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Effect of Storage Time and Storage Conditions on Physicochemical Quality of Sweet Orange (*Citrus sinensis L*)

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ABSTRACT

The effect of storage condition, maturity and storage time on the physicochemical quality of sweet orange (*Citrus sinensis L*) was investigated. Valencia orange was stored under two storage conditions; exposure to ambient room conditions (24-28^{0}C) and to direct sunlight (30-36^{0}C) Physicochemical qualities including Total Soluble Solids (TSS) vitamin C, pH, Titratable Acidity (TA), Total Sugars (TS) Sweetness Index(SI) and Astringency Index (AI) were analyzed over 13 days of storage. It was observed that storage conditions did not have significant effect ($p>0.05$) on TSS and TS. Thus, the exposure of orange to direct sunlight (30-36^{0}C) at the open market and ambient room conditions (24-28^{0}C) did not significantly change ($p>0.05$) TS and TSS of orange. However Storage time of orange had significant effect ($p<0.05$) on the vitamin C and TSS, but maturity of orange did not significantly change ($p>0.05$) TSS during storage. The orange samples kept under the two different storage conditions did not significantly differ ($p>0.05$) in vitamin C content. The reduction in vitamin C content of oranges stored at ambient room temperatures and those exposed to direct sunlight were similar and comparable. Storage time and the level of maturity of orange had significant effect ($p< 0.05$) on the vitamin C and TA.

KEY WORDS: Late Valencia orange, Storage days, Maturity, Sweetness index, Vitamin C, ambient temperature.

INTRODUCTION

Sweet orange (*Citrus sinensis L*) is the most commonly grown citrus fruit in Ghana and they grow and fruit well in all parts of the forest and transitional zones of the country Ghana, a high proportion of the production of sweet orange comes from the Ashanti, Brong Ahafo , Eastern, Central, Western and Volta Regions. The better known local cultivars in Ghana include, Shama, Asuansi, Obuasi and Anomabo [1]. The local varieties have been propagated for several years by means of seed and large number of strains and these types have evolved over the years in various localities as a result of mutation and natural selection [2]. Exotic varieties of orange which are grown in Ghana include Washington navel, Late Valencia, Hamlin and Mediterranean sweet. These vary in growth pattern plant size, colour, juiciness and sugar content. Sweet orange is widely marketed in local foodstuff markets in Ghana. The mode of display and storage of orange in these markets are typically by heaping orange on the bare floor under the mercy of the weather [3]. This mode of storage can affect the quality of the fruit as fruit maturity and storage temperatures determine the rate of conversion of total sugars to reducing sugars [4]. During growth and maturation of orange, sugars and transient starch may be transformed into sugars particularly sucrose, glucose and fructose in fruits [4]. These sugars may also be completely oxidized to carbon dioxide and water with the production of ATP (Adenosine Triphosphate the form in which energy is stored in plant cells) during the post-harvest period. These changes are largely dependent upon the conditions of storage such a temperature, time, maturity and physiological state of fruits [5].

The development of pleasant flavour characteristic for a particular fruit involves a decrease in acidity with corresponding increase in sugar content and the ratio of sugar to acid is particularly useful as index of ripeness. Temperature is the single most important factor in maintaining fruit quality after harvest [6]. Deterioration in market quality is primarily due to transpiration loss of moisture in the peel and pulp (when exposed to high temperatures) which speeds up senescence [7]. Sweet orange is non-climacteric and have low respiration rates, thus are quite amendable to long term storage. However, storage conditions of fruits are cultivar dependent and fruit quality changes occur during prolonged storage [8]. The quality of sweet orange is variable due to variation in skin thickness, juice content, and soluble solids content. The soluble solids content is also used as an indication of fruit maturity and quality [9].

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The production and marketing of Valencia is very lucrative, however there are high post-harvest losses and research on enhancing shelf life of this variety of orange is lacking. Marketing systems such as the mode of storage and handling practices can affect the quality of orange and increase post-harvest loses. The mode of storage at most markets is by openly displaying them on the bare ground or under sheds. Studies on assessing the effect of storage and display practices on quality of Valencia orange in the country is lacking. This study evaluated the effect of two storage conditions on the physicochemical quality of late Valencia orange.

MATERIALS AND METHOD

Materials

A batch of Valencia was bought from the local market, sent to the laboratory and divided into two, one part was stored ambient room temperatures (24-280C), and the other part from the same batch was kept in the open; (under direct sun 30-36 ^{0}Csimilarto how orange is displayed in the open market).

Sample preparation

Orange samples were washed under running tap water, cut into two halves and juice extracted using HAC-605A 40W electric orange squeeze. The Juice obtained was used to carry outphysicochemical analysis. Physicochemical analysis carried out were; Total Soluble Solids (TSS), Titratable Acidity (TA), Total Sugars (TS) and Vitamin C (VC), over 13 day period. Samples were analyzed every fortnight in the first week and daily in the second week).

Analytical methods

Total soluble solids was determined using the Abbe refract meter (AOAC 932.12, 1990). Vitamin C was determined by the Dichloroindophenol method [10], pH was determined using electronic TOA pH meter (HM 305 model japan).
Titratable Acidity of orange juice was evaluated at 28 ^{0}C as outlined in AOAC [10]; approximately 20.0ml of each sample was weighed into a conical flask and diluted with twice its volume of decarbonized distilled water. Two drops of phenolphthalein indicator was then added and titrated with 0.1N NaOH to the first pink acid. The acidity was reported as percentage citric acid by weight. Total sugars were estimated by anthrone [11].
Sweetness Index was derived as the ratio of percent soluble solids to TA (g citric acid /100ml fruit juice). Astringency Index (AI) was expressed as ratio of TA (g citric acid /100ml fruit juice) to percentage TSS. Determinations were done in triplicates.

Data Analysis

All analyses were done in triplicates. Analysis of variance (ANOVA) was used to determine the effect of storage conditions and storage days on the physicochemical quality of orange. Multiple range tests using (LSD at $p < 0.05$) was used for mean separation and to ascertain where differences existed. Data was statistically analyzed by STATGRAPHICS plus, version 3.0 (statistical graphic Corporation, STSC INC,USA).

RESULTS AND DISCUSSIONS

Table 1. Physicochemical attributes of Valencia Orange during storage at ambient conditions (24-28^{0}C).

Storage Time (Days)	LV_{MG}						LV_{MY}					
	TS	VC	TSS	TA	SI	AI	TS	VC	TSS	TA	SI	AI
1	5.62	162.3	10.5	0.99	10.61	0.09	6.55	133.2	10.5	0.95	11.05	0.09
3	6.01	154.0	10.5	0.86	12.21	0.08	6.34	115.5	10.5	0.94	11.17	0.09
5	6.66	125.4	10.0	0.94	10.64	0.09	6.35	101.5	10.0	0.64	15.63	0.06
7	6.23	77.0	9.0	0.80	11.25	0.09	6.41	83.8	10.0	0.64	15.63	0.06
9	6.38	65.4	9.0	0.71	12.68	0.08	6.57	56.7	9.5	0.67	14.18	0.07
10	6.44	62.5	9.0	0.77	11.69	0.09	6.52	54.9	9.5	0.71	13.38	0.07
11	6.48	61.9	9.0	0.75	12.00	0.08	6.57	50.6	9.5	0.67	14.18	0.07
12	6.49	58.5	9.0	0.71	12.68	0.08	6.55	47.4	9.5	0.66	14.39	0.07
13	6.55	58.7	9.0	0.72	12.50	0.08	6.61	50.0	9.5	0.69	13.77	0.07

Total Sugars (%)-TS; Vitamin C-VC (mg/100ml); Total Soluble Solids-TSS(%); Titratable Acidity-TA (% Citric Acid); Sweetness Index-SI and Astringency Index (AI) of Mature Green (LV_{MG})and mature yellow (LV_{MY})Fruits Stored at ambient room conditions (24-28 ^{0}C).Each value is the mean for three replicates.

Table 2: Physicochemical attributes of Valencia orange during storage at Stored in the open-under direct sun (30-36^{0}C).

Storage Time (Days)	LV_{MG}						LV_{MY}					
	TS	VC	TSS	TA	SI	AI	TS	VC	TSS	TA	SI	AI
1	6.55	133.2	10.5	0.95	11.05	0.09	5.84	150.4	10.5	0.91	11.54	0.09
3	6.34	115.5	10.5	0.94	11.17	0.09	6.63	139.8	10.5	0.81	12.96	0.08
5	6.35	101.5	10.0	0.64	15.63	0.06	6.52	112.7	10.0	0.94	10.64	0.09
7	6.41	83.8	10.0	0.64	15.63	0.06	6.05	72.7	10.0	0.69	14.49	0.07
9	6.57	56.7	9.5	0.67	14.18	0.07	6.38	69.6	10.0	0.60	16.67	0.06
10	6.52	54.9	9.5	0.71	13.38	0.07	6.25	61.2	10.0	0.72	13.89	0.07
11	6.57	50.6	9.5	0.67	14.18	0.07	6.07	57.9	9.5	0.70	13.57	0.07
12	6.65	47.4	10.0	0.66	15.15	0.07	5.32	57.9	9.5	0.74	12.84	0.08
13	6.61	50.0	9.5	0.66	14.39	0.07	6.05	58.5	9.5	0.75	12.67	0.08

Total Sugars-TS (%); Vitamin C-VC (mg/100ml); Total Soluble Solids-TSS(%); Titratable Acidity-TA (% Citric Acid); Sweetness Index-(SI) and Astringency Index (AI) of Orange Fruits Stored under direct sun (30-36 ^{0}C) for both Mature Green LV_{MG} and mature yellow LV_{MY} fruits

Table 3. Anova Table of P-values of quality Indices measured on Orange.

Process Variable	TA (%)	VC(mg/100ml)	TS (%)	TSS(%)
Storage condition	0.3191	0.299	0.8899	0.1081
Maturity	0.0215*	0.0002*	0.8113	0.1082
Storage time	0.0004*	0.0003*	0.5346	0.000*

*Values are significant $p<0.05$ at 95% confidence interval

Total Soluble solids (TSS)

A reduction in TSS of 1.0% was recorded for both mature green orange (LV_{MG}) and yellow (LV_{MY}) samples stored under the two storage conditions over 13 days storage (Table 1&2). Analysis of Variance (ANOVA) conducted on the data indicated that the storage time had significant effect ($p< 0.05$) on TSS of Orange, but storage condition did not significantly reduce ($p> 0.05$) TSS. Though there were reductions in TSS for orange stored under both storage conditions, the reductions in TSS were not significantly caused by the mode of storage, but by the number of days the oranges were stored (Table 3). Multiple range analysis using LS Means indicated that, significant difference ($p< 0.05$) in the TSS was observed on 7th and 9th day of storage for LV_{MG} and LV_{MY} stored at ambient room conditions (24-28 ^{0}C).Sweet orange being non- climacteric may not show marked variation in ethylene production and respiration. Non-climacteric fruits such as orange tend to maintain whatever quality they have at harvest without many beneficial changes during storage. Oranges do not produce much ethylene which can modify quality attributes such as TSS. Henceminimal changes in TSS contents were recorded for orange kept under the two different storage conditions. This is similar to results obtained in a study by Sakhale and Kapse [12] where, sweet orange stored under different treatments showed no marked changes in TSS when stored for 24 days at ambient conditions (27± 2^{0}C).TSS level in Moro fruits also remained unchanged when stored at 8°± 2 and 22° ± 2 temperatures[13]. The rind of the orange, could have served as a barrier in reducing the effect of the high temperatures (in the case of the open storage compared to ambient room temperature) on converting TSS to water and carbon dioxide during storage [13].

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Titratable Acidity (TA)

TA for LV_{MG} and LV_{MY} exposed to ambient conditions decreased by 0.27% and 0.26% respectively during storage. LV_{MG} and LV_{MY} exposed to direct sunlight also decreased by 0.26 and 0.16% respectively. High day and night temperatures tend to accelerate the loss of acid in oranges, and reduction in acidity can be said to be primarily a function of temperature (heat accumulation) and rapid respiration during storage. A high respiration rate causes less storage of citric acid in the vacuoles of plant cells and the rapid utilization of acids during metabolism [14]. Even though there were reductions in TA over the storage period, storage conditions did not significantly cause the reduction ($p>0.05$) of TA of orange samples. Maturity of orange and the storage time significantly reduced ($p<0.05$) TA (Table 3). Similarly, citric acid has been reported to decrease in stored citrus fruits [15] and this decline maybe in part due to the use of citric

acids for energy production and alcoholic fermentation during storage and senescence [16].This means that a high respiration rate may occur when fruits are stored over a period under high temperatures and this speeds up the utilization of citric acid present in the fruit.

Total Sugars (TS)

Fruit maturity and storage temperature determine the rate of conversion of total sugars to reducing sugars [2]. During growth and maturation of plants, sugars and transient starch may be transformed into sugars particularly sucrose, glucose and fructose in fruit. These sugars maybe completely oxidized to carbon dioxide and water with the production of Adenosine Triphosphate during the post-harvest storage [2]. These changes are largely dependent upon the conditions of storage such a temperature, time and physiological state of fruits and vegetables. An increase of 0.93% and 0.06% was observed for total sugars of LV_{MG} and LV_{MY} samples stored at ambient room conditions during storage and an increase of 0.06 and 0.21 was also recorded for LV_{MG} and LV_{MY} samples exposed to sunlight. Also a reduction in water from orange (due to exposure to moderate and high temperatures) during storage can result in concentration of the resultant sugars present, thereby increasing TS in the samples. ANOVA conducted on the data indicated the increase in TS observed during storage was not significantly affected ($p>0.05$) by storage time, maturity and storage conditions ($p<0.05$) of orange (Table 3).

Vitamin C

Reduction in ascorbic acid content was observed for all the orange samples over the storage period. A reduction of 103.60 and 83.20mg/100ml was observed in LV_{MG} and LV_{MY} respectively under ambient room conditions and a reduction of 91.90g/100ml and 68.90mg/100ml was recorded for LV_{MG} and LV_{MY} stored at the market. There were higher decreases in vitamin C LV_{MG} than the LV_{MY}. The loss observed in vitamin C was relatively low in the first week of storage. Higher decreases were observed in the second week, during which time many of the oranges got spoilt due heat accumulation in the heap pile of orange during storage (Figure 3). Analysis of Variance conducted on the data indicated that the maturity and the storage time significantly reduced ($p<0.05$) vitamin C (Table 3). However the two storage conditions under which the fruits were kept did not significantly reduce ($p>0.05$) vitamin C. Lee and Chen [5] reported Vitamin C content of fresh oranges ranges between 41-80mg/100ml, vitamin C levels for all orange samples fell above 41mg/100ml after 13 days of storage. The stability of ascorbic acid generally decreases as temperature increases this is because at high temperatures ascorbic acid variably degrades and converts to dehydroascorbic acid which is heat labile and this leaches or escapes out of the fruit (when exposed to high temperature) [3]. However, in the case of orange, the rind acts as protective covering which prevents excessive loss of ascorbic acid when openly exposed to high temperatures as compared to ambient room temperatures. Thus oranges kept under the two different storage conditions did not show significant differences ($p>0.05$) in vitamin C content.

Sweetness Index (TSS/TA)

The increase in TSS for Tarocco and the simultaneous decrease in TA in both varieties resulted in an increase in sweetness/maturity index (TSS/TA). An increase in SI was observed in all orange samples over the storage period. An increase of 10.61-12.50 and 11.05-13.77 was observed in LV_{MG} and LV_{MY} respectively under ambient room conditions. SI ranged between 11.05-14.39 and 11.54-12.67 for LV_{MG} and LV_{MY} respectively stored under open market conditions. Total Soluble solids is known to impact sweetness index than total sugars [17] and fruits which have a SI greater than 19 are regarded as sweet and less acidic in taste [18], SI of all stored samples fell below 19. Orange fruits generally increased in sweetness during storage due to reduction in TA. Increase of the TSS/TA ratio during storage has been observed in blood orange Taroccoby Schirra and Chessa [19] in Hamlin and Valencia orange[20, 21] and in grapefruit [22]. A high SI has generally been regarded as a quality index for orange fruits, but an increase in SI during storage can also be accompanied by the development of off-flavors due to formation of ethanol in the fruit, an indication of spoilage [23]. Astringency Index decreased in both LV_{MG} and LV_{MY} during storage, under both storage conditions an indication of ripeness and reduction in acidity of the fruits during storage.

Conclusion

The exposure of orange to direct sunlight (30-36^{0}C) and under ambient room conditions (24-280C) did not significantly change ($p>0.05$) TS and TSS of orange. Storage time of orange had significant effect ($p<0.05$) on vitamin C and TSS. Maturity level and the storage time significantly reduced ($p<0.05$) vitamin C content of orange; and the two storage conditions under which oranges were kept did not significantly cause ($p>0.05$) the reduction in vitamin C content. Astringency Index decreased in both LV_{MG} and LV_{MY} during storage, an indicator of reduction in acidity and ripeness of the fruits.

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Appendix

Figure 1.Orange samples kept under ambient room condition

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Figure 2. Orange on display at the market, under direct sunlight