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Cereal Quality: Genetics, Environment, Safety, Security

Ahmed Hassan*

Rice Research Program, Agricultural Research Center, Giza, Egypt

***Corresponding Author:** Ahmed Hassan, Rice Research Program, Agricultural Research Center, Giza, Egypt, E-mail: a.hassan@arc.eg

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Abstract

This collection of reviews comprehensively examines critical aspects of cereal grain quality, encompassing genetic and environmental determinants in wheat and barley, advanced breeding strategies, and post-harvest management. It highlights the impact of mycotoxins and climate change on food safety, alongside innovations in non-destructive quality assessment. Emphasis is placed on enhancing nutritional value, such as micronutrient content, and optimizing specific industrial traits like malting quality. The findings collectively underscore the necessity of integrated approaches to improve grain quality, ensure food security, and address global nutritional and processing demands.

Keywords

Grain Quality; Wheat; Cereal Grains; Mycotoxins; Genetic Factors; Environmental Factors; Breeding Strategies; Post-Harvest Management; Food Safety; Micronutrients

Introduction

This article reviews genetic and environmental factors determining wheat grain quality, outlining critical genetic loci, gene functions, and the impact of stressors like drought and heat on key traits. It discusses advanced breeding strategies and genomic tools for improvement, emphasizing the complex interplay between genotype and environment [1].

This review explores advancements in post-harvest management techniques for cereal grains, aiming to enhance food safety and preserve nutritional quality. Strategies include improved drying, storage, pest control, and novel processing. These practices minimize post-harvest losses, prevent contamination, and maintain grain value from farm to consumer [2].

The global prevalence of mycotoxins in cereal grains is a major food safety concern. This article details common mycotoxin types, their producing fungi, and contamination factors. It discusses significant health risks and advocates for stringent monitoring and control measures to ensure grain safety and public health [3].

Recent advancements in understanding the genetic basis of various grain quality traits in wheat are summarized. This includes identifying quantitative trait loci (QTLs) and specific genes for protein content, starch, and dough characteristics. The article highlights how genomic selection and gene editing accelerate breeding for superior wheat varieties, meeting producer and consumer demands [4].

This review discusses climate change's impacts on food crop quality and safety, focusing on mycotoxin contamination. It explains how altered temperature, rainfall, and elevated CO_2 influence crop physiology and fungal susceptibility. The escalating risk of mycotoxin accumulation under climate change and mitigation strategies for global food security are highlighted [5].

Recent advancements in non-destructive techniques for assessing grain quality are presented, emphasizing rapid, accurate, and cost-effective analysis. It covers optical sensing technologies like near-infrared (NIR) spectroscopy, hyperspectral imaging, and machine vision systems. Applications include evaluating moisture, protein, oil, starch, and detecting defects or contaminants, crucial for research and industrial uses [6].

The complex genetic and environmental mechanisms regulating grain protein content (GPC) in wheat are reviewed. It discusses major genes and quantitative trait loci (QTLs) influencing GPC, alongside the significant impact of environmental factors such as nitrogen fertilization. Insights are offered into optimizing GPC for nutritional and processing quality through improved breeding and agronomic practices [7].

Strategies to enhance micronutrient content and bioavailability in staple crops, combating hidden hunger, are the focus. It covers conventional breeding and agronomic approaches, including nutrient-efficient genotypes. The article emphasizes understanding genetic and physiological mechanisms of micronutrient accumulation, particularly iron and zinc, to develop biofortified varieties for improved human nutrition [8].

This comprehensive review examines multifaceted genetic and environmental factors governing durum wheat grain quality. It details the influence of specific genes and genetic loci on traits like protein content, gluten strength, and kernel vitreousness, crucial for pasta making. The article explores how environmental conditions interact with genetics to shape final grain quality for targeted breeding [9].

Latest understandings of the genetic and molecular underpinnings of malting quality in barley are summarized. It discusses key enzymatic activities, such as beta-amylase, and their genetic control, vital for efficient malting and brewing processes. The article highlights genomic tools and marker-assisted selection in breeding new barley varieties with improved malting characteristics [10].

Description

Research highlights the intricate interplay between genetic and environmental factors that govern grain quality in wheat and durum wheat. Key studies delve into genetic loci and gene functions influencing traits such as protein content, gluten strength, and kernel hardness in wheat, alongside the effects of environmental stressors like drought and heat [1]. Similarly, the genetic architecture of various wheat grain quality traits, including starch composition and dough characteristics, has seen advancements, with quantitative trait loci (QTLs) and specific genes identified. Genomic selection and gene editing are now accelerating breeding efforts for superior wheat varieties [4]. Focusing further on specific components, the complex genetic and environmental mechanisms that regulate grain protein content (GPC) in wheat are explored, noting the significant impact of nitrogen fertilization, temperature, and water availability, offering insights for optimizing GPC through breeding and agronomic practices [7]. For durum wheat, a comprehensive review details how specific genes and genetic loci influence traits like protein content, gluten strength, yellow pigment, and kernel vitreousness, all critical for pasta making. Environmental conditions, encompassing soil type, nutrient availability, and climatic stress, interact with genetics to shape the final grain quality, guiding targeted breeding and cultivation [9].

Beyond cultivation, advancements in post-harvest management techniques for cereal grains are crucial for enhancing food safety and preserving nutritional quality. These strategies involve improved drying methods, effective storage technologies, pest and disease control, and novel processing approaches, all aimed at minimizing post-harvest losses and preventing contamination [2]. A significant threat to grain safety is the global prevalence of mycotoxins in cereal grains. Reviews detail common mycotoxin types, their producing fungi, and the diverse factors contributing to contamination worldwide. The associated health risks for humans and livestock are considerable, emphasizing the need for stringent monitoring and control measures [3]. Compounding these challenges, climate change profoundly impacts the quality and safety of food crops, particularly concerning mycotoxin contamination. Altered temperature regimes, rainfall patterns, and elevated CO2 levels influence crop physiology, nutrient uptake, and susceptibility to fungal pathogens. The escalating risk of mycotoxin accumulation under changing climate scenarios necessitates proactive mitigation strategies to safeguard global food security and public health [5].

Innovations in assessing grain quality are also advancing rapidly. Non-destructive techniques offer rapid, accurate, and cost-effective analysis without damaging the sample. Optical sensing technologies, such as near-infrared (NIR) spectroscopy, hyperspectral imaging, and machine vision systems, are discussed for their application in evaluating various quality parameters like moisture content, protein, oil, starch, and for detecting defects or contaminants. These methods prove crucial for both research and industrial applications [6]. Simultaneously, efforts are underway to combat hidden hunger by enhancing micronutrient content and bioavailability in staple crops. This involves various conventional breeding and agronomic approaches, including developing nutrient-efficient genotypes and optimizing fertilization techniques. Understanding the genetic and physiological mechanisms of micronutrient accumulation in grains, particularly iron and zinc, is vital for developing biofortified varieties that significantly improve human nutrition and health outcomes [8].

The focus extends to specific cereal applications, such as malting quality in barley. Recent understandings of the genetic and molecular underpinnings of malting quality are summarized, highlighting key enzymatic activities like beta-amylase and limit dextrinase, and their genetic control. These factors are vital for efficient malting and brewing processes. The application of genomic tools and marker-assisted selection in breeding new barley varieties aims to improve malting characteristics, thereby contributing to better beer and malt product consistency and quality [10]. Collectively, these research areas underscore a holistic approach to improving cereal grain quality, from genetic enhancement and environmental management during growth to advanced post-harvest handling and precise quality assessment. The overarching goal remains to ensure food safety, nutritional value, and meet diverse consumer and industrial demands across various cereal crops.

Ultimately, the collective body of research emphasizes the continuous need for integrated strategies. Combining sophisticated genetic and genomic tools with sustainable agronomic practices, effective post-harvest management, and vigilant food safety measures is paramount. This ensures resilient and high-quality cereal production in the face of evolving environmental challenges and increasing global demand for nutritious and safe food. Such comprehensive approaches are essential for future food security.

Conclusion

Research into cereal grain quality highlights the complex interplay of genetic and environmental factors. Studies explore critical genetic loci and gene functions in wheat, focusing on traits like protein content, gluten strength, and kernel hardness, influenced by stressors such as drought and heat. Genomic selection and gene editing are advancing breeding programs to develop superior wheat varieties. Genetic and environmental controls also significantly impact grain protein content, with nitrogen fertilization and temperature being key modulators, optimizing nutritional and processing quality. Similar detailed analyses extend to durum wheat, where specific genes and environmental conditions dictate pasta-making traits.

Food safety is another critical area, with reviews covering mycotoxin prevalence in cereal grains, detailing fungal sources and contamination factors, and underscoring significant health risks. Climate change exacerbates these issues, altering crop physiology and increasing mycotoxin accumulation risks. To mitigate losses and maintain quality, advancements in post-harvest management, including improved drying, storage, and pest control, are crucial. Non-destructive techniques like NIR spectroscopy and machine vision offer rapid, accurate assessments of grain quality parameters, vital for both research and industrial applications. Efforts to combat hidden hunger involve enhancing micronutrient content in staple crops through breeding and agronomic practices, especially for iron and zinc. Furthermore, genetic and molecular understandings are improving malting quality in barley, benefiting brewing processes. These integrated approaches are essential for ensuring global food security and meeting diverse demands for safe, nutritious, and high-quality cereals.

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