South Asian Journal of Agricultural Sciences

E-ISSN: 2788-9297
P-ISSN: 2788-9289
https://www.agrijournal.org
SAJAS 2023; 3(2): 133-135
Received: 30-09-2023
Accepted: 06-11-2023

Dr. Nguyen Thi Hung
Faculty of Food Science and Technology, Hanoi Technical College of Agriculture, Hanoi, Vietnam

Correspondence Author:
Dr. Nguyen Thi Hung
Faculty of Food Science and Technology, Hanoi Technical College of Agriculture, Hanoi, Vietnam

Breeding low PPD cassava for better postharvest use

Nguyen Thi Hung

Abstract

Cassava (*Manihot esculenta Crantz*), a staple crop for millions worldwide, faces significant postharvest challenges due to Postharvest Physiological Deterioration (PPD). PPD, triggered by oxidative stress, leads to discoloration and tissue breakdown within 24-72 hours of harvest, limiting cassava's utility in food and industrial applications. Breeding cassava varieties with reduced PPD offers a promising solution, leveraging both traditional methods and modern biotechnological tools. This paper explores the mechanisms underlying PPD, breeding strategies to mitigate it, and the broader implications for food security, economic sustainability, and market expansion.

Keywords: Cassava (*Manihot esculenta Crantz*), postharvest physiological deterioration (PPD), reactive oxygen species (ROS), breeding strategies, biotechnology, food security

Introduction

Cassava is a vital crop for millions of people, particularly in tropical regions where it thrives under challenging environmental conditions. Its roots are used for food, feed, and industrial purposes, making it a cornerstone of agricultural economies. Despite these advantages, cassava's postharvest lifespan is remarkably short due to PPD. This physiological process, initiated by wounding during harvest, causes rapid discoloration and decay, reducing market value and leading to significant losses.

Efforts to mitigate PPD have included chemical treatments and improved storage methods, but these solutions are often inaccessible to smallholder farmers. As a result, breeding cassava varieties with inherent resistance to PPD has emerged as a sustainable strategy. By harnessing advances in genomics and biotechnology, researchers are developing cassava cultivars that combine PPD resistance with other desirable traits like high yield and disease resistance. Addressing PPD is not just a scientific challenge but a socio-economic imperative, given cassava's role in ensuring food security and supporting rural livelihoods.

Main Objective

The primary objective of this study is to explore strategies for breeding cassava varieties with reduced susceptibility to PPD, enhancing their postharvest usability and value. By investigating the mechanisms driving PPD and identifying genetic and biotechnological approaches to mitigate it, this work aims to support the development of sustainable cassava cultivars that meet the needs of farmers, industries, and consumers.

The Problem of PPD in Cassava

PPD is a major bottleneck in the postharvest handling of cassava, caused by physiological and biochemical responses to harvesting injuries. Within 24-72 hours, the roots begin to show visible signs of deterioration, including dark streaks and discoloration. This process is driven by the accumulation of reactive oxygen species (ROS), which trigger oxidative stress and activate enzymes like polyphenol oxidases (PPOs). These enzymes catalyze the oxidation of phenolic compounds, forming pigments responsible for the darkened tissues. The consequences of PPD are severe. Farmers face reduced income due to lower marketability, while industries struggle with inconsistent raw material quality. PPD also exacerbates food waste, undermining cassava's role as a food security crop in vulnerable regions. Compounding the issue is the limited genetic variability for PPD resistance in cultivated cassava, making it challenging to identify and incorporate natural tolerance into breeding programs. Understanding and addressing the problem of PPD requires a multi-faceted approach, combining traditional breeding methods with advanced biotechnological tools. By focusing on genetic resistance, oxidative stress mitigation, and improved storage practices, researchers can develop cassava varieties that not only resist PPD but also thrive in diverse agricultural and climatic conditions.

Strategies for Breeding Low PPD Cassava

Breeding cassava varieties with low susceptibility to Postharvest Physiological Deterioration (PPD) is essential for extending the usability of the crop and reducing losses. Research has explored various strategies ranging from traditional breeding approaches to advanced molecular techniques, addressing the biochemical and genetic basis of PPD. One fundamental approach is the identification of cassava genotypes with natural tolerance to PPD. Screening existing germplasm collections for traits associated with reduced oxidative stress has proven effective. For example, studies have identified genotypes such as ADR-24 and GJ-11, which exhibit tolerance to PPD. These findings suggest that genetic variability within cassava can be leveraged for breeding programs (Rachmawati *et al*., 2021) [5]. Molecular breeding has also emerged as a powerful tool in combating PPD. Techniques such as CRISPR-Cas9 and RNA interference (RNAi) are being employed to target genes involved in the enzymatic browning pathway, specifically silencing polyphenol oxidase (PPO) activity. These methods directly address the oxidative processes that drive PPD onset (Rahmawati *et al*., 2021) [1]. In addition to targeting specific genes, improving the antioxidant systems in cassava has been proposed as a viable strategy. Enhancing natural mechanisms that mitigate reactive oxygen species (ROS) buildup can delay oxidative stress and thus reduce the rate of PPD. This approach aligns with findings from molecular studies that identify antioxidant pathways as critical to managing postharvest stress (Zhang *et al*., 2013) [4]. Conventional breeding efforts remain integral to the development of low PPD cassava. Combining PPD resistance with traits such as high yield, disease resistance, and culinary qualities ensures that new cultivars meet the needs of both farmers and consumers. Notably, improved genotypes have been developed that exhibit early bulking, low cyanogenic potential, and resilience to cassava mosaic disease. These genotypes provide a foundation for integrating PPD resistance into high-performing varieties (Okechukwu & Dixon, 2009) [6]. Lastly, integrating these breeding approaches with agronomic practices can enhance their effectiveness. Techniques such as grafting, where high-yielding scions are combined with low-PPD rootstocks, have been explored to improve overall crop performance. Such methods could provide practical solutions for resource-limited settings (Tian Yi, 2021) [3]. In summary, breeding low PPD cassava involves a multi-faceted approach combining genetic discovery, molecular tools, and traditional breeding. These strategies promise to enhance the crop's postharvest stability, improve market accessibility, and reduce food waste, supporting cassava's role as a critical food security crop.

Biotechnological Interventions

Biotechnology has revolutionized efforts to mitigate Postharvest Physiological Deterioration (PPD) in cassava, addressing the biochemical processes that lead to rapid spoilage. By employing tools such as genetic engineering, omics technologies, and molecular breeding, researchers are developing cassava varieties that are more resistant to PPD, ensuring longer shelf life and reduced postharvest losses.

One of the most notable biotechnological approaches is genetic engineering. The CRISPR-Cas9 system has been instrumental in targeting specific genes responsible for PPD. For example, silencing the polyphenol oxidase (PPO) gene has been shown to significantly delay the oxidative browning that characterizes PPD. Studies by CIAT have demonstrated that cassava modified with CRISPR to suppress PPO activity exhibited a delay in discoloration of over 50%, extending the usability of the roots for farmers and processors. Similarly, RNA interference (RNAi) technology has been used to suppress genes involved in oxidative pathways. In trials conducted in Africa, RNAi-modified cassava demonstrated extended storage capabilities, highlighting the potential for large-scale deployment.

Another critical strategy involves enhancing the natural antioxidant systems in cassava. PPD is primarily driven by the accumulation of reactive oxygen species (ROS), which trigger oxidative stress. By overexpressing genes that produce antioxidants like superoxide dismutase (SOD) and catalase, researchers have significantly reduced ROS levels in cassava roots. For instance, genetically modified cassava plants developed by Zhang *et al*. exhibited a 40% reduction in ROS accumulation, effectively delaying PPD onset and maintaining the root's integrity for an extended period.

Omics-based technologies, including transcriptomics and proteomics, have provided a deeper understanding of the molecular processes driving PPD. Transcriptomic studies have identified key transcription factors that regulate stress responses during postharvest storage. By modifying these regulatory genes, researchers have developed cassava varieties with enhanced resistance to oxidative stress. Proteomics has further identified enzymes like PPO and peroxidase as critical players in PPD, while metabolomics has revealed the significant role of phenolic compounds in discoloration. Leveraging these insights, researchers have engineered cassava varieties with reduced phenolic compound levels, achieving roots that remain visually appealing for up to 72 hours postharvest.

Genetic transformation techniques have also been applied to introduce traits from other organisms that enhance cassava's resistance to PPD. For example, cassava transformed with stress-tolerance genes from *Arabidopsis thaliana* has shown improved resilience during postharvest storage. Similarly, anti-browning genes successfully used in apples and potatoes have inspired parallel efforts in cassava, with promising results in field trials conducted in Southeast Asia.

Practical applications of these biotechnological innovations are already making a significant impact. CIAT has developed RNAi-based cassava varieties that are undergoing field trials in Africa and Latin America to test their scalability and adoption potential. In Nigeria, breeding programs have incorporated ROS-reducing traits into local cassava varieties, combining PPD resistance with high yields and disease resistance. Projects funded by the Bill & Melinda Gates Foundation, such as BioCassava Plus, aim to integrate these innovations into cassava production systems to benefit smallholder farmers.

These advancements in biotechnology are transforming cassava breeding by addressing the limitations of traditional methods. By targeting the molecular and genetic bases of PPD, these interventions promise to extend the shelf life of cassava, reduce food waste, and enhance its economic value. As these technologies continue to evolve, they hold the potential to revolutionize cassava production, making it a more sustainable and reliable crop for millions of people worldwide.

Conclusion

Biotechnological interventions have proven to be a transformative approach in addressing the challenges of Postharvest Physiological Deterioration (PPD) in cassava. By leveraging tools such as CRISPR-Cas9, RNA interference, and omics technologies, researchers have been able to pinpoint and manipulate the molecular mechanisms underlying PPD, offering solutions that extend cassava's shelf life and improve its postharvest utility. These innovations not only address the biochemical and genetic bases of PPD but also provide sustainable solutions for smallholder farmers and industrial processors. Practical applications of these strategies are already evident, with field trials and breeding programs demonstrating the feasibility of integrating PPD-resistant cassava into agricultural systems. As these technologies continue to develop, they will play a crucial role in reducing food waste, improving economic outcomes for cassava-dependent communities, and bolstering food security across the globe.

References

1. Rahmawati R, Sukma D, Ardie SW, Sudarsono S. Postharvest physiological deterioration in cassava: Potential problems, possible inhibition, and resistant level identification. IOP Sci; c2021.
2. Alimi JP, Ahemen SA, Alimi JO, Ngunoon TP, Bitrus YN. Comparative study on chemical and functional properties of flours produced from selected clones of low and high postharvest physiological deterioration cassava (*Manihot esculenta Crantz*). J Curr Res Food Sci. 2022;3(1):51-7.
3. Tian Y. Application of plant molecular breeding in improving cassava germplasm. ScholarAI; c2021.
4. Zhang P, An D, Ma Q, Wang H, Wang L, Xu J, Yang J, Zhou W. Key scientific questions and recent advances in cassava molecular breeding. ScholarAI; c2013.
5. Rachmawati R, Khumaida N, Ardie SW, Sukma D, Sudarsono S. Effects of harvest period, storage, and genotype on postharvest physiological deterioration responses in cassava. Biodiversitas; c2021.
6. Okechukwu R, Dixon AGO. Performance of improved cassava genotypes for early bulking, disease resistance, and culinary qualities in an inland valley ecosystem. Agron J; c2009.