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Current Status and Development Trend of Heat Transfer Mechanism Research of Fruit Heat Treatment

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Abstract: *Heat treatment technology is widely considered to be an auxiliary sterilization and post-processing technology which can improve fruit quality, this paper introduced fruits and vegetables heat treatment methods domestic and overseas, including heat transfer model commonly used in heat treatment, measurement method of fruit and vegetable physical parameters which can influent heat treatment process, proposed suggestion for improving heat treatment effect from the point of view of heat transfer, at last analyzed defects of current heat treatment technology comprehensively, as well as the difference of heat treatment domestic and overseas and the development trend in the future.*

Keywords: *Heat Treatment, Heating Method, Heat Transfer Model*

Heat treatment is a technique that uses the thermal characteristics of fruits and vegetables to place the fruits in a hot environment higher than the temperature of the fruit ripening season to extend the fruit preservation period, control diseases and insect pests, and regulate the physiological and biochemical metabolism of the fruits. It can effectively adjust the off-peak season, extend the fresh-keeping period of fresh fruits, and reduce the occurrence of diseases, so as to realize the preservation or appreciation of fruits and vegetables. As people's requirements for food health continue to increase, governments of various countries restrict the use of fungicides for fruits and vegetables. Heat treatment, as an effective postharvest treatment technology with no chemical residues and pollution, has received extensive attention at home and abroad in recent years. [1-2].

The heat treatment process can be described as an unsteady heat transfer process in which heat is transferred from the external medium of the fruits and vegetables to the interior of the fruits and vegetables. The principle of the heat treatment process is difficult to explain from a biological point of view. Since the general treatment medium is fluid, fruits and vegetables transfer heat to the fluid in the form of convective heat transfer on their surfaces. In the interior of fruits and vegetables, as living tissues, fruits and vegetables are not fluid. It is a kind of solid-like tissue that conducts heat conduction and heat transfer. Its heat transfer law is not exactly the same as that of engineering materials. Therefore, the heat transfer of biological systems is an unstable low heat flux transfer and typical.

In the case of small temperature difference heat transfer, the temperature of the external fluid medium and the heat transfer time of fruits and vegetables are the main factors affecting heat transfer. The effect of heat treatment is closely related to the heat transfer process of fruits, and the thermophysical parameters such as the thermal conductivity of fruits and vegetables have a significant influence on the temperature distribution of fruits. Obtaining accurate thermophysical parameters and quantitative analysis of fruit heat transfer for specific fruits and vegetables are the key to studying the effect and efficiency of heat treatment.

The process of temperature transfer and energy exchange is one of the most basic processes in life systems. In the process of modern plant biology research, physical models are playing an increasingly important role. The key to studying the heat transfer characteristics and heat transfer mechanism of fruits and vegetables, including the prediction of the body temperature field, is the acquisition of the thermophysical data of fruit and vegetable tissues. At the same time, the thermophysical data is also a prerequisite for revealing the heat transfer ability of fruits and vegetables and further research on tissue heat transfer [3]. Through the introduction of engineering heat transfer research methods, in-depth research on the heat transfer of fruits and vegetables, exploring the heat transfer law of the fruit storage process, quantitatively analyzing the real-time change law of the temperature field, and studying the

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effects of heat treatment alone and in combination with other treatment methods. Studying the best combination of heat treatment temperature and time in different fruit and vegetable states, such as the types, varieties, maturity, cultivation conditions, and latent infection strains of fruits and vegetables, can provide a reliable theoretical basis for the preservation of fruits and vegetables in cold storage. The selection of post-harvest processing, storage and processing technology for fruits and vegetables has a wide and far-reaching practical significance, and at the same time has the important significance of tracking the international frontier.

1. Common Methods and Functions of Heat Treatment

The common media used in heat treatment are: hot water, hot air, hot steam, far-infrared and microwave, etc., which can act on fruits in different ways, such as hot water soaking, washing, steam or hot air heating, etc. These methods have been proved to be different The fruits and vegetables have a positive effect on post-harvest preservation. Among them, water is the most used heat transfer medium in the heat treatment process. The temperature is usually in the range of 30-50 degrees, and the treatment time ranges from 10 minutes to 90 days. Researchers found that when apples are treated in water at 45 degrees Celsius for 10 minutes, several heat shock proteins and heat shock transcription factors will be upregulated in the peel, and in the process, the resistance to penicillium is enhanced, and the synergistic effect of heat treatment and biocontrol yeast effectively inhibit the occurrence of apple anthracnose [4]. Treating avocados with hot water at 38-42 ℃ for 20-60 minutes can significantly reduce the degree of browning of avocados [5-6]. Treating pears in air at 43 ℃ for 0-30 minutes can accumulate active oxygen in the mold cells and cause damage to proteins and fats, thereby inhibiting gray mold[7]. Strawberries were treated in hot air at 45 ℃ for 3 hours, and then stored at 20 ℃. After 24 hours of storage, the hardness of the former was significantly higher than that of the latter. In addition, similar conditions were found in heat-treated mangoes and apples [8]. After treating the Chinese life peach in the air at 48 ℃ for 4 hours and storing for 90 days, the degree of browning was significantly lower than that of other treatments and controls, and it still maintained good commercial value. But improper heat treatment will aggravate browning [9]. Strawberries were treated with hot air at 45 ℃ for 3 hours, and then stored at 0 ℃, and the titratable acid content was found to be significantly lower than that of the control [10]. After the fresh-cut peach fruits were treated with hot water at 50 ℃ and stored at 5°C for 6 days, the maximum ethylene concentration was 7μLL-1, which was significantly lower than the control concentration of 16μLL-1[11]. The sweet pepper fruit undergoes a short-time heat treatment with hot air at 48-52 ℃ to improve the frost resistance. After the sweet pepper is heat-treated and stored at 0-1 ℃ for 26 days, there are slight cold injury pits on the surface of the sweet pepper fruit. Compared with the control 13d, the cold injury symptoms develop slowly, and the cold injury index is significantly lower than the control. The results show that heat treatment can reduce the sensitivity of sweet pepper fruits to low temperature (0-1 ℃), delay the occurrence time of chilling injury, and reduce the degree of chilling injury[12].

In summary, the heat treatment water temperature of most fruits and vegetables is 38-55 ℃, the time is 30s-10min, and the air treatment is 43-54 ℃, 10-60 ℃. It has a positive effect on the disease resistance and freezing resistance of fruits and vegetables. The treatment effect is not universal, depending on the type of fruit and vegetable, the treatment time is related to the temperature, and it has a certain pertinence.

2. Mathematical Model of Heat Transfer in Heat-treated Fruits

Heat treatment is essentially the process of heat transfer to the interior of fruits and vegetables. With the continuous development of heat transfer theory and the continuous improvement of computational fluid dynamics, it is possible to study the flow field simulation and heat transfer analysis related to fruit heat treatment. In terms of the establishment of heat transfer equations, based on the general model of biological heat transfer, the finite difference method is used to discretize the differential equation to study the factors affecting the heat transfer rate of fruits, or the relationship between the effective parameters of biological tissues is analyzed based on the existing basic biological heat transfer equation. The steady-state model in heat transfer science can predict the temperature changes at different positions of fruits and vegetables such as papaya and golden apple. Considering that the physical parameters of fruits and vegetables, such as thermal conductivity, specific heat capacity, respiration heat and environmental temperature fluctuations, are possible during the heat transfer process It has an impact on the temperature distribution of fruits and vegetables [13-15], and the non-steady-state model

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can also be used to analyze the relationship between temperature and time, which provides a basis for the optimal design of process parameters during the heat treatment of fruits and vegetables. In the natural fermentation process of citrus peel, heat is generated by introducing the internal heat source term in the fermentation process. The calculation model adopts unsteady heat conduction analysis to obtain the temperature distribution expression of the fermentation process, which can provide theoretical guidance for the temperature control of the citrus peel fermentation process. For the calculation of physical property parameters such as ice content, specific heat and thermal conductivity of cold processed foods, a dynamic calculation model can also be established according to the change law of food thermal properties with its chemical composition and temperature.

3. Physical Coefficient Test of Heat Transfer Model of Heat Treatment

Domestic and foreign scholars have conducted a more systematic study on the factors affecting the heat transfer rate of fruits during the heat treatment process by proposing models and corresponding experimental research methods. Through experimental research and model calculations, the probe method is used to measure the thermal conductivity of fruits and vegetables at different temperatures, and the relationship between thermal conductivity and temperature is obtained. The conclusion is that the thermal conductivity increases with the increase in temperature, showing a linear relationship. The thermal conductivity of fruits is measured. , Density and specific heat capacity, and calculate the fruit thermal diffusivity[16]. The researchers used the long cylindrical yam temperature field physical model to quantitatively analyze the temperature field changes during the cold storage of yam, and verified the correctness of the model by comparing the results with experimental measurements, and found that for different fruits and vegetables, the moisture content is linear with the thermal conductivity. The largest influencing factor of the relationship, followed by the content of soluble solids, there is no significant linear relationship between the thermal conductivity and the density of fruits and vegetables [17-19]. If the thermal conductivity is measured by the hot wire method, the influence error caused by the geometric radius and size of the hot wire must be Make corrections [20-21].

4. Analysis of the Shortcomings and Development Trends of Current Research

In the field of heat transfer and heat transfer mechanism research, people have a good grasp of the physiological laws of the heat response of fruits and vegetables from a biological perspective, but most of them emphasize qualitative analysis and empirical research. The relationship between the thermophysical parameters of organisms and external factors is still It is not clear, there are only some empirical formulas, so it is difficult to carry out theoretical calculations. Moreover, heat treatment research mainly focuses on the internal temperature distribution of fruits and vegetables, and lacks the analysis and determination of factors affecting the convective heat transfer coefficient on the surface of fruits and vegetables. The method is limited to experimental varieties, lacks versatility, and lacks the effects of different heat treatment methods and heat transfer rates of fruits and vegetables. There are few quantitative studies on heat transfer in plants, and there are not many studies on the heat transfer laws of plants with vital activity. The difference between high temperature treatment and low temperature treatment is still unclear. The temperature control mode depends on experience and cannot be quantitatively analyzed. To improve the efficiency of heat treatment, it is necessary to study the two important links in the heat transfer process of fruits, that is, the convection heat transfer between fruits and vegetables and external fluids and the occurrence of heat transfer inside fruits and vegetables. Physical parameters are tested and tested, and through experimental research and mathematical model calculations, basic research on the influence of heat transfer rate of fruits and vegetables is carried out. The combination of heat treatment technology and other fruit and vegetable treatment technologies is widely regarded as a promising comprehensive treatment technology in fruit and vegetable storage. There are problems in the heat treatment of fruits and vegetables, such as high operating cost and long processing time, in order to realize the commercial application of heat treatment of fruits and vegetables, and achieve the best effect of heat treatment of fruits and vegetables after harvest, so as to provide reliable theoretical basis for the treatment, storage and processing of fruits and vegetables.

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