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METHODS FOR EXTENDING THE STORAGE LIFE OF POMEGRANATE FRUITS AND CHANGES IN THEIR QUALITY CHARACTERISTICS

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Abstract

This thesis analyzes modern methods for extending the storage life of pomegranate (Punica granatum L.) fruits and evaluates changes in their quality characteristics during postharvest storage. The effectiveness of cold storage, controlled atmosphere (CA), modified atmosphere packaging (MAP), and natural edible coatings, particularly chitosan-based coatings, was investigated. The findings indicate that these preservation technologies significantly reduce weight loss, maintain fruit firmness, suppress microbial decay, and preserve vitamin C, phenolic compounds, and antioxidant activity during prolonged storage. The results highlight the importance of advanced postharvest technologies for reducing economic losses and improving the export potential of pomegranate fruits while maintaining their commercial and nutritional quality.

Keywords: pomegranate, Punica granatum, storage life, cold storage, controlled atmosphere, modified atmosphere packaging, chitosan, quality characteristics, antioxidants, postharvest technology.

Introduction

Pomegranate (Punica granatum L.) is one of the most valuable fruit crops cultivated in many subtropical and temperate regions due to its high nutritional value, antioxidant properties, and increasing commercial demand. The fruit is rich in vitamins, organic acids, polyphenols, anthocyanins, and minerals, making it an important component of a healthy diet and an attractive product for both domestic consumption and international trade. However, despite its relatively thick peel, pomegranate is susceptible to physiological deterioration, moisture loss, microbial decay, and quality degradation during postharvest storage, leading to significant economic losses.Extending the storage life of pomegranate fruits while maintaining their physicochemical and sensory quality has become an important objective in postharvest technology. Various preservation techniques, including low-temperature storage, controlled atmosphere (CA), modified atmosphere packaging (MAP), edible coatings, and natural antimicrobial treatments, have been investigated to reduce weight loss, delay ripening, suppress microbial growth, and preserve nutritional quality. These technologies contribute to maintaining fruit firmness, color, total soluble solids, titratable acidity, and bioactive compounds during prolonged storage.

Changes in quality characteristics throughout storage are influenced by several factors, including cultivar, maturity stage at harvest, storage temperature, relative humidity, and preservation method. Continuous monitoring of these quality indicators is essential for determining the effectiveness of storage technologies and ensuring consumer acceptance. Understanding the relationship between storage conditions and fruit quality provides valuable information for producers, exporters, and the food industry.The aim of this study is to evaluate methods for extending the storage life of pomegranate fruits and to assess changes in their major quality characteristics during storage under different postharvest preservation conditions.

Main Part

Pomegranate (Punica granatum L.) is considered one of the most economically important fruit crops due to its excellent nutritional composition, long marketability, and high antioxidant capacity. Nevertheless, postharvest deterioration remains a major challenge for producers and exporters because fruits gradually lose moisture, firmness, and biochemical quality during storage. The preservation of fruit quality depends not only on genetic characteristics but also on storage temperature, relative humidity, harvesting maturity, packaging materials, and postharvest treatments. Recent studies indicate that the application of modern storage technologies can significantly extend shelf life while maintaining the commercial value of pomegranate fruits [1].Immediately after harvest, pomegranate fruits continue physiological respiration and transpiration. Respiration consumes sugars and organic acids, while transpiration causes water loss from the peel and arils. Excessive moisture loss results in shriveling of the rind, reduction in fruit weight, and deterioration of visual appearance. These changes directly affect consumer preference and market price. Scientific investigations have demonstrated that storage temperatures between **4–7°C** combined with **90–95% relative humidity** considerably reduce physiological weight loss and delay senescence compared with storage under ambient conditions [2].

One of the most effective approaches to extending storage life is refrigerated storage. Low temperatures decrease metabolic activity, respiration rate, and enzymatic reactions responsible for fruit aging. However, temperatures below 4°C may induce chilling injury in sensitive cultivars, causing peel browning, membrane damage, and internal discoloration. Therefore, selecting the optimum storage temperature according to cultivar characteristics is essential for maintaining postharvest quality.Controlled Atmosphere (CA) storage has become another valuable technology in commercial fruit preservation. In this system, oxygen concentration is reduced while carbon dioxide concentration is moderately increased. Such atmospheric modification slows respiration, suppresses ethylene production, and inhibits microbial development. Research has shown that CA storage can extend the commercial storage period of pomegranate fruits by several weeks while preserving firmness, juice content, and antioxidant compounds [3].

Modified Atmosphere Packaging (MAP) is also widely used in fresh fruit preservation. Special polymeric films regulate gas exchange around the fruit, creating an atmosphere with lower oxygen and higher carbon dioxide concentrations than ambient air. This technique reduces dehydration and delays physiological deterioration. Moreover, MAP minimizes mechanical damage during transportation and maintains attractive external appearance throughout distribution.Edible coatings have received considerable scientific attention during the last decade as environmentally friendly alternatives to synthetic preservatives. Natural coating materials such as chitosan, aloe vera gel, starch, pectin, beeswax, and gum arabic form thin protective layers on the fruit surface. These coatings reduce water vapor transmission, decrease respiration intensity, and inhibit pathogenic microorganisms. In addition, several edible coatings possess antimicrobial and antioxidant activities that further improve fruit preservation.

Among these materials, chitosan has demonstrated remarkable effectiveness. Chitosan coatings create semi-permeable barriers around fruits while simultaneously inhibiting fungal growth through natural antimicrobial mechanisms. Numerous studies report that coated pomegranates retain higher firmness, lower weight loss, and improved nutritional quality during prolonged storage compared with untreated fruits [4].Another promising preservation strategy involves the application of plant-derived essential oils. Essential oils extracted from thyme, cinnamon, clove, oregano, and rosemary exhibit strong antimicrobial activity against common postharvest pathogens. When incorporated into edible coatings or packaging materials, these natural compounds effectively suppress fungal infections without leaving harmful chemical residues. Consequently, consumer demand for organically preserved fruits has encouraged increased adoption of natural preservation technologies.

Fruit quality evaluation during storage relies on several physical, chemical, and sensory indicators. Weight loss is generally considered one of the most important physical parameters because

excessive dehydration rapidly reduces market acceptability. Fruit firmness reflects structural integrity of peel tissues and influences resistance to mechanical injury during transportation. Soluble solids content (SSC) provides an estimate of sugar concentration, whereas titratable acidity (TA) indicates changes in organic acid metabolism during storage.Vitamin C represents another important nutritional quality parameter. Although pomegranate fruits naturally contain considerable amounts of ascorbic acid, gradual oxidation during storage reduces vitamin C concentration. Likewise, total phenolic compounds and anthocyanins decrease over time because of enzymatic oxidation and pigment degradation. Since these bioactive compounds contribute significantly to antioxidant capacity, maintaining their stability remains an important objective in postharvest technology.

Color characteristics are also essential commercial quality indicators. Consumers generally associate bright red peel color with freshness and superior quality. Prolonged storage may result in peel browning, discoloration, and pigment degradation. Appropriate storage conditions considerably slow these undesirable changes by reducing oxidative reactions.

The effectiveness of different storage technologies on major quality characteristics is summarized below.

Table 1. Effect of different storage methods on pomegranate quality during storage

Storage method	Storage life	Weight loss	Firmness	Disease incidence	Overall quality
Ambient storage	20–30 days	High	Rapid decrease	High	Poor
Refrigerated storage (5°C)	60–90 days	Low	Good	Moderate	Good
Controlled atmosphere	90–120 days	Very low	Excellent	Low	Excellent
Modified atmosphere packaging	80–100 days	Low	Very good	Low	Very good
Chitosan edible coating	90–110 days	Very low	Excellent	Very low	Excellent

Modern postharvest research increasingly combines several preservation technologies to maximize storage performance. For example, refrigerated storage combined with edible coatings or modified atmosphere packaging provides better protection than individual treatments alone. Such integrated approaches effectively reduce respiration rate, maintain membrane integrity, preserve antioxidant compounds, and minimize microbial decay.

From an economic perspective, extending storage life enables producers to market fruits during off-season periods when prices are generally higher. This improves profitability while reducing postharvest losses throughout the supply chain. Furthermore, improved storage technologies facilitate long-distance export, allowing producers to access international markets with minimal quality deterioration.Overall, available scientific evidence demonstrates that successful preservation of pomegranate fruits depends on maintaining appropriate environmental conditions while minimizing physiological and microbial deterioration. Combining refrigeration with environmentally friendly preservation technologies represents one of the most promising strategies for maintaining commercial quality and nutritional value throughout extended storage periods [1–4].

Conclusion

The findings of this study demonstrate that the storage life of pomegranate (Punica granatum L.) can be significantly extended through the application of appropriate postharvest technologies.

Conventional refrigerated storage remains one of the most effective methods for reducing respiration rate, moisture loss, and physiological deterioration. However, integrating refrigeration with advanced preservation techniques such as controlled atmosphere (CA), modified atmosphere packaging (MAP), and edible coatings provides superior protection against microbial decay while maintaining the fruit's nutritional and sensory quality.The study also indicates that storage conditions have a direct influence on major quality parameters, including fruit weight, firmness, total soluble solids, titratable acidity, vitamin C content, phenolic compounds, anthocyanins, and antioxidant activity. Proper management of temperature and relative humidity effectively slows biochemical changes responsible for quality deterioration and extends commercial shelf life.Among the evaluated preservation methods, edible coatings based on natural biopolymers, particularly chitosan, demonstrated considerable potential as environmentally friendly alternatives to synthetic chemical preservatives. These coatings reduce moisture loss, suppress fungal growth, and preserve the physicochemical properties of pomegranate fruits during prolonged storage. Likewise, controlled atmosphere storage showed excellent performance in maintaining overall fruit quality and reducing postharvest losses.In conclusion, combining refrigeration with modern postharvest preservation technologies offers the most effective strategy for extending the storage period of pomegranate fruits while preserving their nutritional value, commercial appearance, and consumer acceptability. Future research should focus on developing sustainable, biodegradable preservation materials and optimizing integrated storage systems suitable for commercial production and international export.

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