



TRANSFORMING FOOD ANALYSIS AND CONTROL:

NON-DESTRUCTIVE TECHNOLOGIES AND INNOVATIONS

K. Prasad, S. Shekhar, M. K. Paswan and R. Ahuja



Advancing Food Quality, Safety and Sustainability with
Smart, Innovative and Non-Destructive Technologies



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Real-Time Respiration Rate Measurement of Fresh Capsicum Using an IoT-Enabled Smart Chamber

Majahar Ali and Pradeepta Kumar Sahoo 

Abstract. An Internet of Things (IoT)-based airtight smart respiration chamber was developed to enable real-time measurement of the respiratory characteristics of fresh capsicum under ambient storage conditions. The system integrates Arduino Nano 33 IoT and ESP32 microcontroller platforms with a DHT22 temperature–humidity sensor, an electrochemical oxygen sensor (SEN0322), and an NDIR-based carbon dioxide sensor (SEN0220) to continuously monitor headspace O₂ and CO₂ concentrations, temperature, and relative humidity. Sensor data were wirelessly transmitted at 15 s intervals to the ThingSpeak cloud platform for real-time visualisation, storage, and analysis. Respiration rates were determined using mass-balance equations based on measured rates of oxygen consumption and carbon dioxide evolution in the closed system. The results showed a decrease in O₂ concentration from 20.97% to 20.31% and a corresponding increase in CO₂ concentration from 0.0395% to 0.6732%, confirming active aerobic respiration. The calculated rates of O₂ consumption and CO₂ production were 19.575 mL kg⁻¹ h⁻¹ and 18.699 mL kg⁻¹ h⁻¹, respectively. The respiratory quotient (RQ) was found to be 0.96, indicating predominantly carbohydrate-based metabolism. Proper sensor calibration ensured high measurement accuracy and system stability. The developed IoT-based smart chamber demonstrated reliable performance in quantifying respiration dynamics of fresh capsicum and offers a low-cost, scalable, and efficient alternative to conventional laboratory-based respiration measurement techniques. This system provides a scientific basis for optimizing postharvest handling strategies and designing suitable modified atmosphere packaging (MAP) systems to reduce postharvest losses.

Keywords: Internet of Things (IoT), respiration rate, respiratory quotient (RQ), capsicum, smart chamber, postharvest management.

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1. Introduction

Sweet pepper (*Capsicum annuum* L.), commonly known as bell pepper or paprika, is an economically important vegetable crop valued for its attractive appearance, pleasant flavour, and high nutritional quality. It is a rich source of vitamin C, carotenoids, phenolic compounds, and other antioxidant compounds that contribute significantly to human health and nutrition (Howard et al., 2000; Kader, 2024; Singh et al., 2014). The characteristic green, yellow, orange, and red colours of sweet pepper are primarily attributed to chlorophylls and carotenoids, particularly β -carotene, which possess strong antioxidant activity and enhance its nutritional value (Howard et al., 2000). Owing to its nutritional attributes and wide culinary applications in salads, curries, and processed foods, sweet pepper has seen substantial consumer demand worldwide.

Despite its commercial importance, sweet pepper is highly perishable after harvest due to continuous physiological and biochemical activities. Among these, respiration is one of the most critical metabolic processes influencing postharvest quality and shelf life. During respiration, oxygen (O_2) is consumed, and organic substrates such as carbohydrates are oxidized to produce carbon dioxide (CO_2), water, and energy required for cellular maintenance (Kader, 2024). The respiration rate directly affects senescence, moisture loss, softening, colour changes, and nutritional deterioration of fresh produce. Consequently, shelf life is inversely related to respiration rate, measuring O_2 consumption and CO_2 evolution essential for postharvest handling, storage management, and packaging system design (Cameron et al., 1989; Fonseca et al., 2002).

Monitoring respiration behaviour has become increasingly important in modern postharvest technology, particularly in Modified Atmosphere Packaging (MAP), where the concentrations of O_2 and CO_2 surrounding the commodity are manipulated to reduce metabolic activity and prolong storage life. The success of MAP largely depends on maintaining an appropriate balance between product respiration and film permeability (Fonseca et al., 2002). Recent studies have demonstrated that MAP effectively reduces weight loss, maintains firmness, delays physiological deterioration, and extends the shelf life of bell peppers during refrigerated storage (Afolabi et al., 2023; Yeboah et al., 2023). Similarly, advances in MAP modelling have highlighted the importance of accurate respiration data for optimizing package atmosphere and improving storage performance of fresh horticultural commodities (Rashvand et al., 2023). Recent reviews on bell pepper postharvest technologies have further emphasized the need for

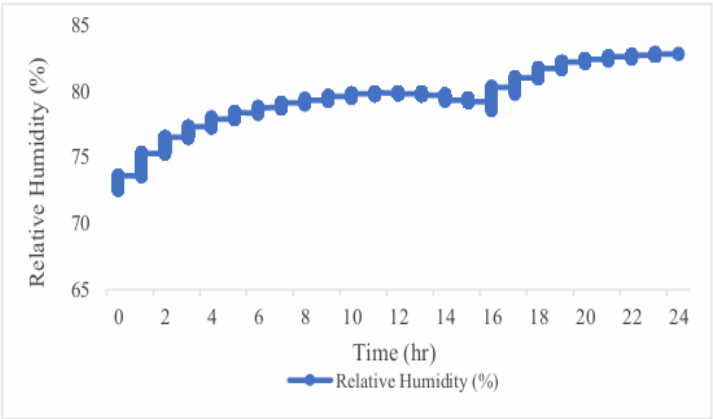


Fig. 12 Relative Humidity variations of fresh capsicum during the experimental period

4. Conclusions

The study demonstrated that the respiration rate of mature green capsicum gradually declined with increasing storage duration, indicating a reduction in metabolic activity during storage. In contrast, respiration rates increased with rising temperature, confirming the strong influence of temperature on the respiratory metabolism of fresh produce. The respiratory quotient (RQ) was found to be 0.96 at $31 \pm 2^{\circ}\text{C}$, suggesting that carbohydrates were the predominant substrates utilized during respiration and indicating normal aerobic metabolic activity under the experimental conditions.

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