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Effect of Ethylene Concentration and Exposure Time on Physico-Chemical Quality and Colour Value of Sapota Fruit (*Manilkara zapota*)

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A study was conducted to optimize the ethylene concentration and exposure time for the ripening of sapota fruit. The fruits were ripened in the metal chamber with three different ethylene concentration (50, 100 and 150 ppm) and exposure time (12, 24 and 36 h). The ethylene treated fruits were analyzed for the quality parameters *viz.,* firmness, physiological loss in weight, pulp to peel ratio, total soluble solid, pH, colour values and organoleptic score. The fruits treated with 100 ppm ethylene concentration for an exposure time of 24 h ripened in 2 days had 2.75 N firmness, 4.1 % physiological loss in weight, 15.89 pulp to peel ratio, 4.93 pH, 24.6° Brix total soluble solid and L value of skin 36.84, a value of skin 8.3, b value of skin 8.3 and scored maximum overall acceptability value of 8.56.

Keywords: Ripening, Sapota, Ethylene treatment, Firmness, Colour, Pulp to peel ratio.

INTRODUCTION

Sapota (*Manilkara zapota*) is the climacteric fruit due to their highly perishable nature [1]. It possesses a delicate characteristic aroma, taste and nutritional value. India is the largest producer of sapota in the world account of 14.57 lakh tonnes in 2014-15 [2,3]. It is widely grown in the coastal regions of India. The popularity of this fruit crop is increasing due to continuous fruiting throughout the year, high production per unit area and very little incidence of pests and disease [4]. Average post harvest losses of sapota in India increased from 5.77 and 9.73 % during 2010 and 2015, due to improper post-harvest management [3].

Ripening is one of the post-harvest management practices, which involve high initial investment and operational cost. Lack of rapid and simple methods for uniform and complete ripening poses a major problem in the fruit processing industry. Normally, the number of days taken for edible ripening of fruits varies for different nature of fruits and prevailing climacteric conditions. For instance, it takes 5 to 7 days for mango and 6 to 7 days for sapota to ripen. In developed countries, fruits are ripened in an artificial chamber having no health hazards. But in India, traders are still using the chemicals like calcium carbide in order to make quick profits. As per PFA Act Section 44AA, use of calcium carbide is banned. The safe, hygienic and widely accepted method of fruit ripening is using natural ethylene gas, which is duly approved by Agricultural and Processed Food Products Export Development Authority (APEDA).

Ethylene is a natural hormone does not pose any health hazards to consumers. Modern ripening chambers used ethylene gas from ethylene generators, cartridges and ethylene cylinders, which required high initial investment and improved skill laborers for proper functioning of the chambers, as ethylene is considered to be unsafe and highly flammable gas. One of the alternative and cost-effective techniques is mixing ethrel with alkali solution in wide mouth vessel to liberate ethylene gas in an air tight chamber. It does not require any special skilled labor and consider being the cheapest method, which makes the farmers easy and convenient to use. Also the ripening in cold storage condition fetches more cost. The PKM 1 cultivar represents a major proportion of export variety from India, nevertheless, information on its post-harvest physiology and degree of ripeness is either scanty or nil. Hence, this study was undertaken to generate an information on the effect of ethylene concentration (50, 100 and 150 ppm) and exposure time (12, 24 and 36 h) on the physico-chemical properties of sapota.

EXPERIMENTAL

Sapota (Variety: PKM 1) were procured from the experimental orchard of Tamil Nadu Agricultural University,

Coimbatore, India. Random samples were drawn from a freshly harvested lot at the time of harvest.

Ripening chamber: An airtight chamber was made with mild steel at 0.064 m^3 volume used for ripening of sapota. It consists of two small holes (3 mm diameter) closed by means of the septum for gas analysis. In addition, polyurethane was pasted in the door to avoid the leakage of the ethylene gas. A small fan was kept inside for uniform distribution of ethylene gas. Sapota ripening study was conducted in the metal chamber at room condition (26 °C and 85-90 % RH). On ethylene treatment the sapota fruits were exposed to different concentrations of ethylene gas (50, 100 and 150 ppm) and exposure time (12, 24 and 36 h).

Physico-chemical characteristics

Physiological loss in weight (PLW): The physiological loss in weight (PLW) was calculated as weight based on the initial fruit weight (before ethylene treatment) and weight recorded at the end of the ethylene treatment. Physiological loss in fruit weight was calculated by the formula given below:

$$\text{PLW}\ (\%) = \frac{\text{Initial weight (g)} - \text{Final weight (g)}}{\text{Initial weight (g)}} \times 100 \quad (1)$$

Pulp to peel ratio: The pulp and peel components of individual sapota fruits were separated and weighed using electronic balance with an accuracy of ± 0.01 g. The ratio of pulp to peel was determined as per the following equation.

$$\text{Pulp to peel ratio} = \frac{\text{Weight of pulp (g)}}{\text{Weight of peel (g)}} \quad (2)$$

Firmness: Firmness of both fresh and ethylene exposed sapota fruit was determined using Texture Analyzer (model: TAXT2, Stable Microsystems). A needle probe of the Texture Analyzer attached to the probe carrier was used to measure the firmness. The load cell was calibrated to 50 N and the firmness was done at a speed of 1 mm/s. Firmness was considered as the first peak force in N. The average values of 10 replications of each treatment are reported.

pH: pH is a measure of the active acidity, which influences the flavour or palatability of a product and affects the processing requirements. It was determined by using a digital pH meter.

Total soluble solids: The total soluble solid (TSS) of fruit pulp was measured with the help of digital hand refractometer. It is expressed as °Brix.

Colour value: The colour change of sapota fruit was measured using colour flex meter (Hunter Associates Laboratory, Virginia) at a wave length ranging from 400 to 700 nm in terms of L (lightness), a (redness and greenness) and b (yellowness and blueness). The sensor was standardized with a black tile and white tile to measure the colour. Mean of six readings is reported.

Organoleptic evaluation: Descriptive sensory quality of the fruits such as appearance, colour, flavour, texture (finger feel), taste and overall acceptability was accessed using 9-point Hedonic scale varying from like extremely (rated as 9) to dislike extremely (rated as 1) by the panel of semi-trained judges.

Statistical analysis: Statistical analysis was carried out to study the effect of different parameters on the dependent variables (physiological loss in weight, pulb to peel ratio, firmness, pH and total soluble solid) by Factorial Completely Randomized Block Design (FCRD) using the statistical software AGRES [5-7]. Analysis of variance (ANOVA) was conducted to determine whether significant effect exists among ethylene concentration and exposure time on ripening of sapota fruits.

RESULTS AND DISCUSSION

Physiological loss in weight (PLW): Fig. 1 shows the physiological loss in weight of sapota fruits treated with different ethylene concentration and exposure time. Where, the highest percentage of (9.9 %) physiological loss in weight was observed in the samples exposed to 150 ppm of ethylene concentration for 36 h while the lowest value (2.2 %) were recorded in the samples exposed to 50 ppm of ethylene concentration for 12 h. It is evident that the physiological loss in weight increased with increase in ethylene concentration and exposure time. This might be due to respiration and transpiration of water through peel tissue and other biological changes in the fruit [8]. The rate of increase in respiration is correlated with the increase in ethephon concentrations [9]. Weight loss during ripening is an important factor, which adversely affects the appearance, flavour and weight of fruit. Banana ripened at higher relative humidity (90 to 95 %) showed less weight loss per day than those at lower relative humidity levels (60 to 65 %) [10]. A study on ripening behaviour of guava fruits treated with ethylene and ethephon are found to be the highest physiological loss in weight (4.8 %) as compared to control (1.9 %) [11]. F value of ethylene concentration, exposure time and associated interaction were significant at 1 % ($P < 0.01$) level on the physiological loss in weight of the fruit (Table-1).

Pulp to peel ratio: From the Fig. 1, it is observed that the pulp to peel ratio increases with increase in ethylene concentration and exposure time. The highest pulp to peel ratio (16.4) was recorded for the samples exposed to 150 ppm of ethylene for 36 h while the lowest pulp to peel ratio (13.2) was recorded for the samples exposed to 50 ppm of ethylene concentration for 12 h. Rise in pulp to peel ratio during fruit ripening was suggested due to change in sugar concentration in the two tissues. A rapid increase in sugar contents in the pulp compared to peel cause to a change in osmotic pressure, as a result of which water gets withdrawn from the peel. Hence, the pulp to peel ratio increases accordingly to sugar concentration changes [12]. Kulkarni *et al.* [13] observed that the pulp to peel ratio of ethrel treated banana fruits increases with an increase in the ethrel concentration during ripening. Little change in pulp to peel ratio was recorded in the control during storage. This confirms the results of present study. The ethylene concentration, exposure time and associated interaction were significant ($P < 0.01$) on the pulp to peel ratio of the fruit (Table-1).

Firmness: Fig. 1 shows that the highest firmness of 4.1 N was observed for the sapota samples exposed for 12 h with 50 ppm ethylene concentration, while the lowest firmness of 1.2 N was recorded in the samples exposed to 150 ppm of ethylene for 36 h in the metal chamber. The rapid decrease in firmness value was observed for 100 ppm ethylene concentration and 24 h exposure time, after that a mild decrease in

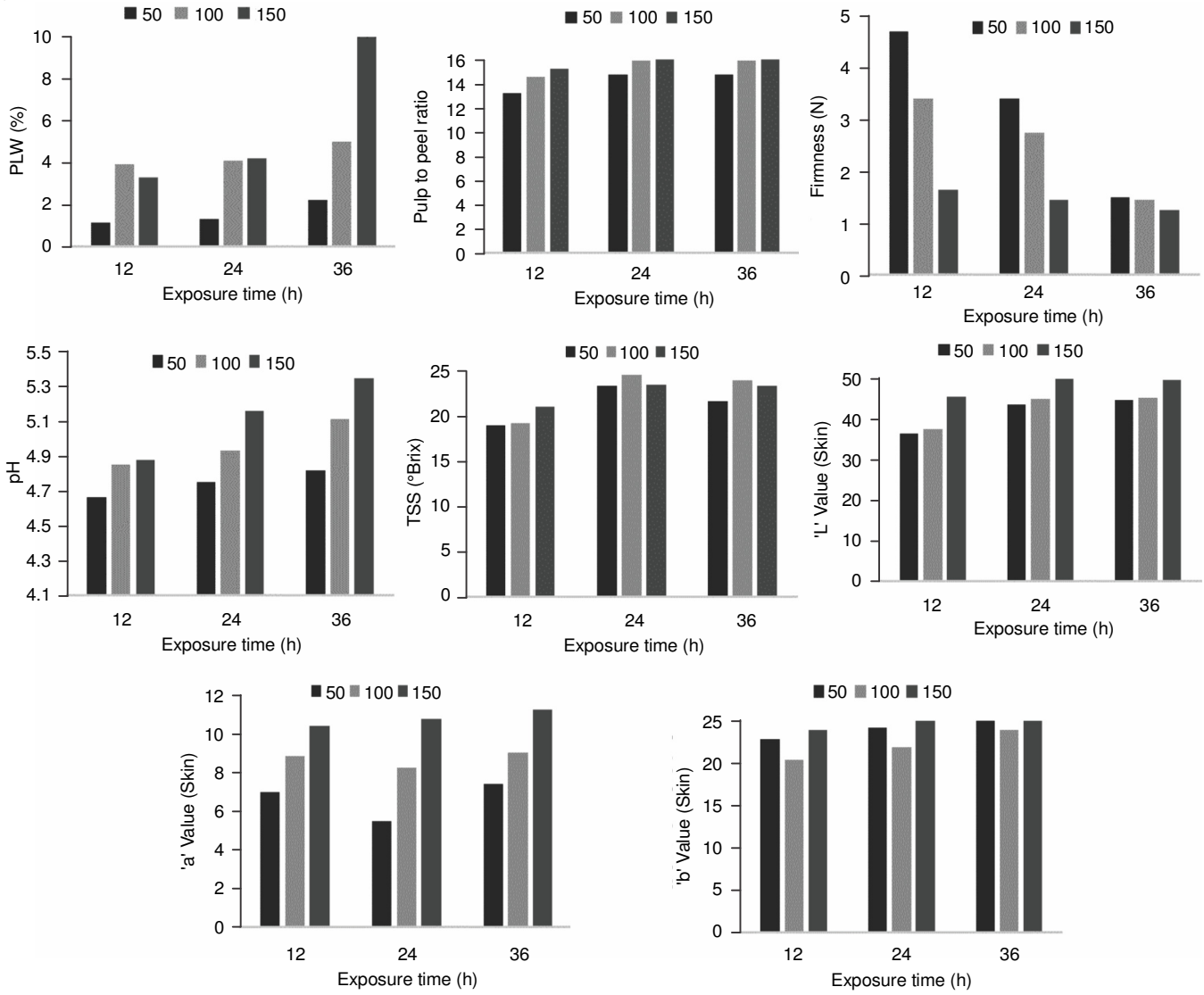

Fig. 1. Effect of ethylene concentration and exposure time on physico-chemical quality and colour value of sapota fruit

TABLE-1
ANALYSIS OF VARIANCE FOR PHYSICO-CHEMICAL PROPERTIES AND COLOUR VALUE OF ETHYLENE TREATED SAPOTA FRUIT

Source	Physico-chemical properties					Colour value		
	PLW	Pulp to peel ratio	Firmness	pH	TSS	L	a	b
Ethylene conc., ppm (C)	921.29**	116.36**	142.96**	117.31**	67.43**	17579.11**	26211.98**	39336.10**
Exposure time, h (T)	1168.68**	1283.45**	40587.39**	522.99**	1287.04**	2649344.51**	6396.87**	608013.01**
C*T	211.24**	12.51**	45.69**	19.70*	35.89**	6091.31*	11704.74*	4603.72**
Total	189.71	119.49	3495.60	55.59	121.00	261548.33	4053.34	55153.07

PLW = Physiological loss in weight, TSS = Total soluble solids, *Significant at 5 % level, **Significant at 1 % level

firmness was observed. The decrease in the texture of fruits may be due to a breakdown of insoluble protopectin into soluble pectin or by cellular disintegration leading to membrane permeability [14]. Changes in pulp texture of sapota during fruit development have been related to continuous enzymatic hydrolysis of pectinmethylesterase (PME), polygalacturonase (PG) and O-galactosidase (P-GAL) on cell wall components. Duan *et al*. [15] observed that the firmness of banana during ripening decreased rapidly from the initial value 11.6 to 1.8 N after 20 days of storage at 25 °C. Firmness decreased rapidly during ripening, which was associated with the increase in the water soluble pectin and the decrease in the acid soluble pectin. Table-1 showed that ethylene concentration, exposure time and associated interaction were significant at 1 % ($P < 0.01$) level on the firmness of the fruit.

pH: From Fig. 1, it is observed that when ripening proceeds, the pH value decreases and the decreases in pH was observed with an increase in ethylene concentration and exposure time. This could be due to an increase in organic acids after ripening [16]. At the time of harvest the pulp pH was 6 and after ethylene

treatment the pH was decreased to 4 at the fully ripe stage [17]. Ward and Nussinovitch [18] reported that the pH of dwarf cavendish banana decreased from 5.4 at stage 1 to about 4.5 at stage 8 during ripening. The decreasing trend in pH at 150 ppm of ethylene concentration may be due to over ripening which leads to the further hydrolysis of sugars. A similar trend in pH was reported by Lustre *et al.* [4]. From Table-1, it was observed that there is significant effect of ethylene concentration and exposure time ($P < 0.01$) on pH of sapota fruit.

Total soluble solids (TSS): Fig. 1 shows that the total soluble solid increased with increase an ethylene concentration. At 50, 100 and 150 ppm of ethylene concentration for 24 h exposure time, the total soluble solid was 23.3, 23.8 and 23.4 °Brix, respectively. There was no significant increase in total soluble solid for the ethylene concentration beyond 100 ppm. Hence, it is clear that 100 ppm is sufficient to ripen the sapota fruits. The rate of increase in total soluble solids was higher when the exposure level increased from 12 to 24 h. The increase in total soluble solid during ripening may result from an increase in concentration of organic solutes as a consequence of water loss [19]. A slight decrease in total soluble solid was observed in 36 h exposure time. This may be due to further hydrolysis of sugars. A similar trend in total soluble solid was reported by Rathore *et al*. [8] for banana. Mohamed-Nour and Abu-Goukh [20] also found that the maximum total soluble solid value reached by white and pink guava at 14 and 12 % in untreated fruits after 16 days, but depending on concentration, the ethrel and ethylene treated fruits reached the maximum total soluble solid value within 6 and 9 days earlier than untreated fruits. Table-1 shows that ethylene concentration, exposure time and associated interaction were significant at 1 % ($P < 0.01$) level.

Colour value

L value: The effect of exposure time and ethylene concentration on 'L' values of sapota during ripening is illustrated in the Fig. 1. It is observed that the lightness value increased during ripening. This may be due to the degradation of chlorophyll, which subsequently reveals the carotenoids pigments. When the exposure time increased from 24 to 36 h, decrease in 'L' value was observed. This might be due to the over-ripening of sapota leading to the development of brown colour. The fruits treated with ethylene (100 ppm) and ethephon (500 ppm) developed uniform yellow colour, whereas ethephon (750 and 1000 ppm) resulted in deep yellow colour with black spots on fruit surface leading to over-softening of fruits [20]. The colour of sapota fruit changed from yellowish brown (mature stage) to dark brown (over ripe stage) during ripening [21].

a value: Fig. 1 shows the increasing trend of 'a' values with an increase in exposure time and ethylene concentration. The increase in ethylene concentration result an increase in 'a' values. This may be due to the breakdown of chlorophyll leading to disappearance of green colour [22]. The highest 'a' value of 11.07 is observed in the samples treated with 150 ppm of ethylene for 36 h, while the lowest value (7.3) was found in samples treated with 50 ppm of ethylene for 12 h. Ethylene gas and ethephon treatment are known to accelerate the chlorophyll degradation and induce yellowness in green tissues [11]. The intensity of greenness in the peel of all ethrel treated fruits decreased with fruit ripening and attained least 'a' values of -2.2, -1.2 and -1.63 in 250, 500 and 1,000 ppm of ethrel treated fruits, respectively, on 6 days of storage [23].

b value: Fig. 1 shows that the 'b' value increase with increase in exposure time. The decrease in 'b' value was observed for the concentration of 50 ppm and 12 h exposure time. This may be due to the over ripening of fruits leads to the development of brown flecks. It is evident that the yellowness value ('b' value) increased during ripening might be due to the development of brown colour skin of fruit and change in colour of pulp from yellow to brown. It follows the same trend as that of lightness value [23]. Table-1 shows that the ethylene concentration and exposure time were significant ($P < 0.01$) on the colour values (L, a, b) of the fruit exception of interaction (ethylene concentration × exposure time) which was significant at five percent level ($P < 0.05$) for L and a values.

Organoleptic evaluation: Table-2 represents the hedonic scale for the sensory evaluation conducted for different treatments. From the table, it can be found that the overall acceptability of the ripened fruits ranged between 3.56 to 8.56. Sapota fruit ripened with 100 ppm ethylene concentration for an exposure of 24 h scored a maximum overall acceptability value of 8.56. This confirms that the sapota fruits ripened with optimum parameter (26° C and 85-90 % RH) in the metal chamber fetch the consumer's acceptability.

Conclusion

In general, it is observed that an increasing the ethylene concentration and exposure time resulted in accelerated rate of ripening and it took only 2 days to attain complete ripening of sapota fruit. The ethylene treatment significantly minimized the ripening time. Physico-chemical properties such as

TABLE-2
ORGANOLEPTIC EVALUATION OF ETHYLENE TREATED SAPOTA FRUIT

Quality characters	Sensory scores (9 point scale)								
	Concentration (ppm)								
	50			100			150		
	Exposure time (h)								
	12	24	36	12	24	36	12	24	36
Appearance	3.6	3.8	4.2	7.0	8.5	8.3	6.9	8.1	8.20
Colour	3.9	4.0	4.1	6.1	8.6	8.5	6.0	8.0	8.10
Texture	3.5	3.9	3.8	7.0	8.3	8.2	6.9	8.0	8.00
Flavour	3.8	3.9	3.7	7.1	8.6	8.1	6.0	8.1	7.90
Taste	3.0	3.2	3.4	6.8	8.8	8.5	7.0	7.7	7.60
Overall acceptability	3.5	3.7	3.8	6.8	8.5	8.3	6.5	7.86	8.02

physiological loss in weight, pulp to peel ratio and total soluble solid increased while the firmness, colour values and pH decreased during ripening of sapota fruit. The changes in physiological loss in weight, pulp to peel ratio, firmness, pH and total soluble solids during ripening of sapota fruits were found to be significant ($P < 0.01$) at 1 % level. A simple and exogenous ethylene treatment in a metal ripening chamber effectively replaces the use of high investment ethylene cylinders and generators.

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