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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 5 (1): 84-87, 2002

Effect of Nonpolar Gases on the Storage of Persimmon Fruits (*Diospyros khaki* L.) at Different Temperatures

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Abstract: Two tests were conducted using xenon (Xe), krypton (Kr) and nitrogen (N_2) for storage of persimmon fruits. Under test-1, fruits were treated with Xe, Kr and N_2 at a partial pressure of 0.3MPa for nine days at 10 °C. In test-2, only Xe gas was applied with 0.3MPa to the fruits for 17 days at 15 °C. In test-1, the estimated respiration rate was the lowest at 3.1 $mgCO_2$ kg^{-1} h^{1} in Xe treated sample, while it was 5.9, 6.7 and 6.9 $mgCO_2$ kg^{-1} h^{1} for Kr, N_2 and control treatments respectively. No significant changes in colour and taste were observed at all. In test-2, Xe treatment showed a lower respiration rate (8.0 $mgCO_2$ kg^{-1} h^{-1}) as compared with the control (10.2 $mgCO_2$ kg^{-1} h^{-1}). The respiration rates were 47 and 22% lower in Xe treated persimmons than that of the control at 10°C and 15°C, respectively. In the control treatment, colour was started to deteriorate after nine days (test -2). Suppression of both the colour change and browning of flesh were observed in the treated sample. Metabolic activity was suppressed in samples treated with Xe. It was concluded that the Xe treated sample was in good condition. Therefore, the Xe treatment could be used for extending the storage life of persimmon fruit.

Key words: Nonpolar gas, persimmon fruit, storage, respiration, colour, browning

Introduction

Persimmons are predominantly grown in subtropical and warm temperate climates. Japanese persimmon (*Diospyros khaki* L.) is one of the important fruits and has been cultivated for centuries in Japan. In recent years the popularity of this fruit is increasing in the world. 'Fuyu' and 'Jiro' cultivars are popular because they lose astringency before they are harvested. These fruits are good source of fibre and vitamins, mainly A and C (Homnava *et al.*, 1990). 'Fuyu' persimmons grown in USA, can be stored at 1 °C and 80-85% RH for about 6 weeks with little change in firmness and taste characteristics (Lyon *et al.*, 1992). The 'Fuyu' grown in Japan could be stored for 5 to 6 months at 0 °C, if individually packed and sealed in polyethylene bags (Kawada, 1982). The same cultivar grown in New Zealand could be stored for only 4 weeks under the same conditions (MacRae, 1987). The prolonged storage is restricted because the temperature can not be lowered below the chilling or freezing point. Respiration activity of fresh produce is an excellent indicator of metabolic activity of the tissue and thus is a useful guide to the potential shelf life of the product. Slowing down the respiration activity will effectively delay the physical and chemical changes, thus also delaying the senences of stored product. When xenon (Xe), a non-polar gas was dissolved into water, a large number of hydrogen-bonded water molecules were formed by a hydrophobic hydration (Tanaka and Nakanishi, 1991). The water in this state is termed as "structured". The number of hydrogen-bonded water molecules is one of the factors governing the motion of water molecules. The viscosity of water is expected to increase when the number of hydrogen-bonded water molecules increases. When the intracellular water of fresh products becomes structured, metabolic activities are thought to be suppressed by a reduction in the diffusion rate of substrate. Studies of structured water using Xenon have been carried out on plant cell, flowers and fresh vegetables (Oshita *et al.*, 1992; 1995; 1996; 1997). It indicated that the storage life of the commodities can be extended.

Therefore, the present study was under taken to examine the effects of the formation of structured water by Xe in persimmon fruits by measuring evolved CO_2, weight loss, colour, flesh browning and taste.

Materials and Methods

Fruits of almost the same maturity and colour were harvested from the farmers' fields at Saitama, Japan between November and December, 1995. Within 2 hrs of harvest the fruits were transported to the Laboratory of Bioprocess Engineering at the University of Tokyo, Japan. The fruits were cleaned and then selected for storage for test- 1 and test- 2. Fruits were placed in acrylic resin containers of volume 0.95 L, having inside diameter of 110×10^{-3} m and height of 100×10^{-3} m. For test-1, four containers were used, including a control (Table 1). Immediately after closing the lids of the containers Xe, Kr and N_2, respectively were superimposed to the atmospheric air at pressure of 0.30MPa and constant room temperature of 20 °C. Then four containers were placed in a chamber at a constant temperature of 10 °C. Gas chromatograph (GC-14A, Shimadzu Co., Japan) was used to measure the CO_2 concentration. About 1-ml gas sample was drawn from the storage containers with the help of gas syringe and was adjusted to 0.5-ml before injecting into a GC, fitted with a thermal conductivity detector at 90 °C. The flow rate for the carrier gas of helium was 30ml min^{-1}. The partial pressure of CO_2 (PCO_2) and CQEC were calculated as mentioned by Oshita *et al.* (1997). Inner pressure (kg/cm^2) of the sample container was measured by the pressure monitor (PM 222, GL Science). The surface colour and weight loss were determined at the initial and final stage of experiment. The changes in surface colour at three different parts were determined and the average value was taken as a colour

Table 1: Experimental test conditions of persimmon fruit during storage at 10° C and 15° C

Test No.	Temperature	Treatment	Total pressure (Mpa)	Period of Xe application (days)
		Control	Air: 0.1	Without Xe
		Xenon		
1	10° C	Krypton	Gas:0.30+ Air:0.1	9
		Nitrogen		
		Control	Air: 0.1	Without Xe
2	15° C	Xenon	Gas: 0.40+ Air:0.1	17

parameter of L*, a*, and b* values for test- 2. The surface colour of fresh products was determined using a colour and colour difference meter (model Z-1001DP, Nippon Denshoku Kogyo Co., Japan). The total colour difference DE was calculated from the initial and final differences of L*, a* and b* values (Maskan, 2001) as follows:

$$DE = \sqrt{(L^*_2-L^*_1)^2 + (a^*_2-a^*_1)^2 + (b^*_2-b^*_1)^2}$$

where,
L* : lightness/darkness, a* : green/light, b* : blue/yellow
L^*_2, a^*_2 and b^*_2 indicates reading at the end while L^*_1, a^*_1 and b^*_1 pertain to initial readings.
The total colour difference value was classified by National Bureau of Standard (NBS) unit. The signs of flesh browning were visually observed at the end of experiment.

Results and Discussion

Partial pressure of gases: The partial pressures of all non-polar gases decreased due to dissolution in the persimmon fruits (Oshita *et al.*, 1997). However, the decrease in partial pressure was the highest for Xe (Table 2). This indicates that the Xe has the highest capability of forming structured water as compared with other nonpolar gases. A similar trend was also observed in test -2 for Xe treatment. Oshita *et al.* (1994) reported that partial pressure of Xe and N_2 gases were decreased to 0.34 and 0.36 MPa from the initial 0.40 MPa during 16 days storage of cut broccoli head in pressure steel container at 6 °C. The decrease in partial pressure of Xe is still greater than that of the decrease on partial pressure of nitrogen. In other words, the quantity of Xe dissolved in broccoli was larger than that of nitrogen. This means that even if the water in nitrogen treated broccoli became structured, the structured level of water was low compared with the water in Xe treated broccoli (Oshita *et al.*, 1994). Fig. 1 and 2 showing the changes in PCO_2 in persimmon fruits for tests- 1 and 2, respectively. Generally, the PCO_2 was lower in the Xe treatment, indicating the greater effect of Xe on the suppression of CO_2 production during storage as compared with the use of other nonpolar gases in this study. In a first few (three) days the difference in partial pressure of Xe comparing with the other non polar gases was not clearly marked out. However a distinct difference was observed due to increasing the rate of structured water formation. Fig.1 also shows that almost the similar effects were observed for N_2 and Kr gases as compared with the control and this further indicates, that the degree of structured water formation was low for N_2 and Kr gases.

Cumulative quantity of evolved CO_2 (CQEC): Fig. 3 shows the changes in CQEC of persimmon fruits in Xe treated and control samples for test- 1 at 10 °C at the end of storage. The CQEC values for Xe, Kr, N_2 and control were 702, 1363, 1467 and 1304 $mgCO_2\ kg^{-1}$, respectively. It was observed that CQEC value was the lowest in Xe treated samples (702 $mgCO_2\ kg^{-1}$). Fig. 4 shows the changes in CQEC in Xe treated and control persimmon for test-2 at 15 °C during 17 days storage. Xenon treatment showed a lower CQEC value of 3212 $mgCO_2\ kg^{-1}$ as compared with control, which was at 4007 $mgCO_2\ kg^{-1}$. Similar reduction of CQEC value has been reported for broccoli (Oshita *et al.*, 1997). The proposed mechanism was supposed to be due to the formation of structured water. The changes in CQEC behaviour pattern is almost similar to PCO_2 gases. For both Figs. 3 and 4, in first few days the suppression of respirable CO_2 gas was not clearly found in the Xe treated sample in comparison with the other samples. However, after three days a marked difference was gradually observed in the Xe treated sample than that in the control sample due to much amount of CO_2 evolved, resulting in deterioration of the control persimmon at 15 °C after termination of storage. On the other hand, deterioration was not observed in any of the treated sample as well as in the control persimmon due to low amount of evolved CO_2 gas at 10 °C.

Table 2: Changes in Xe partial pressure and amount of Xe dissolved into the intracellular water of persimmon fruit

Test No.	Temperature	Treatment	Initial pressure (MPa)	Final pressure (MPa)	Difference (MPa)
		Xe	0.30	0.06	0.24
1	10°C	Kr	0.30	0.28	0.02
		N_2	0.30	0.27	0.03
2	15°C	Xe	0.40	0.37	0.03

Table 3: Changes in total color difference (ΔE) and weight loss in persimmon fruits during storage at 10°C and 15°C

Test No.	Time (d)	Color difference (ΔE)		Weight loss (%)	
1	After	Xe, Kr, N_2	Control	Xe, Kr, N_2	Control
	9	ND	ND	< 1	< 1
2	After	Xe	Control	Xe	Control
	17	7.1	8.4	0.48	0.58

ND: not determined

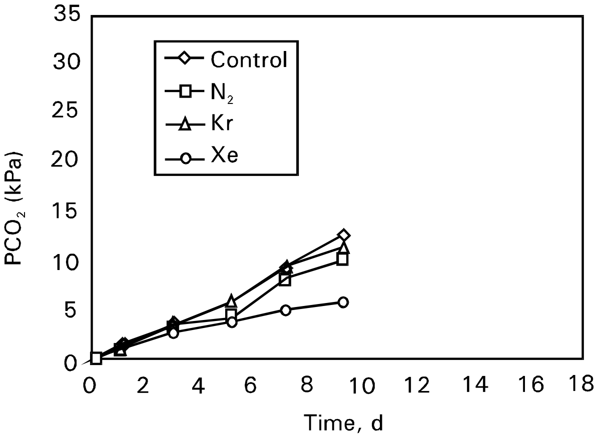

Fig. 1: Changes in partial pressure of CO_2 (PCO_2) during storage of persimmon fruit at 10° C

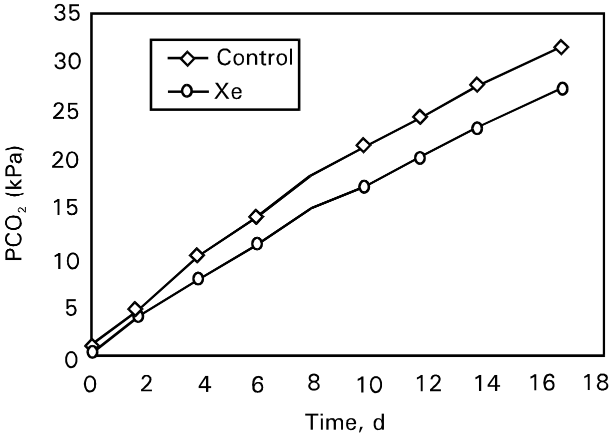

Fig. 2: Changes in partial pressure of CO_2 during storage of persimmon fruits at 15° C

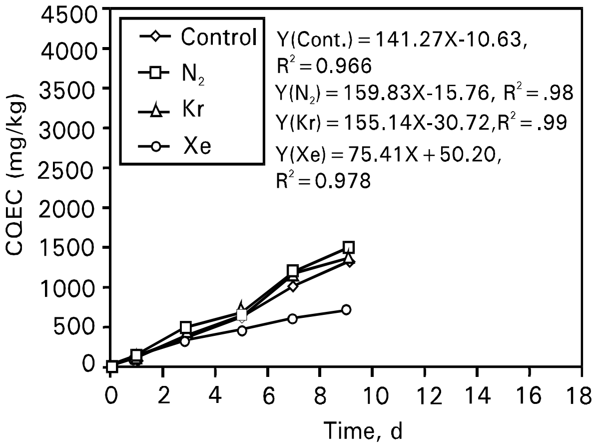

Fig. 3: Changes in cumulative quantity of evolved CO_2 (CQEC) from persimmon fruits during storage at 10° C.

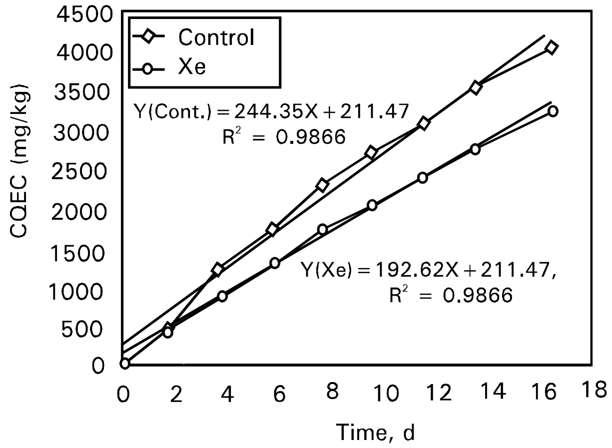

Fig. 4: Changes in cumulative quantity of evolved CO_2 from persimmon fruits during storage at 15° C

Respiration rate: Aerobic respiration occurs in all fresh fruits and vegetables. It evolved respirable CO_2 gas during metabolic process. If its' level exceed 10%, it can deteriorate persimmon fruits (Kader, 1992). Aerobic respiration was calculated for 7 days at 10 °C and for 4 days at 15 °C storage. For comparing the respiration rates between the Xe treated and the control fruit samples, linear regression lines were plotted from the CQEC data in Fig. 3 and 4. The respiration rates were determined from the slope of these regression lines. The values estimated were 5.9, 6.7, 6.5, and 3.1 mgCO_2 kg^{-1} h^{-1} for the control (Y= 141.27X-10.63, R^2= 0.9963), N_2 (Y= 159.83X-15.76, R^2= 0.98), Kr (Y= 155.14X-30.72, R^2= 0.99), and Xe (Y= 75.41X+ 50.2, R^2= 0.978) treatment, respectively (test- 1). The respiration rate in Xe treated persimmon was 47% lower than that for the control. Under test-2, the respiration rates were 8.0 and 10.2 mgCO_2 kg^{-1} h^{-1} for Xe (Y= 192.62X+ 144.25, R^2= 0.994) and control treatment (Y= 244.35X+ 211.47, R^2= 0.994), respectively. The respiration rate in Xe treated sample was 22% lower than that of the control sample. It is clear that the suppression of respiratory metabolism was low at lower temperature than that of the higher temperature, irrespective of using the other treatments. The results suggested that the respiratory metabolism was suppressed by formation of the structured water. It is highly probable that this suppression of respiratory metabolism in Xe treated sample is due to dissolution of Xe into the intracellular water of persimmon. Similar results have also been reported for eggplant and broccoli by Rahman (1996).

Weight loss and surface colour: Table 3 describes the weight loss and colour. Weight loss was less than 1% in both treatments because RH was maintained around 100%. Oshita *et al.* (1994) reported that weight loss was less than or equal to 2% in Xe treated broccoli because of 100% RH. However, the weight loss is slightly higher in the control than the Xe treated sample for test-2. Colour difference value (DE) and changes in visual colour of persimmon were determined. At the beginning of the experiment, the surface colour was light yellow. It started to change in the control fruit after 10 days of storage and markedly changed at the end of 17 days of storage. While, in Xe treated sample slight change in colour was observed. However, according to NBS unit the value of DE did not differ, which was 7.1 and 8.4 for the Xe treated and control sample, respectively. Oshita *et al.* (1994) reported that no appreciable change in colour occurred of cutting surface of broccoli exposed to Xe, while change occurred for the control sample. The suppression of colour changes in Xe treated fruit indicates that senescence or over ripening process occurring was delayed i.e, the fruit can be stored at a longer period than the control without quality deterioration. In test -1, after nine days of storage there was not much change in colour between the Xe treated and control fruit. This might be due to the shorter period of storage.

Browning of flesh: The flesh colour did not change much in both the treated and control samples in test- 1. By contrast, in test- 2, distinct browning of flesh was observed in control sample as compared with the treated sample. This is supported by report that the colour of persimmon fruit changes during the ripening and the colour change is accompanied by a softening of the flesh (Lyon *et al.*, 1992). Browning was suppressed in cut broccoli stem due to Xe application (Oshita *et al.*, 1997). These results are in conformity with our findings. Hence, it confirmed that by the application of Xe gas the browning can be suppressed in fresh products by the formation of structured water. Softness was not measured but judged by handling the fruit. The polyphenol oxidase is reported to be involved in browning of the fruits and vegetables (Barberan and Robins, 1997). In this study enzyme activities or enzyme content were not measured. It is probable that the enzyme activities are suppressed by formation of structured water in Xe treatment.

In conclusions, the application of nonpolar gas Xe in storage of the persimmon fruits resulted in low partial pressure of evolved CO_2 and low respiratory rate. No significant changes in colour and taste were observed for Xe, Kr and N_2 (0.3 MPa pressure) at 10 °C for 9 days. No sign of flesh browning was observed. The quality of fruit as judged by tasting was found to be fresh in Xe treated sample at 15 °C and 0.4 MPa Xe pressure up to 17 days of storage. Therefore, Xe treatment might be a useful storage method for fresh agricultural products.

Detailed studies are required before practical application of xenon gas. It is further suggested that biochemical studies are carried out to determine the mechanism responsible for the suppression of metabolic activities by the formation of structured water with xenon gas.

Acknowledgment

The main author highly acknowledges the Ministry of Education, Science, Sports and Culture, Japan for providing the scholarship and the facilities to conduct this research activity in the Laboratory of Bioprocess Engineering, Department of Biological and Environmental Engineering, Graduate School of Agriculture and Life Sciences, University of Tokyo, Japan. The author extends appreciation to Professor Y. Sagara of the same institution for his helpful and courageous advice in preparing and accomplishing this research activity.

References

Barberan, F.A.T. and R.J. Robins, 1997. Phytochemistry of Fruits and Vegetables. Oxford University Press Inc., New York, pp: 51-61.

Homnava, A., J. Payne, P. Koehler and R. Eitenmiller, 1990. Provitamin A (a- Carotene, b- Carotene and b– eryptozanthin) and ascorbic acid content of Japanese and American Persimmons. J. Food Qual., 13: 85.

Kader, A. A., 1992. Postharvest Technology of Horticultural Crops, 2nd ed., 15-20 University of California, Oakland.

Kawada, K., 1982. Use of polymeric films to extend postharvest life and improve marketability of fruits and vegetables-Unipack: Individually wrapped storage of tomatoes, oriental persimmons and grapefruit, p. 87-99. In:D.G. Richardson and M. Meheriuk (eds.) Controlled atmosphere for storage and transport of perishable agricultural commodities. Sym. 1, Corvalis, Ore. Timber Press, Beaverton, Ore.

Lyon, B. G., S. D. Senter and J. A. Payne, 1992. Quality characteristics of oriental persimmons (*Diospyros khaki* L. cv. Fuyu) grown in the southeastern United States. J. Food Sci., 57: 693-695.

MacRae, E. A., 1987. Development of chilling injury in New Zealand grown "Fuyu" persimmon during storage. New Zealand J. Expt. Agric., 15: 637-639.

Maskan, M., 2001. Kinetics of colour change of kiwi fruits during hot air and microwave drying. J. Food Eng., 48:169-175.

Oshita, S., M.A Rahman, Y. Seo, Y. Kawagoe and Y. Hashimoto, 1997. Storage of Agricultural Products by Making the Water Structured (Part 2). - Suppression of Metabolism of Agricultural Product-. J. Jpn. Soc. Agric. Machi., 59: 29-35.

Oshita, S., Y. Seo and Y. Kawagoe, 1996. Extension of vase life of cut carnations by structured water. Proc. of the Int. Symp .on Plant Production in Closed Ecosystems,-Automation, Culture, and Environment, Acta Hort., Chiba, 440, pp: 657-662.

Oshita, S., Y. Hashimoto and Y. Seo, 1994. Preservation of agricultural products by making intracellular water structured, Proc. of Inter. Symp. on Agril. Eng., Milano, Report no-94-G-007.

Oshita, S., M. A. Rahman, Y. Kawagoe, Y. Seo, K. Koreeda and K. Nakamura, 1995. Storage of Cut Flowers by Making Intracellular Structured Water. Proc. of Inter. Symp. on Automation and Robotics in Bioproduction and Process., Tokyo, 3, pp: 295-300.

Oshita, S., N. Yamaoka and A. Hashimoto, 1992. Basic Study on the Preservation of Plant Cell by Applying Gas hydrate. Proc. of Inter. Agric. Engi. Conf., Bangkok, Thailand.

Rahman, M. A., 1996. Study on the preservation of agricultural products using nonpolar gas, An unpublished M. Sc. Thesis, University of Tokyo, Tokyo.

Tanaka, H. and N. Nakanishi, 1991. Hydrophobic hydration of inert gases. Thermodynamic properties, inherent structures, and normal-mode analysis. J. Chem. Phys., 95: 3719-3727.