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https://doi.org/10.5109/4601

出版情報：九州大学大学院農学研究院紀要. 49 (2), pp.401-408, 2004-10-01. Faculty of Agriculture, Kyushu University
バージョン：
権利関係：

J. Fac. Agr., Kyushu Univ., **49** (2), 401–408 (2004)

Storage Life Extension of Ginseng Using Active Modified Atmosphere Packaging by Nitrogen Generator

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(*Received June 22, 2004 and accepted July 13, 2004*)

The fresh ginseng roots were stored in modified atmosphere system with a nitrogen generator to validate the effect of exchanges by N_2 at interval on the qualities of ginseng in active modified atmosphere packaging (MAP). The effect of low O_2 on the chemical compositions was also determined. The storage life of fresh ginseng could be extended about 150 days in active MAP. Quality analysis showed that higher freshness and better quality of fresh ginseng were obtained from 0.07 mm and 0.05 mm packages with lower decay after 150 days of storage, especially in 0.07 mm package. The firmness of stored ginseng was almost the same as that of harvested ginseng. The chemical compositions in fresh ginseng was also not changed much, especially the content of total saponin. It indicated that fresh ginseng could be stored successfully for 150 days without losing much of its quality and chemical compositions with lower weight loss in active MAP by N_2 generator.

INTRODUCTION

MAP of fruits and vegetables refers to the technique of sealing actively respiring produce in film packages to modify the O_2 and CO_2 concentrations within the package atmosphere. It is often desirable to generate an atmosphere low in O_2 and high in CO_2 levels to influence the metabolism of the product being packaged and the activity of decay–causing organisms to increase storability and shelf life. The deterioration of fresh ginseng is generally associated with a decline in hardness, browning and mould decay. Microbial and physiological effects, physical and chemical changes accelerate deterioration of fresh ginseng. MAP has been proven beneficial in extending the postharvest life span of a wide variety of fresh horticultural commodities (Kader, 1986; Zagory and Kader, 1988). It could be created and maintained by using of polymeric film with different gas transmission (Hening and Gilbert, 1975). It has been reported that the desired atmosphere was obtained by active MAP system for retaining shelf–life of fresh–cut cantaloupe (Bai *et al.*, 2001). The regulation of storage atmospheres using a N_2 generator can be useful for the storage and long–distance transportation of fruits or vegetables with a high

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respiration rate. Equilibration time may be reduced by the injection of a N_2–enriched gas mixture. Optimum atmosphere could be achieved quickly in active MAP with low initial O_2 concentration. But little research has been done on the use of MAP to extend storage life of fresh ginseng under low initial O_2 level in MAP.

Our aim was to evaluate modified atmosphere system with a nitrogen generator to reduce the physiological metabolism and maintain its gas composition of low O_2 during storage. Fresh ginseng roots were used as a sample to validate the effect of exchanges by N_2 at interval on the qualities of ginseng in MAP. The effect of low O_2 on the chemical compositions and quality were also determined.

MATERIALS AND METHODS

Plant materials

Samples of fresh ginseng (six–years old) were harvested from ginseng farms of Jian and Fusong in Jilin Province, China. The harvested fresh ginseng was transported to laboratory within 1 d and sorted by size, shape and appearance. And then they were pre-cooled for 24 h at experimental temperatures.

Measurement of package atmosphere

The fresh ginseng were selected at random and samples of 500 g were placed into the pouches (25 cm×40 cm) of 0.05 mm, 0.07 mm thickness film (LDPE) and heat sealed. Their permeability coefficients were 2632.1×10^{-5} and 2314.3×10^{-5}ml m m^{-2} h^{-1} atm^{-1} for CO_2, 894.4×10^{-5} and 621.7×10^{-5}ml m m^{-2} h^{-1} atm^{-1} for O_2 at 10 °C, respectively. A silicone cap was applied on each package to replace gas inside package by N_2 gas and also permit analysis of package headspace with a micro–syringe. The low O_2 levels were regulated with N_2 produced by carbon molecular sieve (CNS) nitrogen generator (Shan–tao and Liao, 1989) (JTF, China) at month interval. This apparatus was made from fine charcoal which was refined and formed to provide apertures similar to nitrogen (0.317 nm) and oxygen (0.37 nm). When air is passed through the CMS under high pressure, the oxygen molecules are absorbed onto the CMS and the air passing through has an enriched nitrogen level. The void volume in the package was regulated into 300 ml. The pouches were stored at 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. During 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. 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.

Soluble pectin

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).

Total ginseng saponin

Total ginseng saponin content was measured by using method as described by Hu *et al.* (2004). 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).

Total sugar

Total 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

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.

RESULTS AND DISCUSSION

Changes in gas concentration in active MAP

Changes in the O_2 and CO_2 concentrations in active MAP were shown in Fig. 1. Gas compositions in active MAP were different inside packages with various thickness films due to permeability coefficient of film. The gas in package was replaced by N_2 at interval month, O_2 and CO_2 levels were reduced and fluctuated in periodic return of month. In 0.07 mm package, higher CO_2 and lower O_2 levels were maintained during storage. The O_2 level increased quickly from initial 5% to 15.5%, CO_2 increased to 3% at storage of 10 days, and then O_2 trended to increase gradually to 16.5%, CO_2 3.2% due to inhibition of respiration. After one month, gas in package was replaced N_2 again and showed similar change in O_2 and CO_2. For 0.05 mm package, lower CO_2 and higher O_2 levels were maintained comparing to 0.07 mm package after regulating during storage. The O_2 level increased quickly from initial 5% to 17.5%, CO_2 increased to 1.5% at storage of 10 days,

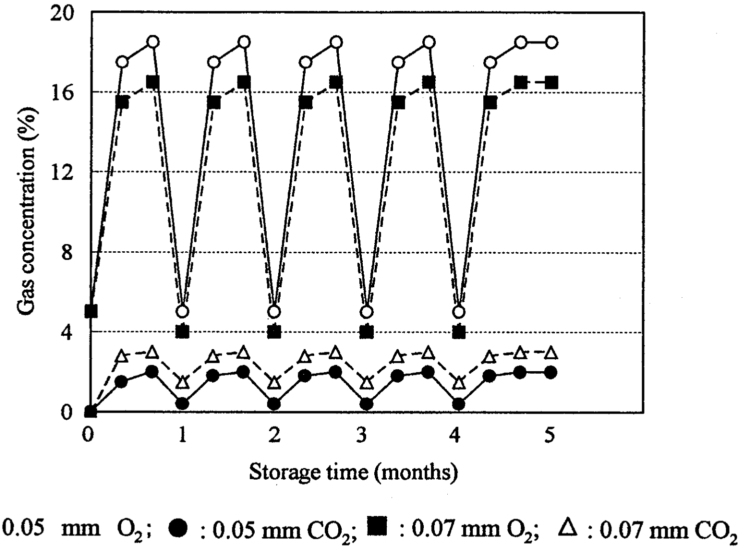

Fig. 1. Changes in gas concentrations inside the different packages.

and then similar trends of O_2 and CO_2 were shown to increase gradually to O_2 18.5%, CO_2 2% due to inhibition of respiration. After one month, gas in package was replaced N_2 again and showed similar change in O_2 and CO_2. It appeared that the metabolic activity of respiration was markedly suppressed in active MAP and this inhibition was more effective in package with lower permeability of 0.07 mm film. 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. Modified atmosphere were created by the interaction of respiration of product and gas transmission through packaging films (Christie *et al.*, 1995). Low O_2 in MAP, especially initial low O_2 is important to inhibit the respiration at initial storage period. In the experiment, although gas concentration was changeable in active MAP due to N_2 regulation and respiration, better quality was obtained from the treatment than control.

Firmness

Significant differences in firmness were found among the treatments in fresh ginseng after 150 days of storage (Table 1). There was the higher firmness in 0.07 mm package. The firmness stored in 0.07 mm package was 112.8 N for Jian ginseng, 102.3 N for Fusong ginseng. In 0.05 mm package, the firmness was 101.6 N for Jian ginseng, 95.0 N for Fusong ginseng. For control, firmness was 92.3 N for Jian ginseng, 82.4 N for Fusong ginseng. It indicated that better quality of fresh ginseng with higher firmness was obtained from active MAP, especially in package with 0.07 mm thickness film. It was shown that active 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. Knee and Bartley (1981) reported that concentration of soluble pectin in

Table 1. The changes in quality of fresh ginseng storage at different conditions*.

Farm	Treatment	Weight loss (%)	Decay (%)	Firmness (N)
Jian	0.07 mm	3.2	0.0	112.8±2.1a
	0.05 mm	15.5	0.0	101.6±1.6b
	Control	16.8	8.0	92.3±2.9c
Fusong	0.70 mm	4.8	4.8	102.3±0.8a
	0.05 mm	12.1	6.0	95.0±1.2a
	Control	13.5	16.4	82.4±1.6b

* 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 aindicate significant differences according to least significant difference (LSD) at the $p<0.05$ level.

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 3) was obtained. It was considered that the combination of lower storage temperature and low O_2 level inhibited markedly the decomposition of pectin and reduced firmness loss significantly.

Weight loss and decay

Storage of fresh ginseng in active MAP seems to be effective in reducing weight loss (Table 1). Ginseng in sealed 0.05 and 0.07 mm packages had less weight loss compared to the control. Ginseng in 0.05 mm package had higher weight loss than that in 0.07 mm package due to much substrate consumed by respiration 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 among the treatments (Table 1). Ginseng in sealed 0.05 and 0.07 mm film pouches had a storage life of 150 days with relative lower decay of 0% for Jian ginseng, 4.8–6.0% for Fusong ginseng. While the control treatment had the highest decay rate of 8.0, 16.4% for Jian and Fusong ginseng, respectively. It was indicated that the storage life of fresh ginseng in active MAP could be extended significantly than those stored in control. 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 active MAP without washing with cold water. It also showed that there was higher storability for Jian ginseng than Fusong ginseng.

It has been reported that the modified atmosphere packaging that best maintain the quality and storage life of products have an O_2 range of 2–8% and CO_2 5–15%. In this experiment, active modified atmospheric conditions of low O_2 level were established quickly by N_2 gas flushing to increase the shelf life and quality of ginseng. The permeability of film was improved by package film to avoid occurrence of much lower O_2 atmosphere. Therefore, atmospheric conditions were modified through the product's respiration and permeability of film to maintain O_2 level during the storage (Exama *et al.*, 1993).

The storage life of fresh products has well been related to the respiration rate of products, the suppression of respiratory metabolism will extend the shelf life of stored fresh product (Lopez–Briones *et al.*, 1992; Kader, 1986). But O_2 and CO_2 levels beyond its tolerance limits can induce anaerobic respiration and CO_2 damage to result in browning and development of off–flavors. It was suggested that better keeping quality for ginsengs could be obtained from low O_2 storage atmosphere above 2.0%. For the effect of initial low O_2, there were no significant differences in changes in O_2 and CO_2 concentrations at replace period. It was also reported that an additional benefit of MAP might be attained by actively flushing the package with the N_2 gas rather than allowing the MAP to develop naturally (Bai *et al.*, 2001). In the previous study, ginseng has much relative higher respiratory activity to consume O_2 and produce CO_2 quickly and lead to browning, soft and decay of ginseng (Hu *et al.*, 2004). In this experiment, relative optimum atmospheric conditions were maintained by regulating initial low O_2 in the package.

Changes in ginseng saponin

Changes in saponin in fresh ginseng before and after storage were shown in Table 2. The analysis of saponin showed that total saponin was not remarkably changed during 150 d of storage. In 0.07 mm packages, total saponin content decreased 3.6% from initial value 47.7 to 46.0 mg g^{-1} for Jian ginseng, 3.8% from 39.2 to 37.4 mg g^{-1} for Fusong ginseng. In 0.05 mm film package, saponin content decreased 5.5% from 47.8 to 45.1 mg g^{-1} for Jian ginseng, 5.0% from 39.2 to 36.8 mg g^{-1} for Fusong ginseng. While for control, saponin content decreased 6.7%. It was also indicated that active MAP suppressed the reduction of saponin content effectively.

Table 2. Changes in soponin in fresh ginseng before and after storage.

Farm	Treatments	Content of saponin (mg g^{-1})		
		Before storage	After storage	Loss rate (%)
Jian	0.07 mm	47.7	46.0	3.6
	0.05 mm	47.7	45.1	5.5
	Control	47.7	44.5	6.7
Fusong	0.07 mm	39.2	37.4	3.8
	0.05 mm	39.2	36.8	5.0
	Control	39.2	36.0	6.7

Changes in reducing sugar, total sugar and pectin

Changes in total sugar, reducing sugar and pectin contents in fresh ginseng were shown in Table 3. The total sugar increased 57.3% from initial 10.2 to 23.9 mg g^{-1} for 0.07 mm package, 61.5% from initial 10.2 to 26.5 mg g^{-1} for 0.05 mm package at end of storage of Jian ginseng, while in control, the total sugar increased 74.1%. Similar results of increase were also found in reducing sugar content. For Fusong ginseng, the total sugar increased 43.3 for 0.07 mm package, 51.3% for 0.05 mm package at end of storage,

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

Farm	Treatments	Total sugar (mg g^{-1})	Reducing sugar (mg g^{-1})	Pectin (mg g^{-1})
Jian	Before	10.2	8.2	20.5
	0.07	23.9	20.2	17.8
	0.05	26.5	22.3	16.2
	Control	39.4	35.5	14.7
Fusong	Before	11.4	7.5	22.1
	0.07	20.1	19.8	18.8
	0.05	23.4	21.8	16.8
	Control	36.8	32.6	15.1

while in control, the total sugar increased 69.0%. The changes trend of reducing sugar was similar as to that of total sugar. It indicated that the increase in total sugar and reducing 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).

Pectin content decreased 13.1% for 0.07 mm package, 21.0% for 0.05 mm package and decreased 28.3% for control after end of storage of Jian ginsneg. For Fusong ginseng, pectin content decreased 14.0% for 0.07 mm package, 24.0% for 0.05 mm package. It decreased 31.7% for control. The reduction of pectin content was much remarkable in 0.05 mm package, especially in control. It showed that the pectin content of fresh ginseng decreased gradually during 150 d storage. But there was higher pectin content in active MAP than that in control, indicating that decomposion of pectin was suppressed and firmness of ginseng was maintained effectively by active MAP. It also showed 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 active MAP under low storage temperature, especially in 0.07 mm film package. The result slowed down metabolism and extended potentially longer storage life of fresh ginseng.

CONCLUSIONS

The storage life of fresh ginseng could be extended about 150 days in active MAP. Higher freshness and better quality of fresh ginseng were obtained from 0.07 mm and 0.05 mm packages with lowest decay after 150 days of storage, especially in 0.07 mm package. The freshness and firmness of stored ginseng were almost the same as that of harvested ginseng. The chemical compositions in fresh ginseng was also not changed much, especially the content of total saponin. It indicated that fresh ginseng could be stored successfully for 150 days without losing much of its quality and chemical compositions in active MAP.

The two main advantages of the oxygen scrubber (N_2 generator), compared with conventional MAP are the possibility of generating any equilibrated atmosphere of lower O_2 level than 21%, and of enabling a manual correction if the storage temperature changes. The system is easy to handle and does not involve any probes or fragile parts. The instrument is very simple and only requires a power supply.

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