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Retraction

Retracted: Combination of Fruit and Vegetable Storage and Fresh-Keeping with Postharvest Heat Treatment

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] Y. Zhao and R. Zheng, "Combination of Fruit and Vegetable Storage and Fresh-Keeping with Postharvest Heat Treatment," *Journal of Chemistry*, vol. 2022, Article ID 8681499, 12 pages, 2022.

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Research Article

Combination of Fruit and Vegetable Storage and Fresh-Keeping with Postharvest Heat Treatment

Yunfeng Zhao[1] **and Ruisheng Zheng**[2]

[1]*Analysis and Testing Center, Yancheng Institute of Technology, Yancheng 224051, Jiangsu, China*
[2]*College of Oceanology and Food Science, Quanzhou Normal University, Quanzhou 362002, Fujian, China*

Correspondence should be addressed to Yunfeng Zhao; zhaoyunfeng1188@126.com

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Hot water treatment can effectively improve the storage quality and shelf life of harvested vegetables. The essence of this method is the heat transfer process in which heat is transferred from the high-temperature treatment medium to the low-temperature fruit and vegetable tissues. However, most of the current research projects only focus on the effect of heat treatment on the biological aspects of fruits and vegetables. From the perspective of fruit and vegetable storage and preservation, there are few internal mechanisms that heat treatment affects biological preservation, and most of the research projects only focus on continuous heat treatment. This article aims to study the combination of storage and preservation of fruits and vegetables with postharvest processing technology. To this end, this article proposes the combined use of heat treatment technology through the analysis and improvement of data acquisition problems in the heat treatment process to make the data obtained more reliable and, at the same time, design experiments to explore the improved heat treatment technology. The experimental results in this paper show that the improved storage and preservation of fruits and vegetables combined with postharvest heat treatment technology improves the preservation of fruits and vegetables by 37%. In addition, the overall taste of fruits and vegetables during the preservation process has not been greatly lost, only reduced by 7%, which can be well applied to actual fruit and vegetable processing.

1. Introduction

Fruit and vegetable agricultural products are rich in nutritional value and low in fat content. They are more and more favored by consumers, and their consumption is increasing year by year. Green fruits and vegetables are perishable. Due to the aggravation of environmental and industrial pollution, the public pays more and more attention to the fresh-keeping quality of fruits and vegetables. However, the fruit and vegetable preservation industry in China started late, the green awareness is weak, and the postharvest processing technology and methods are backward, resulting in a huge waste of resources and economic losses in harvesting vegetables. According to incomplete market statistics, domestic fruit and vegetable rot per year exceeds 80 million tons, plus labor and equipment costs, causing huge economic losses of more than 75 billion yuan in the fruit and vegetable field each year, and the total social industry share is as high as 30% and above.

As a country with a large population, China will have huge market potential in the fruit and vegetable industry for a long period of time in the future. However, in recent years, due to the repeated occurrence of food safety accidents and the over-standard, illegal, and abuse of chemical preservatives, the public has many doubts about the safety and effectiveness of chemical preservatives. Therefore, reducing the hidden safety hazards in the field of fruit and vegetable preservation and enhancing the research of fruit and vegetable preservation and storage technology are urgent to improve the development of China's agriculture and enhance the utilization and safety of food.

As early as the last decade, the heat treatment technology of fruits and vegetables was discovered and put into research in the 20th century. Its safety and effectiveness have made general public approval. For this reason, more and more people have begun to invest in this research. Vigneault et al. believe that although specific physical treatment methods, such as heating and ultraviolet radiation, have been developed to increase the phytochemical composition of horticultural products, there is little information about the engineering aspects of these treatment methods. They reviewed the engineering aspects related to phytochemical enhancement of physical processing to determine the process parameters required to obtain reproducible results, the basic information required for process scale-up, and the key parameters required to ensure proper monitoring and control for commercial applications [1]. Marti-Herrero et al. evaluated the feasibility of treating fruit and vegetable waste from the municipal market in a full-scale anaerobic digester with the lowest implementation and operating costs, that is, no pretreatment, clean water consumption, and active heating or mixing are required. For this reason, under actual operation and weather conditions in Bolivia for a year, a 13.9 m^3 digester was monitored, which forced solids to be submerged, obtained heat through solar radiation, and recirculated sewage [2]. Huang et al. conducted the single factor test based on the Box–Behnken response surface optimization test. The optimal ratio of the compound vegetable and fruit modifier is 11.10% for tomato, 6.53% for ginger, 6.70% for kiwi, and 10.15% for papaya juice, and the sensory score for beef is 95.10 [3]. Namrata et al. believe that the plant hormone ethylene has many beneficial and harmful effects on the postharvest quality and storage life of fruits and vegetables. Given the current global challenge of reducing postharvest loss and waste of fruits and vegetables, the importance of ethylene management in the supply chain is of paramount importance. For this reason, they have applied various methods in the supply chain over the years. However, under real-time storage and transportation conditions, effective management of ethylene is still a challenging task [4]. In his article, Maxkamov focused on the world population's increasing demand for agricultural products year by year, as well as the unequal use of modern technology in solving these problems and agricultural production and exports [5]. Li et al. reported that *Yarrowia lipolytica* was engineered to produce SA from the hydrolysate of fruit and vegetable waste (FVW). They optimized the hydrolysis conditions and then proved the feasibility of using the hydrolysate to produce SA through *Yarrowia lipolytica* PSA02004. Using 100 gL^{-1} of FVW hydrolysate containing glucose and 4% corn steep liquor (CSL) as fermentation medium, the SA titer and yield of 43.1 gL^{-1} and 0.46 gg^{-1}, respectively, were obtained through free cell batch fermentation [6]. George et al. used the Page model to analyze the response surface and determine the key factors affecting drying. The response surface analysis shows that temperature, speed, and initial moisture content are the key drying factors. In order to achieve the drying prediction, a quadratic formula with two variables and a chart relating the drying time to temperature and speed are given, based on a drying moisture content of 10% [7]. Chander and Kannadhasan eliminated the threat by processing and recycling FVW into animal and poultry feed. They outlined the potential of FVW as animal and poultry feed. In addition, they also described the way forward and strategies to cope with restrictions and challenges, with special mention of FVW, emphasized social marketing of waste disposal, and emphasized the collaborative participation of stakeholders involved in the fruit and vegetable value chain [8]. The above-mentioned documents are very detailed in the description of related food insurance and heat treatment technology and also have detailed explanations on the use of related technologies; but none of them combined the two for research and analysis, and there are not many studies on the effects of treatment.

The innovation of this article is to use the heat treatment technology of fruits and vegetables as the technical support, combined with the improvement of the related fruits and vegetables storage and preservation theory, analyze its specific data acquisition methods, improve its data acquisition methods, ensure the accuracy of data acquisition, and ensure the accurate implementation and precise control of heat treatment technology.

2. Heat Treatment and Preservation Methods of Fruits and Vegetables

2.1. Fruit and Vegetable Heat Treatment Unit. Fruit and vegetable heat treatment equipment is the basis for research on heat-treatment-related technologies. At present, there are few research projects on heat treatment equipment at home and abroad, and electric heating methods are mostly used to directly prepare treated water, which has low energy efficiency. In order to improve the energy efficiency of the equipment, this chapter builds fruit and vegetable heat treatment equipment based on the heat pump principle to produce the required hot water. The operation of heat treatment equipment for fruits and vegetables can be divided into the heating stage of the treatment medium and the heat treatment stage of fruits and vegetables [9]. During the heating phase of the treatment medium, the system runs in the reverse cycle to continuously transfer heat to the medium in the fruit and vegetable treatment tank through the plate heat exchanger, and the temperature of the treatment medium continues to rise with the running time. When the temperature of the processing medium reaches the set value, it will enter the fruit and vegetable heat treatment stage [10]. The load of the unit during the heat treatment stage of fruits and vegetables mainly comes from the heat dissipation of the maintenance structure and the heat absorption of fruits and vegetables. Therefore, in the heat treatment stage of fruits and vegetables, the total load of the unit is constantly changing, and the heat generated by the fixed frequency operation of the compressor does not match the load of the unit [11]. Fruits and vegetables are highly sensitive to the temperature of the processing medium, and fluctuations in the temperature of the medium affect the effect of heat treatment, and even heat damage may occur [12]. In order to better improve the temperature control accuracy of the heat treatment medium of fruits and vegetables, this chapter is based on the traditional PID control method in the heat treatment stage of fruits and vegetables, adding the idea of

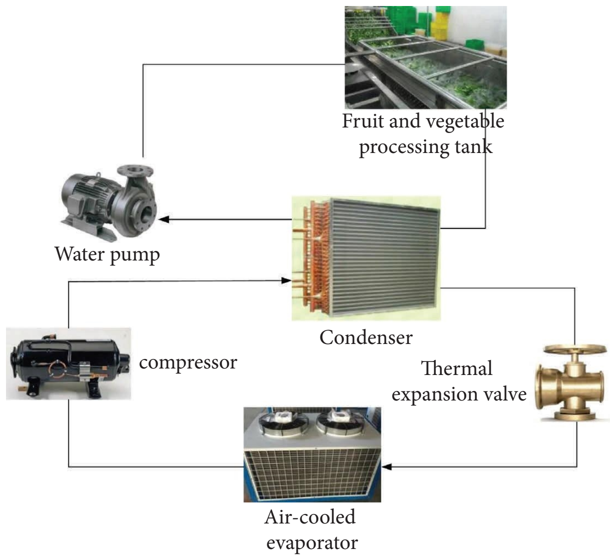

Figure 1: Schematic diagram of the heat treatment system for fruits and vegetables.

feedforward control to improve the control performance of the system. And the automation control program was written based on Siemens PLCS7-200 as the core. The article studies the operating characteristics of fixed frequency (30, 40, 50 Hz) in the medium heating stage, and the parameter law of the medium temperature in the processing tank, the temperature of the fruit and vegetable tissue, and the energy consumption under the PID frequency conversion or the PID frequency conversion control with feedforward during the fruit and vegetable heat treatment phase provide guarantee for further research on heat treatment of fruits and vegetables [13].

The unit mainly includes two subsystems, which are a heat pump system, composed of a compressor, a fin heat exchanger, a throttling device, and a plate heat exchanger, and the fruit and vegetable heat treatment system, composed of a plate heat exchanger, fruit and vegetable processing tank, filter, water pump, etc. [14]. Figure 1 shows the principle diagram of hot water produced by fruit and vegetable processing equipment.

In the fruit and vegetable heat treatment system, the heat treatment medium first exchanges heat with the heat pump working fluid through the condenser, and then it enters the treatment tank under the action of the circulating water pump to heat the fruits and vegetables [15]. Appropriate heat treatment does not affect weight loss, but heat treatment with too high processing temperature will accelerate the weight loss of fruits and vegetables during storage. The higher the temperature and the longer the time, the faster the weight loss of fruits and vegetables.

The harvested vegetables undergo various physiological activities at all times during the storage process. With reference to previous research conclusions, the constructed physical model was divided into several layers to correspond to different organizational structures. To simplify the model, the following assumptions were made: the difference in thermophysical properties only exists between the layers, and the thermophysical properties of the same layer are the same. Fruits and vegetables were simplified into cylindrical shape, and the tissue temperature was uniform before processing. The heat treatment process is relatively short, and the evaporation of surface water can be ignored. During the heat treatment of fruits and vegetables, the surface convective heat transfer coefficient was equal everywhere, ignoring the respiration heat of fruits and vegetables [16].

In the heat treatment process, distilled water is used as the treatment medium, the surface of fruits and vegetables and the treatment medium undergo convective heat exchange, which in turn generates heat exchange, and heat conduction occurs in the internal tissue. Based on the assumptions and simplifications, the internal, central, and external tissues of fruits and vegetables are, respectively, corresponding to the three layers of the physical model: the inner, middle, and outer layers, and each layer has no heat transfer resistance and is closely connected, as shown in Figure 2.

As an important pest quarantine method, heat treatment is to kill the individual insects in the fruit after a period of time under specific temperature conditions. After heat treatment of fruits and vegetables, it can control postharvest diseases caused by more than 20 kinds of bacteria, such as *Colletotrichum, Penicillium*, *Pythium*, Sclerotinia, *Polytrichum*, *Rhizopus*, *Alternaria*, *Chromobia*, *Phoma*, *Mucor*, *Phytophthora*, and *Erwinia*. The effect of heat treatment on the growth and development of insects is mainly manifested in the production of heat shock proteins in their bodies. Within the critical temperature range, the metabolism and respiration of insects increase as the body temperature of insects increases, and the nervous system and endocrine system of insects become disordered with the increase of body temperature. Heat treatment achieves the purpose of improving postharvest quality, enhancing stress resistance, and preventing postharvest diseases by affecting physiological and biochemical changes.

2.2. Determination of the Correlation Coefficient of Fruits and Vegetables. In this paper, a thermal probe test system is used to determine the thermal conductivity of the fruit. The thermal probe method is based on the transient hot wire method model. Its basic principle is to insert a sufficiently thin metal needle (radius $r0$, length L, and $L >> r0$) into a homogeneous and uniform temperature sample. That is, "heating source," applying a constant magnitude of current or power to the metal needle will cause the metal needle to heat up and the temperature will rise, and the metal needle will transfer the heat to the surrounding medium to be measured in a thermally conductive manner, so that the temperature of the medium will rise. The relationship of temperature change with time will vary with the medium to be measured, so it contains the thermal conductivity information of the medium to be measured. According to its "temperature-time" change relationship, the thermal conductivity of the tested sample can be determined.

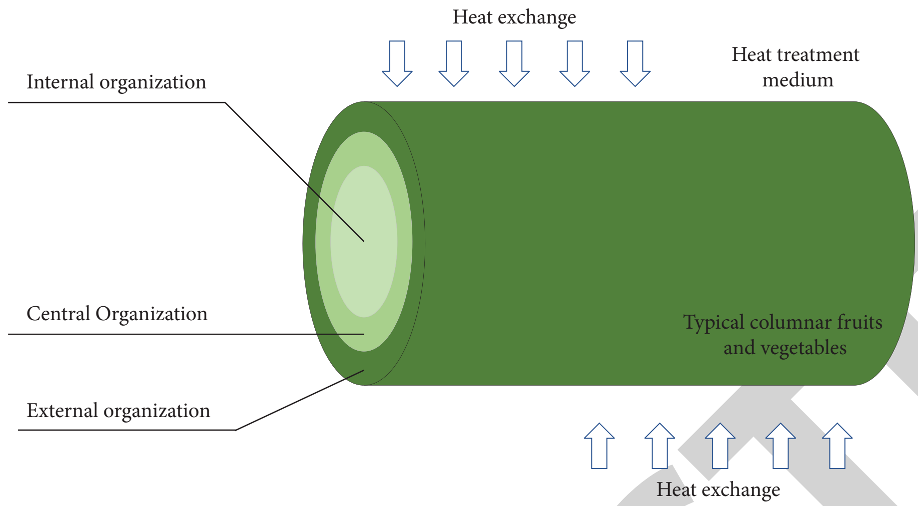

FIGURE 2: Multilayer physical model of columnar fruits and vegetables.

2.2.1. Determination of Thermal Conductivity of Fruits and Vegetables. Figure 3 is a schematic diagram of the thermal probe. A slender copper resistance enameled wire is encapsulated in a stainless steel sleeve. The thermal probe is inserted into the object to be tested, and a constant voltage is applied to both ends of the copper wire. The copper wire conducts equal power heat conduction to the surrounding sample to be tested through the insulating layer and the stainless steel sleeve. Assuming that the thermal probe is an infinitely long heat source body, there is no contact thermal resistance on any two contact surfaces of the above model, and the thickness of the electrical insulation layer can be ignored compared with the thickness of the stainless steel casing. Then, the above heat conduction process can be considered as a one-dimensional heat conduction problem in an infinite, isotropic medium. In the cylindrical coordinate system, the governing formula of the nonsteady-state thermal conduction differential formula is as follows.

For copper wire,

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial t_w}{\partial r}\right)+\frac{q}{\pi r_w^2\lambda_w}=\frac{1}{\alpha_w\partial\tau},\quad 0\le r\le r_w,\tau>0. \tag{1}$$

For casing,

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial t_p}{\partial r}\right)=\frac{1}{\alpha_p}\frac{\partial t_p}{\partial\tau},\quad r_w\le r\le r_p,\tau>0. \tag{2}$$

For the medium to be tested,

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial t_m}{\partial}\right)=\frac{1}{\alpha_m}\frac{\partial t_m}{\partial\tau},\quad r\ge r_p,\tau>0. \tag{3}$$

Boundary conditions:

$$t_w(r_w,\tau)=t_p(r_w,\tau). \tag{4}$$

Between the hot wire and the metal sleeve,

$$\lambda_w\left(\frac{\partial t_w}{\partial r}\right)_{r_w}=\lambda_p\left(\frac{\partial t_p}{\partial r}\right)_{r_p}. \tag{5}$$

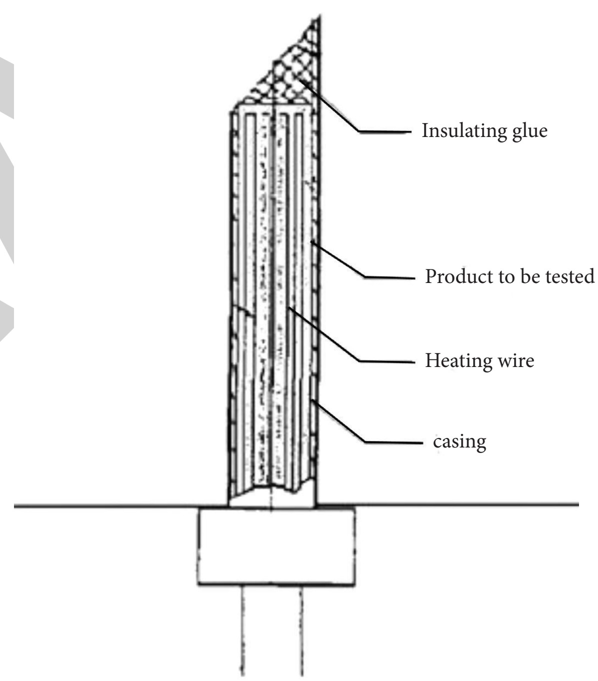

FIGURE 3: Schematic diagram of thermal probe.

Between the metal casing and the medium to be tested,

$$t_p(r_p,\tau)=t_m(r_p,\tau). \tag{6}$$

At the central axis of the hot wire,

$$\lambda_p\left(\frac{\partial t_p}{\partial r}\right)_{r_p}=\lambda_m\left(\frac{\partial t_m}{\partial r}\right)_{r_m}. \tag{7}$$

$t_w(0,\tau)$ is bounded.
Initial conditions:

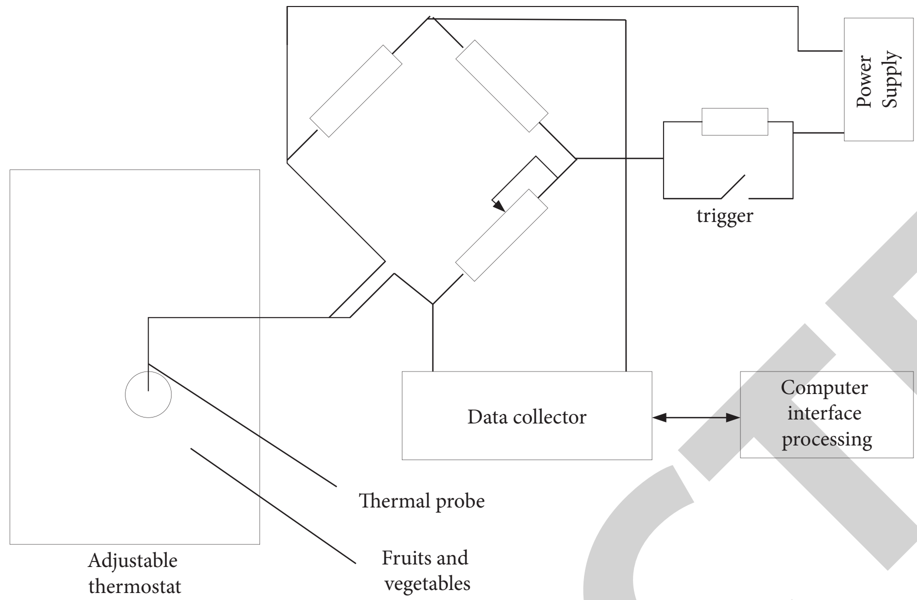

Figure 4: Test system diagram.

$$t_w(r,0) = t_p(r,0) = t_m(r,0). \quad (8)$$

In the formula, t is the the difference between the temperature of the hot wire and the initial temperature, °C; λ is the thermal conductivity, W/(m·°C); α is the thermal diffusion coefficient, m^2/s; τ is the heating time, s; r is the radial coordinate, m; and q is the the heating power of the heating wire per unit length, W/m. The subscripts w, p, m, respectively, represent the hot wire, the metal sleeve, and the medium to be tested.

Laplace transformation was used to obtain the exact solution of the differential control formulas. When $a_m t/r_p^2$ is large enough, the thermal conductivity of the medium to be measured can be expressed as follows:

$$\lambda_m = \frac{(q/4\pi)}{(d\overline{t_w}/d\ln t)}. \quad (9)$$

The above formula is the basic formula for measuring the thermal conductivity of an object by the probe method. In theory, as long as the average temperature of the thermal probe and the logarithmic change of time are obtained, the thermal conductivity of the object can be calculated by using formula (9).

The thermal probe and Wheatstone bridge are combined to form a thermal probe test system. The principle of the thermal probe measuring the thermal conductivity of the object is shown in Figure 4. The basic principle is the bridge balance. According to the characteristic that there is a linear relationship between copper resistance and temperature, in the measurement, a constant power is applied to the thermal probe to make the copper wire inside the probe heat up. The temperatures of the copper wire, the stainless steel casing, and the sample to be tested change, which causes the resistance value of the copper wire to change accordingly. In turn, the deviation voltage in the initial balance circuit changes with time, and the output voltage difference signal is processed by the computer to obtain the linear change relationship of the voltage difference with the natural logarithm of time. The thermal conductivity of the tested sample can be obtained. Because it is very difficult to directly measure temperature accurately, this system adopts an indirect measurement method, which converts the temperature difference signal into an easy-to-measure current and voltage amplified signal.

According to formula (9) and electrothermal theory, the thermal conductivity of the sample to be tested can be obtained:

$$\lambda_m = -\frac{\left(V^3 \alpha_0 R_0 / R_s^2 64\pi L\right)}{(d(\Delta V)/d(\ln \tau))}, \quad (10)$$

which is

$$\lambda_m = -\frac{\left(V^3/R_s^2\right)C}{(d(\Delta V)/d(\ln \tau))}. \quad (11)$$

In the formula, $C = (\alpha_0 R_0/64\pi L)$ is the the instrument constant of the probe, $\Omega/(m \cdot K \cdot s)$; this parameter is only related to the material and length of the probe itself and has nothing to do with the heating power of the test system and the test temperature; ΔV is the the output voltage difference of the circuit, V; τ is the heating time, s; λ_m is the the thermal conductivity of the sample to be tested, $W/m \cdot K$; V is the voltage of regulated power supply, V; and R_s is the the initial resistance of the probe, Ω

2.2.2. Determination of the Density of Fruits and Vegetables. The density of fruits and vegetables is defined using formula (12):

$$\rho = \frac{m}{V}. \quad (12)$$

Table 1: Fruit thermal properties.

Numbering	Name	λ	ρ	C
1	Orange	0.511	911	4.31
2	Snake fruit	0.418	876	3.51
3	Sweet orange	0.461	839	4.86
4	Apple	0.389	917	3.97
5	Apple pear	0.517	1091	4.56

2.2.3. Determination of Fruit Specific Heat Capacity. In this study, the heat flow DSC method was used to measure the specific heat capacity of fruit samples. DSC is a thermal analysis instrument that uses the measured energy difference to study the specific heat capacity of the sample and other thermodynamic properties through temperature scanning under the control of a linear temperature program. It is widely used in the measurement of thermophysical properties of solid and liquid substances such as plastics, food, medicine, metals, and composite materials. According to different design principles and structural differences, DSC can be divided into three categories (power compensation type, amplitude modulation type, and heat flow type), of which heat flow is the most used.

The basic principle of heat flow DSC is as follows.

According to the definition of specific heat capacity,

$$c = \frac{\mathrm{d}H}{\mathrm{d}T} \cdot \frac{1}{M}. \tag{13}$$

Transform the above formula to get

$$\frac{\mathrm{d}H}{\mathrm{d}\tau} = c \cdot m \cdot \frac{\mathrm{d}T}{\mathrm{d}\tau}. \tag{14}$$

In the formula, $\mathrm{d}H/\mathrm{d}\tau$ is the enthalpy conversion rate; c is the specific heat capacity, J/(kg·°C); m is the quality, kg; and $\mathrm{d}T/\mathrm{d}\tau$ is the temperature change rate.

In order to reduce the error, the indirect method is usually used to determine the specific heat capacity. The indirect method is to scan the temperature of the sample and the standard substance under the same conditions and calculate according to the ordinates of the DSC curve. The commonly used standard material is sapphire, its specific heat capacity is known, and the specific heat capacity does not change in the measured temperature range.

The enthalpy change rate of sapphire is

$$\frac{\mathrm{d}H}{\mathrm{d}\tau_s} = y_s = c_s \cdot m_s \cdot \frac{\mathrm{d}T}{\mathrm{d}\tau}. \tag{15}$$

The rate of change of enthalpy of the sample to be tested:

$$\frac{\mathrm{d}H}{\mathrm{d}\tau} = y = c \cdot m \cdot \frac{\mathrm{d}T}{\mathrm{d}\tau}. \tag{16}$$

Dividing the two formulas,

$$c = c_s \cdot \frac{m_s \cdot y}{m \cdot y_s}. \tag{17}$$

2.2.4. Determination of Fruit Thermal Diffusivity. Taking apples and other fruits that need to be heat-treated in the actual production process, their thermal conductivity, density, and specific heat capacity were measured according to the above steps. Three samples of each fruit were taken, and the average value was taken as the measurement result. The thermal diffusivity definition formula $\alpha = \lambda/pc$ was used to determine its value. The results are shown in Table 1.

It can be seen from Table 1 that the thermal diffusivity of the fruits is not much different, distributed around 4×10^{-8} m^2/s, which is very small compared with metal materials.

2.2.5. Determination of the Convective Heat Transfer Coefficient on Fruit Surface. Under the guidance of the basic theory of heat transfer, this article uses similarity theory and dimensional analysis to determine the surface convective heat transfer coefficient values in different states of fruit heat treatment. The similarity principle refers to a way to determine the physical quantities of the prototype through experiments by using a model that is similar to the components of the prototype.

The main characteristic numbers that describe the forced convection heat transfer phenomenon of fruit heat treatment are Nusselt number (Nu), Reynolds number (Re), and Prandtl number (Pr):

$$\mathrm{Nu}_m = \frac{hd}{\lambda_m}, \quad \mathrm{Re}_m = \frac{ud}{\alpha_m}, \quad \mathrm{Pr}_m = \frac{\nu_m}{\alpha_m}. \tag{18}$$

According to the dimensional analysis method, the following relations exist among the three:

$$\mathrm{Nu}_m = f\left(\mathrm{Re}_m, \mathrm{Pr}_m\right). \tag{19}$$

Because the test is in the hot air treatment environment of the fruit, when the air is forced to sweep the surface of the object, its $\mathrm{Pr}_\mathrm{m} \approx 0.7$, which is a constant, so the above formula is generally organized into the following index form:

$$\mathrm{Nu}_m = C\mathrm{Re}_m^n. \tag{20}$$

Among them, according to Newton's cooling formula,

$$h = \frac{\Phi_c}{\left(t_w - t_f\right)A}. \tag{21}$$

In this study, an electric heating wire with adjustable power was used to provide the heat source for fruit heat treatment, and a fan was used to change the air flow rate to provide different heat exchange effects. Under the heat exchange balance, all the heat generated by the electric heating wire is transferred to the fruit, and the fruit exchanges heat with the outside air in two ways: convection heat exchange and radiation heat exchange:

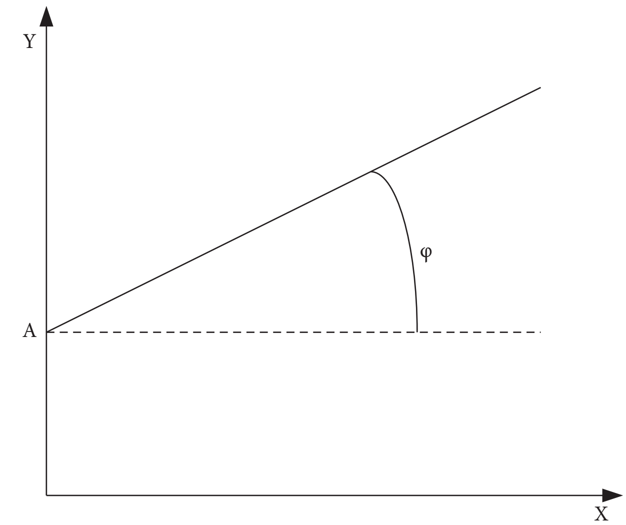

Figure 5: Parameter relationship diagram.

$$\Phi_c = \Phi - \Phi_R,$$
$$\Phi = UI, \tag{22}$$
$$\Phi_R = \varepsilon \cdot C_0 \left[\left(\frac{T_w}{100} \right)^4 - \left(\frac{T_f}{100} \right)^4 \right] \cdot A.$$

It can be seen that, in the heat treatment of the fruit, different values are obtained under different basic parameters. The value under each working condition is expressed in logarithmic coordinates, as shown in Figure 5.

In Figure 5, Y is used to represent $\lg \mathrm{Nu}_m$, and X is used to represent $\lg \mathrm{Re}_m$; then the linear formula of Figure 5 can be expressed as follows:

$$Y = A + \tan \phi X, \tag{23}$$

which is

$$\lg \mathrm{Nu}_m = \lg C + n \lg \mathrm{Re}_m. \tag{24}$$

C and n can be obtained from $\lg C = A, n = \tan \phi$.

2.3. Storage and Fresh-Keeping Technology of Harvested Vegetables. After being harvested, fruits and vegetables are separated from the original growth environment and mother plants. Although they have lost their water and nutrient supply sources, their life activities have not stopped because of this. There are still a series of physiological activities (mainly respiration and evaporation) in circulation and storage. Due to the lack of communication with hormones and nutrient signals in other organs, these processes gradually proceed in the direction of decomposition. They use various organic substances and water stored in themselves, thus making themselves undergo a series of changes (appearance, coloring degree, own weight, tissue hardness, taste characteristics, aromatic smell, etc.) in all aspects.

In the storage environment of fruits and vegetables, even if there is a concentration of one-thousandth of ethylene, it is enough to induce the ripening of fruits and vegetables. Therefore, applying ethylene remover within 1–5 days after harvesting fruits and vegetables can inhibit respiration and prevent postripening and aging.

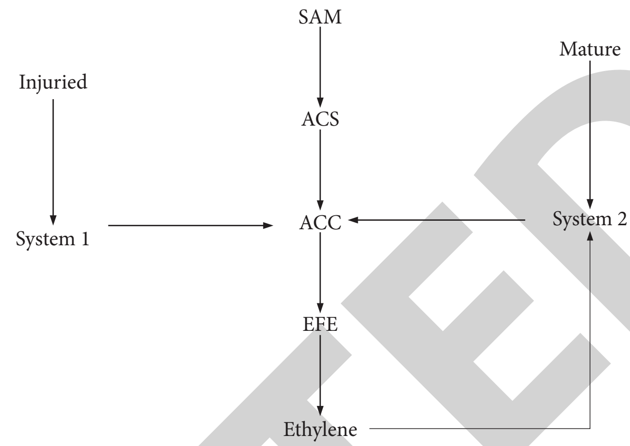

Figure 6: Ethylene biosynthesis and its key steps.

The mechanism of the effect of ethylene ripening is that ethylene initiates the maturation of climacteric fruits, and when climacteric fruits mature, the respiration rises to form a peak. At the same time, a large amount of ethylene can also be seen. Nonclimacteric fruits have no respiratory jump, and the rate of ethylene production during the whole ripening process is very low, and the change is not obvious. This paper proposes two regulating systems for ethylene production in respiratory jump fruits. System I is responsible for the low-concentration basic ethylene production in fruits and vegetables before the jump, and System II is responsible for the large amount of ethylene self-catalyzed production during the ripening process during the jump. System I ethylene is caused by unknown reasons, and the concentration is very low, which can only play a role in controlling and regulating water aging. System I ethylene can start System II ethylene production, which greatly increases the ethylene concentration in the fruit and produces a respiratory jump. The ethylene production rate of nonclimacteric fruits is relatively low, and the changes are stable. During the whole ripening process, only System I ethylene produces ethylene, and System II lacks ethylene production. Figure 6 shows its specific synthesis steps.

The production rate of ethylene in the transition-type fruits and vegetables is very low before the transition, and the corresponding ACC synthase activity, ACC oxidase activity, and ACC content are also very low. Ethylene inhibits the activity of ACC synthase before the respiratory jump, thereby inhibiting the production of ethylene; this is the self-inhibition of ethylene. Ethylene can inhibit ACC synthase before the transition, but it can promote ACC oxidase.

3. Optimization Experiment of Heat Treatment Process for Fruits and Vegetables

3.1. Response Surface Experiment. The traditional heat treatment process of fruits and vegetables mainly involves two parameters: medium temperature and treatment time.

Figure 7: Heat treatment test cucumbers.

Table 2: CCD experimental scheme design table (Fire Phoenix).

Std order	Run order	Coded value		Actual value	
		$x1$	$x2$	$X1$/°C	$X2$/°C
12	1	0	0	42	32
9	5	0	0	42	32
10	3	0	0	42	32

Table 3: CCD experimental program design table (Dutch cucumber).

Std order	Run order	Coded value		Actual value	
		$x1$	$x2$	$X1$/°C	$X2$/°C
12	1	0	0	40	30
9	2	0	0	40	30
10	3	0	0	40	30

Studies have shown that the optimal heat treatment temperature and treatment time for fruits and vegetables of different types, maturities, and sizes are different. In this chapter, Fire Phoenix and Dutch cucumber with different sizes are selected as test materials. In order to obtain the best heat treatment technology for the two cucumbers and minimize the workload of the experiment, it is necessary to design experiments through optimization methods. Because of the two main influencing factors of heat treatment, this chapter adopts the response surface method to realize the optimization design in the optimization of the heat treatment process of fruits and vegetables.

3.1.1. Test Materials. Both the Fire Phoenix and Dutch cucumbers were purchased from the local fruit and vegetable base; cucumbers of uniform size, uniform maturity, no pests and diseases, and no mechanical damage were picked and shipped back to the laboratory immediately, as shown in Figure 7.

The cucumbers were washed with room temperature water (20°C) for 1 min and then randomly divided into 13 groups. The indexes of each group in the fresh state before treatment in turn were tested, and then heat treatment was carried out with different time-temperature combinations on the two kinds of cucumbers according to Tables 2 and 3. After the treatment, the groups were numbered, and then an industrial fan was used to dry the moisture on the surface of the cucumber, and the corresponding indicators were tested after being stored at room temperature for 7 days, including weight loss rate, hardness, color difference, and decay index.

The two cucumber tests were divided into 13 groups, including 5 groups of center point tests, 4 groups of factor tests, and 4 groups of pivot point tests. Among them, the postharvest treatment temperature, treatment time, and axis point values (coded value, actual value) are shown in Tables 2 and 3, respectively.

According to the test methods of each response index, the data results of the fresh state of the Fire Phoenix cucumber and the weight loss rate, hardness, color difference, and decay index after the end of storage were obtained. The details are shown in Table 4.

Table 5 shows the results of the analysis of variance of the response surface regression model of the test index weight loss rate. The results show that the correlation coefficient R-squared of the weight loss rate is 0.981, and the correction coefficient adjusted R-squared is equal to 0.967.

4. Induction of Disease Resistance of Melon Fruit by Heat Treatment

4.1. Screening of the Best Heat Treatment Temperature and Time. There are differences in the diameter of the lesions of the fruits with different heat treatments after injury inoculation for 7 days (as shown in Figure 8). Among them, the diameter of the lesions was the largest when treated at 57°C for 3 minutes, and the diameter of the lesions treated at 53°C for 3 minutes was the smallest. There was little difference between the other treatments; on the 7th day of storage, the diseased spot diameter of the treated fruit was significantly lower than that of the control, which was only 80.6% of the control during the same period. Therefore, heat treatment at 53°C for 3 minutes was the best treatment condition.

4.2. The Effect of Heat Treatment on Fruit Phenylpropane Metabolism. Heat treatment can induce the increase of fruit C4H activity, and it is always higher than that of the control. During the storage period, the C4H activity of the fruit showed a trend of increasing first and then decreasing. It reached the maximum on the 12th day, but there was no

Table 4: Quality test results of each test group after storage.

Run order	Actual value		Weight loss rate	Corresponding value		Decay index
	X1/°C	X2/min		Hardness	Chromatic aberration	
1	42	32	15	5	3.63	0
2	42	32	15.15	4.86	3.45	0.04
3	42	32	15.12	4.82	3.75	0
4	42	7.74	17.40	4.58	2.63	0.04
5	31	32.6	17.18	4.36	3.41	0

Table 5: Analysis of variance results of the regression model.

Source of variance	Sum of square	Degree of freedom	Mean square	F value	P value
A-Temp	18.17	1	18.17	84.28	<0.0001
B-Time	1.48	1	1.48	7.11	0.0328
AB	5.23	1	5.23	24.36	0.0014
A2	36.48	1	36.48	176.25	<0.0001
B2	17.69	1	17.69	87.14	<0.0001

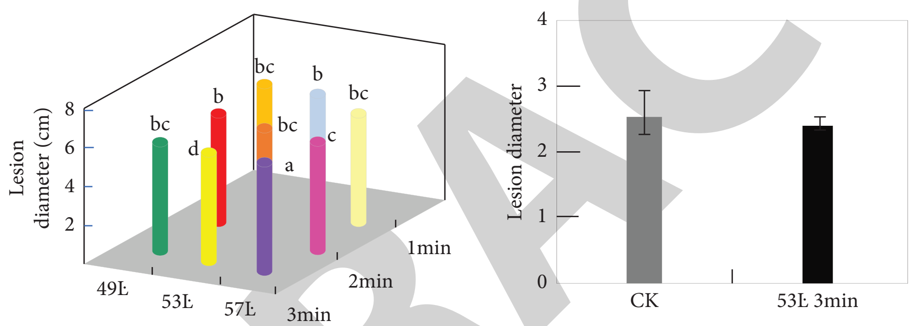

Figure 8: The effect of different heat treatment conditions on the diameter of the lesion 7 days after inoculation of fruit injury. Different letters in the figure represent significant differences ($P < 0.05$), and the vertical line in the figure represents standard error (±SE).

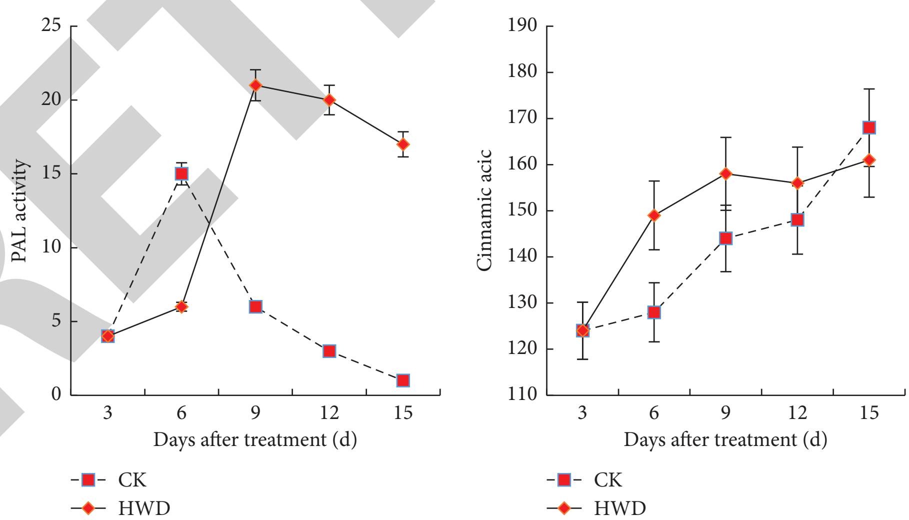

Figure 9: The effect of heat treatment on the activity of PAL, C4H, and the content of cinnamic acid and coumaric acid in fruits. The vertical line in the figure represents the standard error (±SE).

significant difference between the two. On the 3rd day of storage, the C4H activity of the treated fruits was 29.2 times higher than that of the control, and the difference between the two reached the maximum.

Heat treatment can increase the coumaric acid content of fruits. During the storage period, the coumaric acid content of the fruit increased first and then decreased, and both reached the maximum after 9 days of treatment. At this time,

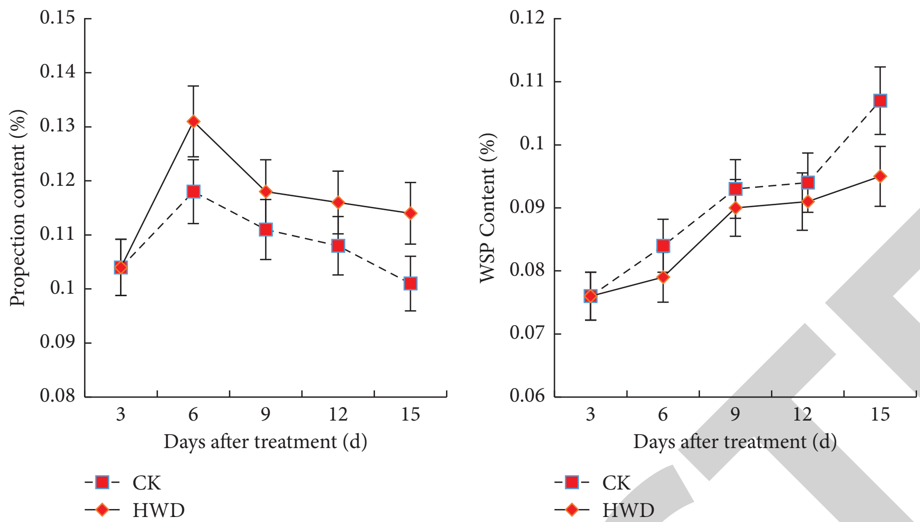

Figure 10: The effect of heat treatment on the content of fruit protopectin, water-soluble pectin, cellulose, and glycoprotein rich in light proline. The vertical line in the figure represents the standard error (±SE).

the coumaric acid content of the treated fruit was 11.7% higher than that of the control; at the end of storage, the difference between the two reached the maximum, and the coumaric acid content of the treated fruit was 25.1% higher than that of the control in the same period. The specific situation is shown in Figure 9.

4.3. The Effect of Heat Treatment on Fruit Cell Wall Components, Related Enzyme Activities, and Epidermal Tissue Structure. As shown in Figure 10, heat treatment can delay the degradation of fruit pectin. During the storage period, the original pectin content of the fruits increased first and then decreased. On the 3rd day after treatment, the content of protopectin reached the maximum value. At this time, the pectin content of the treated fruit was 11.3% higher than that of the control, and the difference between the two was most obvious; the original pectin content of the treatment at the end of storage was 10.8% higher than the control.

With the extension of the storage period, the content of water-soluble pectin showed an upward trend, and the treatment can delay this trend. On the 6th day of storage, the water-soluble pectin content of both reached the highest, and the water-soluble pectin of the treatment was 10.9% lower than the control in the same period, and the changes in both were very small afterwards.

Heat treatment can delay the degradation of fruit cellulose. The cellulose content of the control fruits reached the maximum on the 3rd day, and the treated fruit reached the maximum on the 9th day. At this time, the difference between the two was most obvious, and the cellulose content of the treated fruit was 36.1% higher than that of the control.

Heat treatment can obviously induce the accumulation of HRGP in fruits. In the early stage of storage, the HRGP content of the treated fruits was lower than that of the control. From the 6th day, the HRGP content of the treated fruits was significantly higher than that of the control. On the 12th and 15th days, the difference between the two reached the maximum, and the HRGP content of the treatment was 13.6% and 14.5% higher than that of the control in the same period.

4.4. Storage Insurance Quality. Heat treatment can reduce the SSC content of fruits. During storage, the SSC content of the fruit showed a trend of increasing first and then decreasing. The SSC content of the treated fruit reached the highest on the 6th day, and that of the control reached the highest on the 3rd day. In the later period of storage, the SSC content of the treated fruit was higher than that of the control. On the 6th and 15th days, the SSC content of the treated fruit was 4.5% and 4.2% higher than that of the control in the same period, and the difference between the two was most obvious.

Heat treatment can reduce the TA content of fruits. During storage, the TA content of fruits showed a downward trend, and the TA content of the treated fruit was always higher than that of the control. On the 6th and 15th day of storage, they were 24% and 14.3%, respectively, higher than that of the control in the same period. The specific situation is shown in Figure 11.

Heat treatment can improve the organoleptic quality of the fruit. On the 15th day of storage, the skin and pulp of the heat-treated fruit are milky white, the aroma is coordinated, and the fruit is slightly soft; the control fruit was obviously ripening, the skin and flesh were creamy yellow, and the melon fragrance was prominent. In addition, the skin of the fruit is shrunken, the water loss is serious, the flesh is obviously softened, and the sensory quality is reduced. This shows that heat treatment can delay the ripening of the fruit and maintain the organoleptic quality of the fruit.

Based on the above analysis, we can conclude that, after understanding the heat treatment process of fruits and vegetables and improving the storage of fruits and vegetables, the actual application effect has been greatly improved. The preservation rate of fruits and vegetables has increased

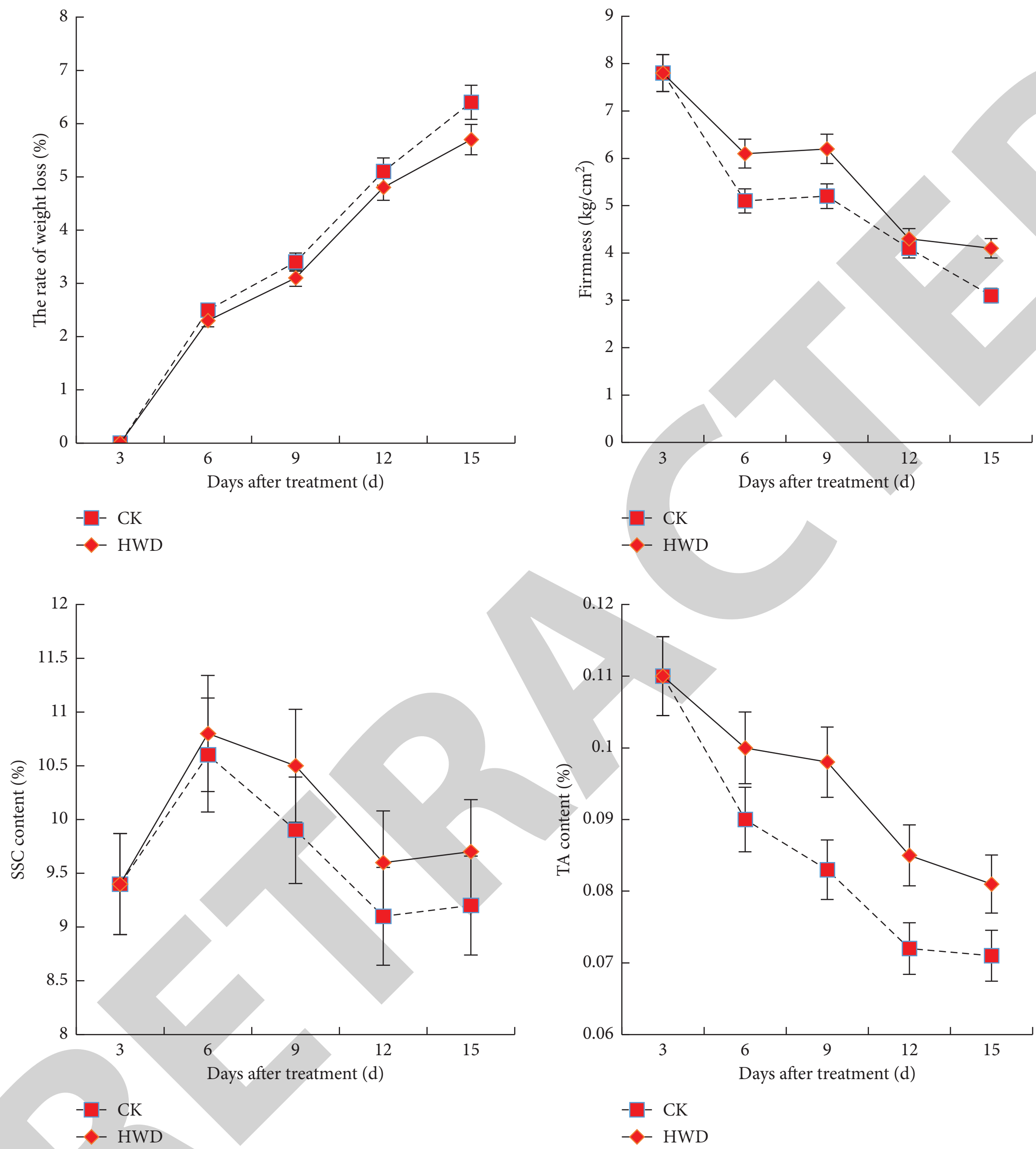

FIGURE 11: The effect of heat treatment on fruit weight loss rate, hardness, soluble solids, and titratable acid content. The vertical line in the figure represents the standard error (±SE).

by 37%, and the loss of taste during the preservation of fruits and vegetables has been reduced by 7%. For the fresh fruit and vegetable market, this level of improvement is very huge, which can greatly reduce the waste in the transportation process.

5. Conclusions

This article mainly studies the combination of the storage and preservation of fruits and vegetables with the post-harvest heat treatment technology. First of all, this article has conducted a certain understanding of the storage and preservation process of fruits and vegetables and technically decomposed the related heat treatment technology. It conducts a separate analysis of the data collection issues involved in the heat treatment process to ensure the accuracy of data collection. Then, it designs related experiments to explore the optimal performance of the heat treatment of fruits and vegetables and finally combines the analysis part to conduct a comprehensive analysis and exploration of the research objectives of this article and to explore the effect of its improvement.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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