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REVIEW ARTICLE

# Post-Harvest Physiological Changes of *Toona sinensis* and Advances in Preservation Technologies

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## Abstract

*Toona sinensis*, a woody vegetable, is highly valued for its nutritional and medicinal properties. However, with the continuous improvement of people's living standards and the general concern about food safety, they want to consume *Toona sinensis* safely and for a prolonged period. Therefore, new requirements have been put forward for the preservation of *Toona sinensis*. In this paper, we summarize the research results of *Toona sinensis* from the perspectives of post-harvest physiological changes and preservation technology, analyze the changes of physiology, biochemistry, and quality of *Toona sinensis* after harvest, and analyze the effects of different post-harvest preservation technologies on the quality of *Toona sinensis*, as well as look forward to the future preservation of *Toona sinensis* and the direction of research. The aim is to extend the storage period of *Toona sinensis*, improve its economic value, provide a theoretical reference for the study of *Toona sinensis* processing and preservation technology, and also provide a reference for the preservation of woody vegetables.

## Toona Sinensis Value and Preservation Significance

*Toona sinensis* (A. Juss.) Roem, a deciduous tree belonging to the Meliaceae family, is widely planted in North and East China, as well as Central and South China, and is one of the common woody vegetables in China. As a woody vegetable with high nutritional value and medicinal value, the young shoots of *Toona sinensis* are rich in proteins, sugars, a variety of minerals and polyphenols, flavonoids and other active substances [1]. Among them, polyphenols can remove free radicals in the body, reduce oxidative stress damage, and play a role in slowing down the aging process [2]. Flavonoids, on the other hand, have anti-inflammatory, antibacterial and other health benefits, and are popular among consumers [3]. However, the consumption of *Toona sinensis* is strictly limited by the season, and after harvesting, it is easy to cause a sudden drop in quality due to aging, browning and other problems, shortening the shelf life, which seriously restricts its economic value [4]. Therefore, an in-depth investigation of post-harvest physiological change rules and high-efficiency preservation technology of *Toona sinensis* is of great significance to prolong the preservation period and enhance the economic value.

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## Physiological Changes of *Toona Sinensis* After Harvesting

Although the *Toona sinensis* is detached from the mother body after harvesting, it still maintains certain life activities, of which respiration is the main part of its metabolic activities. During the respiration process, *Toona sinensis* will continuously consume the nutrients in the body, and release carbon dioxide and heat at the same time, which will lead to a gradual decline in its quality, such as deterioration of taste, loss of nutrients, and so on [5]. Therefore, one of the core objectives of preservation is to slow down the respiration of *Toona sinensis*, thus slowing down their aging process. The post-harvest physiological changes in *Toona sinensis* mainly include both reactive oxygen metabolism and browning. In terms of reactive oxygen metabolism, Reactive Oxygen Species (ROS) are a class of highly active substances produced during cellular metabolism [6]. A moderate amount of reactive oxygen species has a certain regulatory effect on the normal physiological activities of cells, but when reactive oxygen species accumulate in large quantities, they cause damage to biological macromolecules such as proteins, nucleic acids and lipids. This damage destroys the structure and function of the cell, which in turn affects the function of mitochondria. Mitochondria are the "energy factories" of the cell, and their impaired function will lead to an inadequate supply of cellular energy and accelerate cellular aging and death. It has been found that the accumulation of ROS induces oxidative damage to biomolecules in the cell, such as proteins, lipids & nucleic acids, which can predispose the biofilm to oxidation and the formation of lipid peroxides [7]. In addition, the degree of damage to *Toona sinensis* cell membranes under different packaging conditions continued to increase with increasing storage time, which further illustrates the important influence of reactive oxygen metabolism on the postharvest quality of *Toona sinensis* [8].

In terms of browning, browning is an important factor affecting the appearance and quality of *Toona sinensis*, which will make them lose their original color and commercial value. The occurrence of browning is caused by a variety of factors, among which phenolic substances are the material basis for the occurrence of browning, while enzymes such as Polyphenol Oxidase (PPO) and Peroxidase (POD) play an important catalytic role in the browning process [4]. When *Toona sinensis* cells are damaged or during storage, phenolics will come into contact with

these enzymes and oxidize with the participation of oxygen to produce brown substances, thus leading to browning. Storage temperature has a significant effect on the change in the activity of these enzymes. Generally speaking, within a certain range, an increase in temperature enhances the activity of enzymes and accelerates browning, while a low temperature inhibits the activity of enzymes and delays browning [9]. In addition, studies have shown that Lipoxygenase (LOX), CAT (Catalase), APX (Ascorbic acid Peroxidase) and other fruits and vegetables have a certain relationship with browning, SOD (Superoxide Dismutase) can catalyze the intracellular superoxide dismutation reaction to generate H<sub>2</sub>O<sub>2</sub> and O<sub>2</sub>, scavenging reactive oxygen species generated in the process of metabolism, reducing the content of reactive oxygen species needed for enzymatic browning reaction, and inhibiting the effect of browning, and the degree of SOD activity is negatively correlated with SOD activity. The degree of browning was negatively correlated with SOD activity [10].

## Freshness Preservation Technology

In order to prolong the freshness period of *Toona sinensis*, a variety of preservation techniques have been researched and applied, mainly including physical preservation, chemical preservation and biological preservation.

### Physical preservation

Physical preservation is a technology to inhibit the physiological metabolism and microbial growth and reproduction of *Toona sinensis* by changing the environmental conditions, so as to achieve the purpose of preservation. Low-temperature preservation is the most widely used method in physical preservation. Low temperature can effectively inhibit the transpiration and respiration of *Toona sinensis*, reducing the consumption of nutrients and water loss. Studies have shown that the loss of plant weight, vitamin C, and chlorophyll is minimized at a temperature of 1°C and 95% humidity [11]. The longest storage time of *Toona sinensis* was found in the storage environment of 0°C. This is because the respiration and enzyme activities of the *Toona sinensis* are at a lower level at around 0°C, which can maximally delay its aging and browning [12].

Heat treatment is also a commonly used means of physical preservation. Appropriate heat treatment can passivate the enzyme activities, such as PPO (Peroxidase) and POD (Polyphenol Oxidase) in the



body of the *Toona sinensis*, thus inhibiting browning and decomposition of nutrients. For example, using hot water at 95°C to scald and bleach *Toona sinensis* can significantly inhibit the activity of POD and prolong the freshness period of *Toona sinensis*, although it will lead to the loss of some nutrients [13].

Non-thermal sterilization technology is a new type of physical preservation technology developed in recent years, such as ultra-high-pressure sterilization technology. The technology is to apply higher pressure to the *Toona sinensis* at room temperature, using the role of pressure to kill microorganisms, while not causing too much damage to the nutrients of the *Toona sinensis*, and can better retain its original quality and flavor [14].

Gas-conditioning preservation technology, on the other hand, is to inhibit the respiration and microbial growth of *Toona sinensis* by adjusting the ratio of gas components in the storage environment, such as increasing the concentration of carbon dioxide and decreasing the concentration of oxygen [15]. It was found that the use of LDPE (Low-Density Polyethylene) packaging combined with refrigeration can effectively regulate the gas environment inside the package and achieve better preservation [16]. Lin S found that the combination of ozone and polyethylene improved the postharvest quality and shelf life of *Toona sinensis* [17].

Decompression preservation technology is used to reduce the partial pressure of oxygen by lowering the air pressure of the storage environment, so as to reduce the respiratory intensity and ethylene production of *Toona sinensis*, and delay their aging and browning. Specific decompression treatment conditions, such as a certain vacuum degree and temperature, can enable the *Toona sinensis* to maintain better quality for a longer period of time [18].

### Chemical preservation

Chemical preservation is the use of chemical preservatives to inhibit the growth and reproduction of microorganisms, delay the physiological metabolism of *Toona sinensis*, so as to achieve the purpose of preservation. Chemical preservatives have the advantages of good effect and low cost, so they are widely used in actual production.

The mechanism of action of preservatives mainly includes inhibition of microbial growth, passivation of enzyme activity, and reduction of oxidation of

nutrients, etc. Shuhui Z found that bioactive peptides used for food preservation could prolong the shelf life through bacteriostatic and antioxidant effects [19].

### Biological preservation

Biopreservation is a technology that utilizes natural biological substances or their extracts for preservation, which has the advantages of high safety and environmental friendliness [20].

Natural plant extract is one of the commonly used preservatives in the field of biological preservation. It has a significant effect when it is applied to the storage and preservation of fruits and vegetables: such preservatives not only have a clear bactericidal effect, but also can effectively regulate the physiological metabolic process of fruits and vegetables, thereby delaying the occurrence of decay and giving full play to the preservation effect. Ginger has a significant antibacterial effect on *Salmonella typhi*, *Escherichia coli*, *Bacillus subtilis* and other microorganisms. Gingerol and gingerol are considered to be active components, which can lead to swelling and rupture of bacterial cells [21]. Ginger Essential Oil (GEO) has become an ideal natural substitute for chemical preservatives due to its excellent antibacterial and antioxidant activities. After being encapsulated by nanoemulsion, Pickering emulsion and solid particles, it is added to the film matrix to further improve the effect of food preservation [22]. Spraying 6-Benzylaminopurine (6-BA) can effectively delay the senescence of many horticultural plants [23]. Exogenous betaine also has a good fresh-keeping effect. Exogenous betaine treatment has the best fresh-keeping effect on *Toona sinensis* and can effectively maintain the quality of *Toona sinensis*. Exogenous betaine treatment maintained the quality of post-harvest plants by reducing antioxidant capacity and inhibiting the activity of energy metabolism-related enzymes [24]. Mokhtaria BY, et al. [25] have shown that polyphenols and flavonoids in propolis extract have antioxidant capacity and can be used for the preservation of fruits and vegetables.

Composite coating preservation technology involves mixing a variety of polymer materials to form a coating, which is coated on the surface of plants to form a layer of protective film. This protective film can regulate the respiration of plants, reduce the evaporation of water and the loss of nutrients [26]. Shahbazi Y, et al. [27] studied that carboxyl methyl cellulose and chitosan embedded carnation essential oil can be used to make a composite preservative for



fresh strawberry preservation, which can effectively inhibit the reproduction of *Listeria monocytogenes*. Dou L, et al. [28] showed that the addition of 2.0 % Tea Polyphenols (TP) to gelatin and sodium alginate film solution could improve the physical properties and antioxidant activity of the film, and the DPPH free radical scavenging rate reached 90.62 %. Chitosan has the characteristics of easy solubility in organic acids. It is easy to form a transparent film to cover the surface of food. It can adjust the concentration of O<sub>2</sub> and CO<sub>2</sub> inside and outside the film. It has the effect of gas regulation, which can weaken the respiration of food and has a good effect of inhibiting spoilage bacteria [29]. Chitosan has good film-forming and antibacterial properties, and tea polyphenols have strong antioxidant properties. The combination of the two can play a synergistic role and improve the preservation effect [30]. For example, the coating film formed by the combination of chitosan and tea polyphenols can achieve a better preservation effect under a certain concentration ratio [31].

## Research Status and Prospects

At present, there are relatively more studies on the preservation of *Toona sinensis* in China, and certain results have been achieved in the application effects of various preservation techniques. However, most of these studies focus on the observation and evaluation of macro preservation effects, and there is still insufficient research on the deep mechanism of physiological changes after harvesting of *Toona sinensis*. For example, the research on how reactive oxygen metabolism specifically affects the senescence process of *Toona sinensis* cells and the interaction mechanism of various enzymes during browning is not deep enough.

In the future, the research on *Toona sinensis* preservation should be developed in the following directions: firstly, the mechanism of physiological changes should be studied in depth to reveal the essential causes of postharvest senescence and browning of *Toona sinensis*, to provide a theoretical basis for the development of more effective preservation strategies. Secondly, physical and biological preservation techniques should be vigorously developed. Physical preservation technology has the advantages of high safety and no chemical residue, while biological preservation technology meets people's requirements for food safety and environmental protection. Finally, the development of natural bioconservatives should

be increased, highly efficient, safe, and low-cost bioconservatives should be developed by utilizing natural plant extracts, microbial metabolites, etc., to provide stronger support for the practical application of *Toona sinensis* preservation. Through these researchs and developments, it is expected to further improve the preservation effect of *Toona sinensis*, extend its shelf life and enhance its economic value.

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