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Full Length Research Paper

Quality control of fresh sweet corn in controlled freezing-point storage

Xiaolong Shao[1] and Yunfei Li[2,3]*

[1]Institute of Refrigeration and Cryogenic Engineering, School of Power and Energy Engineering, Shanghai Jiao Tong University, 800 Dongchuan Road, Shanghai 200240, P. R. China.
[2]Department of Food Science and Technology, School of Agriculture and Biology, Shanghai Jiao Tong University. 800 Dongchuan Road, Shanghai 200240, P. R. China.
[3]Bor. S. Luh Food Safety Research Center, Shanghai Jiao Tong University, 800 Dongchuan Road, Shanghai 200240, P. R. China.

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The aim of this paper was to evaluate the effects of two kinds of storage (controlled freezing-point storage at -1℃ and common cold storage at 4℃) on the quality of fresh sweet corn. Besides, perforated package and cold acclimation (5 days at 4℃, followed by 20 days at -1℃) were used as assistive technologies in controlled freezing-point storage to reduce chilly injury. Physico-chemical characters (sugar content, moisture content, weight loss and electrolyte leakage), respiration rate, chilly injury index and sensory evaluation were determined. The results showed that controlled freezing-point storage kept lower respiration rate and sugar loss than common cold storage for sweet corn. Perforated package prevented weight loss, reduced the increase of electrolyte leakage and maintained good sensory attributes. Cold acclimation delayed chilly injury and kept better sensory attributes during controlled freezing-point storage, especially in the latter period.

Key words: Sweet corn, controlled freezing-point, chilling injury, cold acclimation, postharvest.

INTRODUCTION

Fresh sweet corn (*Zea mays L. var.rugosa Bonaf.*) is a kind of perishable vegetables with high respiration rate and sweetness lost is the main quality degradation during storage. It was reported that about 60 and 6% of the sugar was lost in a single day at 30 and 0℃, respectively (Brecht, 2004). Postharvest techniques, such as modified atmosphere (Morales-Castro et al., 1994; Rodov et al., 2000), shrink-wrapping (Aharoni et al. 1996), perforated package (Riad and Brecht, 2002) and combination of shrink-wrapping, refrigeration and irradiation (Deak et al., 1987) were applied to maintain its quality. However, most of the strategies focused on the storage temperature above 0℃; the loss of sugar were still highlighted (Zhu et al., 1992) and the effects were limited (Riad, 2004).

Controlled freezing-point storage (CF storage), also named super chilled or super-chilling storage, is a preservation technology in subzero non-frozen temperature range to maintain low respiration rate and other metabolic reactions, which has been applied in storing fresh fruits and vegetables; firstly in Japan (Peng et al., 2009). CF storage has also been considered for storing seafood (Ando et al., 2005; Wang et al., 2008; Lauzon et al., 2009) and animal organ (Nakagawa et al., 1998; Okamoto et al., 2008). CF storage may be a potential method for sweet corn which possessed high respiration rate and sugar reduction after harvest (Guo et al., 2008). However, the disadvantage of CF storage is the physiological disorder for fruits and vegetables, which is due to chilling stress. Low-temperature breakdown, one form of chilling injury, is a typical disorder phenomenon for kiwifruit in CF storage (at non-freezing points below

*Corresponding author. E-mail: yfli@sjtu.edu.cn. Tel: +86 34206918. Fax: +86 34206918.

Abbreviations: CA, Cold acclimation; **CF,** controlled freezing-point; **CI,** chilling injury; **ELL,** electrolyte leakage; **LSD,** least significant difference; **QDA,** quantitative descriptive analysis zero) (Sfakiotakis et al., 2005; Gerasopoulos et al., 2006). Chilling injury was also found in sweet corn during CF storage in our preliminary trails.

Cold acclimation (CA) is a pretreatment for plants to increase their tolerance of freezing injury (Smallwood et al., 2002; Gomez et al., 2005; Galindo et al., 2007), but the effect on chilling injury is unknown. The relative humidity is very low at subzero temperature, which is adverse for fresh fruits and vegetables storage. Perforated bag could maintain high relative humidity in storage environment. Therefore, this work was to investigate the effect of CF storage on the rate of respiration and sugar reduction for sweet corn. Also, the potential effects of cold acclimation and perforated bag packaging on alleviating chilling injury during CF storage were also evaluated. Chemical attributes (sugar content, moisture content), weight loss, electrolyte leakage (ELL), chilling injury (CI) index and sensory evaluation were investigated.

MATERIALS AND METHODS

Plant material and experimental design

Yellow varieties of fresh sweet corn (in husks) were harvested at Nanhui Farm (Shanghai, China) and transported on ice at the same day to our laboratory. After removing the outer dirty blades, external silks and stalk ends, ears were collected for further treatments. All harvested sweet corns were chosen without diseases or pest injury and separated into two batches. One was used for monitoring the respiration rate and sugar content stored at 4℃ for 25 days; the other batch was stored in a microbiological refrigerating incubator (Binder, KBF115, Germany) set at -1℃ (±0.5℃). The whole experiment included the following three treatment: A) unpackaged; B) packaged (perforated package: polyvinylchloride film with 0.55 μm of thickness, each side of the package with one 5 to 6 mm diameter hole); C) packaged + cold acclimation (5 days at 4℃, followed by 20 days at -1℃). Unless otherwise mentioned, ten ears from each treatment were sampled every 5 days for measurement.

Freezing curves measurement

Freezing curves measurements were performed according to former reports (Wang et al., 2003; Rahman et al., 2002). A series of experiments were conducted to establish the freezing curves under freezing conditions. Nucleation (metastable limit) temperatures during freezing were also recorded. Single point thermocouple (T-type, copper-constantan) was used to measure temperatures in the geometric centre of sweet corn kernel at a time. The sweet corn kernel was placed in a test tube. The test tube was placed in a water-ice-salt (20% NaCl) mixture, which had been preserved at -18℃. Temperatures were recorded every 2 s by the data acquisition modules (ADAM-4018, Advantech, Taiwan, China) together with a personal computer.

Measurement of respiration rate

Five sweet corns per treatment were randomly selected and placed in individual 1.45 L jars. Each jar contained one sweet corn. A small hole was made on the lid of each jar and high-strength adhesive tape covered the hole of each lid. Subsequently, the jars containing sweet corns were left at 4 or -1℃ for 3 h. A gas analyzer (CheckMate 9900, PBI Dansensor, Denmark) was used to measure the respiration rate of the sweet corns by sampling the gas through the tape and analyzing the CO_2 concentration in each jar. The measurements were repeated three times. The respiration rates of sweet corns were expressed in ml CO_2 per kilogram per hour.

Determination of weight loss, moisture content and sugar content

Ears weight was recorded initially and after the storage period. Percentage of weight loss was calculated. Moisture content of kernels was determined by drying oven method. The sugar was extracted by 80% ethanol in kernels and then measured using the phenol-sulfuric method (Zhang, 1994). Sugar content was calculated by gram of sugar weight per gram of fresh weight.

Electrolyte leakage

ELL was measured during the CF storage according to the method described by Feng et al. (2005). 12 kernels of sweet corn per treatment were randomly selected and hemisected with a sharp stainless knife. The electrical conductivity was measured using a bench top conductivity meter (FE30, Mettler Toledo, Sweden) with a LE703 conductivity electrode. Sliced samples were rinsed with double-distilled deionized water three times and immersed in 50 ml double-distilled deionized water for 30 min. Subsequently, the initial electrolyte leakage was measured. The samples were then boiled for 30 min. The total electrolyte leakage was assayed after the samples reached room temperature. Each treatment was repeated for three times. ELL was expressed by the relative leakage rate, which was calculated as the percentage of the total electrolyte leakage.

Chilling injury index

The CI index was evaluated upon characteristic symptoms of low temperature damage, using a numerical scale from 0 to 4 as indicated in Table 1. The indices were calculated according to the following formula:

$$CI = \frac{0\times N0 + 1\times N1 + 2\times N2 + 3\times N3 + 4\times N4}{4\times N} \qquad (1)$$

Where, *N0-N4* was the number of sample with corresponding chilling injury index and *N* was the total number of cobs per treatment.

Sensory evaluation

The quantitative descriptive analysis (QDA) method introduced by Riad (2004) was used to evaluate the postharvest sweet corns. Eight panelists participated in the QDA of the stored samples. The members of the panel were previously trained in QDA for different sweet corns. Prior to the shelf life study, one session was hold for training by using sweet corn samples with different storage time at -1℃ without package. The descriptors developed by Riad (2004) for fresh sweet corn in cold storage were used as a basis for this experiment during the training session. The list of descriptors was modified to describe sweet corn during the CF storage as described in Table 2. The appearances of husk, silk and kernel were visual evaluation, kernel firmness was tested by finger press and ear aroma evaluation was done by nose. All indexes were measured using a scale from 0 to 9, where a score of 9 represents excellent quality and a score of 0 represents the lowest quality level.

Table 1. Description of the freeze injury used for the evaluation of sweet corn during storage.

Index	Extent	symptom
0	None	Normal as fresh
1	Slight	Normal color and turgid as fresh sample, watery spot on the scarfskin
2	Moderate	Small circle watery spot ,a few kernels are soft, no kernel is gelatinous
3	Severe	5% or more of kernels are gelatinous and soft, some are translucent
4	Extremely	30% or more of kernels are gelatinous, show serious scald, dark color

Table 2. Description of the sensory quality ratings used for evaluation of sweet corn during storage.

Rating	Description	Organoleptic property				
		Husk appearance	Silk appearance	Kernel appearance	Kernel firmness	Ear aroma
8-9	Field fresh	Field fresh, turgid appearance, dark green	Light color, fresh, and turgid	Fresh with bright, shiny color and very turgid	No kernels showing soft	Fresh grassy odor
6-7	Good	Reasonably fresh, leaves still green and flexible	Not that fresh but still had a light color and turgid texture	Still noticeably bright color and turgid	Few kernels showing soft	Weak grassy odor, no smell
4-5	Fair	Drying and yellowing apparent, some leaves water-soaked	Starting to show some brown color and some drying	Dull appearance with no denting	1% or more showing soft	Weak grassy odor, some rotten smell,
2-3	Nonmarketable	Portion of the leaves show dry appearance or water soaking	Obvious discoloration and dryness with limp texture	Severe dull appearance and some brown of white color	5% or more showing soft	Smell of water-soaked
0-1	Unusable	Completely water soaking or dried out	Limp texture or watery decay	Kernels showing severe water-soaked with dark color	30% or more showing soft	Strong rotten smell, alcohol, sour

Statistical analysis

The experimental design was completely randomized. All figures were generated with Excel. Data were transferred to statistical analysis system software (SAS, 2003) for an analysis of variance. Least significant differences (LSDs) for comparisons between treatment levels were also calculated at the 0.05 level. Treatment means of storage data were separated using Duncan comparisons at a P-value of 0.05.

RESULTS AND DISCUSSION

Figure 1 show representative freezing curve for sweet corn kernels. The mean freezing point and nucleation point was -2.55℃ (±0.18℃) and -5.70℃ (±1.78℃), respectively. The temperature of CF storage was set just above the freezing point to keep fruits or vegetables alive with minimal quality deterioration rate and avoid freezing damage. Taking account of temperature fluctuation, the temperature of -1℃ was chosen for CF storage in this experiment.

Figure 2a display the main characteristics of the respiration rates of sweet corn stored at 4℃ (common cold storage) and -1℃ (CF storage). Postharvest sweet corns kept stable respiration

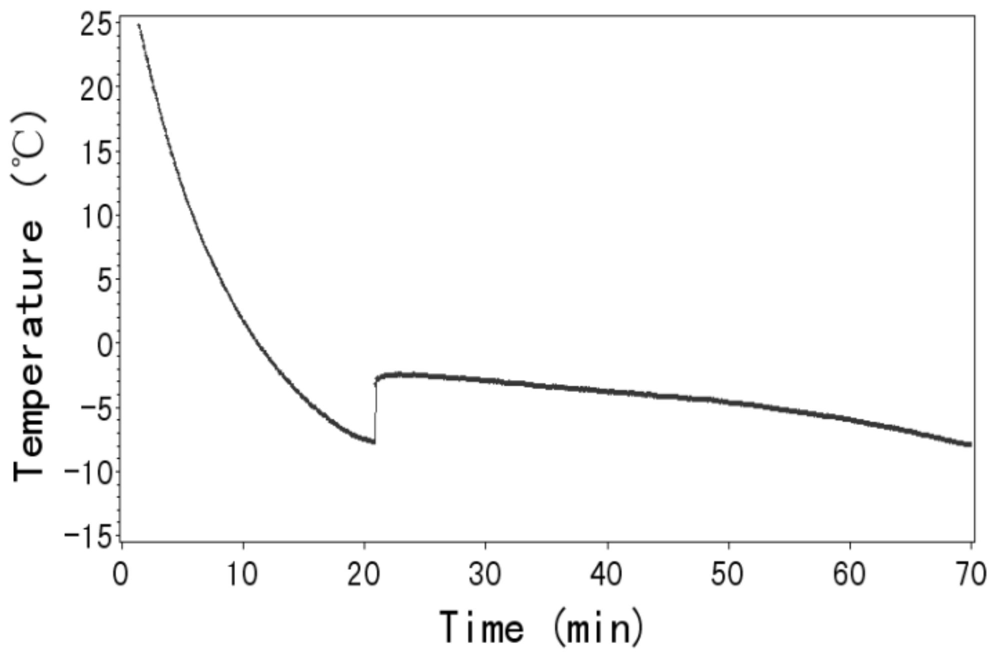

Figure 1. A typical freezing curves of sweet corn kernel.

rate with time. The respiration rate of sweet corn stored at -1℃ was about 1/3 that of 4℃ during the whole storage period.

As shown in Figure 2b, the sugar content of sweet corn was significantly less ($P < 0.05$) than that of fresh samples on day 20, at -1℃ and on day 10, at 4℃ during storage. A decline during the whole period of storage was measured (from 71 mg/g on day 0 to 54 mg/g and 24 mg/g on day 25 at -1 and 4℃, respectively). This was due to the low respiration rate and other metabolic reaction speeds in CF storage. As a result, CF storage can maintain low respiration rates and sugar reduction for postharvest sweet corn.

Results for chemical attributes, weight loss, ELL, chilling injury index and sensory quality of sweet corn with different treatment during CF storage were obtained. As shown in Table 3, packaging and cold acclimation did not seem to affect sugar content, since similar values were observed between the three groups. For sugar content, there was a slight decrease after 5 days of storage; then, a slight increase was observed until day 15 and finally, a sharp fall was detected by day 20 and day 25. Sugar, as one of osmotic active substances, can be induced by cold stress (Galindo et al., 2007), so sugar content increased after 5 days. Sweet corn had low sugar losing rate, losing 2.8, 10.4 and 7.6% by day 20, losing 24.3, 28.1 and 29.3% by day 25 for unpackaged, packaged and packaged + CA, respectively, when compared with fresh corn. The loss rate was about 1% per day at -1℃ in 25 days' storage (Table 3).

Regarding the moisture content, a decline during the whole period of storage was detected. Moisture content decreased significantly ($P < 0.05$) in unpackaged group from day 15 and packaged group from day 20, while there was no significant change in packaged + CA group during the whole storage. Weight loss of unpackaged corns increased dramatically, while that of packaged and packaged + CA group increased a little (Table 3). The decrease of moisture content of corn kernel was slow, but the weight loss of unpackaged was faster than those of the packaged and packaged + CA. The phenomenon indicated that perforated packaged bag can prevent the water loss, which is mainly from the husk.

ELL is an important indicator of plasma membrane integrity of flesh cells, which is related to the quality of fruit (Feng et al., 2005). Gerasopoulos et al. (2006) found that the development of low temperature breakdown (the symptom of CI on kiwi fruit) was closely associated with ELL. As shown in Figure 3, ELL was found to increase during storage in all the three treatments. The ELL of sweet corn increased from 13 to 31% (unpackaged), and was 32% for packaged and 28% for packaged and CA at the end of the storage. Packaged samples had low ELL than the unpackaged ones during storage except at the 25th day. The results indicated that high relative humidity was good for maintaining integrity of plasma membrane. However, there was a rapid increase of ELL at the end of storage, which may be due to high CO_2 concentration in the packaged bag. At the beginning of storage for CA treatment, CA induced a rapid increase of ELL. After 5

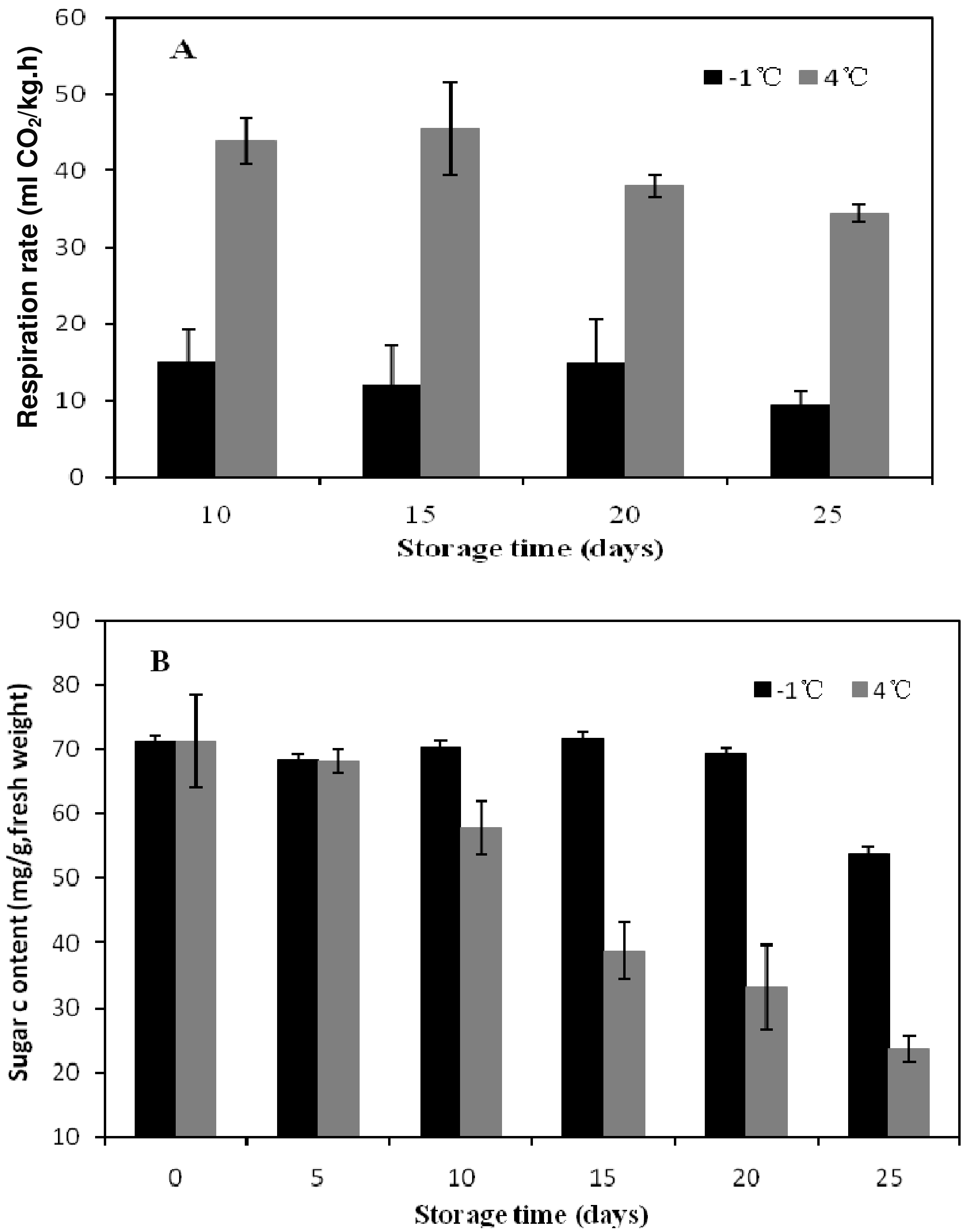

Figure 2. Changes in respiration rate (A) and sugar content (B) at -1and 4°C during 25 days' storage.

days, the change of ELL was slow and ELL was lower than that of the unpackaged samples. It indicated that package and CA were helpful to maintain integrity of the cells.

CI is a physical disorder of fruits and vegetables from tropical and subtropical origin during cold storage. CI was not same with freezing injury, which was a result of damage from ice crystals in tissues stored below their freezing point. Gerasopoulos et al. (2006) also concluded that non-freezing points below zero (-0.5 and -2°C) induced the CI of kiwifruit but not freezing damage. Watery spot, discoloring and gelatinous kernels were the major symptoms of CI for sweet corn. CI affects the appearance of sweet corn directly, especially for that of kernel. Figure 4 shows the CI index of sweet corn during CF Storage. CI was initiated at 10 days for unpackaged (7.5%), 15 days for packaged (5%) and packaged + CA (3%) (Figure 4). The CI index of sweet corn increased from 0% to 100% (unpackaged), 62.5% (packaged) and 22.5% (packaged + CA) at the end of the storage. According to Figure 4, we can conclude that unpackaged and packaged (including packaged + CA) sweet corns

Table 3. Summary of the sugar content, moisture content and weight loss by different treatments.

Parameter	Day	Unpackaged	Packaged	Packaged + CA
Sugar content (mg/g)	0	71.24±7.12[a*]	71.24±7.12[bc]	71.24±7.12[a]
	5	68.28±6.84[a]	68.46±7.35[cd]	65.67±6.48[a]
	10	70.40±4.81[a]	74.923±4.81[ab]	65.66±7.70[a]
	15	71.70±2.59[a]	77.44±1.93[a]	67.86±6.24[a]
	20	69.26±0.96[b]	63.86±6.29[d]	65.85±10.57[a]
	25	53.91±0.97[c]	51.21±2.00[e]	50.37±3.32[b]
Moisture content (%)	0	76.86±0.23[a]	76.86±0.23[a]	76.86±0.23[a]
	5	76.42±0.47[a]	76.85±0.16[a]	76.55±0.35[a]
	10	75.73±0.28[ab]	76.39±0.31[a]	76.41±0.14[a]
	15	75.56±0.78[abc]	76.11±1.02[ab]	76.83±0.86[a]
	20	74.29±1.00[bc]	76.48±0.53[a]	76.33±0.30[a]
	25	74.95±0.50[c]	75.02±0.91[b]	76.06±1.28[a]
Weight loss (%)	5	5.21±0.64[d]	1.46±0.24[a]	1.74±0.43[a]
	10	9.08±1.32[c]	0.86±0.42[b]	2.18±3.31[a]
	15	12.05±1.30[b]	1.09±0.52[ab]	2.01±1.26[a]
	20	17.48±2.40[a]	1.37±0.56[ab]	1.20± 0.78[a]
	25	17.12±0.32[a]	1.26±0.68[ab]	1.06±0.83[a]

*The same letter in the same column indicates no significant difference at $p < 0.05$.

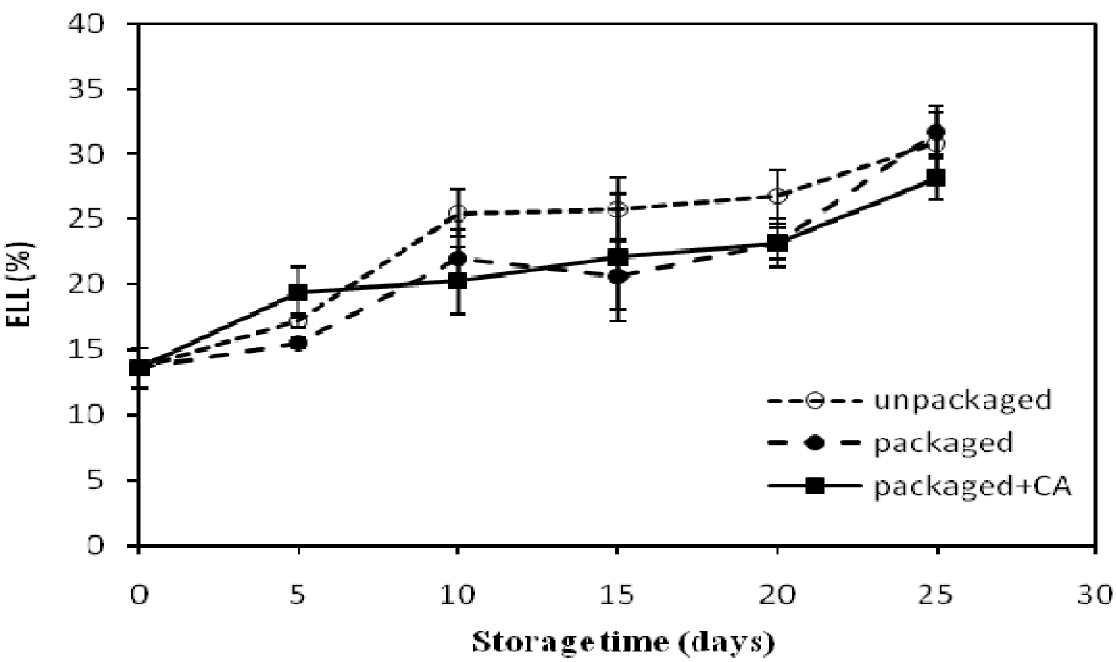

Figure 3. Changes in electrolyte leakage (ELL) with different treatments during 25 days of CF storage.

stored at -1℃ did not show CI for 5 and 10 days, respectively. As a whole, water loss accelerated the development of CI. Treatment with packaging + CA showed less CI than the samples only with packaging.

Sensory attributes such as appearances and characteristic aroma of fresh fruit or vegetables are the truest indicators of shelf-life from the view of consumer. Figure 5 describes the sensory evaluation of whole sweet corn including appearances of husk, silk, kernel, firmness of kernel and aroma of the ear. Scores of husk

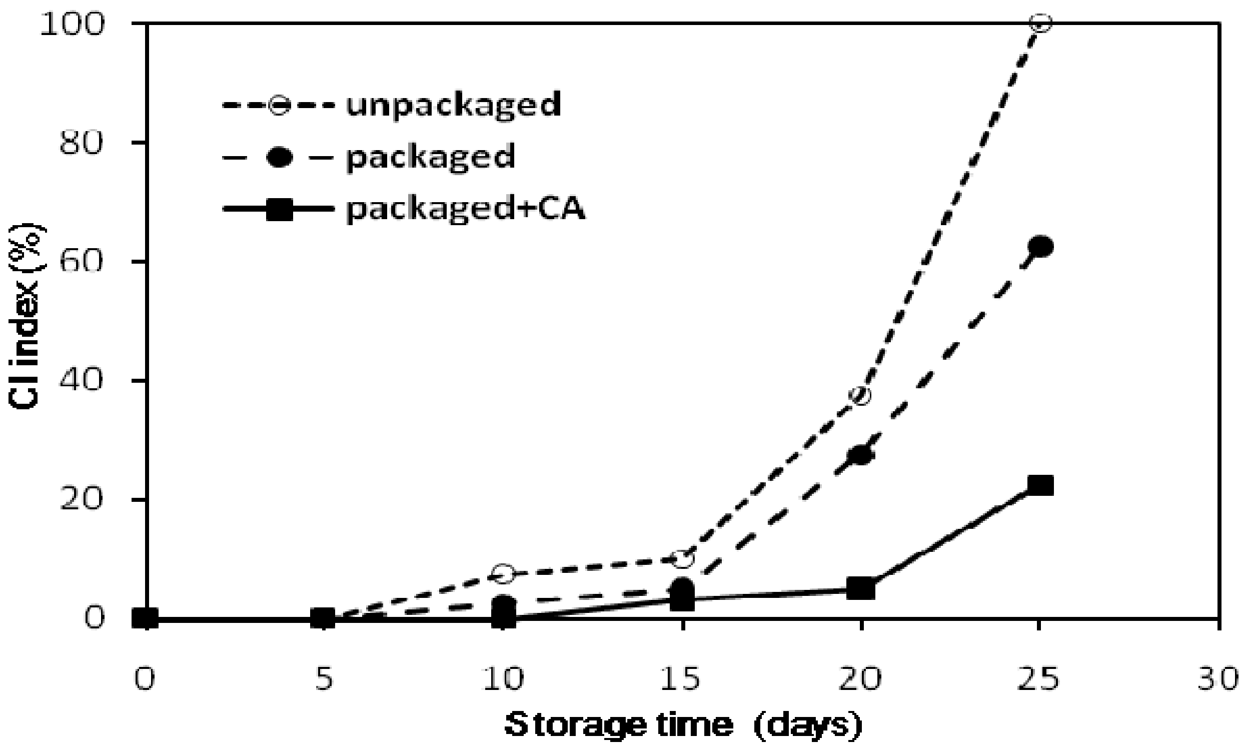

Figure 4. Changes in chilling injury (CI) index with different treatments during 25 days CF storage.

appearance, silk appearance and aroma declined significantly ($p < 0.01$) from day 5 (unpackaged samples), day 20 (packaged samples) and day 25 (packaged + CA), respectively. The appearance of husk, silk and kernel of the unpackaged samples were significantly different from those of the packaged and packaged + CA throughout the storage (except kernel by 5 days). According to this, weight loss and moisture content of the unpackaged samples were significantly different from those of packaged and packaged + CA samples (Table 2). It indicated that water evaporated quickly from husk without package, which was resulted in bad appearance. The hardness of unpackaged samples was significantly different from that of packaged and packaged + CA after day 15. Gelatinous kernels, which resulted in hardness decrease, were one of the major symptoms of CI. The development of CI was closely associated with that of hardness. Bad odors were one kind of physical disorder in the CF storage. According to Figure 5, aroma rating decreased from 7.5 at day 5 to 1.5 (unpackaged), 3.4 (packaged) and 4.8 (packaged + CA) at the end of storage. Aroma of unpackaged samples was different from that of packaged and CA at 15 days. Aroma of CA was different from that of packaged and unpackaged after 20 days.

These sensory attributes of sweet corn were greatly affected by the development of water loss and CI during CF storage. Packaging kept good sensory attributes (especially for the looking appearance) at the beginning of storage. CA alleviated the CI and got higher sensory scores than the other treatments in the latter period of CF storage.

Conclusion

In this work, the mean freezing point of fresh sweet corn was -2.55℃ (±0.18℃) and the mean nucleation point was -5.70℃ (±1.78℃). Compared with common cold storage, CF storage kept low respiration rate and low sugar loss in the sweet corn. Perforated package prevented weight loss, reduced the increase of ELL and maintained good sensory attributes, especially for the looking appearance. The treatment of packaged + CA delayed CI and kept better sensory attributes during CF storage, especially for the latter period. Though CI was not avoided totally by the perforated package and CA in this work, certain effects were taken for sweet corn during CF storage. To develop the applied potential of CF storage, other assistive technologies such as plant growth regulator (ex. ethylene, 1-methylcyclopropene) require further study.

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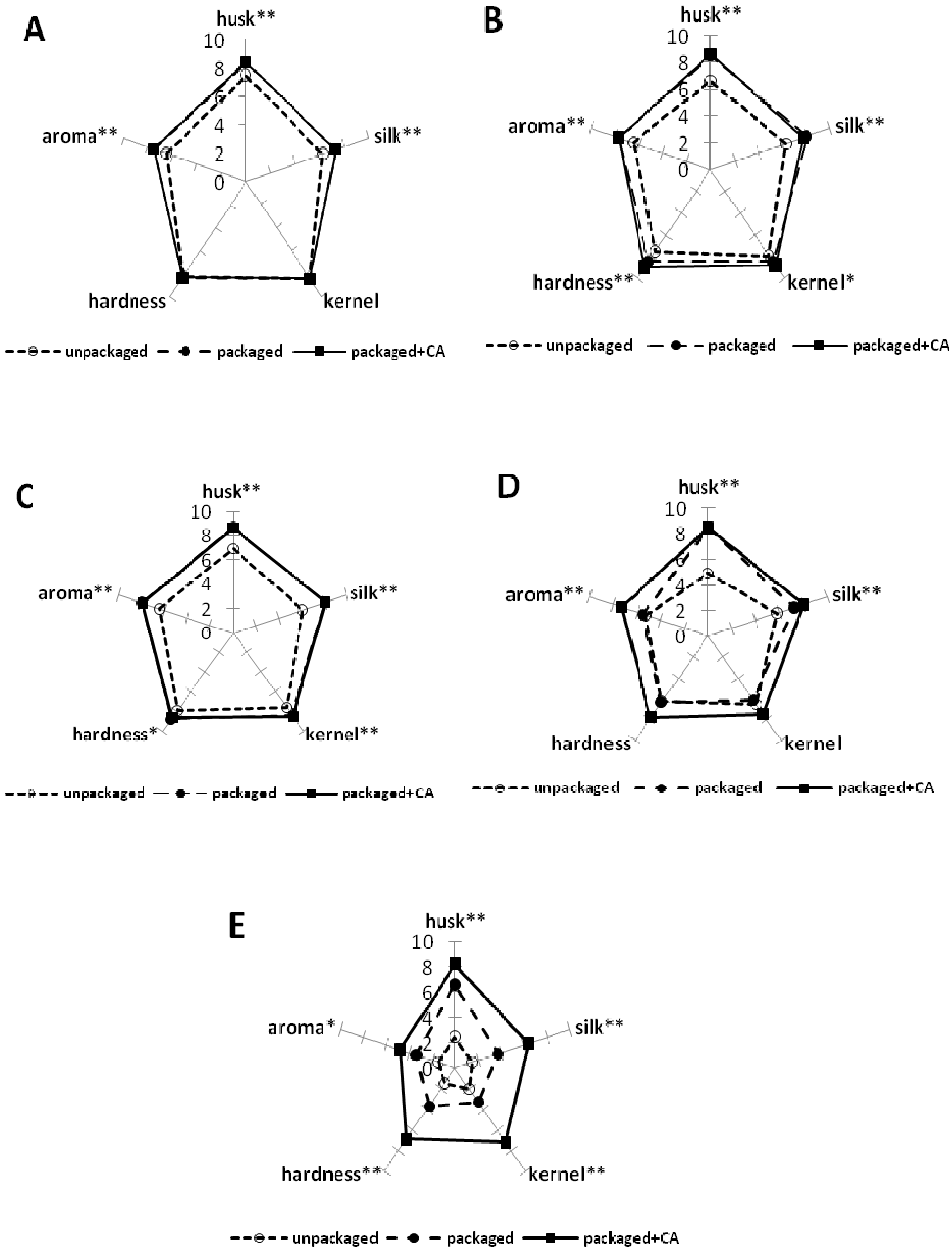

Figure 5. Radar plot of QDA sensory profiles (mean scores) of sweet corns with unpackaged (○), packaged (●) and packaged + CA (■) during 25 days. A, 5 day; B, 10 days; C, 15 days; D, 20 days; E, 25 days of storage at -1℃ (husk, husk appearance; sil, silk appearance; kernel, kernel appearance; aroma, ear aroma

2008BAD91B02).

REFERENCES

Aharoni Y, Copel A, Gil M, Fallik E (1996). Polyolefin stretch films maintain the quality of sweet corn during storage and shelf-life. Postharvest Biol. Tec. 7(1-2):171-176.

Ando M, Takenaga E, Hamase S, Yamane A (2005). Effect of super-chilling storage on maintenance of quality and freshness of swordtip squid Loligo edulis. Food Sci. Technol. Res. 11(3): 355-361.

Brecht JK (2004). Postharvest quality maintenance guidelines. In: Gross K, Wang CY, Saltveit M, editors. The Commercial Storage of Fruits, Vegetables, and Florist & Nursery Crops. 3rd ed. Washington, D.C.USA.

Deak T, Heaton EK, Hung YC, Beuchat LR (1987). Extending the shelf life of fresh sweet corn by shrink-wrapping, refrigeration and irradiation. J. Food Sci. 52: 1625-1631.

Feng GP, Yang HS, Li YF (2005). Kinetics of relative electrical conductivity and correlation with gas composition in modified atmosphere packaged bayberries (*Myrica rubra Siebold and Zuccarini*). LWT - Food Sci. and Technol. 38(3): 249-254.

Galindo FG, Sjöholm I, Rasmusson AG, Widell S, Kaack K (2007). Plant stress physiology: Opportunities and challenges for the food industry. Crit. Rev. Food Sci. 47(8): 749-763.

Gerasopoulos D, Chlioumis G, Sfakiotakis E (2006). Non-freezing points below zero induce low-temperature breakdown of kiwifruit at harvest. J. Sci. Food Agr. 86(6): 886-890.

Gomez GF, Elias L, Gekas V, Herppich WB, Smallwood M, Sommarin M, Worrall D, Sjoholm I. (2005). On the induction of cold acclimation in carrots (*Daucus carota L*) and its influence on storage performance. Food res. int. 38(1): 29-36.

Guo L, Ma Y, Sun DW, Wang P (2008). Effects of controlled freezing-point storage at 0°C on quality of green bean as compared with cold and room-temperature storages. J. Food Eng. 86(1): 25-29.

Wang J, Li T, Dan Y (2003). The correlation between freezing point and soluble solids of fruits. J. Food Eng. 60(4): 481-484.

Lauzon HL, Magnússon H, Sveinsdóttir K, Gudjónsdóttir M, Martinsdóttir E (2009). Effect of brining, modified atmosphere packaging, and superchilling on the shelf life of cod (Gadus morhua) loins. J. Food Sci. 74(6): M258-M267.

Morales-Castro J, Rao MA, Hotchkiss JH, Downing DL (1994). Modified atmosphere packaging of sweet corn on cob. J. Food Process Pres. 18(4): 279-293.

Nakagawa Y, Ono H, Mizumoto S, Fukui A, Tamai S (1998). Subzero nonfreezing preservation in a murine limb replantation model. J. Orthopaedic Sci. 3(3): 156-162.

Okamoto T, Nakamura T, Zhang J, Aoyama A, Chen F, Fujinaga T, Shoji T, Hamakawa H, Sakai H, Manabe T, Wada H, Date H, Bando T (2008). Successful Sub-zero Non-freezing Preservation of Rat Lungs at -2° C Utilizing a New Supercooling Technology. J. Heart Lung Transpl. 27(10): 1150-1157.

Peng D, Deng J, Tan X, Li M (2009).Research progress of controlled freezing point technology on the storage of fruits and vegetables. Packaging and Food Mach. 27(2): 38-43.

Rahman MS, Guizani N, Al-Khaseibi M, Ali AH (2002). Analysis of cooling curve to determine the end point of freezing. Food Hydrocolloid 16(6): 653-659.

Riad G (2004). Atmosphere modification to control quality deterioration during storage of fresh sweetcorn cobs and fresh-cut kernels. [DPhil dissertation]. Florida: Univ. Florida. p.163

Riad GS, Brecht JK (2002). Perforation-mediated modified atmosphere packaging of sweetcorn. Proc. Fla. State Hort. Soc. 115:71-75.

Rodov V, Copel A, Aharoni N, Aharoni Y, Wiseblum A, Horev B, Vinokur Y (2000). Nested modified-atmosphere packages maintain quality of trimmed sweet corn during cold storage and the shelf life period. Postharvest Biol. Tec. 18(3): 259-266.

Smallwood M, Bowles DJ (2002). Plants in a cold climate. Philos. T. Roy. Soc. B 357(1423): 831.

Wang T, Sveinsdóttir K, Magnússon H, Martinsdóttir E (2008). Combined application of modified atmosphere packaging and superchilled storage to extend the shelf life of fresh cod (*Gadus morhua*) loins. J. Food Sci. 73(1): S11-S19.

Zhang W (1994). Biochemical Technology of Carbohydrate Compounds. Hangzhou, China: ZheJiang University Press. 11-12.

Zhu S, Mount JR, Collins JL (1992). Sugar and soluble solids changes in refrigerated sweet corn (*Zea mays L.*). J. Food Sci. 57(2): 454-457.