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A holistic overview of research on the impact of farming techniques and processing steps on the nutritional quality of food crops.

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Abstract
Crop nutritional quality can be impacted by a number of factors, either directly or indirectly. These include the crop and cultivar; postharvest handling and storage; fertilizer applications and cultural practices; weather and climatic factors, such as temperature, rainfall, and light intensity; soil characteristics, such as pH, available nutrients, texture, organic matter content, and soil-water relationships. In order to assess how farming systems, processing, and post-harvest methods affect the nutritional quality of food crops, this paper examines many studies. The nutritional value of field crops, fruits, and vegetables is influenced by fertilizer, cultural management techniques, and specific environmental conditions. The nutritional quality of crops cultivated using organic or chemical fertilizers is examined in earlier studies. These studies have frequently produced conflicting findings about agricultural yields as well as the mineral and vitamin contents of crops. Regarding food safety and quality and their effects on human and animal health, additional elements are examined, including ripeness at harvest, postharvest handling and storage, anti-nutritive components, and residues of chemical fertilizers and pesticides. Although production and other quality characteristics may differ, research indicates that organic farming frequently increases bioactive substances like phenolics and antioxidants. Nutrient availability is also greatly impacted by processing techniques like milling and storage. In order to guarantee food security and quality, the assessment emphasizes the necessity of integrated strategies that combine ecological farming with efficient processing.

Keywords: Nutritional quality; Organic farming system; Conventional farming system; Post-harvest; Processing

Introduction
A better and healthier lifestyle for everyone requires more nutrition and complicated components like proteins and amino acids. They are essential to the development of both adults and children. Since plants are the main source of the nutrients that humans require, people rely on them to supply these elements. A human's diet must have a variety of nutrients in order for the body to function properly and for him to live a healthy life. Protein, fat, carbohydrates, vitamins, and minerals are some of these nutrients. The body needs a certain amount of each nutrient in order to develop, maintain, and perform different tasks. Directly and indirectly, a number of these nutrients are provided by plants. Because of this, a plant that is high in nutrients is more important for human consumption in regular meals. The entire regional and national food supply, as well as any gaps between supply and demand, are referred to as "food security." Given that agriculture is the primary source of income and has the capacity to significantly increase food and nutritional security (Foster, 1992). Currently, Indian farmers have placed less emphasis on improving nutrition outcomes in favor of increasing crop and animal resource production, productivity, and profitability. However, the issue of malnutrition cannot be solved by merely increasing agricultural output. Therefore, it is necessary to implement the nutrition-enriched agriculture intervention with a sufficient feeding system for the people. Improving food's nutritional quality, which includes essential nutrients like vitamins A, C, and E, minerals like iron, zinc, and calcium, and bioactive substances like antioxidants, is a critical component of sustainable farming. By preventing malnutrition, increasing immunity, and lowering the risk of chronic illnesses, nutrient-dense foods are essential for advancing public health (Mason *et al.*, 2019) [29].

Addressing the twin issues of satisfying dietary demands and preserving environmental health requires an understanding of how various farming strategies affect the nutrient content of crops and animal products. Crop rotation, organic farming, and agroecology are examples of sustainable agricultural methods that present viable approaches to improve the nutrient density of food, hence promoting public health and food security.

In this regard, a relevant topic that emerges is how India's population's nutritional consumption has been affected by the country's shifting dietary patterns. The nutritional status of the rural poor has been reported to have deteriorated due to the decrease in per-capita consumption of cereals, especially coarse cereals (Kumar *et al*., 2007b; Chand and Kumar, 2002) [23 10]. This suggests that, overall, increased consumption of calories from milk, fruits, vegetables, meat, etc. has somewhat offset the decrease in calorie intake from cereals. The National Family Health Survey (NFHS) III (2005-06) provided important information about the nation's sample families' nutritional and health conditions. Based on estimates, approximately 40.4% of children under three are underweight and 44.9% are stunted; 36% of adult women and 34% of adult men have chronic energy deficiency; and 56% of women and 79% of children are anemic (IIPS and Macro International, 2007). Between 2000 and 2016, the percentage of undernourished people decreased from 17% to 15.2%, the percentage of wasted children over the age of five decreased from 17.1 to 15.1%, the percentage of stunted children under the age of five decreased from 54.2 to 38.7%, and the percentage of under-five deaths decreased from 9.1 to 4.8%. However, among the 118 nations included in the 2016 Global Hunger Index, India's ranking fell from 83 to 97 over the previous 15 years. India's rating is now worse than it was fifteen years ago, and the country's food security situation has reached a concerning level.

The goal of the Green Revolution was to increase food availability, and following it, India was able to satisfy its own food demands. However, it had a negative effect on conventional food crop kinds, leading to widespread issues with micronutrient deficiencies, such as those found in Indian soils and around the world. Due to a change in the grain mineral density of staple foods, the increase in calorie intake was followed by a decrease in dietary diversity, which had detrimental effects on human health, including obesity and chronic diseases. In fact, diet-related illnesses are non-communicable diseases (NCDs) that are made worse by undernutrition and malnutrition, both of which are brought on by soil degradation and its consequences. Additionally, the proportion of all food grain imports has dropped. Agricultural methods and food production systems have changed significantly since the 1950s. In order to meet the demands of a fast growing global population, agriculture has been intensified in industrialized countries and expanded in emerging regions during this period (Valenzuela, 2016, Wolff, 2004). Therefore, a key feature of contemporary agriculture is its focus on particular results, including maximizing crop quantity to guarantee food supply and using biofortification to address pervasive nutrient deficiencies (Dhaliwal *et al*., 2022, Reeve *et al*., 2016, Valenzuela, 2016). Nevertheless, the systemic and environmental effects of this strategy have become a major worry despite the observable advancements made. There is substantial evidence that current agricultural systems are a major cause of climate change and biodiversity loss, posing a serious threat to the health of the planet (Maitima *et al*., 2009, Perrings and Halkos, 2015, Raven and Wagner, 2021). As a result, long-term global food security and agricultural sustainability are gravely threatened by this environmental degradation. However, Swaminathan realized that the Green Revolution would only offer a temporary fix and that, in order to achieve productivity indefinitely without causing ecological and social harm, the cultivation system needed to be changed into an eco-friendly resource-poor small and marginal farmer-friendly, sustainable system (Swaminathan, 2008).

The nutritional value of crops is also greatly impacted by contemporary agriculture methods. Changes in crop biochemical composition are closely linked to these cultivation techniques (Coelho *et al*., 2018, Devlet, 2021). Since the middle of the 20th century, nutritional quality has significantly declined, according to numerous research (Coelho *et al*., 2018, Devlet, 2021, Hasanaliyeva *et al*., 2023, Tscharntke *et al*., 2012). For instance, the levels of vital minerals in typical Mediterranean foods like wheat and barley are noticeably lower. Zinc, selenium, and phytochemicals are among them (Hasanaliyeva *et al*., 2023). Beneficial component concentrations are reduced by methods like flood irrigation, high chemical input, and extensive tillage. Concurrently, these actions may also lead to increased levels of harmful substances. Cereals, fruits, vegetables, dairy products, and meats from small ruminants and fish have all been found to be contaminated (Coelho *et al*., 2018, Devlet, 2021, Hasanaliyeva *et al*., 2023).

Growing techniques, harvesting time and type, postharvest treatment, storage management, and transportation methods are some of the aspects that influence the overall quality of grain (Brooker *et al*., 1992). The type or variety of grain that a farmer chooses can affect the quality of the grain. Climate and soil conditions during the growth season, cultivation methods, harvest weather, and harvesting methods will all have an impact. Grain producers can use their produce for a variety of purposes, such as selling it, using it as seed, or feeding their family or livestock. Grain trading can encompass a wide range of final applications. The uniformity of supply that comes with using grain standards would be advantageous to a number of end users, including the commercial producers of food products including beverages, baked goods, and animal feed, as well as the purchasers of food security reserves. Therefore, from the perspective of the consumer, grain quality is crucial. Therefore, when choosing plants to separate generations, grain quality characteristics must be taken into consideration. By removing the grain's nutrient-rich outer layers, milling lowers the flour's nutritious content (Oghbaei and Prakash, 2016). The protein content, particularly the amount of gluten proteins and the characteristics of the starch granules, are influenced by the size and quality of the grain during harvest, which in turn affects the flour yield and quality (Angelidis *et al*., 2016; Baasandorj *et al*., 2015).

Therefore, in order to overcome yield-restricting biotic and abiotic factors and produce high-quality, sufficient amounts of nutrient-rich foods to meet the demand for nutrient-rich foods, it is imperative that the agricultural and related sectors adopt improved cultivation practices. Additionally, technological intervention is required to minimize post-harvest losses.

Effect of chemical fertilizer application on composition

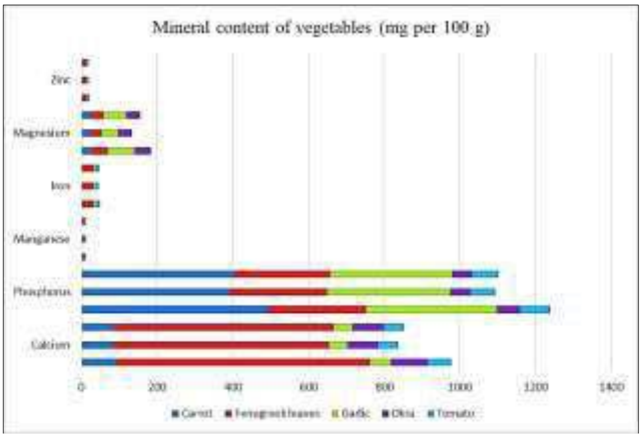
Applying fertilizer to the soil and/or plants to improve crop growth involves providing nutrients like potassium, phosphorus, and nitrogen. Fertilizers are typically applied to improve yield and address nutritional deficiencies (Gumus *et al*., 2024; Mohr and Schopfer, 2012). According to El Naqma *et al*. (2024), Gumus *et al*. (2024), and G. Martirosyan *et al*. (2024), the type and quantity of fertilizer applied can change nutrient uptake and impact the composition of molecules like proteins, vitamins, and minerals in plant tissues. The application of micronutrient fertilizers, such as zinc, boron, iron, and manganese, to address trace element shortages has also been documented in a number of studies (Alves *et al*., 2020, 2020; Bashir *et al*., 2023; Liu *et al*., 2024; Maqbool *et al*., 2023). In order to emphasize possible synergistic effects, organic fertilizers and mixtures of organic and inorganic inputs were also studied (H. Martirosyan *et al*., 2024; Nikoogoftar-Sedghi *et al*., 2024; Yn *et al*., 2021). Certain research revealed nutrient reductions under certain situations, despite the fact that several interventions improved crop composition. For instance, in crops like teff, excessive nitrogen treatment decreased carbohydrate content by at least 15% as metabolic activity moved toward protein synthesis (Dagnaw *et al*., 2024; Liang *et al*., 2024; Sun *et al*., 2024; Szatkowski *et al*., 2024). Increased protein accumulation at the expense of carbohydrates results from nitrogen's promotion of nitrate absorption, which is transformed into amino acids through the glutamine synthetase-glutamate synthase pathway (Britz *et al*., 2023; Cwalina-Ambroziak *et al*., 2022; Szatkowski *et al*., 2024). Similarly, due to competitive interactions in the soil, excessive phosphorus treatment decreased zinc bioavailability by over 18% (Ali *et al*., 2024; El Naqma *et al*., 2024; Gomes *et al*., 2021). The precipitation of phosphorus with zinc in calcareous soils causes an antagonistic relationship, which restricts plant uptake (Bashir *et al*., 2023; El Naqma *et al*., 2024).

Comparative effect of conventional and organic practices on composition

Organic agriculture is a special kind of production management that supports and improves the health of the agroecosystem, including soil biological activity, biological cycles, and biodiversity. By definition, organic agriculture does not utilize conventional fertilizers, synthetic pesticides, pharmaceuticals, or genetically modified plants or animals (Roitner-Schobesberger *et al*., 2008). The heavy reliance on nonrenewable resources, decreased biodiversity, contaminated water resources, chemical residues in food, soil degradation, and health risks to farm workers handling pesticides are all consequences of conventional agriculture's use of chemical fertilizers, synthetic pesticides, growth regulators, etc. These factors raise concerns about the sustainability of the conventional farming system (Zhu *et al*., 2000; Reganold *et al*., 2006). Because they included more total phenolic compounds, organic cultures of lettuce, arugula, and common chicory crops had higher antioxidant activity, according to a study by Arbos *et al*. (2010). Consuming more polyphenols and antioxidants has been linked to a lower chance of developing chronic illnesses like heart disease, neurological disorders, and some forms of cancer (Baudry *et al*., 2018). Similarly, the organic fruit farming approach promoted a rise in postharvest quality, resulting in fruits with greater amounts of sugars, total carotenoids, ascorbic acid, and folates, according to studies by Maciel *et al*. (2011) and Kohn *et al*. (2015) with mango and melon, respectively. Additionally, the fruits had superior phytochemical quality and were more balanced. Polyphenol, flavonol, and lutein levels were found to be greater in organic food when wheat, barley, potatoes, carrots, and onions grown in conventional systems were compared. These substances belong to a class of metabolites that have been linked to antioxidant qualities as well as neuroprotective, cardioprotective, and chemopreventive effects. They have also been linked to lower rates of cancer, gastrointestinal disorders, liver diseases, atherosclerosis, obesity, and allergies (Skwarlo-Sonta *et al*., 2011; Rodríguezrednicka-Tober *et al*., 2013). The majority of organically grown crops have higher dry matter, sugar content, titratable acidity, protective substances, antioxidant potential, flavonoid and total phenol levels, and content of elements like Ca, Mg, P, Zn, and Fe than conventionally grown crops, according to a number of earlier studies [Brandt, K *et al*., 2011; Hallmann, E *et al*., 2017; Gill, B.S & Kaur, K., 2020]. Acetic acid, alanine, arginine, histidine, glutamine, fumaric acid, lactic acid, isoleucine, leucine, malic acid, galactose, mannose, methionine, phenylalanine, threonine, tyrosine, proline, sucrose, valine, and trigonelline were all found to be higher in organic pomegranate juices than in their conventionally grown counterparts [Villa-Ruano, N *et al*., 2020]. Conventional-grown butternut squash had higher levels of folic acid and β-carotene, whereas organic squash had higher levels of tocopherol, K, Mg, Na, and Mn (Armesto, J *et al*., 2020).Higher Ca, Mg, Na, K, and P contents were found in organically cultivated parsley root, celery, and potatoes than in conventionally grown ones (Gałowska, M. & Krawczyk, J., 2019). On the basis of several comparison studies, organic agricultural products have a higher ratio of vitamin C and Fe, Mg, Zn, Cu, and P than conventional crops (Yu, X.F *et al*., 2018; Datta, P. & Das, K., 2017). In the meantime, starch is higher than in conventional potatoes (Lombardo, S *et al*., 2017) and vitamin C is equal or higher in organic potatoes (Foods 2023, 12, 351 6 of 19) (Kazimierczak, R *et al*., 2019). Because of their quality and nutritional characteristics, micronutrient levels in conventional and organic goods have been the subject of several research (Table 1).

Table 1: Comparative study on the nutritional value of conventional versus organic grains, fruits, and vegetables

Name of food crops with botanical name	Principal Impacts of the Organic vs. Conventional Agricultural System	References
Cauliflower	Increased levels of antioxidants, polyphenols, carotenoids, and ascorbic acid in org	Lo Scalzo, R *et al*., 2013
Tomato	Organically produced tomato have higher nutritional value, including vitamin C and flavonoid content, 3-quercet in rutinoside, and myricetin. They also contain more soluble solids, and total phenolics. They also contain more health-promoting nutrients such as lycopene, vitamin C, flavonoids, and polyphenols. They also contain more Mo, Cu, Zn, K, and Ba, but less Mn, Co, Na, Mg, and Cd. They also contain more caffeic acid and chlorogenic acid, but less ferulic acid and naringen.	
Lettuce	Higher levels of ash, protein, total phenolic compounds and flavonoids, and antioxidant activity in organically grown lettuce	Negrão, L.D *et al*., 2021
Bringal	Organically grown bringal has lower polyphenol oxidase activity but a higher overall phenolic content and nutritional value (K, Ca, Mg, and Cu)	Raigón, M.D *et al*., 2010
Rice	There were no discernible variations in org for K, Cu, Zn, Rb, Mo, or Cd.	Yuan, Y *et al*., 2018
Wheat	Lower protein content and levels of Ca, Mn and Fe, as well as toxic elements (i.e., Al, As, Cdand Pb), but higher levels of K, Zn, Mo and quality proteins in organic wheat flours, No differences in protein content of whole wheat and refined flours, but phenolic content and total antioxidant capacity tended to be lower in organic wheat, Overall, no difference in total amounts of phenolics and phenolic acid.Higher levels of rutin and phenolics in organic wheat, decreased yield, flour proteins, and bread-making quality	Vrˇcek, I.V. *et al*., 2014; Park, E. Park, E.Y. *et al*., 2015; Mazzoncini, M *et al*., 2015; Živkas, V. *et al*., 2016
Foxtail millet	Increased level of glucose and fructose content in organic practices	Choudhary, K *et al*., 2022
Strawberries	Strawberries grown organically have higher antioxidant enzyme activities, higher antioxidant and flavonoid content, higher dry and optical residue values, and higher levels of glucose, sucrose, vitamin C, and ß-carotene but lower nitrate; total titratable acidity, lipids, anthocyanins, phenolic compounds, antioxidant activity, and vitamin C are all the same.	Jin, P *et al*., 2011; Conti, S *et al*., 2014;Kobi, H.B *et al*., 2018



Source: Bajpai, P., & Punia, D. (2015)

Fig 1: Comparative effect of organic, inorganic and conventional practices on mineral composition of vegetables

It was found that all of the organically cultivated vegetables—carrots, fenugreek leaves, garlic, okra, and tomatoes—had much greater magnesium values than their conventionally and inorganically grown equivalents. The magnesium content of garlic cultivated conventionally was much higher (58.67 mg/100g) than that of garlic grown inorganically (42.33 mg/100g). Only the manganese content of garlic and fenugreek leaves grown under organic conditions differed significantly from that of garlic and fenugreek leaves grown under inorganic conditions. The manganese content of organically grown carrots, okra, and tomatoes was significantly higher than that of inorganically grown carrots, okra, and tomatoes and conventionally grown carrots, okra, and tomatoes. When the mean zinc content values of fenugreek leaves, okra, and tomatoes grown organically and inorganically were compared, it was found that all of these vegetables had substantially higher zinc contents when grown organically than when grown conventionally or inorganically. Zinc is frequently found in animal feed supplements. The application of manures, which is more common in organic farming, may serve as an extra source of zinc for the soil and plants, which could account for the higher concentrations of zinc in the organic samples (Bolan *et al*., 2003; Zhao *et al*., 2005).

Conclusion

By providing vital nutrients like nitrogen, phosphorous, and potassium, the use of chemical fertilizers is necessary for increasing crop development and output. However, their effects on crop composition are complicated and heavily reliant on the kind, amount, and balance of nutrients used. While using fertilizer appropriately can increase the accumulation of proteins, vitamins, and minerals, applying it excessively or unevenly can have detrimental effects on nutritional quality, such as lowering the amount of carbohydrates or decreasing the bioavailability of micronutrients because of nutrient antagonism. On the other hand, crops grown in organic farming systems typically have higher amounts of antioxidants, polyphenols, vitamins, and vital minerals, as well as better nutritional quality and phytochemical composition. The use of natural nutrient sources, increased biological activity, and better soil health are the main causes of these advantages. However, there are differences based on the kind of crop and the growing environment, and in certain situations, conventional systems might be superior in terms of particular nutrients. In general, crop composition is greatly influenced by farming methods and fertilizer management. The best method for attaining sustainable crop production while preserving or enhancing nutritional quality seems to be a balanced and integrated approach that combines organic and inorganic inputs.

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