21

Ice-Temperature Storage Technology of Fruits and Vegetables

Liu Bin, Cai Bihao and Shen Jiang
Tianjin Key Lab of Refrigeration Technology, Tianjin University of Commerce, P.R.China

1. Introduction

The ice-temperature storage technology belongs to the no-freezing storage technology, in which the food is stored at a temperature from 0ºC to the freezing point. The fundamental thought of ice temperature storage technology is that the stored product is a living organism. After the cooling disposition on certain conditions, it can reach to an approximate “hibernate” state. Preserved at this state, the product can be maintained in good quality and its life can reach to the longest level since its metabolic rate is the smallest and so is the energy consumption.

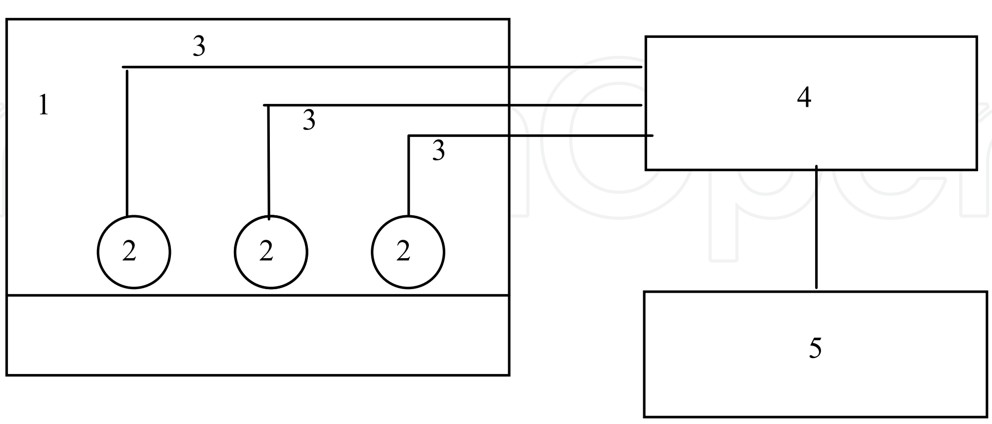
The ice-temperature storage technology was originated from Japan. Their found that the freeze point of the snake, frog and meat is below 0°C for the antifreeze substance such as the sugar, the protein and alcohol and they can be kept as a living organism. The results pointed out that the temperature limit of life and death is below zero centigrade and at which temperature, the cell can be kept a living state. The effect of the ice-temperature storage technology on the fresh food mainly includes the followings.

1. The ice-temperature storage can inhibit respiration, delay the respiratory peak and reduce the loss of nutrients. The exhaled volume of CO2 in the ice-temperature (-0.8°C) is less than that stored in normal temperature about 30% to 60%.
2. The ice temperature storage won’t destroy the cells, but improve the quality of fruits and vegetables in the vicinity of freezing temperature. In order to prevent from forming ice, fruits will secrete large amounts of antifreeze (its main ingredients are glucose, amino acids, aspartic acid etc.) to reduce the freezing point, or decompose the starch into sugar. These physiological changes improve the quality of fruits and vegetables in different degrees.
3. The ice temperature can inhibit the growth of microbial efficiently. Under the condition of the ice temperature, water molecules in fruits or vegetables are arranged in an orderly state, which reduce the content of free water available for the microbial. In the short-period storage, the ice temperature can inhibit multiplication of microorganisms, better than the frozen temperature. In the long-term storage, the ice temperature and the frozen temperature maintain the same level of a reproduction rate of bacteria, fungi and low-temperature bacteria, which is much smaller than that of the cold temperature.
4. Since ice temperature can inhibit chemical reaction strongly, the food quality in ice temperature is better than that of the normal cold storage. The ice temperature also can inhibit lipid oxidation, non-enzymatic and other chemical reaction.

Based on these advantages of the ice temperature storage, the study of the ice temperature technology on fruits and vegetables was carried out in our lab. The obtained result shows that the key for the ice temperature preservation is to realize a hibernation state of the product. The "hibernation" process is a cooling process during which the product can reduce its activity ability and energy consumption through the self adaption, starting from the change of components within cells, and at the same time ensuring their own living life characteristics. It is a typical phenomenon of natural adaption. However, the traditional precooling process ignores that and the storage effect couldn't reach to the best level.
Consequently, for the ice temperature storage technology, the prime technical key points are determination of the freezing point, the cooling process and the stability of storage environment. According to these key points, studies of the influence of freezing point, processing and storage environment were carried out.

2. Determination of freezing point

The freezing point is the storage critical point of all the cryogenic stored products and plays a decisive role in corresponding storage process. Therefore, the research of the freezing point has not only formed the basis of refrigeration field, but also been a hot researching topic. The moisture in food is not pure water, but liquor including organic and inorganic substances. So the ice crystals won't produce until the temperature of food reduce to subzero. According to LaWuEr second law, the reduction of liquor freezing point is proportional to the solute concentration. Freezing point will decrease 1.86°C with increasing 1 molar concentration. Due to the difference of food types, the stored conditions after harvest and the concentration of muscle plasma etc, different food has different freezing point. The freezing point of general food is from -0.5°C to -2.5°C.
There are two common ways to measure the freezing point, one is the traditional freezing method, and the other is DSC testing method. In this study the first method was adopted, for that we can clearly see the cooling process, the corresponding supercooling points and phase change during the measuring time in the method. Figure 1 shows the test setup.



1. alternating thermostatic box, 2. tested items
3. Thermocouple, 4. Data collector, 5. computer

Fig. 1. Diagram of the setup testing the freezing point

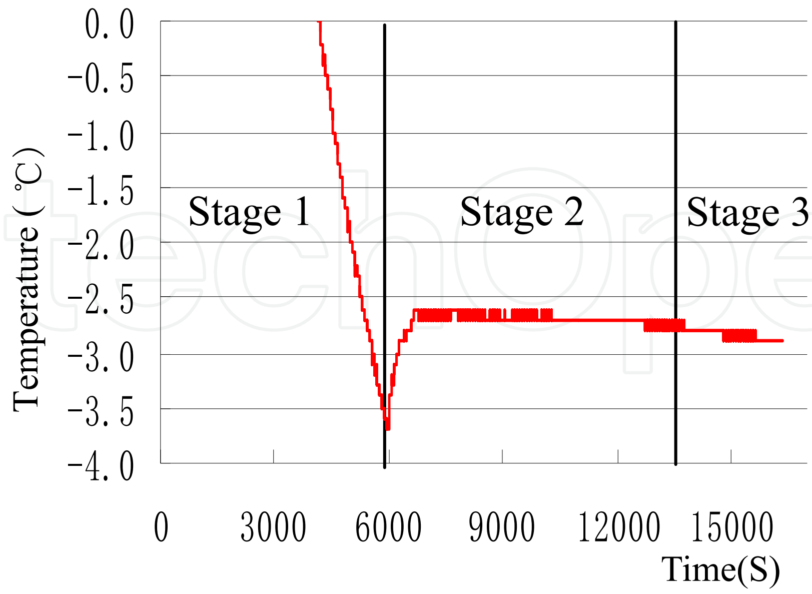


Fig. 2. Curve of temperature change during freezing

From the Figure 2, the temperature profile can be divided into three stages:
The first stage: the food's temperature is reduced from the initial temperature to the freezing point, the heat releasing from food is sensible heat. Compared with the total heat, this value is small, so the cooling speed is fast and the freezing curve is relatively steep.
The second stage: the food's temperature is almost kept at a constant temperature, which value is from 0°C to -5°C. At this stage, most of the water in food is frozen and release a lot of latent heat which is about 50~60 times as much as sensible heat. It is in the second stage that most of the heat in food freezing process is released. So there is a flat segment in the curve.
The third stage: the food's temperature reduce from the phase change temperature to the final temperature, the heat released at this time is partly due to ice cooling ,and partly because of the residual small amount of water getting frozen. The freezing curve in this stage is also relatively steep.

2.1 Influence of reducing sugar on freezing point

The freezing point shown in Fig. 3 has an increasing trend with the increase of mass fraction of reducing sugar, which is not apparent. But it doesn't match traditional recognition. Usually the freezing point is believed to drop with the increase of mass fraction of reducing sugar. The tendency of pear's freezing point just reflects the relationship in Fig. 4.The reason maybe that kiwi has a large amount of acid which influence the effect of sugar on freezing point. This is just reflected in figure 7 and figure 8.

2.2 Influence of total sugar on freezing point

From the trend line of relationship between freezing point and total sugar in Fig. 5 and Fig. 6, we can find that freezing point increases with the increase of mass fraction of total sugar, but this relationship is weak.

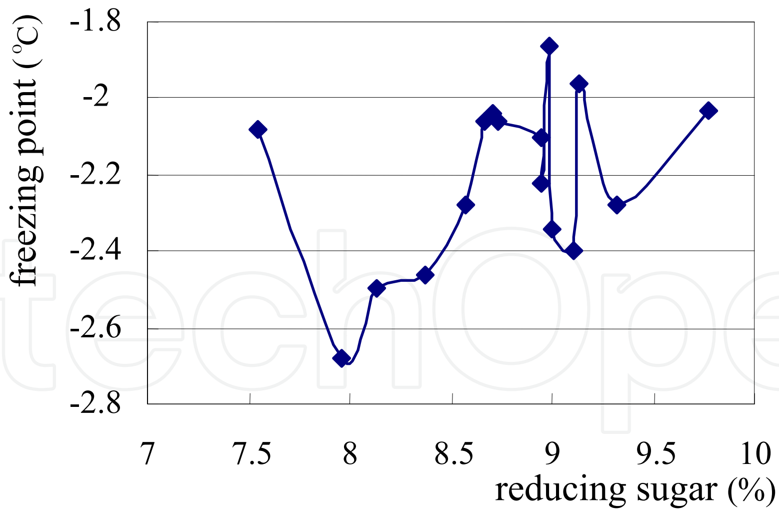


Fig. 3. freezing point of Kiwi vs. reducing sugar

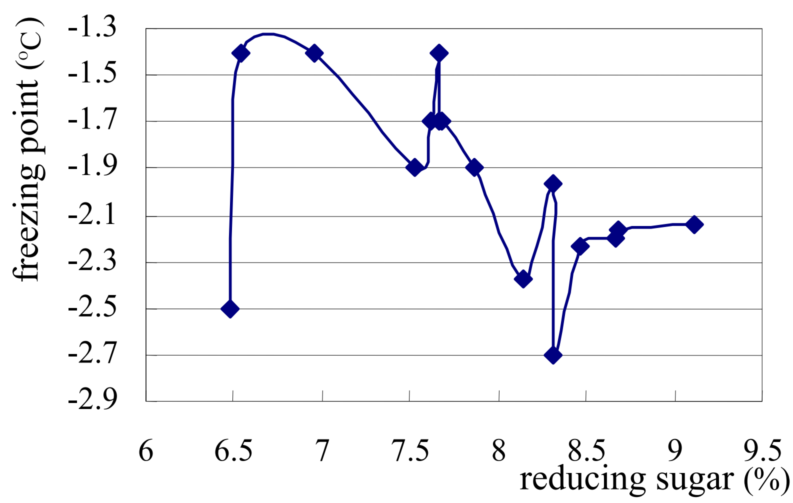


Fig. 4. freezing point of pear vs. reducing sugar

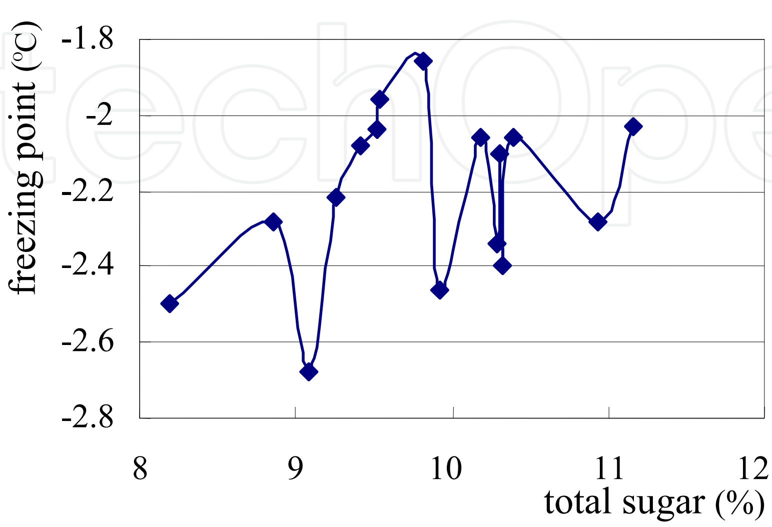


Fig. 5. freezing point of kiwi vs. total sugar

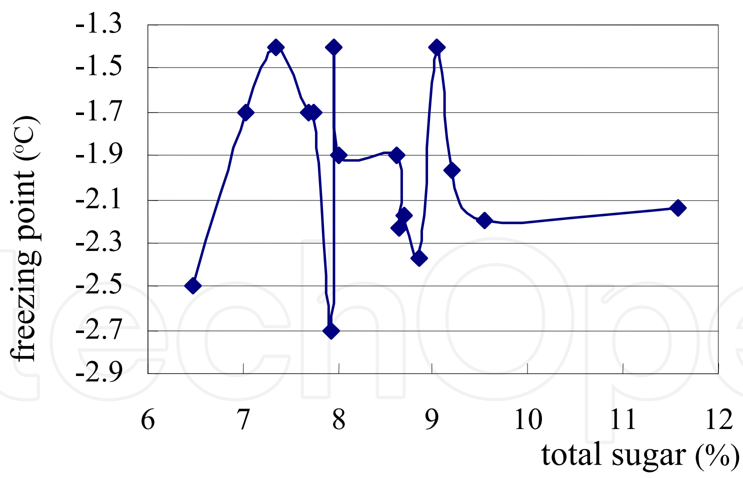


Fig. 6. freezing point of pear vs. total sugar

2.3 Influence of acid on freezing point

From Fig.7 and Fig.8 it can be found that the relationship between freezing point and acid is not apparent, but the freezing point has a downward tendency with the increase of acid in the case of smaller acidity.

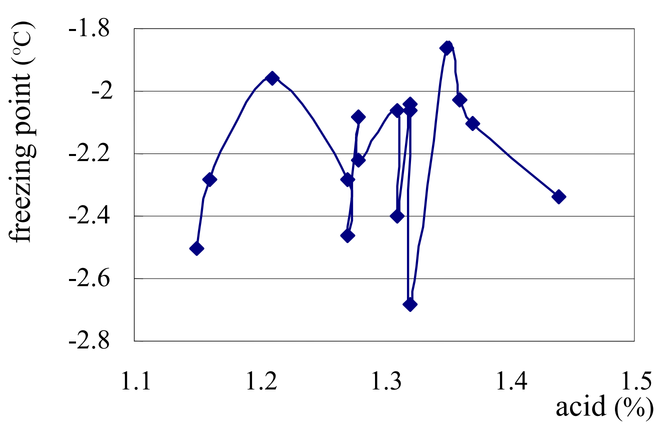


Fig. 7. freezing point of kiwi vs. acid

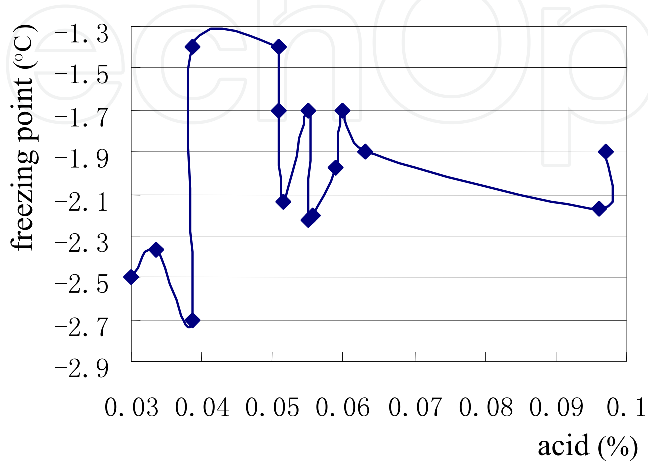


Fig. 8. freezing point of pear vs. acid

2.4 Influence of soluble solid on freezing point

Seen from Fig.9 and Fid.10, the freezing point has a downward tendency with the increase of mass fraction of soluble solid, but the decline rate of kiwi's freezing point is smaller than that of the pear.

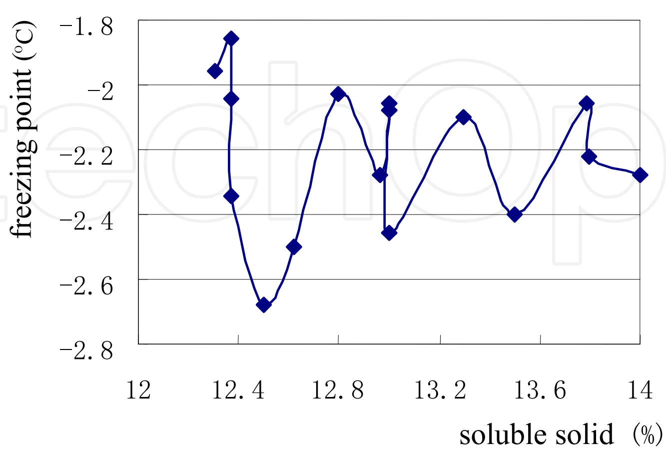


Fig. 9. freezing point of kiwi vs. soluble solid

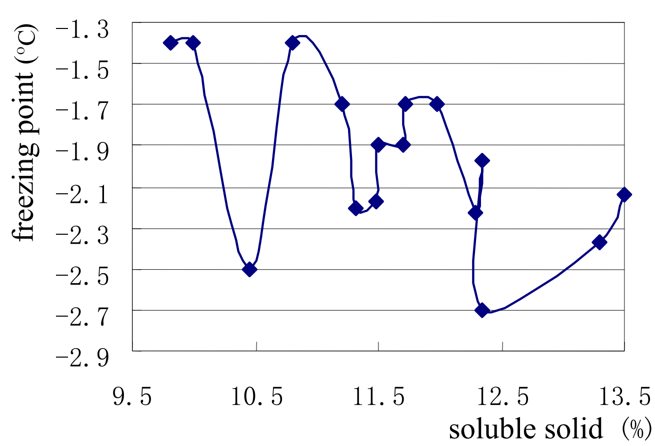


Fig. 10. freezing point of pear vs. soluble solid

From the curve relationship between above four kinds of nutrition and freezing point, it can be found that there is a strong relationship between freezing point and the nutritional proportions for a defined fruit. The experimental results show that freezing point of fruits is related with multiple nutritional proportions, among which the interaction effect may influence the changes in freezing point. For example, the acid has a reverse effect on sugar. In general, the freezing point will drop accordingly as sugar content increases. However, this effect becomes weak in the role of acid, which can be verified by the relationship between the freezing point and reducing sugar and total sugar shown in Fig. 3 and Fig.5.

2.5 Regression of freezing point and mass fraction

Based on the experimental data, the linear regression of the relationship between freezing point and the mass fraction of each component were carried out shown in Eq.(1) and Eq.(2) as follows.

Kiwi:

$$t = 0.117198 \times x_{reducing\ sugar} + 0.055817 \times x_{total\ sugar} + 0.095504 \times x_{acidity} - 0.07142 \times x_{soluble\ solid} - 2.97913 \quad (1)$$

Pear:

$$t = -0.39643 \times x_{reducing\ sugar} + 0.213383 \times x_{total\ sugar} + 5.746773 \times x_{acidity} - 0.14007 \times x_{soluble\ solid} + 0.669404 \quad (2)$$

By the checking, calculation, the freezing point of pear by Eq.(1) is calculated, the maximum error is 15%and the minimum error is 1.7%,while calculated by Eq.(2),the maximum error of pear is 25% and the minimum error is 1%. The predicted results coincide better with experimental ones.

3. Influence of precooling process

As living organizations, the fruit and vegetable are affected by severe environmental changes in precooling process. During the precooling process, there are physiological changes in the inside of the fruit and vegetable to adapt to the environment, which can be reflected from two aspects. One is the change of physical structure, such as the body stress, epidermal pore and so on; another one is biochemistry changes in vivo like respiratory intensity and nutrition. In order to investigate the effect of the precooling process, the preceooling experiments of three kinds of fruits were carried out, and the results were compared with the traditional one.

3.1 Material preparation and test method

In this experiment, the experimental storage of different precooling processes on three fruits was carried out, including kiwi, pear and peach.

3.1.1 Precooling process of kiwi

The kiwi was produced in Shengxi Province, after harvested, they was transported to lab in 24 hours.

Traditional storage process of kiwi: kiwi is precooled rapidly from 29°C to 3°C in 3 hours and be stored in the storehouse of which the ambient temperature is 3°C and the relative humidity is 85%.

The variable cooling rate precooling process of kiwi: the kiwi was precooled rapidly from 29°C to 5°C in 2.5 hours, then change the precooling rate, the kiwi was cooled slowly to 3°C in 24 hours ,then to 0°C in 10 hours ,then to -0.8°C in 10 hours, and at last to the storage temperature -1.3°C in 10 hours, stored in the ice-temperature storehouse at -1.3°C and its relative humidity is 85%.

$$29°C \xrightarrow{2.5 hours} 5°C \xrightarrow{24 hours} 3°C \xrightarrow{10 hours} 0°C \xrightarrow{10 hours} -0.8°C \xrightarrow{10 hours} -1.3°C$$

3.1.2 Precooling process of pear

The pear was produced in Xingjian Province, and after harvest they were transported to lab in 48 hours.

Traditional storage process of pear: pear was precooled rapidly from 29ºC to 3ºC in 3 hours and was stored in the storehouse of which the ambient temperature is 3ºC and the relative humidity is 85%.

The variable-rate pre-cooling process of kiwi: the kiwi was precooled rapidly from 29ºC to 5ºC in 3 hours, then cooled the kiwi slowly to 3ºC in 24 hours, then to 0ºC in 10 hours, then to -1ºC in 10 hours, and at last to the storage temperature -1.7ºC in 10 hours, after that stored the kiwi in the freezing storehouse at -1.3ºCand its relative humidity is 85%.

$$29°C \xrightarrow{3hours} 5°C \xrightarrow{24hours} 3°C \xrightarrow{10hours} 0°C \xrightarrow{10hours} -1°C \xrightarrow{10hours} -1.7°C$$

3.1.3 Precooling process of peach

The peach was produced in Beijin City, and after harvested they were transported into lab in 24 hours.

Traditional storage process of peach, A: the peach was precooled rapidly from 28ºC to 2.5ºC in 3.5 hours and be stored in the storehouse of which the ambient temperature is 3ºC and the relative humidity is 85%.

In order to verify the influence of the precooling at different cooling rate on the storage of peach, two precooling experiments were carried out, after the precooling, the peaches were stored in the storehouse at -0.7ºC with a relative humidity of 85%.

(1)the pre-cooling process of peach at slow cooling rate, B: the peach was precooled from 28ºC to 5ºC in 3.5 hours, then cooled the peach slowly to 3ºC in 3.5 hours, then to 1.7ºC in 24 hours ,then to 1ºC in 24 hours, then to 0.5ºC in 24 hours ,then to 0ºC in 24 hours, then to -0.3ºC in 24 hours, and at last to the storage temperature 0.7ºC in 24 hours, after that stored the peach in the freezing storehouse at -1.3ºC and its relative humidity is 85%.

slow cooling rate，B:

$$28°C \xrightarrow{3.5h} 5°C \xrightarrow{35h} 3°C \xrightarrow{24h} 1.7°C \xrightarrow{24h} 1.0°C \xrightarrow{24h} 0.5°C \xrightarrow{24h} 0°C$$
$$\xrightarrow{24h} -0.3°C \xrightarrow{24h} -0.7°C$$

(2) the precooling process of peach at fast cooling rate, C: the peach was precooled from 28ºC to 5ºC in 3.5 hours, then cooled the peach slowly to 2.5ºC in 24 hours, then to the storage temperature 0.7ºC in 24 hours. After that, stored the peach in the freezing storehouse at -0.7ºC and its relative humidity is 85%.

②rapid cooling rate, C:

$$28°C \xrightarrow{3.5h} 0.5°C \xrightarrow{24h} 2.5°C \xrightarrow{24h} 0.5°C \xrightarrow{24h} -0.7°C$$

3.1.4 Measurement of respiration rate and nutrients

During the experiments, according to different types of fruit, different fruit has different components in fruits were measured, including the respiration rate, the water-soluble vitamin C, the total sugar, the acidity. The respiration rate is determined by gas flow processes, the vitamin C is measured by GB 6195-86 (Chinese), the total sugar is measured GB 6194-86 (Chinese) and the acidity is measured by GB 12293-90 (Chinese). Except the measurement of respiration, six samples were measured and the average value of 6 measurements was used in the analysis.

3.2 Experimental results and discussion

3.2.1 Experimental results and analysis of kiwi

Fig.11 and Fig. 12 show curves of the respiration rate of kiwi and the change of water-soluble vitamin C over storage time in preservation process.

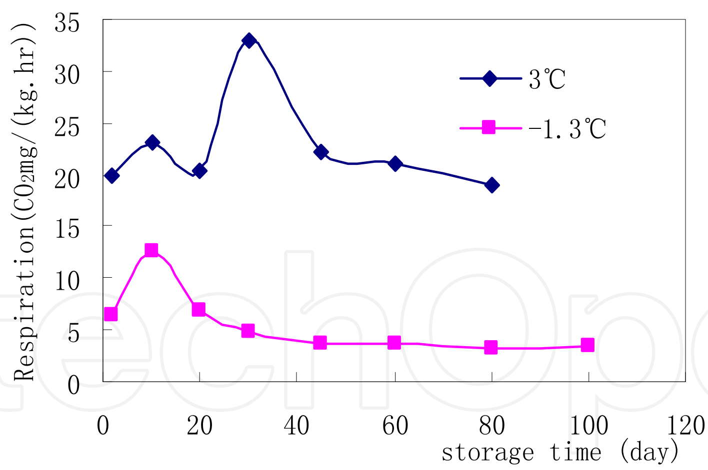


Fig. 11. Curves of kiwi respiration v.s. storage time

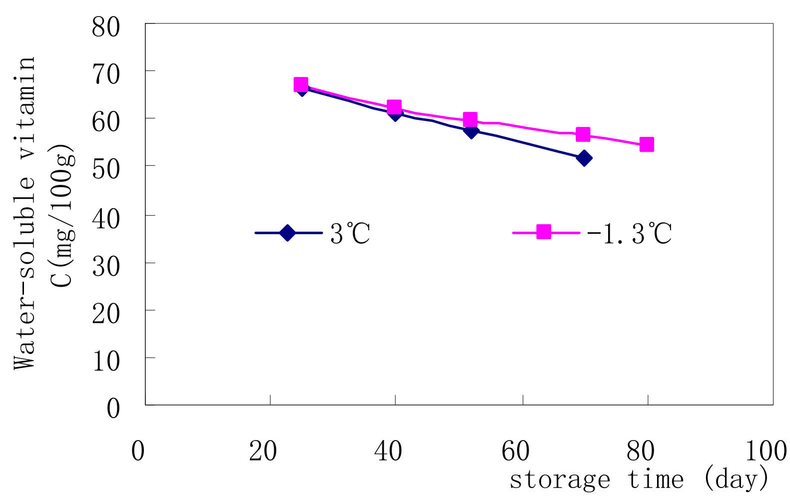


Fig.12 Curves of kiwi water-soluble vitamin C v.s. storage time

From Fig.11, it can be found that the kiwi has two reparatory peaks under the traditional storage condition, while under the condition of the ice temperature, there is only one reparatory peak, and on both storage conditions, the time to show the first reparatory peak is almost the same. The main reason is that when kiwi was put into the storehouse, the stimulation of the low temperature strengthened the respiration rate to protect itself in cold environment. So there is a minor reparatory peak in both the storage conditions. As for the second reparatory peak under the traditional condition, the reason is that the kiwi belongs to breathing-type fruit, the reparatory peak is delayed under the traditional storage condition. But as the the fruit precooled at variable cooling rate and stored in ice temperature, it dosen't has the second reparatory peak .The main reason for that is in the pre-cooling process with different cooling rate, the kiwi has adapted the surrounding well and is stored in the vicinity of ice temperature.

Compared the respiration rate of the two storage conditions, it can be found that the respiratory rate decline rapidly in the vicinity of freezing point, which doesn't match the law of temperature coefficient. From the two figures, the temperature difference between these two storage conditions is only 4.3ºC, but the ratio of respiration rate is about 5, which does not meet with the common views.

3.2.2 Experimental results and analysis of pear

Fig. 13 to Fig. 15 show the curves of the respiration rate, the total sugar and the acid of pear over storage time.
From Fig.13, we can found that the pear under traditional storage condition has a reparatory peak after 70 days, which means that the pear has begun dying to death. As for the pear precooled at variable cooling rate, it has a smaller reparatory peak at the beginning of storage (ten days) at -1.7ºC and at other time the respiration maintains at a smaller value, which prolong storage time in a certain degree. The main reason for this smaller reparatory peak of the pear with different cooling rate is that when pears are just stored in the storehouse at -1.7ºC, they show a conditional stimulation reaction.
From the nutrition showed in Fig.14 and Fig.15, the pear precooled at variable cooling rate has higher sugar content and acidity, so that it can ensure a better quality.

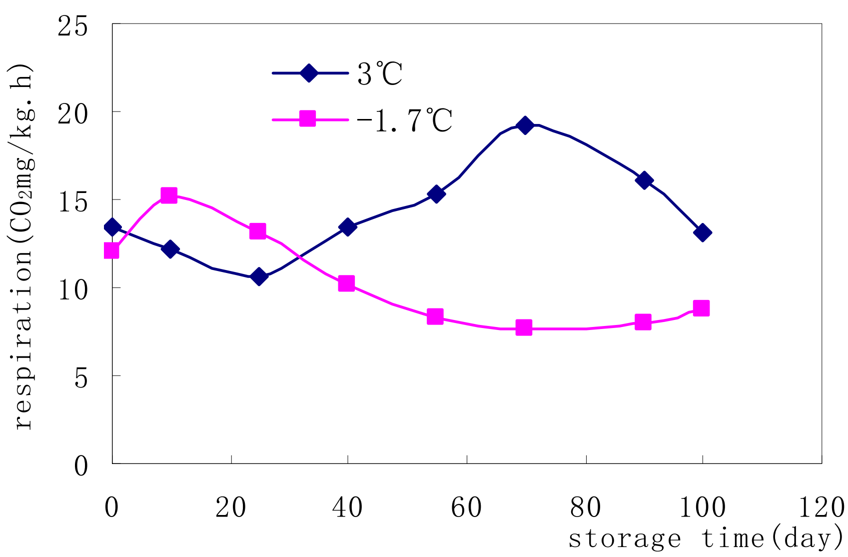


Fig. 13. Curves of pear respiration v.s. storage time

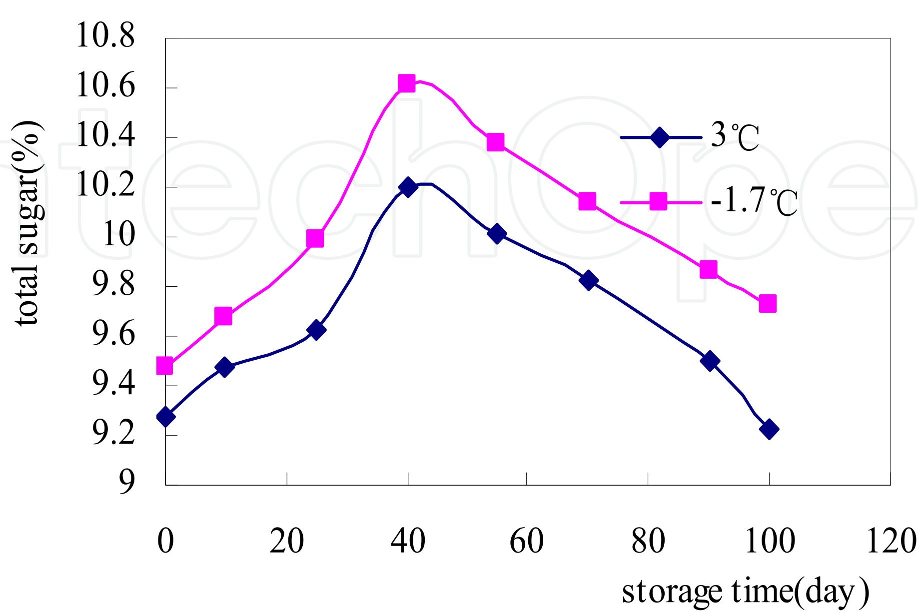


Fig. 14. Curves of pear total sugar v.s. storage time

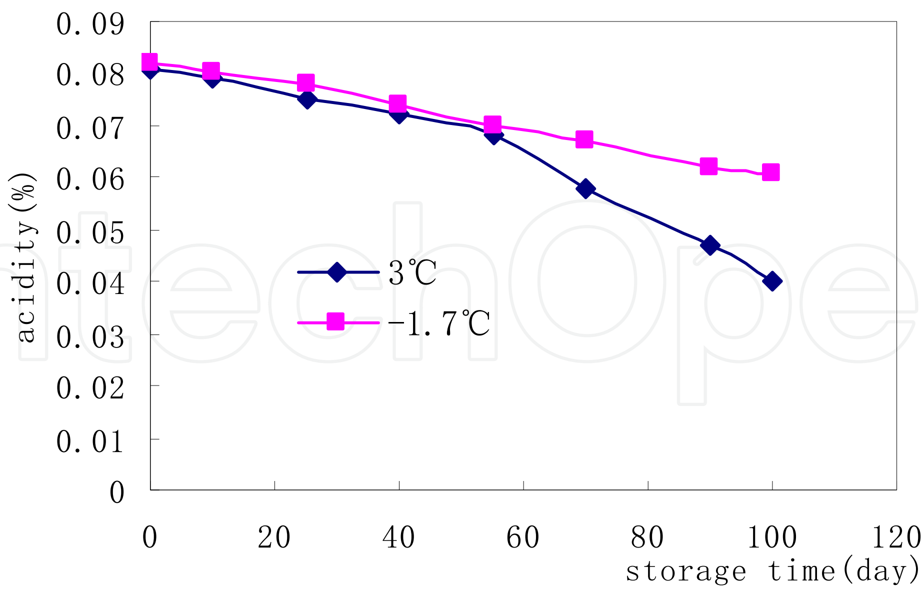


Fig. 15. Curves of pear acidity v.s. storage time

3.3 Experimental results and analysis of peach

Fig.16 to Fig.18 show the curves of the respiration rate, the total sugar and the acid of peach over storage time.

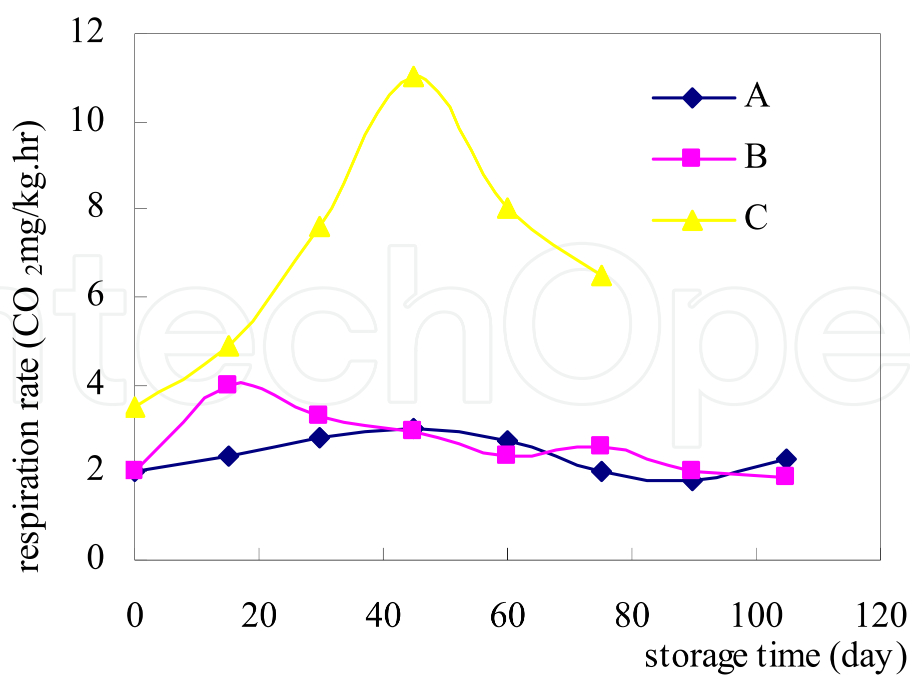


Fig. 16. Curves of peach respiration v.s. storage time

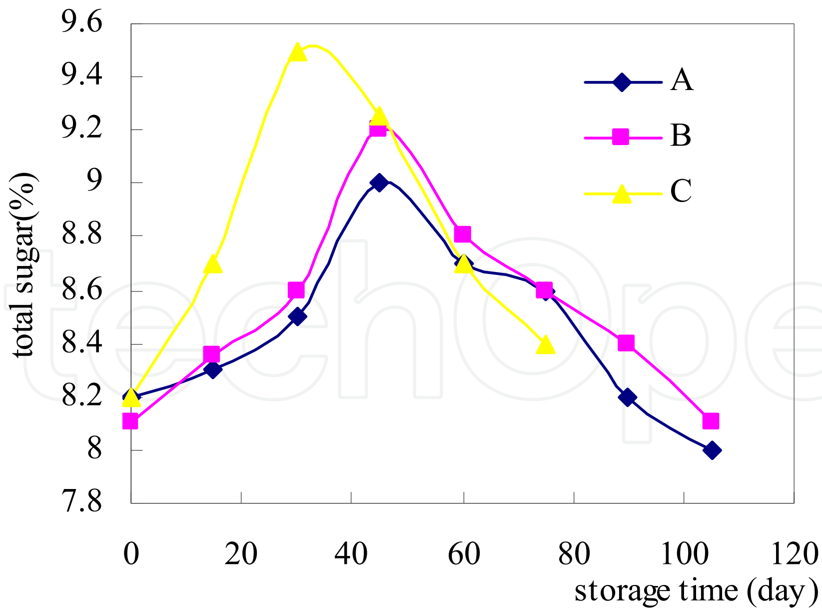


Fig. 17. Curves of peach total sugar v.s storage time

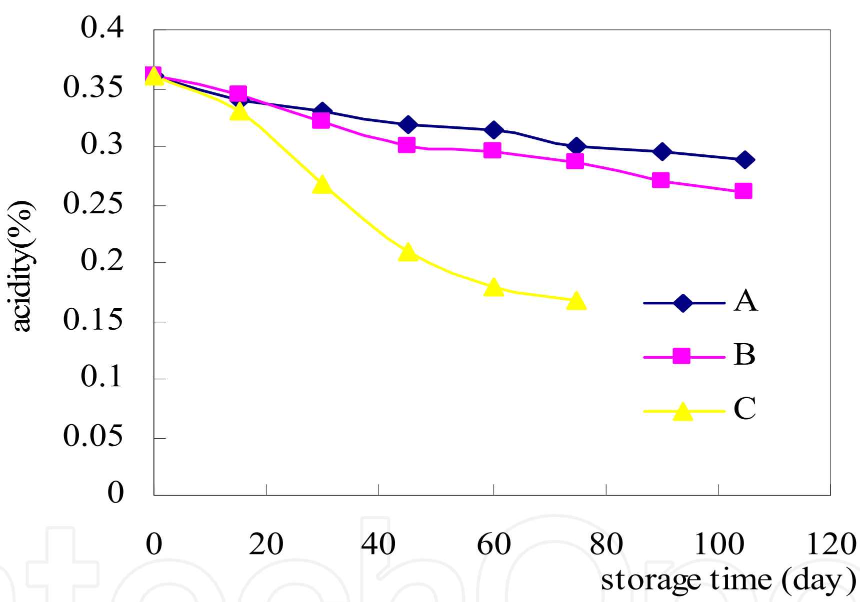


Fig. 18. Curves of peach acidity v.s storage time

As it can be seen from Fig.16, the peach has the first reparatory peak after 45 days in traditional storage while the ones precooled at variable cooling rate does not have. Compared with the two processes with different cooling rate, the peach cooled by the slower cooling rate shown a smaller reparatory peak, but which doesn't influence the respiration rate in the whole storage time. And from Fig.17, it can be found that the total sugar always has a peak value in the storage period. And the peak value of the peach cooled by variable cooling rate was smaller than that of the peach cooled in a traditional method. Fig. 18 shows that the acidity of peach precooled at variable rate is smaller than that of the one cooled in traditional method. However, after stored 100 days, the peach cooled by variable cooling rate still had better appearance and hardness shown in Fig.19, there is a serious decline in sugar and the flavor become worse.

the peach feature stored with A processing after 75 days

the peach feature stored with A processing after 105 days

the peach feature stored with C processing after 75 days

Fig. 19. the peach feature at different storage time

Compared with the color of the peach shown in Fig.19, we can find that the peach cooled by the variable cooling rate has a better appearance than that of the peach treated by the traditional method. After 75 days in storage, the stored peach in the ice temperature has little difference with the new peach in color, hardness, etc., while the peach with traditional treatment has reached to the end of shelf period. And after 105 days, the peach at ice temperature reach to the end of shelf period with low sugar concentration shown in Fig.17.

Experimental results show that precooling process with variable temperature can make the fruit to adapt the low temperature environment and delay the emergence of the respiratory peak. Compared to the conventional low temperature storage, the fruit stored under the ice temperature has smaller respiratory rate, which guarantee the quality of stored fruit effectively and extend the storage time by 30%.

4. Effect of ice temperature storage

As discussed in 2, the cooling rate and heating rate of fruits before and after the ice temperature storage finally influence the storage period、shelf life and nutrition.

Under normal circumstances, the organization with rapid cooling stress will take over the depth of the cooling method to keep warm, and the one with slow cooling stress will take over the way of ice frost in the cells [5-10]. Slowly and staging cooling the organization can reduce the critical lethal temperature, thus making some of the critical lethal temperature higher than the organization of plant in the zero and can be preservation for a long time at 0ºC or below zero, extend their storage period. Different heating rate after storage at ice-temperature has different effects on the shelf life of fruits. The reason is the act of fruit tissue self-adaption. For the study of the reactions of kiwi and pear under the processing conditions, the experimental studies were carried out to a better understanding the mechanism of ice-temperature storage.

According to the difference of respiratory type, two kinds of fruits were chosen to do the ice-temperature storage research, one is pear (breathing -jump variant), the other is kiwi(non-breathing-jump variant).After certain days, the storage temperature was increased in different warming ways. The results showed that compared with the comparison group, ice-temperature storage can maintain the nutrients in fruits better; as to the carbohydrate material, slow cooling is helpful to maintain the sugar during storage period. Ice-temperature storage by slow cooling can make the fruits have higher acidity while the fast cooling one make the fruits have more soluble solids.

4.1 Experimental materials and equipments

In this study, the mostly used equipments included two equipments. One is the DSC (Differential Scanning Calorimetry) used to measure the ice point and the thermal action of experimental materials in cooling or heating, but at here the results were not shown. The other equipment is two setups of ice-temperature with two parts. One part is used to cooling or heating the stored fruit, the other part is used to store the fruit. The two equipments are illustrated respectively on Figure 1 and 2.
The thermal dynamic process is a tool and the fruit quality is the goal. The total sugar, the total acid and the soluble solid of Kiwi and Pear fruit are measured. The measurement method are according to Chinese National Standard GB 6194-86, GB 12293-90 and GB12295-90.

Fig. 20. Diagram of DSC

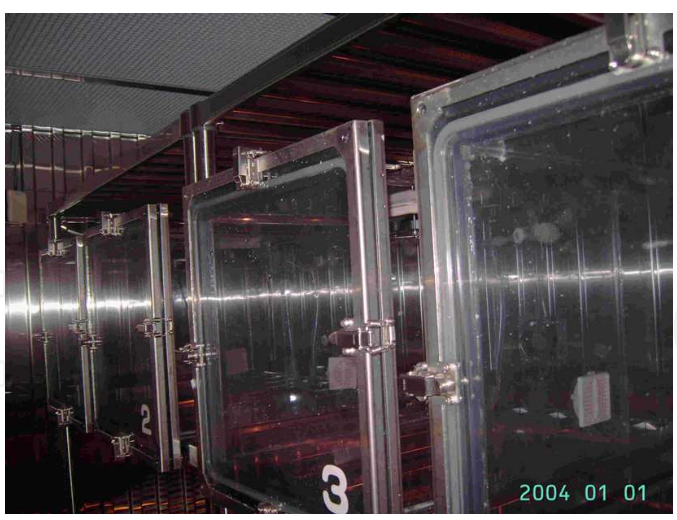


Fig. 21. Experimental setup of Ice temperature

In experiments, two fruits were selected. One is the pear produced in Xinjiang Province, which was harvested in September 2006 and stored with a temperature of 5ºC. The other is the Kiwi produced in Shanxi Province, which is harvested in October 2006 and stored with a temperature of 6ºC. In Jan 6, 2007, the two fruits were transported to Tianjin University of Commerce and was stored in two cold room with a temperature of 5ºC. The two fruits were transfered to the ice-temperature lab (the Jan 12, 2007), where the temperature of Kiwi was 5.8ºC and 4.6ºC, and the temperature of pear was 5.9ºC and 4.3ºC. In Table 1, the processes of cooling of the two fruits were shown. In order to compare to the experimental results, before the cooling, the two fruits were cooled to 5ºC and 3.5ºC.

The thermal treatment consists of three steps, where the first step is a cooling process in order to bring the fruit to the ice temperature, the second stage is a storage period (one month) at ice temperature and the last step is the heating step in order to warm the fruits to a temperature of 15°C.

Type of fruit	Processing mode (name)	Initial Temperature	Final Temperature	Begin of cooling Jan 16th, 2007. 16 : 00	End of cooling Jan 17th, 2007 10:00
Kiwi	fast cooling (KF)	5.0ºC	0.0ºC		
	slow cooling (KS)	3.5ºC	0.0ºC		
Pear	fast cooling (PF)	5.0ºC	0.0ºC		
	slow cooling (KS)	3.5ºC	0.0ºC		

Table 1. The step 1 of thermal cooling processes of experimental materials

After the two fruits were cooled down, they were stored one month in the ice temperature rooms with a set temperature of -1ºC and -0.2ºC. During the third step, the fruit were moved out of the ice temperature rooms, they were heated as shown in Table 2.

Heating mode	fruit	Cooling mode (name)
Referenced group（5.7ºC）	Kiwi	5.7ºC
	pear	5.7ºC
Slow heating :	Kiwi	Fast cooling (KF-S)
		Slow cooling (KS-S)
	Pear	Fast cooling (PF-S)
		Slow cooling (PS-S)
Fast heating :	Kiwi	Fast cooling (KF-F)
		Slow cooling (KS-F)
	pear	Fast cooling (PF-F)
		Slow cooling (PS-F)

*Temperature rise : slow (from -1ºC to 15ºC in five days) and fast (from -0.2ºC to 15ºC in three days)

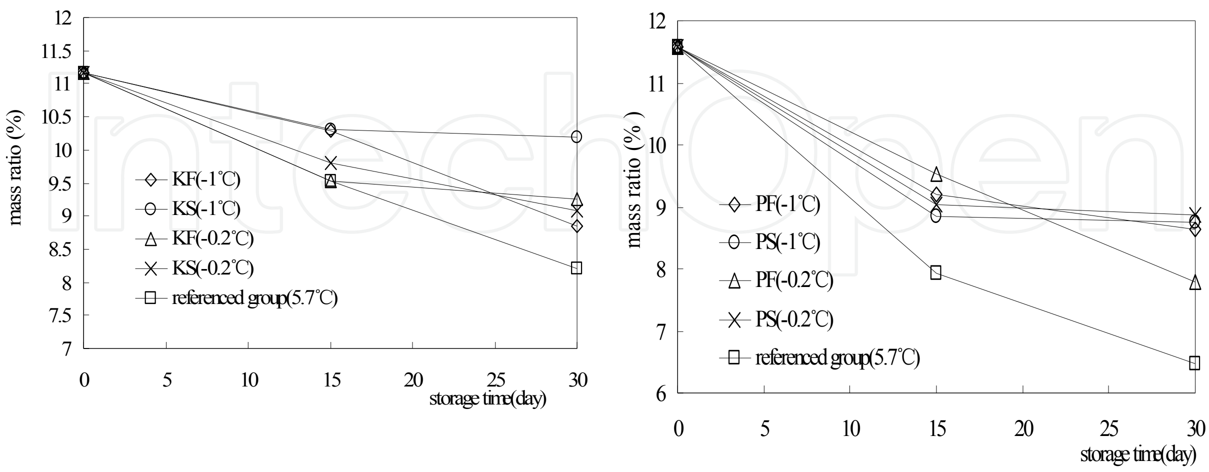
Table 2. The step 3 of thermal heating processes of experimental material

4.2 Results and discussions

During the step 2, one month storing time, the total sugar, the acidity and the soluble solid were measured each two week, and each measurement is an average of six samples. The results were shown in Figure 22 to Figure 24.

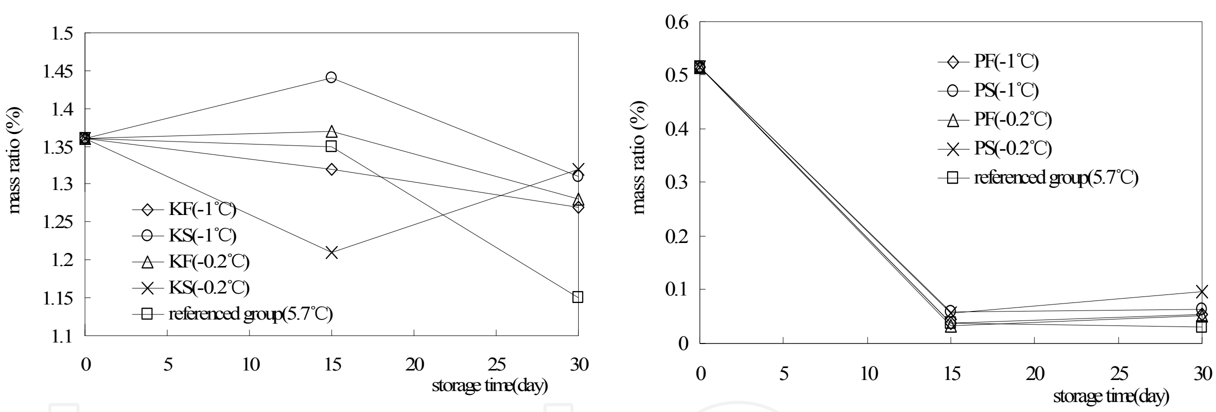
From Fig. 22 it can be easily found compared with the referenced group, t the total sugar of Kiwi and pear is higher, which means that a certain thermal process is needed before the cold storage and also means that the method of the ice-temperature is better than the method of cold storage. As for the different cooling processes, the difference is not obvious. But for different fruits, the cooling process plays an important role.

After 30 days in the ice-temperature storage, the total sugar of Kiwi stored in No.1 setup with -1ºC by slow cooling is the highest, while the total sugar of pear stored in No.2 setup with -0.2ºC by slow cooling is the highest.



(a) total sugar of kiwi fruit (b) total sugar of bergamot pear

Fig. 22. Curves of total sugar vs. storage time

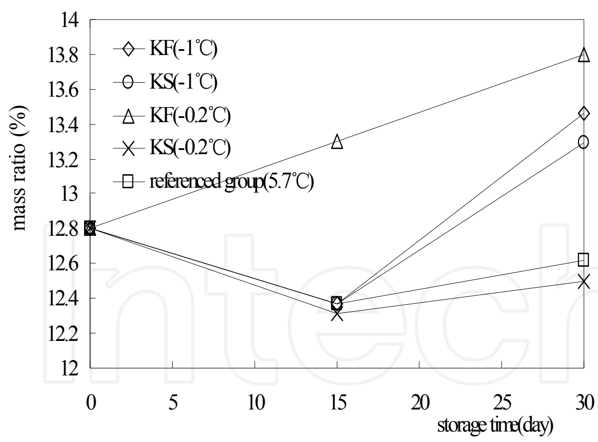


(a) total acidity of kiwi fruit (b) total acidity of bergamot pear

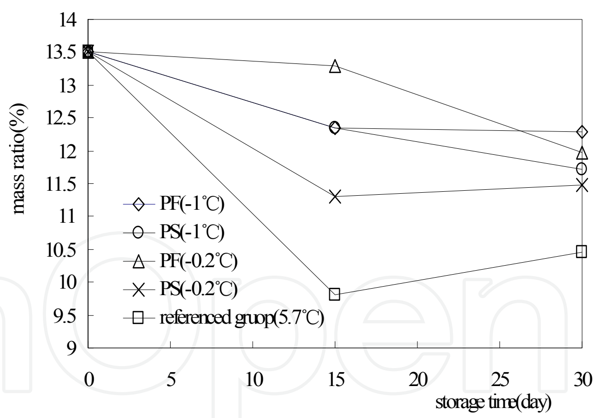
Fig. 23. Curve of total acidity vs. storage time

From Fig.23-a, it can be found that the acidity of Kiwi first increased with the storage time, and after some days, it reduced. But in Fig. 23-b, the acidity of pear reduced with the time, and after some days, it rose a little. Comparing the different thermal processes in Figure 4, the acidity in the referenced group without any process is the lowest, and the acidity in the group by slow cooing is higher that that of fast cooling. Fig.5 shows the curves of soluble solid vs. time.

In Figure24-a, it can be found that the soluble solid of Kiwi increased with the storage time, but in Fig.24-b it can be found that the soluble solid of Pear increased with the storage time. While we can find that the two fruits processed by fast cooling all have a higher soluble solid. Table.3 shows the content change after different heating model. Table.3 shows the content change after different heating model.



(a) soluble solid of kiwi fruit



(b) soluble solid of bergamot pear

Fig. 24. Curve of soluble solid vs. time

Heating model	Total sugar		Acidity		Soluble solid	
	Before heating	After heating	Before heating	After heating	Before heating	After heating
Kiwi referenced(5.7ºC)	8.2	10.94	1.15	1.16	12.62	14
Pear referenced (5.7ºC)	6.47	7.35	0.03	0.051	10.4569	10
KF-S	8.85	9.92	1.27	1.27	12.96	13
KS-S	10.19	10.33	1.31	1.31	13.79	13.5
PF-S	8.64	7.04	0.055	0.055	12.28	11.2
PS-S	7.75	8.62	0.06	0.063	11.72	11.7
KF-F	9.26	9.41	1.28	1.28	13.8	13
KS-F	9.08	10.4	1.32	1.32	12.5	13
PF-F	7.68	7.96	0.051	0.051	11.97	10.8
PS-F	8.69	8	0.096	0.097	11.49	11.5

Table 3: content change after heating

From Table 3, it can be found that the acidity is not affected by the heating model, but the total sugar and the soluble solid are affected strongly.

The above results were obtained by experiments with little theoretical analysis. In our opinions, the fresh fruits have an ability to adapt to the change of environment. When the fresh fruit is processed by different thermal processing, they will change their inner contents to make them comfortable in a new environment and to prolong their life time liking human being. In future, more works should be paid on thermal action of fresh fruits when they are undertaken thermal processions, such as heat and mass transfer of cells.

5. Conclusion

Based on the characteristic that fruit and vegetable are living organisms, the ice temperature storage technology of fruit and vegetable enable them to adjust to the cryogenic environment by regulating the precooling process in order to prolong their life period. The ice temperature storage can greatly reduce the metabolic rate, resulting in obvious deviation of breathing index from the value at common temperature. It is a kind of cryogenic physical storage technology of fruit and vegetable which will has an significant development in the future.

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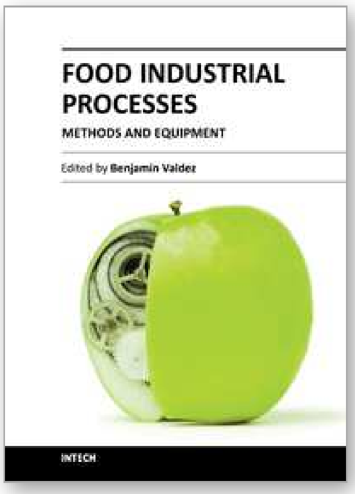

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The global food industry has the largest number of demanding and knowledgeable consumers: the world population of seven billion inhabitants, since every person eats! This population requires food products that fulfill the high quality standards established by the food industry organizations. Food shortages threaten human health and are aggravated by the disastrous, extreme climatic events such as floods, droughts, fires, storms connected to climate change, global warming and greenhouse gas emissions that modify the environment and, consequently, the production of foods in the agriculture and husbandry sectors. This collection of articles is a timely contribution to issues relating to the food industry. They were selected for use as a primer, an investigation guide and documentation based on modern, scientific and technical references. This volume is therefore appropriate for use by university researchers and practicing food developers and producers. The control of food processing and production is not only discussed in scientific terms; engineering, economic and financial aspects are also considered for the advantage of food industry managers.