is evident in its wide usage across various cuisines and its increasing utilization as a raw material by the processing industry. It is fascinating to learn about the diverse quality requirements for potatoes depending on the end product, emphasizing the significance of selecting the right cultivars. Ensuring that potatoes meet specific chemical composition and quality standards for processing is crucial. Particularly for chipping purposes, certain attributes such as tuber shape, size, dry matter content, and sugar levels play a vital role in achieving excellent chip ~~quality~~quality ~~.~~ (Kumar and Jhariya, 2013)

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The amelioration of potato quality characteristics by utilizing biochar, inorganic fertilizers, and Bio-zyme granules represents a multidimensional strategy that capitalizes on the combined impacts of these amendments. Biochar, derived from the pyrolysis of biomass, has been acknowledged for its capacity to enhance soil characteristics and boost agricultural productivity. Its porous composition can augment soil moisture retention, offer a habitat for soil microbes, and enhance nutrient accessibility, especially advantageous for potato cultivation. When coupled with inorganic fertilizers, biochar has the potential to decrease nutrient leaching, thus enhancing the efficiency and eco-friendliness of fertilization practices. Bio-zyme granules, categorized as a type of biofertilizer, introduce valuable enzymes and microorganisms that can further enhance soil fertility and plant development.

Research has indicated that combining biochar with inorganic fertilizers can significantly improve the quality of potatoes. This highlights the potential of biochar to serve as a carrier for organic and inorganic nutrients, making them more accessible to plants. Additionally, the adoption of biochar-infused fertilizers has been linked to supporting plant growth and providing protection by enhancing soil microflora development and mitigating various stresses that plants may face.

The utilization of biochar in conjunction with both organic and inorganic fertilizers has been demonstrated to enhance plant defenses against stressors, consequently improving the efficiency of nutrient utilization. Moreover, the integration of biochar and potassium fertilizer has been shown to enhance soil physical and chemical characteristics, thereby positively influencing the development and yield of sweet potatoes. These discoveries highlight the potential of biochar as a sustainable soil enhancement that can supplement conventional fertilization techniques. Implementation of biochar and inorganic fertilizers alongside Bio-zyme granules necessitates thoughtful consideration of the specific requirements of the potato crop and the soil attributes. Precision in the application rate and timing is essential to ensure the potatoes receive the appropriate nutrients at the optimal time. Farmers must also consider the environmental repercussions of inorganic fertilizers and endeavor to use them in a manner that mitigates any adverse impacts.

This investigation aims to explore the synergistic implications of incorporating biochar, Inorganic fertilizers and Ascophyllum nodosum on the characteristics of potatoes. By assessing factors like potato yield, size distribution, nutritional content, and post-harvest durability, our goal is to clarify the collective influence of these agricultural inputs on potato quality. Through an extensive examination, this study strives to offer valuable insights into sustainable agricultural practices that maximize potato output while preserving environmental sustainability and improving food security.

Materials and Methods:

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During the *Rabi* season of 2022--2023 and 2023-24, a potato experiment involving three distinct factors was initiated at the central experimental farm of the Department of Soil Science and Agricultural Chemistry, located at the Naini Agricultural Institute, SHUATS, India. The experiment was meticulously arranged into three replications, measuring 3 meters in width and 3 meters in length, containing a total of 5 rows within the potato plots. The seed tubers, characterized by a diameter falling within the range of 35-55mm, were meticulously planted following the prescribed norm of 2.5-3.0 t ha^{-1}. A spacing of 20 cm was maintained between tubers, while the distance between rows was set at 60 cm. The soil of the experimental farm is Inceptisol, according to the World Reference Base classification (FAO, 2014), and the texture of the soil is sandy loam soil. Nutrient management practices were **T_1-** Biochar@2.5 t ha^{-1} + RDF @50% + Bio-zyme @25 kg ha^{-1}**, T_2-** Biochar@2.5 t ha^{-1} + RDF @50% + Bio-zyme @50 kg ha^{-1}**, T_3-** Biochar@2.5 t ha^{-1} + RDF @75% + Bio-zyme @25 kg ha^{-1}**, T_4-** Biochar@2.5 t ha^{-1} + RDF @75%+ Bio-zyme @50 kg ha^{-1}**, T_5-** Biochar@2.5 t ha^{-1} + RDF @100% + Bio-zyme @25 kg ha^{-1}**, T_6-** Biochar@2.5 t ha^{-1} + RDF @100% + Bio-zyme @50 kg ha^{-1}**, T_7-** Biochar@5 t ha^{-1} + RDF @50% + Bio-zyme @25 kg ha^{-1}**, T_8-** Biochar@5 t ha^{-1} + RDF @50% + Bio-zyme @50 kg ha^{-1}**, T_9-** Biochar@5 t ha^{-1} + RDF @75% + Bio-zyme @25 kg ha^{-1}**, T_{10}-** Biochar@5 t ha^{-1} + RDF @75% + Bio-zyme @50 kg ha^{-1}**, T_{11}-** Biochar@5 t ha^{-1} + RDF @100% + Bio-zyme @25 kg ha^{-1}**, T_{12}-** Biochar@5 t ha^{-1} + RDF @100% + Bio-zyme @50 kg ha^{-1}**, T_{13}-** Biochar@7.5 t ha^{-1} + RDF @50% + Bio-zyme @25 kg ha^{-1}**, T_{14}-** Biochar@7.5 t ha^{-1} + RDF @50% + Bio-zyme @50 kg ha^{-1}**,T_{15}-** Biochar@7.5 t ha^{-1} + RDF @75% + Bio-zyme @25 kg ha^{-1}**, T_{16}-** Biochar@7.5 t ha^{-1} + RDF @75% + Bio-zyme @50 kg ha^{-1}**, T_{17}-** Biochar@7.5 t ha^{-1} + RDF @100% + Bio-zyme @25 kg ha^{-1}**, T_{18}-** Biochar@7.5 t ha^{-1} + RDF @100% + Bio-zyme @50 kg ha^{-1}. All the experimental plants were provided same cultural practices i.e., fertilizer application, irrigation, gap filling, earthing-up, weed management, haulm cutting and plant protection measures during whole period of investigation. Under quality parameters of potato tubers, the observations i.e., protein content in tuber (%), tuber dry matter content (%), specific gravity, starch (%), total soluble solid (%), carbohydrate (%), and total sugar (%).

Results and Discussion

Protein content in tuber

The results displayed a lack of significant variance among all the years (Table 1). The data indicated that during the initial and second years, the highest protein content (%) in tubers (2.07 and 2.31) was observed in treatment T18 (Biochar@7.5 t ha-1 + RDF @75% + Bio-zyme @50 kg ha-1), while the lowest protein content (%) in tubers (1.36, and 1.60 %) was noted in treatment T1 (Biochar@2.5 t ha-1 + RDF @50% + Bio-zyme @25 kg ha-1) during the first and second-year averages, respectively. The rise in protein content was achieved with an escalation in the levels of additives and fertilizers in this research. The combination of biochar, synthetic fertilizers, and bio-enzyme granules plays a crucial role in boosting the protein content in potato tubers by impacting various soil characteristics and plant biochemical processes. When combined with synthetic fertilizers, biochar can notably boost the accessibility of vital nutrients such as nitrogen, phosphorus, and potassium, which are crucial for the production of amino acids - the fundamental components of proteins in plants. Influence of N, P, and K in nutrient absorption and their function in the breakdown of polysaccharides, transformation of organic acids into amino acids, and increased conversion of insoluble starch into amino acids leading to protein formation. The outcomes are consistent with the study conducted by Mona *et al.* (2012), which found that the protein content of potato tubers increased with the rise in N, P, and K fertilizer levels.

Dry Matter content in tuber

The dry matter content (%) of tubers was documented for various treatments as shown in Table 1. It is evident from the results that there was no significant difference in the data when different amounts of fertilizer were applied in both years. Treatment T16 exhibited the highest dry matter content (20.98%and 21.96%, respectively) among the various fertilizer treatments in the first and second years. Conversely, the lowest dry matter content (15.61%and 16.59%), respectively in the first and second years) was observed in T1. The primary function of biochar, along with inorganic fertilizers and bio-zyme granules, is to improve the growing conditions for potatoes. This includes enhancing soil quality, increasing nutrient availability, and stimulating beneficial microbial action. These practices can lead to higher dry matter content in potato tubers, indicating better quality produce that is resilient to storage and processing conditions. As the demand for sustainable agriculture rises, incorporating biochar and bio-zyme granules with inorganic fertilizers offers a promising approach to meet this demand while ensuring top-notch potato yield. This ultimately leads to higher accumulation of photo assimilates in the tubers. Kavvadias *et al.* (2012) also highlighted the importance of dry matter content in potatoes.

Total Sugar in Tuber

Data of all treatments for total sugar (%) did not show significant differences during both years (Table 1). The data related to total sugar indicated non-significant variations. Specifically, treatment T16 exhibited the highest total sugar content (0.58%and 0.59%) in the first year, second year, and overall mean, respectively. Conversely, the lowest values (0.38% and 0.39%) were recorded for T1 in the first and second years. This increase in total sugar content may be attributed to various factors such as the hydrolysis of polysaccharides, conversion of organic acids into soluble sugars, and improved solubilization of insoluble starch, facilitated by higher levels of amendment and fertilizer. Jatav *et al.* (2017) noted that total sugar content tends to increase with higher fertilizer levels. Similarly, Mona *et al.* (2012) reported a similar observation.

Starch Content in Tuber

Data in Table 2 presents the impact of various treatments on the starch contents (%) in potato tubers. The data clearly indicates a notable difference in starch content (%) as a result of applying biochar and fertilizer. Among the treatments in the first and second years, T16 showed the highest starch content (13.54% and 14.12%, respectively), followed by T18 in both years. Conversely, the lowest starch content was found in treatment T1 (8.96% and 9.54%, respectively, in the first and second years). The higher starch content achieved with the application of biochar 7.5 t/ha and a greater dosage of NPK fertilizers with biozyme granules might be attributed to the positive response of the crop to essential nutrients such as nitrogen, phosphorus, and potash. Nutrients play a crucial role in the process of photosynthesis, the translocation of photosynthates from leaves to tubers, and the subsequent synthesis of starch through the activation of the starch synthase enzyme (Kumar et al., 2008). These findings align closely with those ofMona *et al.* (2012), who also noted a significant increase in starch content with higher fertilizer application. Similar outcomes were observed by El-Hadidi *et al.* (2017), Mankotia *et al.* (2020), and Gautam *et al.* (2012).

Total Soluble solid (%)content in tuber

The data on total soluble solid (%) were carefully collected post-harvest and subjected to thorough statistical analysis (Table 2). Upon reviewing the data, it was found that the total soluble solid (%) was significantly affected by the various fertilizer treatments applied in this research. Notably, among the different treatments, the highest total soluble solid (6.44 and 6.72%) was observed in treatment T18 during the initial and subsequent years. Conversely, the lowest total soluble solid (5.38 and5.71%) was noted in T1 during the corresponding years. Throughout the study, it became evident that an increase in nutrient application led to a rise in total soluble solid levels. This escalation in total soluble solids could be attributed to the breakdown of polysaccharides, the transformation of organic acids into soluble sugars, and the conversion of insoluble starch into soluble form, all of which are facilitated by higher fertilizer levels. Jatav *et al.* (2017) also highlighted that total soluble solid in tubers increased with nitrogen levels up to 150kg/ha. Similarly, El Latif*et al.* (2011)reported a similar trend in total soluble solid content, aligning with these findings.

Carbohydrate (%) content in tuber

Upon careful examination of the data presented in Table 2, it becomes evident that there is a significant difference in the carbohydrate levels between the first and second years of the study. Specifically, the analysis of various treatments revealed that the potato tubers exhibited varying carbohydrate concentrations, with the highest levels (14.58%and 14.81%) observed in treatment T18 during both the initial and subsequent years. Conversely, the lowest carbohydrate content (10.87%and 11.14%) was noted in treatment T1 for the same respective periods. It is noteworthy that the study indicates a direct correlation between the application of higher levels of fertilizer and increased carbohydrate content in the tubers. This phenomenon can be attributed to the enhanced supply of essential nutrients such as nitrogen, phosphorus, and potassium to the plants, leading to improved nutrient absorption and subsequently, a more efficient synthesis of carbohydrates, ultimately enhancing the quality of the tubers. As supported by the findings of Bashir and Qureshi (2014), there is a clear trend of escalating carbohydrate levels with higher nitrogen input. These results are in alignment with Haddad *et al.* (2016), further strengthening the validity and reliability of the present study.

Conclusion

In conclusion, the results obtained for different quality parameters in the years 2022-23 and 2023-24, such as tuber dry matter content (20.98% and 21.96%), starch content (13.54% and 14.12%), and total sugar (0.58% and 0.59%) show a significant increase with the use of T16. It is truly remarkable to witness the substantial improvement in quality parameters due to the adoption of T16, highlighting a notable enhancement in the overall produce quality. This improvement proves the effectiveness of T16 in the cultivation process and emphasizes its positive impact on the final product. The highest protein content (2.07 and 2.31%), carbohydrate (14.58% and 14.85%), and total soluble solid (6.44% and 6.77%) were achieved with T18 following recommended practices. The results from T18 implementation are genuinely outstanding, indicating the potential to attain optimal levels of protein, carbohydrates, and soluble solids in the produce. This stresses the significance of adhering to recommended practices and employing suitable techniques to enhance the nutritional value and quality of crops. The findings clearly illustrate the positive outcomes resulting from diligent adherence to best practices. On the other hand, the lowest values were recorded for T1, highlighting the considerable influence of application techniques on the studied parameters. While recognizing the lower values linked to T1 is important, it also serves as a valuable learning opportunity to comprehend the effects of different application techniques on quality parameters. This emphasizes the idea that careful consideration and correct implementation of agricultural practices can lead to marked improvements in produce quality. The results emphasize the necessity of continuous assessment and adaptation to achieve optimal outcomes in crop cultivation.

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Table 1. Total Sugar in tuber, Protein content in tuber (%) and tuber dry matter content (%)influenced by different levels of factors during consecutive years, from 2022-23 to 2023-24.

Treatments	Total Sugar (%)		Protein in tuber (%)		Dry matter content tuber (%)	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
T_1	0.38	0.39	1.36	1.60	15.61	16.59
T_2	0.39	0.4	1.39	1.63	15.83	16.81
T_3	0.40	0.41	1.41	1.65	15.88	16.86
T_4	0.41	0.42	1.51	1.75	16.30	17.28
T_5	0.43	0.44	1.46	1.70	16.62	17.60
T_6	0.45	0.46	1.59	1.83	16.88	17.86
T_7	0.46	0.47	1.66	1.90	17.15	18.13
T_8	0.49	0.5	1.66	1.90	17.78	18.76
T_9	0.53	0.54	1.74	1.98	17.88	18.86
T_{10}	0.54	0.55	1.76	2.00	17.97	18.95
T_{11}	0.54	0.55	1.68	1.92	18.02	19.00
T_{12}	0.55	0.56	1.78	2.02	18.72	19.70
T_{13}	0.56	0.57	1.81	2.05	18.99	19.97
T_{14}	0.55	0.56	1.85	2.09	19.13	20.11
T_{15}	0.56	0.57	1.90	2.14	19.82	20.80
T_{16}	0.58	0.59	1.95	2.19	20.98	21.96
T_{17}	0.56	0.57	2.05	2.29	20.01	20.99
T_{18}	0.57	0.58	2.07	2.31	20.88	21.86

Table 2. Starch content in tuber,TSS content in tuber (%) and Carbohydrate (%)influenced by different levels of factors during consecutive years, from 2022-23 to 2023-24.

Treatments	Starch in tuber (%)		TSS in tuber (%)		Carbohydrate (%)	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
T_1	8.96	9.54	5.38	5.71	10.87	11.14
T_2	8.99	9.57	5.31	5.64	10.92	11.19
T_3	9.15	9.73	5.76	6.09	11.10	11.37
T_4	9.26	9.84	5.77	6.10	11.18	11.45
T_5	9.50	10.08	5.82	6.15	11.20	11.47
T_6	9.98	10.56	5.87	6.20	11.92	12.19
T_7	10.01	10.59	5.98	6.31	11.97	12.24
T_8	10.21	10.79	6.01	6.34	12.40	12.67
T_9	10.82	11.4	6.10	6.43	12.46	12.73
T_{10}	11.07	11.65	6.08	6.41	12.66	12.93
T_{11}	11.33	11.91	6.15	6.48	12.74	13.01
T_{12}	11.54	12.12	6.21	6.54	12.78	13.05
T_{13}	11.81	12.39	6.25	6.58	12.88	13.15
T_{14}	12.15	12.73	6.32	6.65	13.40	13.67
T_{15}	12.64	13.22	6.40	6.73	13.68	13.95
T_{16}	13.54	14.12	6.42	6.75	13.97	14.24
T_{17}	12.72	13.30	6.41	6.74	14.40	14.67
T_{18}	13.01	13.59	6.44	6.77	14.58	14.85