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CHANGES IN WATER STATE IN WHEAT GRAINS AND THEIR EFFECT ON GRAIN QUALITY

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Abstract: The quality of wheat grain is largely determined by physiological and biochemical processes occurring during ripening, among which the state of water plays a key role. This study examines the changes in water state and their influence on grain quality in *Triticum aestivum*. During the early stages of grain development, a high proportion of free water ensures active metabolism, including synthesis of proteins, starch, and other essential compounds. As ripening progresses, the total moisture content decreases, and water transitions from free to bound forms associated with macromolecular structures. This transformation leads to stabilization of the grain structure, reduction of metabolic activity, and preparation for storage. The shift in water state significantly affects technological properties such as milling quality, resistance to mechanical damage, and storage stability. In particular, the predominance of bound water at full maturity enhances grain durability and reduces susceptibility to microbial spoilage. The results demonstrate that the control of moisture content and understanding of water-binding mechanisms are essential for optimizing harvesting time and improving post-harvest processing.

Keywords: wheat grain, water state, free water, bound water, ripening, moisture content, grain quality, storage stability

Introduction

Wheat (*Triticum aestivum*) is one of the most widely cultivated cereal crops and plays a fundamental role in global food security. The quality of wheat grain depends on a complex set of physiological and biochemical processes that occur during its development and ripening. Among these processes, the state and behavior of water within the grain are of particular importance, as water directly influences metabolic activity, structural formation, and technological properties.

At the early stages of grain formation, water is present mainly in a free form, providing a medium for enzymatic reactions, nutrient transport, and intensive biosynthesis of macromolecules such as proteins and carbohydrates. As the grain matures, the overall moisture content gradually decreases, and water becomes increasingly bound to structural components of the cell, including starch granules, protein matrices, and cell wall polysaccharides. This transition from free to bound water reflects a shift from active metabolism to physiological maturity and dormancy[1-18].

Changes in the state of water significantly affect grain quality indicators such as hardness, milling efficiency, germination capacity, and resistance to storage deterioration. In particular, the predominance of bound water at later stages enhances structural stability and reduces the risk of microbial growth and biochemical degradation. At the same time, uneven distribution of water among different anatomical parts of the grain—such as the endosperm, embryo, and outer layers—contributes to variability in functional properties.

Therefore, studying the changes in water state and their influence on grain quality is essential for understanding the mechanisms of grain maturation and for optimizing harvesting, storage, and processing technologies. The aim of this work is to investigate the transformation of water forms in wheat grains during ripening and to evaluate their impact on the quality characteristics of the grain.

Materials and Methods

The study was carried out using grains of *Triticum aestivum* grown under field conditions. Samples were collected at three main stages of development: milk stage, dough stage, and full maturity. To ensure representativeness, grains were taken from several randomly selected plants and combined into composite samples for each stage. Immediately after harvesting, the samples were cleaned from impurities and placed in airtight containers to prevent changes in moisture content.

Before analysis, the grains were sorted according to maturity stage and, when necessary, separated into anatomical components such as the endosperm, embryo, and outer layers (bran). This allowed a more detailed investigation of water distribution within the grain structure. The total moisture content was determined using the standard gravimetric method. For this purpose, samples (3–5 g) were weighed and then dried in a laboratory oven at 105°C until a constant mass was reached. The loss in weight was used to calculate the percentage of moisture.

To evaluate the state of water, thermal and sorption methods were applied. Thermal analysis enabled differentiation of water fractions based on their evaporation characteristics at different temperatures. Free water was identified as the fraction that evaporates easily, whereas bound water required higher temperatures due to its association with macromolecules such as proteins and starch. Additionally, sorption–desorption experiments were conducted under controlled humidity conditions to determine the water-binding capacity of grain tissues. Based on these analyses, water was classified into free, weakly bound, and strongly bound forms.

The distribution of water within the grain was studied by stepwise separation and analysis of individual anatomical parts. Each fraction was examined for moisture content to determine the gradient of water distribution between tissues. Microscopic observations were also performed to qualitatively assess tissue hydration and structural differences during ripening.

All experiments were conducted in triplicate under controlled laboratory conditions (temperature 20–25°C, relative humidity 50–60%). The obtained data were processed using standard statistical methods, including calculation of mean values and standard deviations. The results were presented in tabular and graphical forms to facilitate comparison and interpretation Fig-1..

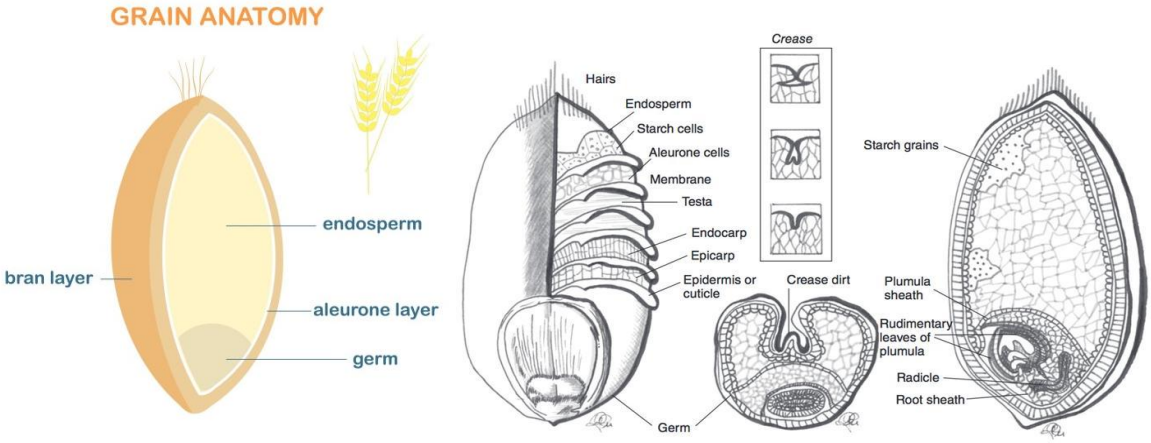


Fig-1. Distribution and transformation of water in wheat grain during ripening

The figure illustrates the internal structure of wheat grain (*Triticum aestivum*) and the distribution of water during different stages of ripening. In the early (milk) stage, water is present in high amounts and mainly in free form, uniformly distributed across tissues. During the dough stage,

moisture content decreases and water begins to bind with macromolecules. At full maturity, the overall water content is minimal, and most of it exists in a bound state. The embryo retains relatively higher moisture compared to the endosperm, while the outer layers show variable water content due to environmental interaction. This gradient reflects the functional specialization of grain tissues and directly influences grain quality and storage stability.

Results and Discussion

The results show that the ripening of wheat grain (*Triticum aestivum*) is accompanied by pronounced changes in both the amount and physicochemical state of water, which directly influence grain quality parameters. At the milk stage, the moisture content of the grain was highest (approximately 60–70%), with water predominantly in a free (capillary) form. This high level of free water обеспечивал интенсивные метаболические процессы, включая синтез белков, крахмала и других биополимеров, а также активный транспорт питательных веществ.

As the grain transitioned to the dough stage, the moisture content decreased to about 30–40%. At this stage, a significant portion of free water was converted into weakly bound water due to interactions with accumulating macromolecules. The increase in dry matter, especially starch in the endosperm, led to partial immobilization of water molecules. This change marked a reduction in metabolic activity and the beginning of structural consolidation of the grain.

At full maturity, the moisture content reached 12–14%, which is considered optimal for harvesting and storage. At this stage, most of the water existed in a strongly bound form. The predominance of bound water is associated with the formation of a dense matrix of starch–protein complexes, which enhances the mechanical strength of the grain and reduces susceptibility to microbial spoilage. This condition is critical for maintaining grain quality during long-term storage.

The analysis of water distribution revealed a heterogeneous pattern within the grain. The embryo consistently retained higher moisture compared to the endosperm, reflecting its physiological role in germination and higher enzymatic activity. The outer layers (bran) also showed relatively elevated and more variable moisture levels due to their direct interaction with environmental conditions. In contrast, the endosperm became progressively drier as ripening advanced, corresponding to its function as a storage tissue rich in starch.

These changes in water state had a direct impact on technological properties. The reduction of free water improved milling performance by increasing grain hardness and reducing deformation during grinding. Additionally, lower moisture levels at maturity minimized biochemical degradation and microbial growth, thereby enhancing storage stability. However, excessive drying could negatively affect germination capacity, particularly due to dehydration of the embryo.

Overall, the findings confirm that the transition from free to bound water and the redistribution of moisture within grain tissues are key factors determining the final quality of wheat grain. Proper control of these parameters is essential for optimizing harvesting time, improving processing efficiency, and ensuring safe storage conditions.

Conclusion

The conducted study confirms that during the ripening of wheat grains (*Triticum aestivum*), significant quantitative and qualitative changes occur in the state of water. From the milk stage to full maturity, the overall moisture content decreases steadily, reflecting the gradual completion of metabolic processes and the transition of the grain to a physiologically stable state.

A key outcome of the research is the transformation of water from free to bound forms. In the early stages, free water predominates and supports intensive biochemical reactions, while in later stages, bound water becomes dominant due to its interaction with proteins, starch, and other

structural components. This transition plays a crucial role in stabilizing the internal structure of the grain and reducing its biological activity.

The study also demonstrates that water distribution within the grain is uneven. The embryo retains relatively higher moisture compared to the endosperm, ensuring its viability for germination, while the outer layers show variable moisture due to environmental exposure. The endosperm, as the main storage tissue, becomes increasingly dehydrated as ripening progresses.

These changes have a direct impact on grain quality. The reduction of free water and increase of bound water improve mechanical strength, milling performance, and resistance to microbial spoilage, thereby enhancing storage stability. At the same time, maintaining optimal moisture levels is essential to preserve germination capacity and overall grain viability.

In conclusion, understanding the dynamics of water state and distribution in wheat grains is essential for optimizing harvesting time, improving post-harvest handling, and ensuring high-quality grain production.

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