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Full Length Research Paper

Application of new physical storage technology in fruit and vegetable industry

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With the development of science and technology, consumers not only require food to be safe, but also require them to keep the original natural flavor and nutritional value as well, while the traditional chemical storage method has been increasingly unable to satisfy consumers' demand. When compared with chemical method, physical technology has more obvious advantage. This article introduces some commonly-used chemical methods and some modern methods.

Key words: New physical storage technology, plasma storage technology, electrolyzed reduction water technology, super ice-temperature technology.

INTRODUCTION

As the living standard of people rise gradually, the requirements of the quality of fruit and vegetable for consumers is higher than before. People not only require them to be fresh and secure, but also need them to keep their original natural flavor and nutritive value, but fresh fruit and vegetable still have living organisms. After picking, their respiratory metabolism is very exuberant and extremely easy to deteriorate, stale, decay and thus cause loss. How to improve the preservation technology to reduce unnecessary loss and ensure the quality of products has become the focus of this subject, although, the traditional chemical preservation method is gradually not able to meet these requirements. With the development of modern science and technology, physical technology has been widely applied in fruit and vegetable storage, because it is more secure than the traditional chemical technology, it does not cause chemical pollution, it does not destroy the food nutrition structure and natural flavor, thus it has received extensive attention in the application of food industry and related research.

STATUS QUO OF FRESH-KEEPING TECHNOLOGY

Temperature is one of the main factors that affects the respiration and enzyme activity of fruit and vegetable, temperature fluctuations can cause respiration intensity and metabolic rate change drastically, and affect their preservation effect. In the practice of storage, low temperature storage is a basic method. Currently, the most common preservation method of fruit and vegetable at home and abroad is combining controlled atmosphere storage and low temperature storage methods.

In addition, preservatives are used in great quantities among which are mainly chemical preservatives, sulfur dioxide and sulfide are used mostly and have become the worldwide effective method to prevent decay. The EPA regulates that 10 ug/g-1 is the highest allowed concentration of sulfide residues, but the concentration used in commercial storage is usually more than the allowed concentration and this will cause bleaching damage of fruit and vegetable, thus, it seriously influences the commodity value. Sulfur dioxide as preservative will be replaced gradually.

COMMON PHYSICAL STORAGE AND FRESH-KEEPING TECHNOLOGY

Low temperature storage and fresh-keeping technology

Respiration is the main cause of fruit and vegetable metamorphism. Problems about respiration and storability

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(delay respiration and consume nutrition) happen during metamorphic process. Storability refers to the quality of fruit and vegetable that has no significant change over storage period, the quality loss is minimal. Storability is not only determined by a single kind of character, it is the comprehensive reflection of all kinds of physical, chemical, physiological and biochemical natures. To solve these mentioned problems, plants' respiration must be controlled. In order to store them for long term, their living state must be remained and at the same time, their breathing must be weakened. Low temperature can weaken respiration and prolong storage time.

Low temperature fresh-keeping technology has a long history and mature experience in the world. It is the commonly-used physical storage technology.

Low temperature preservation method is mainly done through low temperature. It abates the respiration intensity and metabolism to achieve preservation effect, and then inhibit microbes breeding, weaken food oxidation and slow corruption speed.

Food after low temperature storage has better tolerance to low temperature and can inhibit the growth of high temperature resistant pathogen, but this kind of preservation is energy-consuming and needs large-scale mechanical equipment. Besides, its one-time investment is large, and the capital recovery period is long. Consequently, long time storage can cause physiological damage of cold sensitive food that originated in tropical and subtropical areas, promote low temperature resistance bacteria and virus reproduction, thus influencing edible safety. Therefore, attention must be paid to choose the appropriate temperature and storage time in this application.

Controlled atmosphere storage and fresh-keeping technology

The principle of controlled atmosphere storage is to maintain food in a relatively closed storage environment, change and adjust the ratio of oxygen, carbon dioxide, nitrogen and other gas, and then keeping them within a certain range of concentration(Artes V, et al , 2002).

During controlled atmosphere storage, physiological metabolism of fruit and vegetable falls to the lowest level because of the inhibition effect of storage conditions; however, the nutrient and energy consumption is minimal, the capacity of resistance to microbes is strong, so storage period is prolonged. When it turns from storage period to circulation period, environmental factors change apparently. Therefore, food after storage must have strong endurance to environment so as to satisfy the requirements to food character changes during the circulation period. This ability, to a great extent, depends on the quality of food at the end of storage. Under the same conditions, the quality of controlled atmosphere storage food was obviously better than that of low temperature and other methods of storage food, so they have a longer shelf life.

Post-harvest heat treatment technology

Heat treatment is a process of treating fruit and vegetable at the appropriate temperature (general for 35 to 50℃) after picking. This treatment kills or inhibits the pathogen, thereby reducing the activity of the enzyme so as to achieve the effect of fresh-keeping.

The moderate heat treatment can reduce activity of polygalacturonase (PGase) in fruit and vegetable, prevent quickly softening and aging. Previous test shows that after appropriate heat shock treatment, membrane permeability and malondialdehyde (MDA) accumulation as well as polyphenol oxidase (PPO) activity of peach reduce, and to some extent, it can delay mature and aging of fruit (Han et al., 1996). The test of Liu (1998) shows that heat treatment not only can effectively enhance the activity of superoxide dismutase (SOD), but can also increase the activity of peroxidase (POD), improve the ability to eliminate the toxicity of Hydrogen peroxide (H_2O_2), and eventually prolong storage time(Liu Shu, 1998). Lu Jianbo et al (2007) found that heat treatment is useful in resisting to chilling injury of crop.

As a non-damaging physical treatment method, post-harvest heat treatment have been applied for controlling insects pests and diseases, modifying fruit responses to other stresses and maintaining fruit quality during post-harvest storage.

Pressure regulating storage and fresh-keeping technology

Pressure regulating storage, including reduced pressure storage also known as low pressure storage (LPS) and high pressure storage is based on the traditional gas adjustment containers used to draw some of the gas from the storage room. It reduces pressure to a certain degree, thus restrict the microbial reproduction and keep food's minimal respiratory need, so as to achieve the purpose of keeping fresh.

Another way to regulate pressure is high pressure storage, its ideological system is similar to reduced pressure storage, many researches on this aspect were conducted in Japan, according to the reports, food after pressurization and sterilization can prolong food storage time and preserve them in close to fresh state for a long time.

Ionizing radiation storage and fresh-keeping technology

The technology mainly uses γ-rays emitted by Co^{60} and Cs^{137}, accelerated electronic, X-ray to penetrate organism, ionize water and other substance, generate

free radicals or ion so as to achieve the effect of disinfection, sterilization and mold prevention.

Using ionizing radiation to store food is a quickly-developed technology. Radiation treatment has the insecticidal, sterilization, disinfection and preservative effect, it does not destroy food appearance and can keep their original flavor and nutrients, prolong storage time at normal temperature, save energy and avoid chemicals residue. A large number of experiments show that using small doses of radiation can kill many kinds of parasitic pests and bacteria in food. For example, using 0.15 to 0.3 kGy ray to irradiate fruit and vegetable can cause pests death thoroughly without any bad influence. In addition, irradiation technology has the characteristics of low dose and cold processing, besides, it can kill microorganisms and pests without causing any harm to the human body. Of course, some disadvantages also exist in the application of this technology, for example, excessive radiation dose may accelerate the aging of food; although, a very small dose cannot affect sterilization and fresh-keeping.

At present, over 30 countries in the world have approved more than 500 kinds of irradiated food for sale in the market. Since the 1980s, the irradiation processing technology in our country has been developed over 20 provinces, municipalities and autonomous regions that conducted a related research.

High-pressure electrostatic field storage and fresh-keeping technology

High-pressure electrostatic field storage and fresh-keeping technology mainly adopts high-voltage electric field to influence moisture and metabolic process of food to different extent. Many experiments show that the application of the electrostatic field processing fruit and vegetable not only can play the role of disinfection, but can also keep the original color and taste, besides, it will not reduce vitamin C and amino acid content. A lot of the experimental results indicate that high pressure electrostatic field is favorable to inhibiting microbes and the processing of agricultural products, especially the fresh-keeping of fruit and vegetable. Biological electromagnetism is a new subject. It is a cross discipline which studies the interrelationships and interaction between plants and animals' system and it involves biology and physics, and postharvest physiology. Also, it determines other correlative subjects and must be combined with the study of food storage problem under electric field, due to the fact that the research is very difficult, repeatability is poor and the studies about mechanism are insufficient.

Magnetic field sterilization processing technology

Magnetic field sterilization can be divided into high frequency and low frequency magnetic field sterilization. It does not damage nutrition composition, change quality characteristics and pollute fruit and vegetable. At the same time, it is safe. Studies have found that by putting food in a constant magnetic field of certain intensity, the purpose of sterilization and disinfection can be achieved without influencing their nutrition and flavor. According to Liu et al. (1999), it was reported that by keeping tomatoes in the constant magnetic field with certain intensity, their respiration intensity was obviously restrained, water evaporation was reduced, and the process of mildew was slowed down. In addition, some fruits and vegetables in the magnetic water have longer storage time and better preservation effect than those of the normal group. At present, magnetic field fresh-keeping technology is still at the experimental and research stage, thus cannot be put into large scale application.

Ultraviolet radiation treatment technology

With the increase in the demand for organic food, as a kind of alternative method of preservative, short wave ultraviolet (UVC) has a large potential market. At present, there are many researches on ultraviolet (UV) radiation. Study showed that after processing fruit and vegetable by UV, their titration acidity increases, the hardness of fruit after processing is higher than that of the normal one. The results of using UVC to treat tomatoes showed that the activity of cell wall degrading enzyme (pectin cellulose enzyme, methyl enzyme, xylanase and protease) was significantly lower than that of the control group, so UVC processing can slow down the maturation and rotting of tomatoes so as to achieve the purpose of keeping fresh.

NEW FRESH-KEEPING TECHNOLOGY

Ozone storage and fresh-keeping technology

Ozone (O_3) is a kind of favorable fungicides, therefore, sterilization using ozone can rapidly oxidate and decompose ethylene generated by the breathing of fruit and vegetable, reduce metabolism and extend the storage time(Li, 2005).

Recently, ozone sterilization is basically thought through the oxidation of newly generated oxygen after decomposition. Ozone firstly reacts with double bond of lipid of cell walls, penetrates and then goes into cell wall to reacts with outside lipopolysaccharide and inside lipoprotein, and this change the cell permeability, and finally leads to cells dissolving and death.

It was reported that ozone has good disinfection effect (Li, 2005). Candan Gu¨rakan et al. (2005) reported Gaseous ozone treatment has bactericidal effect on *S. enteritidis* inoculated on the surface of the tomatoes and

can be used for surface sanitation of *S. enteritidis* on tomatoes before storage at different conditions. The ozone gas treatment had a fungicidal effect on Botrytis cinerea (Toussaint Barboni, 2010); Ozone is a good alternative sanitizer for fresh fruits and vegetables (Han et al., 2002; Yousef et al., 1999). It can destroy micro-organisms through progressive oxidation of vital cellular components (Das et al., 2006).

In addition to killing molds or inhibiting its growth to prevent food decay, ozone can also prevent aging and keep fresh. The mechanism is that ozone can oxidate and decompose ethylene that is generated in physiological metabolism. The research and review of Dickson and Rice (2003) showed that it can reduce the amount of ethylene in the storage environment and can quickly oxidate and decompose ethylene, and finally generate carbon dioxide and water. Ozone can oxidate many kinds of organic or inorganic. In refrigeration and controlled atmosphere storage, fruits normally accumulate ethanol, aldehyde and other harmful substances as a result of the usual unsuitable temperature and gas composition.

Studies have pointed out that when ethanol concentration accumulates to 0.3 mg/kg and acetaldehyde concentration accumulates to 0.04 mg/kg or above, cell will be poisoned, thus symptoms such as fruit browning, peel scald, core rot will appear. Ozone can narrow stomatal in the fruit and vegetable epidermis, reduce moisture transpiration and nutrient consumption, at the same time, due to strong penetration ability, negative oxygen ion created can hinder the normal glucose metabolism and decrease metabolism level.

During the storage period of Beijing white pears, Li (1993) processed them by ozone regularly, it is found that they were weightless, the change of flesh hardness was delayed, and the breathing of fruit was promoted. Ozone treatment could achieve the highest overall quality of cilantro during storage and also maintained the typical cilantro aroma (Hua Wang, 2004). Skog et al. (2003) reported that 0.09 mg/m^3 ozone can obviously extend storage time of broccoli and seedless cucumbers at 3℃, but the effect on mushrooms at 4℃ and cucumbers at 10℃ under the same concentration is not obvious.

Plasma fresh-keeping technology

Plasma is the fourth state of matter. Low temperature plasma can be produced through the specific electric field and silent discharge. In this process, high energy electron collides with gas molecular, a series of physical and chemical reactions happen and gas is activated, many active groups are produced. Low temperature plasma has obvious effect on fresh-keeping of fruit and vegetable and degradation of pesticide residues, besides, it can remove ethylene, ethanol and other metabolites, induces stomatal narrow, reduce respiration intensity. Moreover , it can effectively prevent and kill fungi, bacteria and also have certain inhibitory effect for virus. All of these indicate that plasma has certain physiological regulation function and can also inhibit and prevent as well as cure disease to some extent.

Electrolyzed reduction water technology

The so-called electrolyzed reduction water is strong acidic water and strong alkaline water being obtained after special electrolysis processing. In the early 1990s, Japan first studied sterilization function of strong acidic water. Recently, some scholars' research shows that electrolyzed reduction water can kill germs and microorganisms, more importantly, when exposed to the air after sterilization, it will gradually restored to water without any pollution and harm to human body. Hua Wang et al (2004) found that use acidic electrolyzed water to treat cilantro can resulted in moderate control of aerobic bacterial growth during storage. Keiko O, Kazuo H (2000) placed rose, (Rosa hybrida L.) flowers in half-strength of electrolyzed anode water (EAW ; pH 2.9, 26 mg・liter^<-1> available chlorine) to test the effect of EAW on the vase life. They found that three days after treatment, no bacteria were detected in these test solutions and the effect of EAW on the vase life of cut roses is due to sterilized action by low pH and chlorine compounds such as hypochlorous acid.

Ultrasonic processing technology

Ultrasonic is a kind of propagation process of mechanical vibration in the medium. Its frequency is generally above 20 kHz and has the mechanical, heating and cavitation effect. Instantly, high temperature and temperature variation, instant high pressure and pressure change produced by ultrasonic cavitation effect in liquid are used to kill some bacteria, inactivate virus or even damage cell wall of some smaller microbial so as to extend the storage time of fruit and vegetable.

Super ice-temperature technology and ice film storage technology

Current research on ice-temperature technology is entering a new stage which is super ice-temperature technology. By adjusting the cooling speed and using other special techniques, temperature even below freezing point also can successfully keep super-cooled state, so in super ice-temperature field, though the temperature is below the normal freezing point, organisms also won't freeze. Super ice-temperature technology further widens the ice-temperature application field. If the research on this technology can be further

developed, super fresh-keeping era will come. Presently, it has confirmed that comparing with positive temperature field in which oxidation and aging reaction happens, reduction reaction of some seeds in ice-temperature and super ice-temperature field can happen basically without oxygen.

Ice-temperature storage must preserve food in negative temperature area that is below 0°. Because when storing some low sugar food especially for that of layered structure such as cabbage vegetables at ice temperature, they can easily appear the phenomenon of dry consumption, low temperature cold injury or partly frozen. A lot of experiments and research successfully advance ice film storage technology, which means that by covering a layer of artificial ice or snow or other protective film on the food surface, dry consumption and low temperature cold injury phenomenon could be avoided because of cold air directly through the surface of food.

CONCLUSION

Compared with the traditional storage technology, physical preservation technique can fully retain food nutrients and the original flavor, and even generate some favorable special flavor, so the application of physical technology in fruit and vegetable fresh-keeping has huge production potential and a promising prospect.

At the same time, we should also realize that many physical fresh-keeping technologies are still in the experimental and research phase, the sterilization and preservation principle is not very clear which has limited their application.

Other physical fresh-keeping technologies also require further study, so that its sterilization and preservation mechanism and influence factors can be thoroughly understood to achieve the best effect of preservation. Above all, the future research focuses are: Mechanism, influence factors and applied conditions of physical preservation technology; further reducing costs; combining different physical preservation techniques to achieve the best effect of fresh-keeping.

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