# Effects of Climate Change on Quality, Nutritional Value, and Postharvest Physiology of Edible Horticultural Crops

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**ABSTRACT**

*Climate change is a global challenge, which has a special impact on the agricultural sector. Increasing global average temperatures and extreme climatic events, changing precipitation patterns, and intensifying drought and salinity stresses can significantly affect not only the quantitative yield of horticultural crops, but also their sensory quality, nutritional value, and physiological characteristics in the pre- and postharvest stages. Since fruits and vegetables are major sources of micronutrients, antioxidant compounds, and bioactive compounds in the human diet, any changes in the chemical composition and postharvest stability of these products have significant impacts on food security and public health.*

*This article aims to comprehensively investigate the mechanisms of climate change effects on the quality, nutritional value, and postharvest physiology of edible horticultural products. In this regard, the effects of key climate factors including temperature increase, atmospheric carbon dioxide concentration, drought stress, light fluctuations, and combined stresses on plant physiological processes such as photosynthesis, respiration, hormonal balance, synthesis of primary and secondary metabolites, and antioxidant status have been analyzed. In this regard, the consequences of these changes on postharvest quality indicators including ripening speed, ethylene production, tissue softening, color change, reduced shelf life, occurrence of physiological abnormalities, and susceptibility to microbial spoilage have been investigated.*

*The role of adaptation and key strategies including selection of stress-tolerant cultivars, optimization of irrigation and nutrition management, application of growth regulators, new packaging technologies, controlled atmosphere, edible coatings and utilization of smart monitoring and forecasting systems in reducing the negative effects of climate change on post-harvest quality is discussed. The results of this review indicate that interdisciplinary approaches integrating plant physiology, biochemistry, post-harvest technology and climate science are essential to maintain nutritional quality and increase the sustainability of the horticultural supply chain in future climatic conditions.*

*In general, a detailed understanding of the physiological and biochemical responses of horticultural crops to climate change can be the basis for developing effective management strategies, improving food security and promoting community health. The findings of this paper provide a scientific framework for future research and policy-making in the field of sustainable production of horticultural crops in changing climatic conditions.*

***Keywords:*** **Climate change; Edible horticultural crops; Product quality; Nutritional value; Postharvest physiology; Systematic review.**

## 1. *INTRODUCTION*

In recent decades, climate change has emerged as one of the most important and serious environmental and global challenges in the fields of environment, agriculture and food security, and has had widespread impacts on the agricultural sector The phenomenon of climate change has been recognized as one of the most complex challenges facing humanity since ancient times.

Increasing global average temperatures, changing precipitation patterns, drought, salinity, and extreme climatic events not only affect the quantitative yield of horticultural crops, but also alter their quality, nutritional value, and physiological characteristics after harvest. Since horticultural fruits and vegetables constitute an important part of the human diet and are the main source of vitamins, antioxidant compounds, and minerals, any change in their nutritional quality can have significant consequences for food security and public health.

Edible horticultural crops, including fruits and vegetables, have a special place in food security due to their high economic value and key role in human nutrition. The quality of these products from the consumer and market perspective includes a set of physical, chemical, sensory and nutritional attributes that are strongly influenced by the environmental conditions of the pre-harvest stage. Scientific evidence shows that climatic stresses can disrupt plant growth and development processes and disrupt the metabolic balance between primary and secondary pathways.

From the perspective of post-harvest physiology, the climatic conditions governing the growth stage of the product can determine the rate of aging, the intensity of oxidative reactions, the stability of cell membranes and the activity of enzyme systems after harvest.

For example, an increase in temperature during the growth period can increase the activity of enzymes associated with cell wall degradation, resulting in a rapid loss of tissue firmness and reduced shelf life. Despite the significant increase in studies in recent years, most of the research has been conducted in a case-by-case and crop-based manner, and a comprehensive framework that explains the effects of climate change on the quality and post-harvest behavior of horticultural crops has received less attention.

Climate stresses, by affecting plant physiological processes, including photosynthesis, respiration, secondary metabolite synthesis, and hormonal balance, cause changes in the chemical composition and tissue structure of horticultural crops. These changes continue in the post-harvest stage and affect indicators such as ripening speed, storage life, sensitivity to oxidative stress, the occurrence of physiological abnormalities, and the rate of quality loss. In addition, the complex interaction between plant genotype, pre-harvest environmental conditions, and post-harvest management is the ultimate determinant of product quality in the food supply chain; an issue that becomes doubly important in conditions of climate change.

Despite the increasing number of studies related to the effects of climate change on agricultural yields, a comprehensive study of its consequences on the nutritional quality and postharvest physiology of horticultural crops still requires more in-depth research and multidisciplinary approaches.

The aim of this study is to investigate the processes of the impact of climate change on the quality, nutritional value and postharvest physiological characteristics of edible horticultural crops, as well as to provide management and technological adaptation strategies to maintain quality and increase production sustainability in climatic conditions.

The increase in the concentration of greenhouse gases in the Earth's atmosphere, especially carbon dioxide, methane and nitrogen oxides, has led to an increase in the average surface temperature of the Earth, changes in precipitation patterns, and an increase in the frequency of extreme climatic events such as heat waves, frost heaves, prolonged droughts and destructive floods. These changes not only threaten the sustainability of natural systems, but also directly and indirectly affect the production and quality of agricultural products, especially edible horticultural products. Since a significant part of the human nutritional needs for vitamins, minerals, dietary fibers and bioactive compounds are met through horticultural fruits and vegetables, any change in the quantity and quality of these products can have profound consequences for human health and global food security.

Due to their specific physiological nature, horticultural crops are highly sensitive to environmental conditions. Temperature, light intensity and quality, water availability, carbon dioxide concentration, and biotic and abiotic stresses all affect the processes of growth and development, cell division and differentiation, photosynthesis, respiration, and primary and secondary metabolism of the plant.

By disrupting the balance of these processes, climate change can alter the chemical composition of plant tissues, the accumulation of sugars, organic acids, pigments, phenolic compounds, flavonoids, carotenoids, and vitamins.

In many cases, increasing temperature accelerates fruit ripening, reduces growth period, decreases the accumulation of soluble solids, and reduces the sensory quality of the product, while mild stresses may increase antioxidant compounds in some species.

These contradictory responses indicate the complexity of the interaction between plant genotype and environment under variable climatic conditions. In addition to the pre-harvest stage, climatic conditions also have a significant effect on the post-harvest physiological characteristics of horticultural crops. Post-harvest quality is a function of the physiological state of the fruit at harvest, cell wall structure, activity of enzymes related to tissue softening, respiration intensity, ethylene production, antioxidant capacity, and susceptibility to oxidative stress. Increasing the temperature of the growing environment can reduce the shelf life of the product by accelerating metabolism and reducing carbohydrate reserves and increase its susceptibility to physiological abnormalities such as surface spots, tissue browning, water scald, and post-harvest decay. Also, changes in precipitation patterns and the occurrence of drought stress can affect cuticle thickness, tissue strength, and fruit skin permeability, thereby changing the rate of moisture loss and susceptibility to pathogens.

The nutritional value of horticultural crops is also strongly influenced by climate conditions. Several studies have shown that increased atmospheric carbon dioxide, although it may increase the vegetative growth and yield of some plants, can reduce the relative concentration of essential mineral elements such as iron, zinc, and magnesium in edible tissues; a phenomenon known as “nutritional dilution.”

On the other hand, thermal and light stresses can activate biosynthetic pathways of secondary compounds and affect the levels of antioxidants, polyphenols, and vitamins.
Therefore, climate change affects not only the amount of production, but also the nutritional quality and health function of horticultural crops.

One important aspect in investigating the effects of climate change is to pay attention to the interaction between pre-harvest factors and post-harvest management. Modern strategies such as the use of stress-tolerant cultivars, optimal irrigation and nutrient management, the application of growth regulators, modern packaging technologies, controlled atmospheres, edible coatings, and biological treatments can partially reduce the negative effects of climate change on postharvest quality. However, the effectiveness of these strategies depends on a detailed understanding of the physiological and biochemical mechanisms of plant response to variable climatic conditions. Despite significant advances in climate change-related research, many previous studies have focused more on quantitative crop yields, and a comprehensive study of the effects of this phenomenon on the quality, nutritional value, and postharvest physiology of horticultural crops still faces knowledge gaps. Also, the heterogeneity of the response of different species and cultivars, the difference in climatic conditions of different regions, and the complexity of environmental interactions have made it difficult to generalize the results.

Materials and Methods: According to the studies designed and research conducted in recent years, the extracted data included crop type, climatic factor, experimental conditions, quality indicators, nutritional components, and postharvest physiological responses. Due to the heterogeneity of the methods, the analysis was conducted qualitatively and based on thematic comparison.

**Results**

A comprehensive review of related studies showed that climate change, through a set of simultaneous environmental stresses, exerts significant effects on the quality, nutritional value, and postharvest physiology of edible horticultural crops. The most important effective climatic factors include increasing average temperature, severe temperature fluctuations, increasing atmospheric carbon dioxide concentration, stress Drought and changing light radiation patterns were, each of which, alone and in interaction with each other, caused different physiological responses in plants.

1. Effect of temperature increase on postharvest quality and physiology

The results showed that increasing temperature during the growth period was generally associated with accelerated fruit ripening, increased respiration rate and ethylene production, which led to a decrease in storage life and increased susceptibility to physiological abnormalities. In many horticultural crops, higher temperatures caused faster tissue softening, decreased cell wall strength and accelerated pectin degradation. Also, increasing temperature was associated with increased oxidative stress and accumulation of reactive oxygen species, which ultimately exacerbated the occurrence of tissue browning, surface spots and reduced visual quality.

**Conclusion**

Climate change is a serious threat to the quality and storage life of edible horticultural crops. This systematic review shows that understanding physiological mechanisms and applying scientific adaptation strategies can play an important role in maintaining quality and reducing postharvest losses under changing climate conditions.

2. Effect of increased atmospheric carbon dioxide on nutritional value

Although increased carbon dioxide concentration was associated with increased vegetative growth and carbohydrate accumulation in many studies, it was simultaneously reported to decrease the concentration of essential mineral elements such as iron, zinc, and magnesium in edible tissues. This phenomenon, which is interpreted as nutritional dilution, can have negative consequences for the nutritional quality of the human diet.

3. Effect of drought stress and water deficit

Pre-harvest drought stress was recognized as one of the most important factors affecting postharvest characteristics. The results showed that water deficit can cause:

Increase in cuticle thickness and accumulation of surface waxes
Reduce fruit size but increase in soluble solids concentration
Increase in phenolic compounds and antioxidant activity

However, severe drought was associated with reduced stability of cell membranes, increased electrolyte leakage and increased susceptibility to microbial decay during storage. Therefore, the severity of stress is considered a determining factor in the qualitative response.

4: Changes in biochemical and metabolic indices

Data analysis showed that climate change directly affects metabolic pathways related to:
Synthesis of sugars and organic acids
Biosynthesis of pigments (carotenoids and anthocyanins)
Phenolic and flavonoid compounds
Vitamin C and other antioxidants.

These changes ultimately determine the sensory characteristics, color, flavor and health value of horticultural products. In many cases, mild stress conditions increased defensive metabolites and severe stress conditions reduced overall quality.

5. Consequences of climate change on shelf life and supply chain

The overall results showed that climate change is often associated with reduced shelf life, increased post-harvest losses, and reduced supply chain sustainability. Increased temperature and environmental stresses increase the rate of microbial spoilage and physiological abnormalities, and increase storage and transportation costs. This can have direct effects on food security and economic access to fresh fruits and vegetables.

6. The role of adaptation strategies in reducing negative impacts

A review of studies showed that the use of management and technological strategies can mitigate some of the negative impacts of climate change. The most important results included:
Improving quality and shelf life by selecting tolerant varieties
Reducing physiological stresses through careful irrigation and nutrition management
Increasing shelf life by using controlled atmosphere and modern packaging
Reducing oxidative stress with edible coatings and biological treatments. Also, the application of precision agriculture and smart monitoring systems showed an important role in predicting stresses and optimally managing the post-harvest chain.

Discussion

The findings of this study indicate that climate change, through a complex interaction of environmental factors, exerts multidimensional and sometimes contradictory effects on the quality, nutritional value and postharvest physiology of edible horticultural crops. Increased average temperature, severe temperature fluctuations, drought stress and increased $CO_2$ concentration each activate different physiological and biochemical pathways in the plant that affect the quality characteristics of the final product. These results are consistent with the prevailing view in the scientific literature that horticultural crops are highly sensitive to pre-harvest environmental conditions and indicate that post-harvest quality is a direct reflection of the physiological state of the plant during the growth period.

Increasing temperature, as one of the most prominent components of climate change, was mainly associated with accelerated metabolism, increased respiration rate and ethylene production, and consequently shortened storage life. This phenomenon can exacerbate physiological abnormalities and microbial spoilage by accelerating cell wall degradation, increasing oxidative stress, and disrupting antioxidant balance. However, the observation of an increase in some phenolic and antioxidant compounds under mild heat stress indicates that the plant response is not simply a reduction and that, depending on the severity of the stress, there is also the possibility of activating defense pathways. This duality of responses highlights the importance of studying species-specific and management conditions.

On the other hand, although the increase in atmospheric carbon dioxide in many cases increased carbohydrate accumulation and biomass growth, it also brought about a relative reduction in essential mineral elements; a phenomenon that could have significant consequences for the nutritional quality of the human diet. This finding suggests that the assessment of agricultural success in future climate conditions should not be based solely on quantitative yield, but also on nutritional and health-related indicators.

Drought stress also showed a dual role in the quality of horticultural products. At mild levels, increases in soluble solids, phenolic compounds and antioxidant capacity were observed, which could lead to improvements in some quality traits; however, severe drought was associated with cell membrane damage, increased electrolyte leakage and increased susceptibility to postharvest spoilage. This suggests that the severity and timing of stress are the determining factors in the physiological and quality response of the product.

The results also emphasize that climate change could threaten the sustainability of the horticultural supply chain through reduced shelf life, increased waste and higher storage and transportation costs. Such a trend will have direct consequences for food security, economic access to fresh food and the sustainability of agricultural systems, especially in arid and semi-arid regions that are more sensitive to climate fluctuations.

In this context, the role of management and technological adaptation strategies is highlighted. The findings showed that selecting tolerant cultivars, careful water and nutrient management, adjusting harvest time, and using novel postharvest technologies such as controlled atmosphere, active packaging, and edible coatings can significantly improve the quality and shelf life of products. In addition, the use of precision agriculture, smart monitoring systems, and climate prediction models has great potential to reduce the risks of climate change. Such interdisciplinary approaches can provide an effective framework for the sustainable adaptation of horticultural production systems.

Despite these findings, important knowledge gaps remain, including the lack of long-term field studies, limited data on simultaneous responses to combined stresses, and insufficient information on genotype × environment × management interactions in determining nutritional quality. Addressing these gaps is essential to more accurately predict the future of horticultural production under changing climate conditions.

Conclusion

Overall, the results of this study indicate that climate change has profound, multifaceted, and stress-dependent effects on the quality, nutritional value, and postharvest physiology of edible horticultural crops. The prevailing trend is accelerated ripening, reduced shelf life, increased susceptibility to oxidative stress, and a potential decline in the nutritional quality of some minerals; although under mild stress conditions, there is also the possibility of increased bioactive compounds. This complex pattern suggests that the future of horticultural crop quality will be highly dependent on climate-adapted management.

Accordingly, moving towards climate-smart agriculture, genetic modification for stress tolerance, optimization of pre- and postharvest management, and development of new storage technologies are essential to maintain nutritional quality and reduce waste. Achieving these goals requires interdisciplinary collaboration between horticultural sciences, plant physiology, nutritional sciences, postharvest technology, and climate sciences.

Ultimately, a detailed understanding of the mechanisms of horticultural crop response to climate change can inform effective policymaking in the areas of food security, public health, and agricultural sustainability. Future research should focus on developing quality prediction models, evaluating the response of different cultivars under real-world field conditions, and designing regional adaptation strategies to enable sustainable production of high-quality horticultural crops in a changing climate of the future.

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