바이오시스템공학 (*J. of Biosystems Eng.*)
Vol. 35, No. 5, pp.316~322 (2010. 10)
DOI:10.5307/JBE.2010.35.5.316

숯 가공 포장재가 배의 품질변화에 미치는 영향

정현모 김만수 Rafael Auras

Effects of Packaging Materials Processed with Oak Charcoal on the Quality of Oriental Pears during Storage and Distribution

H. M. Jung M. S. Kim R. Auras

Abstract

The packaging of fruits is very important because appropriate packaging can optimize the maintenance of freshness of fruits during their distribution in low or normal temperatures until the products reach consumers. The focus of this study was on the use of functional packaging materials for the post-harvest maintenance of the freshness of fruits. Oak charcoal has excellent far infrared emission and ethylene absorption qualities, and we developed a charcoal-processing packaging linerboard to evaluate the possibility for the use of charcoal as a functional packaging material for pears. Oriental pears of the Niitaka cultivar used in this study account for about 70% of pears harvested every year, and are a very popular domestic fruit in Korea. Pears packaged in packaging materials processed with charcoal were of significantly higher quality ($p<0.05$) than those packaged with conventional packaging materials, suggesting that charcoal-processed packaging materials can be used as functional packaging material for extending the storability and distribution time of fruits. Charcoal-coated linerboard was shown to be the most appropriate packaging material based on its compression strength, ethylene absorption performance, and the firmness and minimal weight loss of pears.

Keywords : Charcoal, Ethylene, Weight loss, Firmness, Packaging, Pear

1. INTRODUCTION

Continuous improvements in the standard of living and increasing consumer demands are creating the changing patterns of fruit consumption in a variety of ways. Quantity-wise consumption patterns are a thing of the past. People are now more aware of the importance of quality and they tend to opt for higher quality products. Furthermore, the opening up of international markets has resulted in the wide scale import of agricultural products. Producers are forced to find ways to improve the quality of their products and minimize degradation during the distribution process to maintain a competitive edge. Unlike processed food products, fruits continue respiring and are physiologically active during storage and distribution. They are susceptible to various biochemical processes, which may result in the decrease of firmness, change of pigment contents, and loss of water, vitamins, and sugar contents (Brusewitz and Bartsch, 1989; Garcia et al., 1995). Also, contamination by microorganisms can spoil fruit before they reach the consumers. Post-harvest fruit loss of as much as 15% due to quality degradation during distribution at normal temperatures has been reported (Fallik et al., 2001).

Many studies have been carried out to find ways to keep

The article was submitted for publication on 2010-09-06, reviewed on 2010-09-27, and approved for publication by editorial board of KSAM on 2010-10-12 The authors are Hyun Mo Jung, Assistant Professor, Dept. of Packaging, Kyongbuk Science University, Man Soo Kim, Professor, Dept. of Biosystems Machinery Engineering, Chungnam National University, Rafael Auras, Assistant Professor, School of Packaging, Michigan State University. Corresponding author: H. M. Jung, Assistant Professor, KSAM member, Kyongbuk Science University, Chilgok, Kyongbuk, 718-851, Korea; Fax: +82-54-972-9557; E-mail: <hmjung@kbsu.ac.kr>.

fruit fresh and prevent them from spoiling during the course of distribution from the producer to the consumer (Holt et al., 1981; Park et al., 2005; Fisk et al., 2007; Zutahy et al., 2008). The main focus has been the development of post-harvest handling to maintain the commercial value of agricultural products in various stages within the entire distribution process from sorting, pre-cooling, storage, packaging, and transportation (Amarante et al., 2001). To maintain the quality of the fruits, several other techniques such as controlled atmosphere (CA) and modified atmosphere (MA) methods are used. These techniques can be used to provide atmospheric conditions during storage and reduce the oxygen concentration and increase the carbon dioxide concentration during distribution to slow down the metabolic processes within the fruits. Cool storage is also used to keep the fruit at a low temperature within the range that minimizes low temperature damage (Kader et al., 1989; Chung and Choi, 1999; Park et al., 2006). Packaging is also very important for preserving the freshness of fruits, and appropriate packaging can maintain fruit freshness during distribution at low or normal temperatures until the product reaches consumers.

After the harvest, fruits emit ethylene gas that promotes aging. The amount of ethylene gas generated by respiration of fruits increases dramatically at higher temperatures causing serious damage to their commercial value, resulting in economic loss. Ethylene is a growth hormone affecting physiological activities such as post-harvest maturing, aging, coloration, falling, and growth. A number of techniques are used to improve the storability of fruits including the absorption or inhibition of ethylene gas, low temperature storage to slow metabolic processes, and MA using atmospheric control. Furthermore, there are several studies currently in progress that are focusing on the use of functional packaging materials for the post-harvest maintenance of fruits freshness (Lin et al., 1991; Watkins et al., 2000; Choi, 2005; Kang et al., 2006).

Charcoals attracted a lot of attention in recent years because they are environmentally friendly and because of their unique functional characteristics such as catalysis, moisture and gas absorption, soil conditioning, filtering, deodorization, purification, carrier for microbial activity, specific stiffness, corrosion and friction resistance, far-infrared ray emissivity, and their electromagnetic shielding capacity (Kercher and Nagle, 2002). This study was to evaluate the use of charcoal as additives for packaging of pears, a popular fruit in Korea, by analyzing its ethylene absorption performance and changes in the quality of pears for each storage and distribution stage.

2. MATERIALS AND METHODS

A. Charcoal-processed linerboard and fruit materials

Oak charcoal (commonly known as black coal) was used in this study, as it is known to have excellent far infrared emission and ethylene absorption qualities (Kercher and Nagle, 2002). Crushed oak charcoal was ground to a fine powder in a mortar and added to a process of linerboard (KA^{210}) manufacture to produce charcoal-containing linerboard. Also, coated linerboard was produced by coating the mixture of charcoal ground to a fine powder with starch binder. Polyethylene (PE) films containing charcoal were manufactured using extruder of PE resin with charcoal powder and used on the prepared linerboard (KA^{210}). A uniform amount of charcoal per unit area (20 g/m^2) was used in all these packaging material preparations. Oriental pears of the Niitaka cultivar of uniform weight (450±30 g) were sampled from the harvest of commercial farm in October 2007 for the experiments and selected according to the absence of blemishes and defects. These pear samples were used after placing them to controlled conditions (23℃, RH 75%) for 5 hours before using them in the experiment.

B. Ethylene absorption assessment

To evaluate the ethylene absorption performance of the various types of charcoal-processed packaging materials prepared, each was cut to a uniform size of 200 mm×200 mm and placed into a sealed container without pear sample as shown in Fig. 1, and 20 ppm of ethylene gas was injected into the container using syringes. The change of internal atmospheric concentration of ethylene was then measured on an hourly basis. Furthermore, one pear of the same weight was placed into a sealed container together with each type of charcoal-processed packaging material and 20 ppm of ethylene gas was injected into the container as shown in Fig. 1.

The change in internal atmospheric concentration of

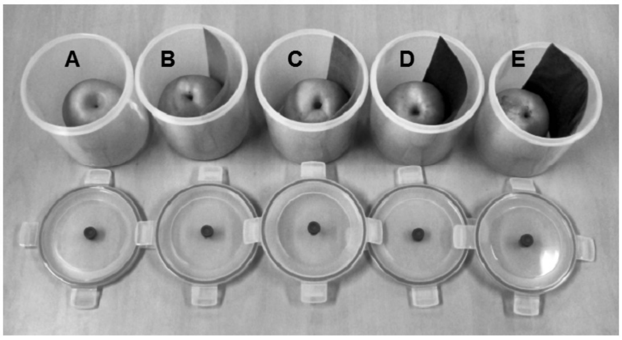

Fig. 1 Charcoal-processed linerboard and pear in sealed container to test changes in quality. (A) Pear sample with no linerboard, (B) Pear sample with no treatment linerboard, (C) Pear sample with charcoal-containing linerboard, (D) Pear sample with charcoal-coated linerboard, (E) Pear sample with charcoal-filmed linerboard.

ethylene was then measured. Tests were repeated 10 times during 12 days. Four syringes of 1 ml were used for the collection of air from each container and the collected gas was measured for changes in the concentration of ethylene gas using gas chromatography (GC-6890, Hewlett Packard, USA) with 2 m active alumina SUS column, FID.

C. Weight loss and firmness assessment

Changes in water content relative to the weight of the pears for each time period were measured. And we did the compression test using universal testing machine (SY-0023, Sunyoung-systec co., Korea) and 5 mm/min loading rate was applied and changes in the firmness of pears using a cylinder compression jig of 10 mm diameter were measured in accordance with ASABE S368.3 DEC2000 every 8 days. Firmness is a quality factor of fruits with a very close relationship to storability. The firmness was measured at four points on the surface of each sample: top, bottom, left, and right. Bioyield strength, a firmness factor was measured for the evaluation of damage level.

To facilitate aging of pears as they mature, they were kept in the atmosphere at 23℃ and 75% RH. Also, corrugated fiberboard boxes with charcoal-processed linerboard were manufactured and quality changes of weight and bioyield strength of pears in those boxes were measured in the same environmental conditions every 4 day. The weight loss rates of pears were estimated using the following equation (ASHRAE Handbook - Fundamental, 2008):

$$\dot{m} = k_t(P_{ss} - P_{va}) \quad (1)$$

where m is the weight loss rate of fruits (ng/kg·s), k_i is transpiration coefficient (ng/kg·s·Pa), P_{ss} is saturated vapor pressure (Pa) and P_{va} is vapor pressure (Pa).

D. Statistical anaysis

To determine whether significant differences ($p<0.05$) existed among the measured values using charcoal processed packaging materials, the one-way analysis of variance (ANOVA) and Duncan's multiple range tests were used by means of STATISTICA 7.1 for Windows (StatSoft, Inc, Tulsa, OK, USA).

3. RESULTS AND DISCUSSION

A. Ethylene absorption performance and stiffness of charcoal-processed materials

Table 1 shows how the ethylene concentration was changed for each packaging material in 4-hour intervals. As shown in Table 1, the linerboard that contains a charcoal component absorbed the most ethylene, followed by the charcoal-coated linerboard, paper with a charcoal-processed film, and non-processed linerboard. All of the charcoal-processed packaging materials showed some degree of ethylene absorption, which was more pronounced during the initial period of observation and created a significant difference ($p<0.05$) in absorption compared to no treatment linerboard. Changes in the concentration of ethylene were stabilized over time. In the case of the charcoal-coated linerboard, a portion of the open surface of charcoal was covered by adhesive starch, resulting in lower absorption of ethylene compared with the linerboard containing the charcoal itself. The linerboard with charcoal-processed film showed even lower ethylene absorption performance because most of the charcoal particles were locked inside the film layer.

As packaging material used for fruits can cause damage to the fruits due to the pressure at the bottom of the packaging box during storage and distribution, resulting in economic losses, we identified the most appropriate charcoal-processed packaging material for the packaging of fruits by measuring ring crush and bursting strength, which directly influence the compressive strength of the packaging box of each packaging material. As shown in Table 2, ring crush was measured by preparing the samples in accordance with ASTM D 48826-88 specifications, and bursting strength

Table 1 Ethylene concentration (ppm) in sealed container including charcoal-processed packaging linerboards, according to storage time

Storage time	No linerboard	No treatment linerboard	Charcoal-containing linerboard	Charcoal-coated linerboard	Charcoal-filmed linerboard
0 hour	19.9 (±0.2)	19.7 (±0.2)	19.9 (±0.2)	19.8 (±0.2)	19.7 (±0.2)
4 hour	19.5 (±0.1)	18.6 (±0.3)	13.1 (±0.2)	15.4 (±0.3)	16.7 (±0.4)
8 hour	19.1 (±0.4)	18.4 (±0.2)	12.7 (±0.3)	15.2 (±0.1)	16.5 (±0.3)
12 hour	18.9 (±0.3)	18.3 (±0.2)	12.6 (±0.3)	14.8 (±0.4)	16.2 (±0.6)
16 hour	18.8 (±0.5)	17.9 (±0.5)	12.4 (±0.4)	14.7 (±0.5)	15.8 (±0.8)
20 hour	18.7 (±0.9)	17.8 (±0.6)	12.0 (±0.7)	14.2 (±0.6)	15.6 (±0.9)
24 hour	18.6 (±1.3)	17.4 (±0.9)	11.6 (±0.8)	13.6 (±0.8)	15.5 (±1.2)

Table 2 Ring crush and bursting strength of charcoal-processed packaging materials

	No treatment linerboard	Charcoal-containing linerboard	Charcoal-coated linerboard	Charcoal-filmed linerboard
Ring crush (N)	193.26 (±17.29)	172.90 (±11.98)	327.89 (±19.23)	287.92 (±16.48)
Bursting strength (N/cm^2)	76.52 (±12.35)	69.13 (±7.24)	135.23 (±9.76)	115.76 (±10.94)

Table 3 Ethylene concentration (ppm) in sealed container including charcoal-processed packaging linerboards and pear according to storage time

Storage time	No linerboard	No treatment linerboard	Charcoal-containing linerboard	Charcoal-coated linerboard	Charcoal-filmed linerboard
Day 0	20.0 (±0.7)	20.0 (±0.9)	20.0 (±0.7)	20.0 (±0.6)	20.0 (±0.9)
Day 4	21.4 (±0.8)	21.0 (±1.1)	17.4 (±1.3)	18.5 (±0.9)	18.8 (±0.8)
Day 8	24.4 (±1.2)	23.1 (±1.5)	18.0 (±1.2)	19.6 (±0.6)	19.9 (±1.2)
Day 12	26.6 (±1.5)	25.5 (±1.9)	18.6 (±1.4)	20.4 (±1.6)	20.2 (±1.4)

was measured in accordance with ASTM D 774M-97. The ring crush and bursting strength measured for each charcoal-processed packaging material are shown in Table 2. Both of these were highest in the charcoal-coated linerboard. The charcoal-containing linerboard, which had the highest ethylene absorption ability, showed more than 50% lower ring crush and bursting strength than the charcoal-coated linerboard. Therefore, the packaging box using charcoal-coated linerboard was found to be the most appropriate packaging material for fruits.

Twenty ppm of ethylene gas was injected into the sealed container containing a pear and a type of charcoal-processed packaging material. Fruits generally mature by reacting with self-generated ethylene gas, which accelerates the process of aging. However, the pear samples used in this study were processed in such a way that would prevent them from being stressed by vibrations and shocks. Treated as such, pears will generate smaller amounts of ethylene themselves. Therefore, most of the ethylene that contributes to the maturation of the pear would be from the injected gas. To expedite quality change during storage, we kept the pears at room temperature and measured the changes in the concentration of ethylene gas every 4 days. Table 3 shows changes in ethylene concentration for each sample of charcoal-processed packaging material. It shows that the change in ethylene concentration was highest for charcoal-containing linerboard, which had the best ethylene absorption performance. The next highest change of ethylene concentration was observed with charcoal-coated linerboard, followed by linerboard with charcoal-processed film, and non-processed linerboard.

B. Effect of charcoal-processed materials on weight loss of pears

The weight losses of pear samples were measured to evaluate the effect of packaging material on moisture content. Table 4 shows the changes in measured weight in 8-day intervals. As shown in Table 4, the amount of change was dependent on the duration of storage. The least change was observed when the charcoal-containing linerboard was used. Charcoal-coated and charcoal-filmed materials showed

Table 4 Weight (g) changes of pears in sealed containers according to storage time

Storage time	No linerboard	No treatment linerboard	Charcoal-containing linerboard	Charcoal-coated linerboard	Charcoal-filmed linerboard	Simulation (ASHRAE)
Day 0	450.2 (±10.6)	451.1 (±13.2)	449.6 (±12.6)	450.5 (±16.8)	452.3 (±12.2)	450.0
Day 8	441.4 (±9.1)	442.5 (±10.6)	443.3 (±11.2)	442.4 (±12.6)	445.4 (±11.6)	435.3
Day 16	422.7 (±9.8)	428.2 (±9.6)	437.1 (±12.9)	434.8 (±9.3)	432.6 (±11.4)	420.6
Day 24	409.4 (±12.4)	415.2 (±9.2)	434.6 (±10.1)	430.7 (±11.6)	428.2 (±10.8)	405.9
Day 32	396.0 (±10.5)	402.2 (±11.4)	428.1 (±8.6)	425.4 (±10.4)	420.7 (±8.6)	391.2

Table 5 Changes of bioyield strength (kPa) of pears in sealed container according to storage time

Storage time	No linerboard	No treatment linerboard	Charcoal-containing linerboard	Charcoal-coated linerboard	Charcoal-filmed linerboard
Day 0	183.24 (±29.4)	184.56 (±24.5)	180.29 (±16.3)	182.43 (±20.6)	181.38 (±28.2)
Day 8	159.45 (±34.3)	163.53 (±20.2)	174.12 (±26.6)	168.09 (±16.7)	163.42 (±10.6)
Day 16	143.56 (±25.6)	147.32 (±22.3)	163.45 (±21.4)	158.86 (±14.0)	150.29 (±18.2)
Day 24	131.45 (±34.1)	139.01 (±34.2)	154.22 (±16.2)	146.18 (±20.4)	145.30 (±12.7)
Day 32	110.32 (±38.3)	115.33 (±18.6)	141.56 (±20.9)	134.24 (±15.1)	129.81 (±16.4)

similar levels of change. Charcoal-processed packaging materials generally have a lesser effect on the change of moisture content than ordinary packaging materials, indicating that they are appropriate when little change in the moisture content is important. As they absorb less water than ordinary linerboard materials, we concluded that they could be used as a means to prevent a decrease of compressive strength caused by the absorption of water by the packaging box. Also, the weight loss rate was 0.1744 g/kg·hr following Eq. 1. The transpiration coefficient of the pears was 69 ng/kg·s·Pa (ASHRAE Handbook - Fundamental, 2008), and the saturated vapor pressure of 2.81 kPa and vapor pressure of 2.11 kPa at 23℃ and RH 75% were estimated under a standard atmospheric pressure of 101.3 kPa by using a Psychrometric chart.

C. Effect of charcoal-processed materials on firmness of pears

Fig. 2 shows the force-deformation curve of a pear evaluated using a compression test, and Table 5 shows the results of the compression test performed for each time period of storage in 8-day intervals to measure the changes in the firmness according to the charcoal-processed packaging material. In this test, bioyield strength, bioyield point divided by contact area, for the evaluation of storability and damage was measured. When designing agricultural and packaging machinery for handling fruits, bioyield strength becomes an important design variable regarding the damage (Kim et al., 2005). A high bioyield strength of fruits means they can be stored for a longer time under the same environmental conditions and they are less susceptible to damage by impacts during transportation. Measurements of bioyield strength were taken for each time period of storage, as were the measurements of weight loss.

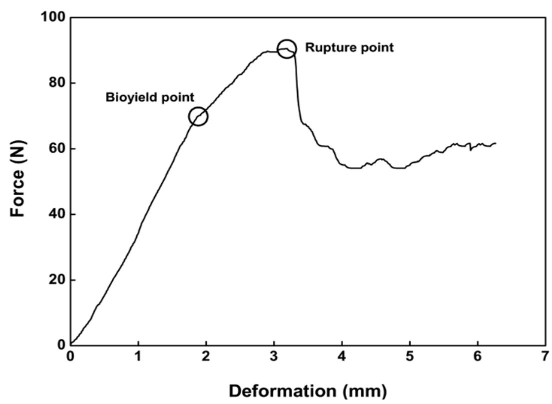

Fig. 2 Force–deformation curve of a pear by compression test.

All of the charcoal-processed packaging materials showed excellent ethylene absorption qualities. They also minimized the change in moisture content and firmness of the fruits. These packaging materials can therefore be used to reduce the rate of maturation and aging during the distribution processes. Considering the distribution environment of harvested fruits in stacked packaging boxes, corrugated fiberboard with charcoal-coated linerboard was shown to be the most appropriate packaging material as it improves the compressive strength of the packaging box and ethylene absorption performance.

D. Quality changes of pears in developed charcoal-processed packaging box

We measured weight loss and bioyield strength of pears every 4 days during storage in boxes with charcoal-coated linerboard inside the corrugated fiberboard box and boxes that were made out of non-processed corrugated fiberboard. The rate of weight loss rate was estimated using Equation 1.

As indicated in Fig. 3, the pears stored in the corrugated fiberboard packaging box using charcoal-coated linerboard showed significantly less weight change about 7.1% in average at storage period of about 1 month than those stored in the conventional fiberboard box in same storage environmental condition. This also means less change in moisture content and less weight change about 4.2% on average than simulated weight change by using Equation 1.

The measurement results of bioyield strength also showed significantly less change about 14.7% in average in the pears stored in the box made with charcoal-coated linerboard compared to the box made with non-processed corrugated fiberboard at storage period of about 1 month in same storage environmental condition, as shown in the Fig. 4. These results suggest that use of charcoal-processed packaging material can maintain the freshness of fruits for a longer period of time at the same conditions than conventional packaging material.

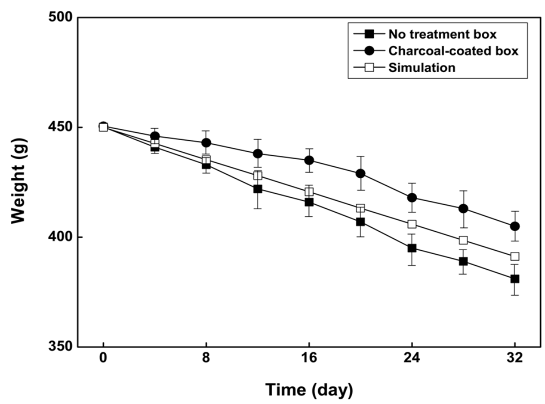

Fig. 3 Weight change of pears in charcoal-processed packaging box according to storage time. (●) Weight changes of pears in charcoal-coated box, (■) Weight changes of pears in no treatment box, (□) Simulated weight changes of pears by ASHRAE Handbook equation (Equation 1).

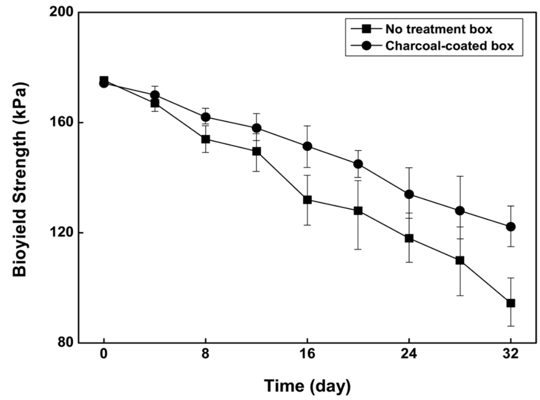

Fig. 4 Decreasing of bioyield strength of pears in charcoal-processed packaging box according to storage time. (●) Bioyield strength of pears in charcoal-coated box, (■) Bioyield strength of pears in no treatment box.

4. CONCLUSIONS

This study was carried out to evaluate charcoal as a functional packaging material. We used charcoal-processed packaging linerboards and demonstrated that they could be used as a functional packaging material to extend the storability and distribution time of fruits. Charcoal-containing linerboard was the most appropriate packaging material when considering its ethylene absorption performance, bioyield strength, and weight loss of pears, although this linerboard was difficult to apply practically in fruit packaging because of the distribution environment of temperature, relative humidity, and stacking; the compression strength of this packaging linerboard was the lowest among the developed packaging materials. Therefore, charcoal-coated packaging linerboard is the most appropriate packaging material to maintain the freshness and quality of transported fruits.

REFERENCES

1. ASABE, 2008, ASABE S368.3 DEC2000 Compression Test of Food Materials of Convex shape. ASABE International, St. Joseph, MI.
2. ASHRAE, 2008, ASHRAE Handbook - Fundamentals, ASHRAE International, Atlanta, GA.
3. ASTM, 2007. ASTM D 4826-88 Standard Practice for Units of Measurement and Conversion Factors for Pulp, Paper and Paperboard. ASTM International, West Conshohocken, PA.
4. ASTM, 2007. ASTM D 774M-97 Standard Test Method for Bursting Strength of Paper. ASTM International, West

Conshohocken, PA.
5. Amarante, S., N. H. Banks and B. Ganesh. 2001. Effects of coating concentration, ripening stage, water status and fruit temperature on pear susceptibility to friction discolouration, Postharvest Biology and Technology 21:283-290.
6. Brusewitz, G. H. and J. A. Bartsch. 1989. Impact parameters related to post harvest bruising of apples, Transactions of the American Society of Agricultural Engineers 32: 953-957.
7. Choi, S. J. 2005. Comparison of the change in quality and ethylene production between apple and peach fruits treated with 1-Methylcyclopropene (1-MCP). Korean Journal of Food Preservation 12(6):511~515. (In Korea)
8. Chung, H. S. and J. U. Choi. 1999. Production of ethylene and carbon dioxide in apples during CA storage. Journal of Postharvest Science and Technology. 6(2):153-160. (In Korea)
9. Fallik, E., T. A. Sharon and X. Feng and S. Lurie. 2001. Ripening characterization and decay development of stored apples after a short pre-storage hot water rinsing and brushing. Innovative Food Science Emerging Technology 2:127-132.
10. Fisk, C. L., A. M. Silver, B. C. Strik and Y. Zhao. 2007. Postharvest quality of hardy kiwifruit (Actinidia arguta 'Ananasnaya') associated with packaging and storage conditions. Postharvest Biology and Technology 47:338-345.
11. Garcia, J. L., M. Ruiz-Altisent and P. Barreiro. 1995. Factors influencing mechanical properties and bruise susceptibility of apples and pears, Journal of Agricultural Engineering Research 61:11-18.
12. Holt, J. E., D. Schoorl and C. Lucas. 1981. Prediction of bruising in impacted multilayered apple packs, Transactions of the American Society of Agricultural Engineers 24:242-247.
13. Kader, A. A., D. Zagory and E. L. Kerbel. 1989. Modified atmosphere packaging of fruits and vegetables. Critical Reviews in Food Science and Nutrition 28:1-30.
14. Kang, I. K., C. Choi and D. G. Choi. 2006. Effect of aminoethoxyvinylglycine dipping treatment on ethylene production and cell wall composition of 'Tsugaru' apple fruits during cold storage. Korean Journal of Bio-Environment Control 15(1):75-82. (In Korea)
15. Kercher, A. K. and D. C. Nagle. 2002. Evaluation of carbonized medium-density fiberboard for electrical applications. Carbon. 40(2):1321-1330.
16. Kim, M. S. and H. M. Jung and K. B. Kim. 2005. Durability of corrugated fiberboard container for fruit and vegetables by vibration fatigue at simulated transportation environment. Journal of Biosystems Engineering 30(2):89-94.
17. Lin, Y., Y. M. Wu and X. Hua. 1991. Effects of storage conditions on ethylene biosynthesis in apple fruits. Horticulture Science 26:696.
18. Park, S. I., S. D. Stan and M. Z. Daeschel1. 2005. Antifungal coatings on fresh strawberries (Fragaria ananassa) to control mold growth during cold storage. Journal of Food Science 70:197-201. (In Korea)
19. Park, H. W., S. H. Kim, H. S. Cha, Y. H. Kim, S. A. Lee and S. M. Rabie. 2006. Freshness of tomatoes cultivated in Egypt by packaging functional MA film. Journal of Korean Society of Packaging 12(1):41-44. (In Korea)
20. Watkins, C. B., J. F. Nock and B. D. Whitaker. 2000. Responses of early, mid and late season apple cultivars to postharvest application of 1-methylcyclopropene (1-MCP) under air and controlled atmosphere storage conditions, Postharvest Biology and Technology 19:17-32.
21. Zutahy, Y., A. Lichter, T. Kaplunov and S. Lurie. 2008. Extended storage of 'Red Globe' grapes in modified SO_2 generating pads. Postharvest Biology and Technology 50:12-17.