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Biochemical Changes in Millet Seeds During Accelerated Ageing with Special Reference to Protein and Reducing Sugar Content

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Abstract:

Seed viability, vigour, and agricultural yield are influenced by seed ageing. Seed ageing in millets is known to produce biochemical reactions, which affect germination and seedling development negatively. This study presents a literature review on accelerated seed ageing as it relates to seed protein denaturation and degradation, and reduction in the level of seed sugar production. Accelerated seed ageing causes protein denaturation and degradation through the action of proteases and oxidative reactions and decreases protein levels. In addition, complex carbohydrates such as starch undergo degradation, leading to the formation and accumulation of reducing sugars, which may act as precursors to non-enzymatic browning (Maillard reaction).

Keywords: Seed deterioration, Accelerated ageing, Millet, Protein metabolism, Reducing sugar accumulation, Reactive oxygen species (ROS)

1. INTRODUCTION

Millets constitute an important group of small-seeded cereal crops that play a vital role in global food security, particularly in arid and semi-arid regions. Owing to their high nutritional value, including significant amounts of proteins, dietary fibre, vitamins, and minerals, millets have gained increasing attention as climate-resilient crops (Saleh et al., 2013). However, maintaining seed quality during storage remains a major challenge, as seeds undergo gradual deterioration, leading to reduced germination potential and vigour (McDonald, 1999).

Seed ageing is an inevitable and complex process influenced by environmental factors such as temperature, humidity, and oxygen availability (Bewley et al., 2013). Wherein seeds are exposed to elevated temperature and relative humidity to mimic natural ageing within a shorter time frame (Delouche and Baskin, 1973). This approach has been extensively used to evaluate seed longevity, vigour, and storage potential. The process of seed ageing is primarily associated with a series of biochemical and molecular changes. Proteins, which function both as storage reserves and enzymatic components, are highly susceptible to oxidative damage and enzymatic degradation during ageing (Priestley, 1986). Concurrently, the hydrolysis of complex carbohydrates results in the accumulation of reducing sugars, which may further contribute to seed deterioration through non-enzymatic reactions such as the Maillard reaction (Murthy et al., 2003).

The excessive generation of reactive oxygen species (ROS) leads to damage of cellular macromolecules, including proteins, lipids, and nucleic acids, ultimately affecting membrane integrity and metabolic efficiency (Bailly, 2004). Seed deterioration is further characterised by progressive biochemical damage, including protein degradation and accumulation of reducing sugars, which serve as important indicators of declining seed quality (Mahjabin et al., 2015)

In millets, similar patterns of biochemical deterioration have been reported under accelerated ageing conditions, highlighting the importance of biochemical markers in assessing seed quality (Kumar et al., 2015). Therefore, understanding the changes in protein content and reducing sugar levels provides valuable insights into the mechanisms of seed ageing. This review aims to synthesise existing knowledge on biochemical changes during accelerated ageing in millet seeds, with special emphasis on protein degradation and reducing sugar accumulation as key indicators of seed deterioration.

2. MATERIALS AND METHODS

In the case of this literature review, information was gathered from scientific journals. The sources of information were obtained by using scientific databases such as Google Scholar, PubMed, Scopus, Science Direct, and Web of Science. Some keywords used for searching were "seed ageing in millets," "accelerated aging," "protein degradation in seeds," "reducing sugars in seed deterioration," and "oxidative stress in seed aging." Recent articles that had been peer-reviewed were preferred.

2.1 Study Design

This current study makes use of secondary sources that have been obtained from the scientific literature that has been documented in the literature. A narrative review methodology was employed in analysing the biochemical processes that take place in the accelerated aging of the millet seeds. Protein degradation, reduction sugars, and oxidative stress form the basis of the analysis.

2.2 Inclusion and Exclusion criteria

In terms of **inclusion criteria** for this literature review, articles must be written in the English language, be reviewed by peers, and appear in scientific journals to ensure scientific validity. Articles that contained information on millet seed ageing and any information related to the process were included in the scope of this review. The literature review will focus on research on the biochemical reaction taking place during accelerated ageing and will be focused particularly on the degradation of proteins. For the **exclusion process**, those duplicates of papers that appeared on various databases were eliminated. Papers that did not relate to millet crops, seed ageing, or seed deterioration biochemistry were also eliminated from the review to maintain the specific nature of the research question. Those editorials, opinions or conference papers that lacked comprehensive data were also not included because there was no enough scientific data in them. Studies that did not have proper scientific methods or data presentation were also excluded for similar reasons.

2.4 Information Sources and Search Strategy

Literature was obtained from established scientific sources, including Google Scholar, PubMed, Scopus, Science Direct, and Web of Science. Keywords used include:

- Accelerated ageing of seeds
- Degeneration of millet seeds
- Protein catabolism in seeds
- Reduced sugar synthesis
- Oxidative damage in seed ageing
- Seed vitality and viability

2.5 Selection Process

The process of selecting studies involved several steps. First, titles and abstracts of articles were analysed to select those that are relevant. Inclusion criteria included studies related to biochemical changes in seeds under ageing.

2.6 Data Extraction

Relevant data were extracted manually from selected studies using a structured format. The following information was recorded:

- Author(s) and year of publication
- Type of study and experimental conditions
- Biochemical parameters studied (protein, reducing sugar, enzymes)
- Methods used for analysis
- Key findings and conclusions

2.7 Data synthesis

The Data analysis in this review was conducted on a descriptive basis, wherein the information obtained from selected studies was systematically organised and classified into major thematic areas such as protein degradation. Protein degradation was analysed in terms of loss of storage proteins and increased proteolytic activity, while carbohydrate metabolism was evaluated based on the breakdown of complex polysaccharides and subsequent accumulation of reducing sugars (Bailly, 2004; Murthy et al., 2003).

3. BIOCHEMICAL CHANGES DURING SEED AGEING

Accelerated ageing of seeds is characterised by many biochemical changes that occur as a result of seed deterioration. The first biochemical change associated with seed deterioration is oxidative stress, where the accumulation of reactive oxygen species causes damage to important biomolecules such as proteins, lipids, and nucleic acids. Moreover, enzyme activities are affected during the process of seed ageing, with an increase in the levels of proteolytic enzymes and the activities of enzymes associated with carbohydrate metabolism, such as amylases. Accelerated ageing also affects metabolic functions through a reduction in the efficiency of metabolic pathways as well as an impairment in the germination ability of seeds.

3.1 Changes in Protein Content During Seed Ageing

One of the most important biochemical alterations noted during seed ageing is that of protein degradation. Proteins present in the seeds act both as energy storage material and as part of the enzyme system in metabolic reactions. As a result of ageing, they become more prone to oxidative stress due to ROS, which leads to their structural damage in the form of fragmentation and denaturation. Moreover, the activity of protease also increases, leading to the breakdown of storage proteins into peptides and amino acids. Protein degradation leads to the deterioration of enzyme activity, loss of integrity of membranes, and metabolism. Consequently, it impacts negatively on germination. It has been noted through several investigations that there is a steady reduction in the protein content of aged millet seeds.

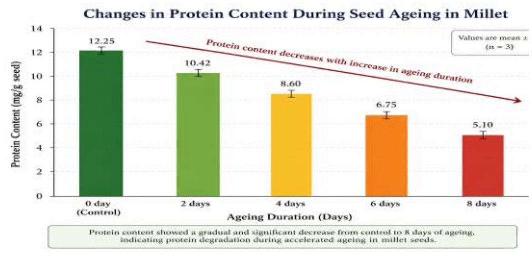

Fig 1: Changes in Protein Content During Accelerated Ageing of Millet Seeds"

3.2 Changes in Reducing Sugar Content During Seed Ageing

Accelerated ageing of seeds involves the degradation of polysaccharides into simpler forms and is facilitated by enzymes, particularly amylases. High levels of reducing sugars cause an increase in metabolic activities, such as respiration, whereas an excess amount is toxic. Reducing sugars can easily react without the help of enzymes through a process known as the Maillard reaction, resulting in the creation of toxic substances. Moreover, any imbalance in carbohydrate metabolism will impact energy production adversely. Research has indicated that there is an increase in reducing sugars with advancing age of seeds..

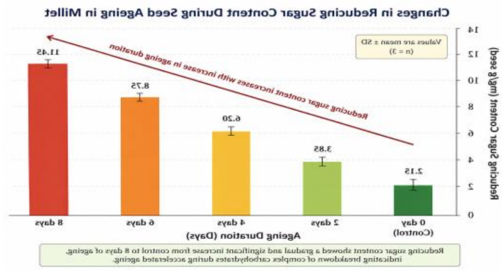

Fig 2 : Changes in Reducing Sugar Content During Accelerated Ageing of Millet Seeds"

3.3 Significance

An analysis of biochemical processes that take place during accelerated ageing of millet seeds is highly relevant and necessary to ensure a thorough knowledge of seed deterioration, viability, and long-term storage possibilities. Millets are nutrient-rich plants that can thrive in arid climate zones. To sustain agriculture, it is imperative to preserve the quality of these seeds. During accelerated ageing, several biochemical processes take place in seeds, such as protein hydrolysis and the accumulation of reducing sugars because of carbohydrate decomposition. These processes are an indication of loss of vigour, which affects the ability of seeds to germinate.

This review is important since it examines the existing literature devoted to the analysis of the biochemical processes taking place in millet seeds. Such a work may help discover the key aspects of seed ageing and detect the areas requiring further investigation.

4. FUTURE PROSPECTS

1. **More Insights into Molecular Pathways**
   A possible future trend would be a more detailed study of the mechanisms of seed ageing using approaches from genomics, proteomics, and metabolomics. These investigations should lead to the elucidation of important genes, proteins, and metabolic pathways regulating protein degradation and the accumulation of sugars (Bewley et al., 2013).
2. **Innovative Storage Methods for Prolonging Viability**
   Another area that requires considerable attention would be the creation of more advanced methods for extending the viability of seeds. Controlled atmosphere storage, humidity control, and low temperature storage methods may help mitigate seed deterioration via reduction of biochemical damage caused by the ageing process (McDonald, 1999).
3. **Using Antioxidants to Improve Seed Longevity**
   Another future trend may involve the use of natural or synthetic antioxidants to slow down seed ageing. Enhanced antioxidant capacity may allow for the reduction of ROS in the seeds as well as prevent oxidative damage to the components (lipids, proteins, DNA, RNA) (Bailly, 2004).
4. **Identification of Reliable Biochemical Indicators**
   More research is needed to identify reliable biochemical markers of seeds' early ageing processes. Such parameters as protein content, reducing sugar content, enzyme activity, and lipid peroxidation can serve as criteria of seed quality and be standardised in order to facilitate their fast assessment (Murthy et al., 2003)..
5. **Utilisation of Biotechnological Techniques**
   Several promising biotechnological approaches may be employed to extend the life span of seeds. Genetic modification of millets for greater resistance to oxidative stress and prevention of biochemical ageing is among such measures.
6. **Application of Modern Analytical Techniques**
   There are modern techniques available today that could help improve the efficiency of seed quality analysis. Spectroscopy and other modern techniques of molecular imaging and modelling may prove useful in identifying

biochemical alterations and ageing-related changes at an earlier stage.

5. CONCLUSION

Ageing of seeds is a natural phenomenon that causes deterioration in the viability and vigour of seeds of millets. Accelerated ageing causes several biochemical modifications, including protein breakdown and an increase in sugar content. The loss of proteins is due to enzymatic degradation and oxidation, while high levels of reducing sugars are caused by the breakdown of carbohydrates and cause additional deterioration. Moreover, ROS are known to damage cell components and cause loss of membrane integrity and decreased germination ability. It is necessary to understand the above-mentioned modifications to improve seed storage techniques.

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