J Food Sci Technol (November–December 2011) 48(6):763–768
DOI 10.1007/s13197-011-0360-x

SHORT COMMUNICATION

Response of different maturity stages of sapota (*Manilkara achras* Mill.) cv. Kallipatti to in-package ethylene absorbent

Wangdup Bhutia · R. K. Pal · Sangita Sen · S. K. Jha

Revised: 3 January 2011 / Accepted: 31 March 2011 / Published online: 12 April 2011
© Association of Food Scientists & Technologists (India) 2011

Abstract Sapota fruits are highly perishable due to their climacteric nature. The rapid softening of fruits is primarily due to high activity of many oxidative enzymes and liberation of ethylene. Harvest maturity plays a crucial role in deciding the marketability of climacteric fruits in general. Attempt has been made to evaluate the response of ethylene absorbent on variable maturity groups of harvested Sapota cv. Kallipatti with the objective to delay the ripening during transit and extend its marketability during storage at ambient condition (27–32 °C & 65–75% R.H.). Harvested fruits having three different degree of ripeness (as maturity indices viz. mature, half-ripe and ripe) were packed with or without ethylene absorbent sachets (Bioconservación, France) in 10 kg CFB boxes and transported from Dahnu to Delhi covering a distant of approximately 2500 KM by truck on road along with conventional packaging as control. The fruits were evaluated immediately on arrival at Delhi and subsequently during storage for various physical, physiological, biochemical and decay parameters. Mature fruits with ethylene absorbent exhibited maximum delay in ripening, low ethylene liberation, weight loss and high fruit firmness. The response of ethylene absorbent to extend the marketability of ripe fruit was not significant.

Keywords Maturity stage · Ethylene absorbent · Kallipatti · Respiratory rate · Sapota · Packaging

W. Bhutia · R. K. Pal (✉) · S. Sen · S. K. Jha
Handling and Storage Laboratory, Division of Postharvest Technology, Indian Agricultural Research Institute (IARI), Pusa, New Delhi 110012, India
e-mail: rkrishnapal@gmail.com

Introduction

In India, sapota ranks fifth both in production and consumption next to mango, banana, citrus and grapes. It is cultivated mainly in the coastal regions of India from where it is distributed throughout the country. Sapota is a climacteric fruit (Lakshminarayana and Subramanyam 1966; Broughton and Wong 1979) and its rapid postharvest ripening and senescence followed by spoilage is due to high rate of ethylene liberation. Reducing the level of ethylene in the atmosphere around harvested sapota could delay the onset of its ripening. One of the simplest ways to remove ethylene from the atmosphere is to absorb and oxidize it with potassium permanganate to produce CO_2 and H_2O. The ability of potassium permanganate in reducing the ethylene concentration in the atmosphere around horticultural produce was first demonstrated by Forsyth et al. (1967) in apples. It was demonstrated that $KMnO_4$ retarded the ripening of many fruits (Scott et al. 1970; Wills et al. 1989).

The Kallipatti cultivar represents a major proportion of export of sapota from India, nevertheless, information on its postharvest physiology, degree of ripeness for long distant marketing is either scanty or nil. Hence, this study was undertaken to generate the information on the efficacy of in-package ethylene absorbent with respect to the degree of ripeness of harvested sapota for extending its marketability.

Materials and methods

Sapota (*Manilkara achras* Mill.cv. Kalipatti) fruits were obtained from a commercial fruit grower at Dahnu,

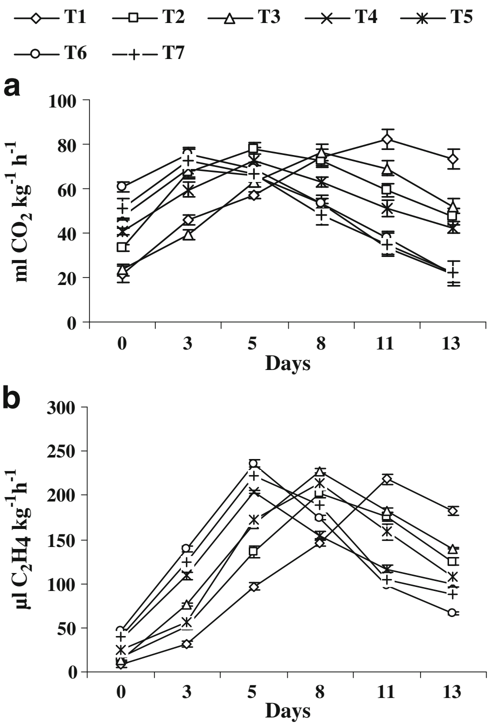

Fig. 1 Effect of harvesting stages and ethylene absorbent on respiratory rates (**a**) and ethylene production (**b**) of Sapota cv. Kallipatti during ripening at ambient (25–29 °C) for 13 days; *n*=3. *Vertical bars* represent S.E. of Means. T_1: Mature + ethylene absorbent; T_2: Mature; T_3: Half Ripe + ethylene absorbent; T_4: Half Ripe; T_5: Ripe + ethylene absorbent; T_6: Ripe; T_7: Control-Conventional Method

Maharashtra State. Fruits were harvested at three different stages viz. mature, half ripe and ripe stage based on skin color, texture, ease of removal of pedicel and skin dust during washing (Edy and Narendra 2002). These were sorted for uniformity in size and freedom from defects.

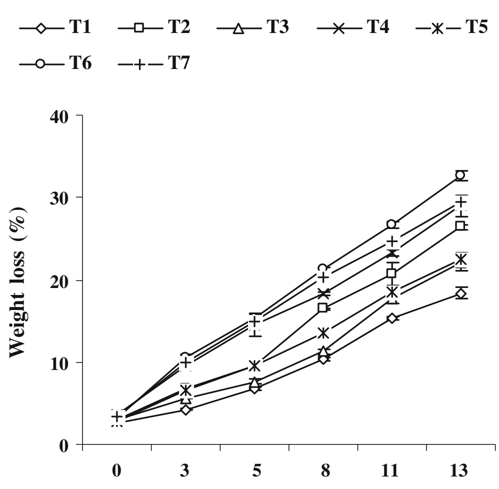

Fig. 2 Effect of harvesting stages and ethylene absorbent on physiological loss in weight of sapota cv. Kalipatti during ripening at ambient (25–29 °C) for 13 days; *n*=3. *Vertical bars* represent S.E. of Means. Refer Fig. 1 for treatment details

Packaging and transport of sapota Ten kg fruits from each maturity class were packed separately in corrugated fiber board (CFB) three ply boxes of 14″×12″×12″ dimension without vent holes. The boxes were cushioned with paper shredding and four super-absorbent sachets of Bioconservación containing $KMnO_4$ impregnated inert materials having capacity to absorb 7 ml of ethylene per pouch. For each maturity class three boxes were transported. These fruits were brought to the Postharvest Handling and Storage Laboratory at Indian Agricultural Research Institute (IARI), New Delhi. It took 2 days to reach the laboratory. In the laboratory, fruits were again sorted to remove bruised and defective ones. On 3rd day of harvesting observation on physiological and biochemical parameters were recorded and fruits of different maturity stages packed in similar condition with or without ethylene absorbent were kept at ambient condition (27–32 °C with 70±5% R.H.) for further observation. The conventionally packed fruits kept without any cushioning materials or ethylene absorbent or maturity grading at ambient condition served as control.

Measurement of ethylene evolution and respiration rates Ethylene evolution and CO_2 production by fruits were measured immediately after transport i.e., 2 days after harvest and thereafter subsequently at 3 days interval during storage using static headspace gas analysis technique. Three fruits from each replication were selected at random and enclosed in a hermetically sealed container (1,000 ml), fitted with a silicon rubber septum, for 1 h or less. The concentrations of O_2 and CO_2 were recorded in the headspace of container using a gas analyzer (Model Checkmate 9900 O_2/CO_2, PBI Dansensor, Denmark). The rate of respiration was expressed as ml CO_2 kg^{-1} h^{-1}. To determine ethylene, 1 ml of the headspace atmosphere of the container was withdrawn with a gas tight syringe and injected into a gas chromatograph (Model HP 5890, Hewlett Packard, USA) which was calibrated using standard ethylene gas (Laser Gases, New Delhi). The gas chromatograph was equipped with Porapak-N (80–100 mesh) column and a flame ionization detector (FID). Nitrogen was used as the carrier gas at a flow rate of 30 ml min^{-1}, while hydrogen and air were fuel gases which had flow rates of 25 and 250 ml min^{-1}, respectively. The temperatures of injector, column and detector were maintained at 110, 60 and 275 °C, respectively. The ethylene production rate was expressed as μL kg^{-1} h^{-1} as described by Singh and Pal (2008).

Measuring the fruit firmness Fruit firmness was measured using a texture analyzer (Model: TA+Di, Stable Micro

Table 1 Effect of harvesting stages and ethylene absorbent on firmness (Kg) of Sapota cv. Kalipatti

Treatment**	Days after harvest				
	At harvest	3	8	13	Mean (days storage)
T_1	3.5^{a}	$*3.2^{ab}$	2.4^{d}	1.1^{g}	2.5
T_2	3.5^{a}	1.8^{e}	1.1^{g}	1.0^{gh}	1.8
T_3	3.1^{b}	2.9^{bc}	1.9^{e}	1.2^{fg}	2.3
T_4	3.1^{b}	1.9^{e}	1.0^{g}	0.9^{gh}	1.7
T_5	2.8^{bc}	2.5^{cd}	1.6^{ef}	1.2^{fg}	2.0
T_6	2.8^{bc}	1.2^{g}	0.6^{hi}	0.2^{j}	1.2
T_7	2.9^{b}	1.7^{e}	1.2^{g}	0.5^{ij}	1.6
Mean	3.1	2.2	1.4	0.9	
C.D. (0.05) for treatment means = 0.2					
C.D. (0.05) for storage interval means = 0.1					

(n=3)

*Mean values of a parameter irrespective to treatments and storage intervals followed by the same lower-case superscript letters (a–i) are not significantly different (LSD, $P<0.05$)

**Refer Fig. 1 for treatment details

Systems, UK) using puncture test. The mean values of the firmness were expressed as kilogram (Kg) of force.

Estimating the soluble solids content (SSC), titratable acidity (TA) and total sugar For determination of SSC and TA, five fruits per replication were homogenized and the homogenates filtered through a cheese cloth to obtain clear juice. The SSC (%) was recorded with a hand refractometer (Model: Fisher, Japan) and the values were corrected to 20 °C. The other biochemical parameters viz., total sugar and TA were determined as per the method described by Singh and Pal (2008).

Calculating decay incidence Percentage of decay incidence was calculated from the number of fruits that showed sign of decay over the initial number of fruits. The cumulative decay during storage and ripening was recorded and expressed as a percentage.

Statistical analysis The experiment was laid out in a completely randomized design in a factorial layout with two factors viz. maturity stages and ethylene absorbent. The results were subjected to analysis of variance (ANOVA) and the treatment means were compared using the least significant difference (LSD) values at a significance level of $P<0.05$. All analyses were conducted using procedures of the Statistical Analysis System (SAS Institute Inc., Cary, NC, USA). For respiration and ethylene production rates, means ± S.E. are presented.

Results and discussion

Ethylene absorbent treatment exhibited low ethylene and CO_2 production immediately after long distance transportation and subsequent ambient storage depending upon the maturity stages of the fruit (Fig. 1). Fruits at ripe stage showed higher rate of ethylene and CO_2 evolution as compared to mature and half ripe stage. Fruits packed with ethylene absorbent sachets showed minimum rate of ethylene and CO_2 evolution irrespective of the maturity stages. The highest rate of ethylene evolution was detected on 5th day of storage in ripe fruits stored without ethylene

Table 2 Effect of harvesting stages and ethylene absorbent on SSC (%) of Sapota cv. Kalipatti

Treatment**	Days after harvest				
	At harvest	3	8	13	Mean days storage
T_1	19.0^{l}	$*19.8^{jk}$	21.2^{i}	23.8^{ef}	21.0
T_2	19.0^{l}	22.9^{h}	24.4^{d}	24.9^{bc}	22.6
T_3	19.7^{k}	20.3^{j}	22.2^{h}	23.7^{ef}	21.5
T_4	19.7^{k}	23.7^{fg}	24.9^{bc}	25.1^{b}	23.3
T_5	20.1^{jk}	21.2^{i}	23.2^{g}	24.6^{cd}	22.3
T_6	20.1^{jk}	23.5^{fg}	24.4^{d}	25.6^{a}	23.4
T_7	19.9^{jk}	22.3^{h}	24.2^{d}	24.4^{d}	22.7
Mean	19.7	21.8	23.5	24.6	
C.D. (0.05) for treatment means = 0.3					
C.D. (0.05) for storage interval means = 0.2					

(n=3)

*Mean values of a parameter irrespective to treatments and storage intervals followed by the same lower-case superscript letters (a–i) are not significantly different (LSD, $P<0.05$)

**Refer Fig. 1 for treatment details

Table 3 Effect of harvesting stages and ethylene absorbent on TA (%) of Sapota cv. Kalipatti

Treatment**	Days after harvest				
	At harvest	3	8	13	Mean days storage
T_1	0.5^b	*0.3^b	0.2^b	0.2^a	0.3
T_2	0.4^b	0.2^a	0.1^a	0.1^a	0.2
T_3	0.3^b	0.2^b	0.2^a	0.1^a	0.2
T_4	0.3^b	0.1^a	0.1^a	0.1^a	0.2
T_5	0.3^b	0.2^b	0.2^a	0.1^a	0.2
T_6	0.3^b	0.1^a	0.1^a	0.0^a	0.1
T_7	0.3^b	0.2^a	0.1^a	0.1^a	0.2
Mean	0.3	0.2	0.1	0.1	

C.D. (0.05) for treatment means = 0.2

C.D. (0.05) for storage interval means = 0.1

(n=3)

*Mean values of a parameter irrespective to treatments and storage intervals followed by the same lower-case superscript letters (a–i) are not significantly different (LSD, $P<0.05$)

**Refer Fig. 1 for treatment details

absorbent sachet. Ethylene absorbent reduced the rate of ethylene evolution in half ripe and mature fruits. Peak of respiration was observed before the peak of ethylene production. The maximum rate of respiration was observed in control and ripe fruits without ethylene absorbent. This result (Fig. 1) is in agreement with the findings of Ben-Arie and Zutkhi (1992). Active ingredient ($KMnO_4$) present in ethylene absorbent might have oxidized the ethylene gases into harmless CO_2 and water. Rates of ethylene evolution were also dependent on the maturity stages of fruit. Maturity stages determined the rate and intensity of physiological changes in the fruit. At ripe stage, rate and intensity of ethylene evolution and CO_2 production was higher than mature stage and half ripe stage. Low ethylene production rates and consequently the delay of ripening could probably increase the produce resistance to water loss (Fig. 2). Pekmezci et al. (2004) reported that loss in weight of kiwifruit in mature stage is lesser comparison with ripe fruits. More loss in ripe fruits at the end of storage could be due to larger amount of loss of respiratory substrates.

Increased weight loss was observed with the increase in storage period irrespective of the treatment. Ripe fruit exhibited high rate of weight loss as compared to mature and half ripe ones. Fruits from each maturity stages treated with ethylene absorbent showed less weight loss as compared to fruits without ethylene absorbent (Fig. 2). The fruit firmness followed a normal declining trend with the advancement of storage duration after harvest. Ethylene absorbent significantly retained the firmness of sapota fruits after harvest. Fruit firmness of mature fruits at harvest was significantly higher than half ripe and ripe fruits. Firmness retention was significantly higher in fruits treated with ethylene absorbent irrespective of the maturity stages on 3rd day of harvesting. Retention of firmness on 8th day was significantly low in all cases compared to 3rd day. But the less retention of firmness was observed in all untreated fruits irrespective of the maturity stages. At the end of 13 days, all the treated fruits had significantly higher firmness retention (>1 kg) than control (Table 1). The loss of firmness with the advancement of storage period could be due to enhancement of ripening process. It has been

Table 4 Effect of harvesting stages and ethylene absorbent on total sugar (%) of Sapota cv. Kalipatti

Treatment**	Days after harvest				
	At harvest	3	8	13	Mean days storage
T_1	8.0^n	*8.8^{kl}	9.3^j	10.3^h	9.1
T_2	8.0^n	9.7^i	10.5^{gh}	11.5^e	9.9
T_3	8.2^{mn}	9.2^{jk}	9.8^i	10.9^{fg}	9.5
T_4	8.2^{mn}	10.3^h	11.9^d	12.7^{bc}	10.8
T_5	8.6^l	9.7^i	11.3^e	12.9^b	10.7
T_6	8.6^l	12.4^c	13.7^a	13.8^a	12.1
T_7	8.6^{lm}	11.3^{ef}	12.3^c	12.9^b	11.3
Mean	8.3	10.2	11.3	12.2	

C.D. (0.05) for treatment means = 0.2

C.D. (0.05) for storage interval means = 0.1

(n=3)

*Mean values of a parameter irrespective to treatments and storage intervals followed by the same lower-case superscript letters (a–i) are not significantly different (LSD, $P<0.05$)

**Refer Fig. 1 for treatment details

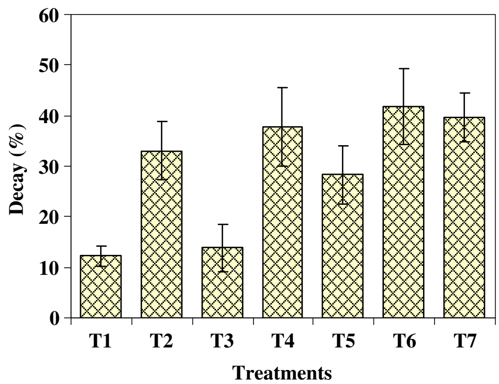

Fig. 3 Effect of harvesting stages and ethylene absorbent on decay percentage of Sapota cv. Kalipatti during ripening at ambient (25–29 °C) for 13 days; $n=3$. *Vertical bars* represent S.E. of Means. Refer Fig. 1 for treatment details

observed that the hydrolysis of starch (Garcia and Lajolo 1988; Diaz-Perez et al. 2000) and pectin degradation of the cell walls of the flesh parenchymatous tissue (Arenas-Ocampo et al. 2003) occurred during ripening process. Similar decrease in the fruit softening of Japanese Persimon fruits by use of ethylene absorbent was reported by Kurahashi et al. (2005).

Soluble solids content increased gradually after harvest with the advancement of storage duration as was expected. In-package ethylene absorbent significantly checked the rapid increase in soluble solids throughout the storage period in mature and half-ripe fruits. The response of ethylene absorbent in ripe fruits was inconsistent during the storage with respect to the changes in SSC. The SSC was found maximum in ripe fruits (20.12%) and minimum (19.03%) in mature fruits at harvest. The rate of increase in SSC was delayed by ethylene absorbent application irrespective to stage of harvest (Table 2). Vijayalakshmi et al. (2004) also reported similar results in sapota cultivars CO 1 and CO 2 by ethylene absorbent treatment. The SSC level of 20% was found to be optimum palatable.

The content of TA decreased with the advancement in degree of ripeness (Table 3). Fruits at mature stage recorded the maximum (0.38%) TA content whereas it was minimum at ripe stage (0.28%) at the time of harvest. Fruits treated with ethylene absorbent showed significant high value of TA throughout the storage duration irrespective of the maturity stages. There was no significant difference in TA between the fruits harvested at half ripe and ripe stages. More retention of TA was directly correlated with the low content of soluble solid (Table 2).

Total sugar content of sapota fruits increased with the advancement in storage duration. Fruits harvested at ripe stage showed maximum (8.63%) content of total sugar as compared to fruits at mature and half ripe stages. Ethylene absorbent significantly slowed down the accumulation of total sugar during storage (Table 4). At the end of storage period mature fruits had lower total sugar content than other fruits. Reddy and Haripriya (2002) also reported similar slow accumulation of total sugars and high retention of acidity in mango cv Bangalora when treated with ethylene absorbent. All these biochemical changes are observed in ethylene induced ripening and senescence. This is supported by the present finding on rate of ethylene evolution of sapota fruits (Fig. 1). Bairwa and Dashora (1999) observed that application of $KMnO_4$ resulted in low total sugar accumulation at the end of storage in mature and half ripe banana fruits.

Ethylene absorbent lowered down the decay incidence in sapota fruits irrespective of the maturity stage. At the end of 13 days of storage the minimum cumulative decay incidence (less than 12%) was observed in mature and half ripe fruits. Incidence of decay was more than 30% in fruits packed without ethylene absorbent irrespective to the degree of ripeness. Fruits packed with ethylene absorbent on the 13 day of storage had significantly low decay (Fig. 3). Low ethylene production rates and subsequent delay in ripening probably increase product resistance to decay incidence. Observations by Szczerbanik et al. (2005) with respect to reduced severity of decay incidence by ethylene absorbent support the findings.

Conclusion

The study revealed that use of ethylene absorbent in CFB boxes during long distant transportation and subsequent ambient storage could be a promising postharvest technology for delaying softening, decay development and weight loss without much altering SSC, TA and total sugar content. This is primarily due to lowering down the ethylene accumulation in the package thus blocking the autocatalytic production of ethylene and slowing down the metabolic activities. The use of in-package ethylene absorbent is dependent on degree of ripeness of sapota. The response of in-package ethylene absorbent was maximum in mature fruits. Ethylene absorbent has the potential to delay ripening of sapota fruit and extend marketable life up to 13 days at ambient temperature (25–27 °C) if harvested at mature stage as evident from the drastic reduction of post harvest decay (from approximately 40% to around 12–15%, Fig. 3).

References

Arenas-Ocampo ML, Evangelista-Lozano S, Arana-Errasquin R, Jimenez-Aparicio AR, Davila-Ortiz AG (2003) Softening and biochemical changes of zapote mamey fruit (Pouteria sapota) at different development and ripening stages. J Food Biochem 27:91–107

Bairwa LN, Dashora LK (1999) Effect of KMnO4 and $AgNO_3$ on post-harvest shelf-life of banana (Musa paradisiaca L.). Adv Hortic For 7:9–15

Ben-Arie R, Zutkhi Y (1992) Extending the storage life of 'Fuyu' persimmon by modified atmosphere packaging. Hortic Sci 27:811–813

Broughton WJ, Wong HC (1979) Storage conditions and ripening of chiku fruits *Achras sapota* L. Sci Hortic 10:377–385

Diaz-Perez JC, Bautista S, Villanueva R (2000) Quality changes in sapota mamey fruit during ripening and storage. Postharvest Biol Technol 18:67–73

Edy B, Narendra N (2002) Physical and chemical characteristics of sapota fruit at different stages of maturation. Pesqui Agropecu Bras 37:127–134

Forsyth FR, Eaves CA, Lockhard CL (1967) Controlling ethylene levels in the atmosphere of small containers of apples. Can J Plant Sci 47:717–718

Garcia E, Lajolo FM (1988) Starch transformation during banana ripening: the amylase and glucosidase behavior. J Food Sci 53:1181–1186

Kurahashi T, Matsumoto T, Itamura H (2005) Effects of 1-methylcyclopropene (1-MCP) and ethylene absorbent on softening and shelf life of dry ice-treated Japanese persimmon 'Saijo' harvested at various maturation stages. J Jpn Soc Hortic Sci 74:63–67

Lakshminarayana S, Subramanyam H (1966) Physical, chemical and physiological changes in sapota fruit [*Achras sapota* Linn. (Sapotaceae)] during development and ripening. J Food Sci Technol 3:151–154

Pekmezci M, Erkan M, Gubbuk H, Karasahin I, Uzun I (2004) Modified atmosphere storage and ethylene absorbent enables prolonged storage of 'Hayward' kiwifruits. Acta Hortic 632:337–341

Reddy NS, Haripriya K (2002) Extension of storage life of mango cvs. Bangalora and Neelum. South Indian Hortic 50:7–18

Scott KJ, McGlasson WB, Roberts EA (1970) Potassium permanganate as an ethylene absorbent in polyethylene bags to delay ripening of bananas during storage. Aust J Exp Agric Anim Husb 10:237–240

Singh SP, Pal RK (2008) Response of climacteric-type guava (*Psidium guajava* L.) to postharvest treatment with 1-MCP. Postharvest Biol Technol 47:307–314

Szczerbanik MJ, Scott KJ, Paton JE, Best DJ (2005) Effects of polyethylene bags, ethylene absorbent and 1-methylcyclopropene on the storage of Japanese pears. J Hortic Sci Biotechnol 80:162–166

Vijayalakshmi D, Bangarusamy U, Vijayakumar RM (2004) Post-harvest treatments to extend the shelf life of sapota fruit cultivars Co 1 and Co 2. Crop Res (Hisar) 27:219–226

Wills RBH, McGlasson WB, Graham D, Lee TH, Hall EG (1989) Postharvest an introduction to the physiology and handling of fruit and vegetables. Chapman & Hall Inc., New York