NUTRITIONAL CHANGES DURING CEREAL STORAGE AND ENVIRONMENT CONTROL

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ABSTRACT

Cereals are popular foods consumed as part of a healthy lifestyle due to their beneficial nutritional content, such as fiber, vitamins, minerals, and phytochemicals. Local cereals like corn, millet, and sorghum have the potential to be developed as breakfast cereal products with nutritional content that is not inferior to wheat. Cereal storage is critical in the food supply chain because it can cause nutritional changes and deterioration of quality due to oxidation reactions, enzymatic activity, microbial growth, temperature, humidity, and environmental exposure. During storage, there may be a decrease in fat, fiber content, and changes in carbohydrates and proteins, as well as the formation of off-flavor and toxic compounds. To maintain the nutritional quality of cereals, it is necessary to control factors such as temperature, humidity, oxygen, light, and contamination through appropriate packaging, the addition of antioxidants, and processing technologies. In addition, natural preservatives such as plant extracts, modified atmosphere packaging, vacuum packaging, and low-temperature drying can also be used as an environmentally friendly quality control strategy.

Keywords: Cereals; Nutrition; Nutritional changes; Quality control; Storage

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INTRODUCTION

Cereal grains are staple foods for humans that are produced from stable cereal plants grown worldwide, which produce two-thirds or more of the world's developed food calories (Thapa et al., 2023). The fact that cereal production is used as a staple food in the world, which is estimated to produce around 2785 million tons according to FAO (2023), is highly dependent on global food security, further evidence of the importance of cereals and cereal products (Laskowski et al., 2019).

Wheat is a good source of protein, minerals, B-group vitamins, and dietary fiber (Shewry, 2007). Wheat provides almost 55% carbohydrates and 20% food calories. It contains 78.10% carbohydrates, 14.70% protein, 2.10% fat, 2.10% minerals, and a large amount of vitamins (thiamine and vitamin B) and minerals (Shewry, 2006). Wheat is also a source of minerals such as selenium and magnesium, essential nutrients for good health (Topping D, 2007). Research shows that the main parameters that determine the beneficial effects of cereals on the body are an increase in the amount of fiber, protein, and calcium, and a reduction in fat content.

At least 10,000 human populations worldwide consume cereal plants, the yields of which are cereal grains. The cereal grains consumed include three major food crops: wheat, corn, and rice (Ji et al., 2023). Cereals are made from grains such as wheat, rice, corn, or oats that are processed by milling or extrusion. The nutritional content of cereals can vary, such as carbohydrates, proteins, vitamins, fiber, and antioxidants (Hartvigsen et al., 2014). These components are not only a significant energy source, but also play a role in maintaining human health by reducing the risk of chronic diseases (Garutti et al., 2022).

Despite their global importance, cereal grains are highly susceptible to quality deterioration during post-harvest handling and storage. Improper storage practices can result in significant losses in both nutritional value and market quality (Workineh & Lemma, 2020). Critical factors such as excessive moisture, temperature fluctuations, pest infestations, and microbial contamination can accelerate biochemical and physiological damage to stored grains (Prabha, 2019). The decline in nutrient content, particularly protein, vitamins, and antioxidants, not only reduces the nutritional value of cereals but can also compromise food safety (Augusti et al., 2016). To address these challenges, the implementation of effective storage technologies and quality control measures is crucial. Maintaining optimal storage conditions can minimize nutrient loss, extend shelf life, and meet food safety standards. This highlights the need for further research into scientifically proven preservation strategies to maintain cereals' nutritional quality and physicochemical properties during storage.

Therefore, proper quality control strategies are needed to maintain the nutritional value and quality of cereals during storage.

CHANGES IN CARBOHYDRATES

Nutritional changes can be caused by various factors that affect the main components in food. Carbohydrates can experience a decrease in viscosity and hardness of the final product due to the activity of enzymes such as amylase, as well as experience color changes and the formation of off-flavor compounds through non-enzymatic browning reactions such as the Maillard reaction. Mechanical damage during storage and transportation can also damage the carbohydrate structure (Zralý et al., 2022).

CHANGES IN PROTEIN

Factors influencing changes in protein content in cereal grains, quantitative (decrease in concentration) and qualitative (changes in structure and function), include protein denaturation, which is a change in protein structure due to high temperatures, excessive humidity, or environmental fluctuations. Additionally, hydrolysis by endogenous protease enzymes can break down proteins into peptides and free amino acids, which can affect nutritional quality and taste (Esfandi et al., 2019). Proteins are highly susceptible to oxidation, particularly those containing sulfur-containing amino acids such as methionine and cysteine, which can lead to a decrease in water-binding capacity and cross-linking formation, resulting in a reduction in protein nutritional value (Bensik et al., 2022).

CHANGES IN LIPID

Lipids can undergo oxidation, resulting in rancidity and off-flavor compounds, either through the activity of lipolytic enzymes or metal contamination, such as iron. Light exposure, especially ultraviolet, can trigger fat photooxidation (Gao et al., 2023). In addition, lipid hydrolysis triggered by the activity of endogenous lipase enzymes and microbes that

can break down triglycerides into free fatty acids and glycerol, high water content, and warm temperatures can accelerate lipase activity, thereby increasing the conversion of fat into fatty acids (Kumar et al., 2021).

The formation of toxic compounds during storage can also be a food safety issue (Kroh et al., 2022). To minimize the impact of nutritional changes, controlling factors such as temperature, humidity, oxygen, light, and contamination is essential. Appropriate packaging, the addition of antioxidants, and the application of processing technologies can also help extend the shelf life and maintain the nutritional quality of cereals (Milani et al., 2022).

ENVIRONMENT CONTROL

Packaging can influence the reduction of nutritional content in cereals, as it is known that there are several factors that can cause damage to cereal grains and legumes during the storage process (Ktenioudaki, 2019). Forms of damage due to weight loss and reduced nutritional value can occur due to high water content. Cereals generally contain around 70-75% amylopectin. For example, corn contains around 75-80% amylopectin of its total starch, as does rice (Rehman, 2019).

Meanwhile, wheat and sorghum have around 70-75% amylopectin, like wheat and barley, and sorghum contains 70-80%. The protein content in cereals ranges from 6-15%. In cereals, fat is a minor nutrient component. The amount of lipids in cereals varies from 1-3% in millet, rice, black wheat, and wheat, 5-9% in corn, and 5-10% in wheat (Shewry, 2015). Carbohydrates decrease due to hydrolysis and respiration of starch, which can reduce the quality of cereals (Krishnan, 2021).

During cereal storage, cereals undergo several biochemical changes during the post-harvest and storage processes that can affect their quality. These include Starch Retrogradation, Lipid Oxidation, and loss of vitamins (Rehman, 2019). As with starch retrogradation, cereals undergo a process of re-crystallization of amylose and amylopectin after undergoing heating and cooling processes. This causes the texture of the cereal to become harder, drier, and more brittle during storage.

Meanwhile, lipid oxidation occurs when cereals are oxidized during storage, resulting in rancidity and unpleasant flavors, which in turn cause vitamins to deteriorate and essential fatty acids to be damaged (Rashid et al., 2022). Browning Reaction (Maillard) is also a form of deterioration, where the Maillard reaction occurs between reducing sugars and amino acids during storage, resulting in an undesirable brown color and taste (Ruan et al., 2018). Another factor is the moisture content of the cereal; the moisture content of the cereal during storage causes the cereal to become brittle and dry (Peleg et al., 2015). Another cause is the growth of microorganisms; if humidity and temperature are not controlled, molds and bacteria can grow during storage, causing spoilage and contamination (Suleiman et al., 2018).

The solution to maintaining the nutritional content of cereals during storage is that cereals must be stored in airtight packaging at low temperatures and humidity. The addition of antioxidants and the use of heat treatments can also help extend the shelf life of cereals (Petcu et al., 2023). Modified Atmosphere Packaging (MAP) can extend cereals' shelf life (Czerwiński et al., 2021). Research conducted by Siregar et al. (2017) on rice showed that using packaging with modified atmosphere (80% nitrogen and 20% carbon dioxide) could extend the shelf life of rice up to 6 months without significant changes in rice quality.

Low-temperature storage has also been proven effective in maintaining the quality of cereals (Cao et al., 2023). Research conducted by Manalu et al. (2016) on corn showed that storing corn at low temperatures (10°C) could extend the shelf life of corn up to 3 months while maintaining the nutritional content and physicochemical properties of corn.

Natural preservatives such as plant extracts can also be used as an environmentally friendly control strategy (Pinto et al., 2023). One example is the use of botanical pesticides in environmentally friendly quality control during seed storage. According to Kadir et al. (2014), one example of a botanical pesticide in environmentally friendly quality control during seed storage is studying the effectiveness of lemongrass leaves as a botanical insecticide by One example is the use of botanical pesticides in environmentally friendly quality control during seed storage. According to Kadir et al. (2014), one example of a botanical pesticide in environmentally friendly control during seed storage is studying the effectiveness of lemongrass leaves as a botanical insecticide by burning the leaves and making them into a powder to suppress attacks by corn weevils (*Sitophilus spp*.) during corn seed storage. Additionally, garlic can be used for environmentally friendly control during seed storage, as garlic extract functions as an insect

repellent (Anwar et al., 2014). The essential oils in garlic contain active acidic components. Hasnah and Hanif (2010), also studied the effect of garlic extract, and the results of their study suggest that garlic extract is effective as a botanical insecticide, and it has been proven to have a low percentage of corn seed damage.

Another effort in using natural preservatives in environmentally friendly quality control is vacuum packaging. Vacuum packaging has also been proven effective in extending the shelf life of cereals (Bauer et al., 2022). Research conducted by Sari et al. (2019) on corn showed that vacuum packaging can maintain corn quality for up to 6 months by minimizing damage from oxidation and microbial growth. Minimal processing, such as drying, can also be used as an environmentally friendly quality control strategy (Wu et al., 2024). In addition to corn, natural, environmentally friendly preservatives have been used for rice, like the research conducted by Marpaung et al. (2018) on rice, which showed that the addition of cinnamon bark extract could inhibit fungal growth and extend the shelf life of rice up to 4 months. Research conducted by Suparjo et al. (2018) on rice showed that drying rice at low temperatures (40°C) could maintain rice's nutritional content and physicochemical properties well.

CONCLUSION

In conclusion, maintaining the nutritional quality and safety of cereals during storage requires comprehensive control of environmental factors and the application of appropriate and sustainable preservation technologies to prevent nutrient loss and quality deterioration.

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