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Effects of Packaging Film and Storage Temperature on the Quality of Fresh Ginseng Packaged in Modified Atmosphere

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The effects of packaging film and storage temperature on the quality of fresh ginseng (*Panax Ginseng*) packaged in modified atmospheres and storage at 0 and 10 °C for 150 days were determined. The changes in chemical compositions were also measured before and after storage. The results showed that modified atmosphere packaging (MAP) significantly extended the storage life of fresh ginseng with high quality for 150 d. The decay rate was only 2.4 and 1.3% after 150 days of storage at the combinations of 0 °C–0.05 mm and 0 °C–0.07 mm, respectively. The results of saponin analysis indicated that the contents of total saponin were not changed much in treatments, decreased 8.4% for treatment of 0 °C–0.07 mm, 17.6% for the control at the end of storage at 0 °C. The content of reducing sugar increased from 238.7 to 306.5%, total sugar showed similar increasing trend as reducing sugar after 150 days of storage in film packages at 0 °C. While pectin content decreased 19.2–21.5% for MAP, decreased 26.7% for control after end of storage at 0 °C. The reduction of pectin content was much remarkable at 10 °C. It was considered that MAP was very effective storage method for keeping quality better with minimal quality loss and lower decay rate at lower temperature.

INTRODUCTION

Ginseng (*Panax Ginseng*) is an important medicinal plant that has been used for a long time as a miraculous medicinal panacea for many kinds of diseases and a functional health food in Asian countries. It is one kind of herbs and significant useful for health protection for human body and high commercial value in international market. Ginseng is usually dried for storage and marketing because fresh ginseng has short storage life due to deterioration within short time under normal ambient conditions after harvest. Postharvest storage of fresh ginseng root has been become a major concern of grower. Moreover, people have been preference to consume fresh ginseng root over dried one. The deterioration of fresh ginseng generally associated with a decline in hardness, browning and mould decay. Microbial and physiological effects, physical and chemical changes accelerate deterioration of fresh ginseng.

Modified atmosphere packaging (MAP) has been proven beneficial in extending the postharvest life span of a wide variety of fresh horticultural commodities (Kader, 1986;

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Zagory and Kader, 1988). The basic principle of MAP is to subject given commodity dealing with packaging in plastic film to modify atmospheres of O_2 and CO_2 concentrations by respiration and film permeability. It could be created and maintained by using of polymeric film with different gas transmission (Hening and Gilbert, 1975). Packaging film with different quality and thickness was shown to affect gas composition and respiratory metabolism of commodity inside package (Exama *et al.*, 1993). But little research has been done on the use of MAP to extend storage life of fresh ginseng. The objective of this study was to investigate the effects of packaging film and storage temperature on the quality of fresh ginseng packaged in modified atmosphere. The quality attributes and chemical compositions of fresh ginseng were also determined.

MATERIALS AND METHODS

Plant materials and film

Samples of fresh ginseng were harvested from six-year-old ginseng farm of Jian, in Jilin Province, China. The harvested fresh ginseng was transported to laboratory within 4 h and sorted by size, shape and appearance. And then they were precooled for 24 h at experimental temperatures. The thickness of low-density polyethylene (LDPE) film used for ginseng packaging was 0.05, 0.07 mm. The permeable coefficients of them were given in Table 1.

Table 1. Gas permeability coefficients of film used for packaging fresh ginseng ($\times 10^{-5}$ml m $m^{-2}h^{-1}$ atm^{-1})

Thickness (mm)	0 °C		10 °C	
	CO_2	O_2	CO_2	O_2
0.05	2302.3	689.3	2632.1	894.4
0.07	1863.2	436.1	2314.3	621.7

Measurement of package atmosphere

The fresh ginseng roots were selected at random and samples of 1.5 kg were sealed into the pouches (30 cm × 40 cm) of thickness 0.05, 0.07 mm film. The pouches were stored at 0 and 10 °C. For control, ginseng samples without packaging with film were placed in open plastic basket covered with the sand (moisture content about 70%) and stored at the same temperature as those in MAP. Throughout storage, 1 ml gas sample was withdrawn by gas-tight syringe to determine gas compositions by a gas chromatography (Shimadzu GC-14A, Tokyo, Japan) equipped with a thermal conductivity detector (TCD). Helium was used as carrier gas and the flow was 30 ml min^{-1}. Oven temperature was kept at 50 °C whereas injector and column temperatures were set at 100 and 80 °C, respectively. The column was WG-100 with molecular sieve 5A. Finally, the packages were opened to evaluate the quality attributes and analyze chemical compositions of fresh ginseng after storage.

Firmness and weight loss

The firmness of each ginseng root was measured by sclerometer (model FHK,

Fujihira Industry, LTD, Tokyo, Japan) equipped with 5 mm plunger. The measurement was made at 4 different points on each ginseng. Dial readings were assessed in kg force (kgf) and then values were multiplied by 9.807 N kgf^{-1} to Newton (N). Weight loss was also determined and expressed as the percentage with respect to the initial weight before and after storage.

Sensory evaluation

The decay incidence was performed after 5 months of storage at different temperatures and the number of ginseng manifesting decay symptoms was determined in each treatment and expressed as the decay percentage. The evaluation was scored on a 5-point scale: 1=excellent, 2=very good, 3=fair, 4=poor, 5=bad, ginseng with scale above 3 was considered commercially unacceptable as decay. Measurement of ten ginseng roots was carried out for each treatment.

Measurement of composition in ginseng

Total ginseng saponin content was measured by follow method. The dried ginseng sample of 2 g was taken and placed in extractor to extract ginseng saponin with methanol for 12 h. The residue was dissolved with distilled water after methanol was retrieved. And then the extraction was carried out with *n*-butanol after de-fatted with ether and *n*-butanol was retrieved. The residue was determined to 10 ml with methanol. Saponin Re was used as standard of ginseng saponin, the absorbance was measured at 560 nm by Infrared Spectrophotometer (FTIR-8100, Shimadzu, Japan). However, the data on chemical attributes were presented only before and after storage, as the changes were negligible during the storage periods. Soluble pectin was extracted as described by Bartkey *et al.* (1982). Soluble pectin was precipitated from 80% acetone and estimated as an-hydro-galacturonic acid using 3-phennyl-phenol (Blumenkrantz and Asboe-Hansen, 1973).

Soluble sugar was determined by high performance liquid chromatography (HPLC) equipped with NH2P-50 column (4.6 mm ϕ ×250 mm) at 40 °C. The column was packed with SUS 316. The mobile phase was acetonitrile : water=75 : 25 at a flow rate of 1.0 ml min^{-1} and injection volume is 20 μl as described by Ajilouni *et al.* (1995).

Reducing sugar was examined using 3,5-dinitro-salicylic acid (DNS) method as described by James (1995). The absorbance of each sample solution was measured at 540 nm on Shimadzu spetrophotometer (FTIR-8100, Japan). Total reducing sugars were calculated based on the calibration curve of glucose.

Statistic Analysis

The experimental design was completely randomized. Data were subjected to analysis of variance (ANOVA) and the significance among the means of treatments was determined by least significant difference (LSD) at the $P<0.05$ level.

RESULTS AND DISCUSSION

Gaseous composition

Changes in the O_2 and CO_2 contents in 0.05 mm film packages at 0 and 10 °C were

shown in Fig. 1A and 1B. The O_2 level decreased quickly from 21.2 to 16.5% at initial one month, and then trended to be constant at about 15.3% level in 0.05 mm packs during storage at 0 °C (Fig. 1A). The CO_2 concentration increased markedly at initial one month, and showed the fluctuation at about 4.8% O_2 until the end of storage. At 10 °C, the O_2 concentration decreased much quicker than that at 0 °C, and change in CO_2 concentration showed the similar trend to that at 0 °C. Modified atmosphere were created by the interaction of respiration of ginseng and gas transmission through packaging films (Christie *et al.*, 1995). It appeared that the metabolic activity of respiration was markedly suppressed in MAP and this inhibition was more effective in package with lower permeability of film (Murr and Morris, 1975; Roy *et al.*, 1996). The high permeable film (0.05 mm) gave the lower CO_2 concentration and higher O_2 concentration in package, while low permeable film (0.07 mm) gave high CO_2 concentration throughout storage. In general, film permeability coefficient increases as temperature increases, while CO_2 permeability coefficient

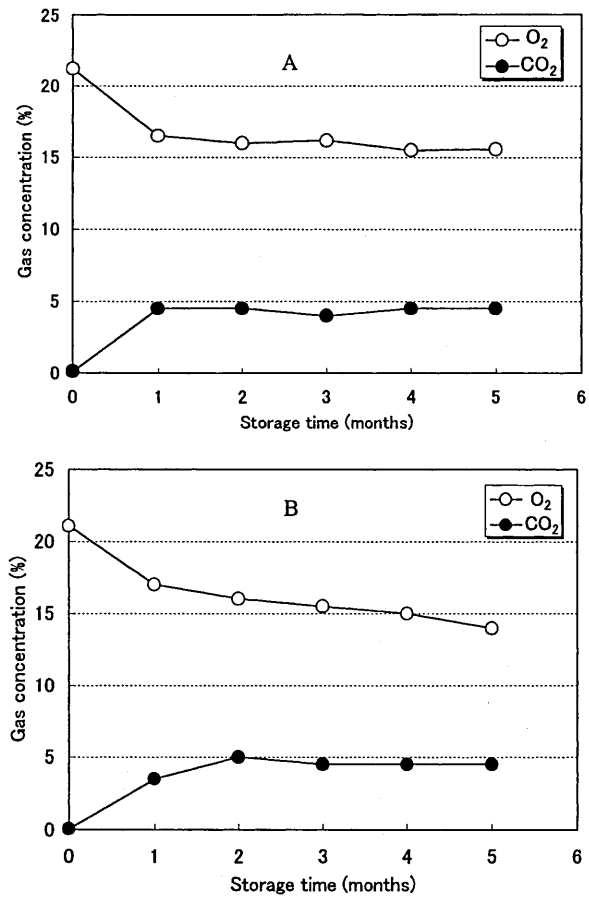

Fig. 1. Changes in gas concentrations in 0.05 mm packages during storage at different temperatures

responds more quickly than that of O_2. This implies that a film is appropriate for MAP at one temperature may not be appropriate at other temperatures.

Changes in the O_2 and CO_2 contents in 0.07 mm film packages at 0 and 10 °C were shown in Fig. 2A and 2B. The O_2 level decreased gradually in 0.07 mm film packages from initial 20.5 to 14.3% at the end of storage at 0 °C (Fig. 2A). While CO_2 concentration increased from 0.03 to 6.1% during 4 months of storage, and then showed the constant change. At 10 °C, O_2 concentration decreased and CO_2 concentration increased quickly for 3 months of storage. And then the shift of CO_2 decrease and O_2 increase occurred after 3 months. It was reasoned that respiration rate of ginseng root declined and the respiration was suppressed, while gas permeability coefficient of film was not changed under this condition and regulated the gas concentrations in the package.

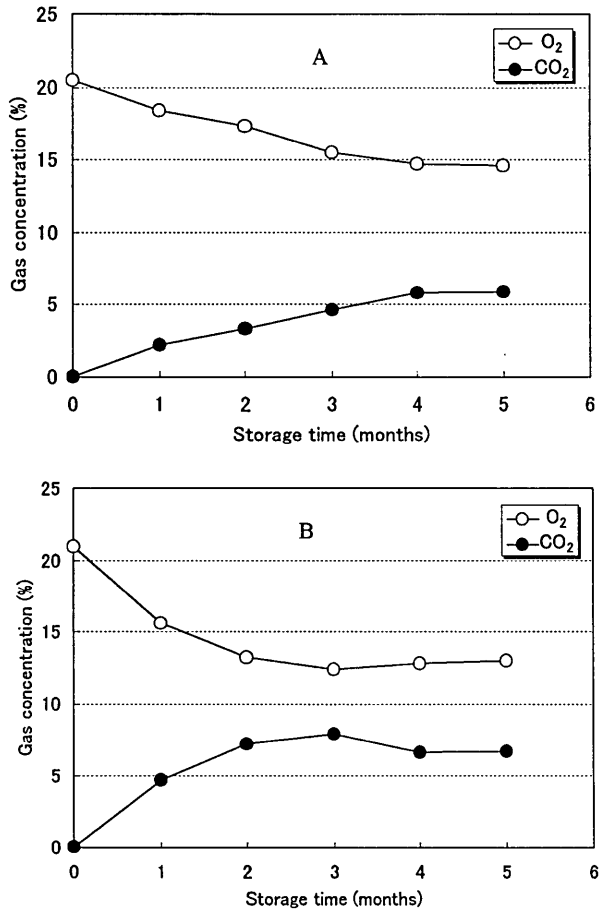

Fig. 2. Changes in gas concentrations in 0.07 mm packages during storage at different temperatures

Firmness

Significant differences in firmness were found among the treatments in fresh ginseng after 150 days of storage (Table 2). There was the higher firmness at 0 °C than that at 10 °C. The firmness stored in 0.07 mm package was 120.9 N at 0 °C, 111.6 N in 0.05 mm package and 102.3 N in control. At 10 °C, firmness in 0.07 mm package was 96.3 N at 0 °C, 95.6 N in 0.05 mm package and 86.4 N in control. It was shown that MAP had significant effective in reducing loss of firmness of ginseng root. Among the all treatments, firmness of fresh ginseng showed the greatest value stored in 0.07 mm film packages at 0 °C. Knee and Bartley (1981) reported that concentration of soluble pectin in apple fruit increased during softening and it has been suggested that this is a result of the degradation of cell wall pectin (Bartley, 1978). For fresh ginseng, similar result (Table 4) was obtained. It was considered that lower storage temperature inhibited the decomposition of pectin and reduced firmness loss significantly.

Table 2. The changes in quality and saponin contents of fresh ginseng storage under different conditions*

Temperature (°C)	Treatment	Weight loss (%)	Decay (%)	Firmness (N)	Total saponin (mg g^{-1})
0	0.07 mm	1.9±0.2a	2.4±0.3a	120.9±4.1a	43.8[a]
	0.05 mm	3.0±0.3b	3.0±0.1a	111.6±3.6b	42.2
	Control	5.6±0.2c	12.8±0.3b	102.3±0.9c	39.4
10	0.70 mm	4.9±0.4a	9.4±0.2a	96.3±0.2a	42.0
	0.05 mm	5.1±0.1a	13.3±0.5b	95.6±3.2a	38.5
	Control	5.6±0.3b	21.8±0.8c	86.4±0.6b	36.3

* Measurements were taken after 5 months of storage. Means and standard errors are given from ten ginsengs of each treatment. Means followed by different letters are significantly different according to least significant difference (LSD) at the $P<0.05$ level.

[a] Initial value of total saponin content is 47.8 mg g^{-1} in ginseng.

Weight loss and decay

Storage of fresh ginseng in MAP seems to be effective in reducing weight loss (Table 2). Ginseng in sealed 0.05 and 0.07 mm packages had less weight loss compared to the control. For the effects of temperature, there was the lowest weight loss at 0 °C than that at 10 °C. It was reasoned that much substrate was consumed by respiration at higher temperature and much more moisture in package permeated out through the film. The ginseng in MAP was still fresh with very slight browning and the development of disease at the end of storage, while ginseng in the control showed discoloration, soft and browning. It was also shown that relative humidity within packages reached 95–98% and remained this level for the duration of the experiment.

The lower decay rate was obtained from the combination of 0 °C–0.07 mm (1.3%). The decay of fresh ginseng increased as the increase of storage temperature. It was considered that infection in field growing could occur as latent with the senescence of fresh ginseng during storage. It was indicated that the storage life of fresh ginseng in MAP

could extended significantly than those stored in sand in open basket (control). Ginseng in sealed 0.05 and 0.07 mm film pouches had a storage life of 150 days with relative lower loss weight and decay, while the control treatment had the highest decay rate (12.8–21.8%) among the all treatments (Table 2). Jeon and Lee (1999) reported that deterioration of fresh ginseng was decreased by washed with antimicrobial agent before storage. In this study, longer storage life with lower decay rate was obtained from ginseng stored in MAP without washing with cold water.

Changes in ginseng saponin

Saponin is well-known the major biological activity compound in ginseng. The analysis of saponin showed that total saponin was not remarkably changed during 5 months of storage (Table 2). In 0.07 mm packages, total saponin content decreased 8.4% from initial value 47.8 to 43.8 mg g^{-1} at 0 °C, and decreased 12.1% from 47.8 to 42.0 mg g^{-1} at 10 °C. For 0.05 mm packages, total saponin content decreased 11.7% at 0 °C and decreased 19.5% at 10 °C, respectively. While in control, total saponin content decreased 17.6% at 0 °C and decreased 24.1% at 10 °C, respectively. It was concluded that saponin was relatively stable under MAP treatments, especially at lower temperature. The lowest loss in saponin content was obtained from the combination of 0 °C–0.07 mm (8.4%). The total sponin of ginseng decreased much less stored in MAP than that in the control.

Changes in reducing sugar, total sugar and pectin

Reducing sugars in fresh ginseng are an important quality factors that affect the color and appearance of ginseng during processing. Because the Millard reactions that react between reducing sugar and amino acid occur during heat treatment and dry. Changes in total sugar, reducing sugar and pectin contents in fresh ginseng were shown in Table 3. The reducing sugar increased 109.7% from initial to 13.0 mg g^{-1} after 3 months of storage and 238.8% from 6.2 to 21.0 mg g^{-1} at end of storage for 0.07 mm package at 0 °C. In

Table 3. Changes in total sugar, reducing sugar and pectin contents in fresh ginseng

Temperature (°C)	Treatment	Storage time (months)	Total sugar (mg g^{-1})	Reducing sugar (mg g^{-1})	Pectin (mg g^{-1})
		Before storage	10.2	6.2	21.4
0	0.07 mm	After 3 months	15.3	13.0	19.3
		End of 5 months	25.8	21.0	17.3
	0.05 mm	After 3 months	18.6	18.1	18.2
		End of 5 months	30.4	25.2	16.8
	Control	After 3 months	24.2	23.1	16.9
		End of 5 months	38.4	41.2	15.7
10	0.07 mm	After 3 months	22.3	15.0	17.8
		End of 5 months	30.1	25.0	16.8
	0.05 mm	After 3 months	28.2	21.1	16.2
		End of 5 months	35.4	28.2	15.2
	Control	After 3 months	30.3	28.1	15.8
		End of 5 months	42.1	44.2	14.1

0.05 mm package, the reducing sugar increased 191.9% from initial 6.2 to 18.1 mg g^{-1} after 3 months of storage and 306.5% from 6.2 to 25.2 mg g^{-1} at end of storage at 0 °C. While it significantly increased 564.5% from initial 0.62 to 41.2% in fresh ginseng at end of 150 days of storage for control. For 10 °C storage, reducing sugar increased greatly 303.2% for 0.07 mm package, 354.8% for 0.05 mm package and 612.9% for control after 5 months of storage, respectively.

Changes in total sugar was similar as reducing sugar, indicating that it was increased markedly during storage, especially in 0.05 mm packages and storage at 10 °C. It was considered that the increase in reducing sugar and total sugar to supply the respiratory substrates for respiration of fresh was from decomposing oligosaccharide or starch in ginseng. Respiration in plants is the oxidative breakdown of starch, sugar, and organic acids to simple molecules CO_2 and H_2O, with a concurrent production of energy. One of the primary effects of MAP is the reduction of respiration rate, which decreases the rate of substrate depletion, CO_2 production, O_2 consumption and release of heat (Roy *et al.*, 1995). The result slowed down metabolism and extended potentially longer storage life of fresh ginseng. The result of determined the activity of β–amylase which catalyzes the conversion of starch to maltose also showed that β–amylase had lower activity in ginseng stored in MAP at lower temperature (data not shown).

Pectin content decreased 19.2% for 0.07 mm package, 21.5% for 0.05 mm package and decreased 26.7% for control after end of storage at 0 °C. The reduction of pectin content was much remarkable at 10 °C, ie decrease of 21.5% in 0.07 mm package, 29.0% in 0.05 mm package and 34.1% for control after storage, respectively. It showed that the pectin content of fresh ginseng decreased gradually during 5 months storage. But there was higher pectin content in MAP than that in control, indicating that decomposion of pectin was suppressed and firmness of ginseng was maintained effectively by MAP. It also indicated that respiratory metabolism was effectively suppressed by MAP and resulted in less consumption of substrate and biological activity compound in ginseng. The firmness of ginseng decreased less than that in control due to retarding degradation of pectin. Higher freshness and better quality of fresh ginseng was achieved in MAP under low storage temperature, especially in 0.07 mm film package.

CONCLUSIONS

The storage life of fresh ginseng could be extended about 150 days in MAP. Higher freshness and better quality of fresh ginseng were obtained from the combination of 0 °C–0.07 mm with lowest decay after 150 days of storage. Sensory analysis showed that the freshness and firmness of stored ginseng were almost the same as that of harvested ginseng. The analysis of chemical compositions was also indicated that effective compositions in fresh ginseng was not changed much, especially the content of total saponin. It was indicated that fresh ginseng could be stored successfully for 150 days without losing much of its quality and chemical compositions in MAP.

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