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RESEARCH ARTICLE

Physico-chemical composition and sensory acceptability of sweet orange (*Citrus sinensis* L. Osbeck) fruits degreened with some climacteric fruits

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ABSTRACT

The practice of degreening sweet orange fruits was developed to promote colour development on the rind to make the fruits more attractive to consumers. This study was carried out to assess the efficacy of some climacteric fruits as a source of ethylene to degreen sweet orange fruits and to assess the sensory acceptability after degreening. Sweet orange fruits (Agege 1 variety budded on Cleopatra mandarin rootstock) were harvested at mature green ripe stage from an 8-year old organic citrus orchard at the Federal University of Agriculture, Abeokuta, Nigeria in the early season harvests of 2015 and 2016. Fruits of similar weight were stored in different plastic containers (9 litre capacity) at ambient condition (28-290C and 75-80% RH). Degreening was induced with climacteric fruits namely: Apple (*Malus domestica*), Avocado (*Persea americana*) and African bush mango (ABM) (*Irvingia gabonesis*) fruits while the un- induced sweet orange fruits served as control. Sweet orange fruits degreened with apple, avocado and ABM fruits had comparable pH, titratable acidity, total soluble solids, juice content and juice colour values. Vitamin C contents of sweet orange fruits degreened with apple fruits improved the quantity of vitamin C contents at 39.65 mg/100ml and 38.38 mg/100ml in 2015 and 2016 early harvests respectively with degreening and were significantly higher ($p<0.05$) than values obtained in other treatments. Rind color change from green to full yellow was earliest in sweet orange fruits degreened with apple fruits at 3 days after exposure in both years and had the overall best consumer's acceptability in terms of appearance, taste and aroma. Use of apple fruits could be a source of ethylene to degreen sweet orange fruits on a small scale.

Key words: Colour development, ethylene, early season, fruits, quality, sensory acceptability

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INTRODUCTION

Sweet orange (*Citrus sinensis* L. Osbeck) is a dicotyledonous, perennial evergreen of the Rutaceae family that leads other Citrus species in both production area and value (Ritenour, 2016). Other members of the family include mandarins, lemons, grapefruits and limes (Davies and Albrigo, 1998). World leading producers of citrus include China, Brazil and India, Mexico United States of America and Spain. Nigeria only produces 3.9 million tonnes of citrus with a world share of 2.8% according to

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FAO statistics in 2014 (Factfish, 2018). Agege 1 is a popular sweet orange variety in south western Nigeria because of its adaptability and high yield (Olaniyan and Fagbayide, 2005).

Sweet orange fruit is a major source of vitamins, especially vitamin C. It also has sufficient amount of folacin, calcium, potassium, thiamine, niacin, magnesium (Angew, 2007), flavonoids, carotenoids (provitamin A) and other nutraceutical compounds (Iglesias et al., 2001). Consumption of citrus fruits has been associated with improved health and reduction of risk of both cancer and cardiovascular diseases (Iglesias et al., 2001; Okwu and Emenike, 2006).

Climate has a significant effect on citrus yield, growth, fruit quality and economic returns. In growing regions where the average temperatures remain high such as tropical regions all year, the fruit peel chlorophyll does not degrade, oranges and tangerines remain green (Zekri, 2011; Ritenour, 2016; Porat, 2008). The internal, edible portion of the fruit which is the pulp usually reaches maturity with the external peel green (Davies and Albrigo, 1998). The consumer's perception is however, highly influenced by external quality as green fruits are linked with poor quality and sometimes immaturity. Fully coloured citrus fruits are more appealing to consumers than mature green fruit. Consequently, citrus fruits are often subjected to ethylene degreening before they can be marketed (Mditshwa, 2017). This process accelerates fruit color changes and renders the fruits more acceptable for marketing and economic benefit.

Climacteric fruits generally are characterized by a ripening associated increase in respiration and concomitant burst of ethylene production (Pua and Davey, 2010) resulting from autocatalytic stimulation of ethylene synthesis. This process is distinctly visible in fleshy fruits such as apple, banana, apricots, tomato, avocado, etc. (Malik, 2014). Sweet oranges are however, non-climacteric in nature, producing small amounts of ethylene. Ethylene is a plant hormone that is produced naturally by the plant or synthetically in the laboratory (Ladaniya, 2008). It occurs in a gaseous form or in the form of an ethylene-releasing compound that decomposes in fruits tissues, leading to degreening and improving of appearance of citrus. The method selected for applying ethylene depends on the cost, convenience and safety factors. Degreening of various sweet orange fruits with ethylene is widely done on commercial scale throughout the world (Kumar and Purohit, 2011) especially in the developed countries, using ethylene generating machines. This method is however expensive for most under- developed and some developing countries who cannot afford such machines, especially the smallholder producers that are resource-poor (Goonatilake, 2008). The sweet oranges are usually sold with non-uniform green-yellow colour which makes them less attractive. There have also been reported cases of food safety issue in the use of banned chemicals by producers and traders to improve the colour of fruits for improved market acceptability (Ojetayo et al., 2014). This study was carried out to assess the efficacy of some climacteric fruits as a source of ethylene to degreen sweet orange fruits and to determine the sensory acceptability after degreening.

MATERIALS AND METHODS

Field management and source of plant materials

Sweet orange fruits were harvested from an organic fruit orchard situated at the Federal University of Agriculture, Abeokuta (70, 15'N, 30 25'E, 100m) in South western, Nigeria. This area of land lies within the forest savanna transition zone (Aiboni, 2001). The location has an average rainfall of 1062.5mm with bi-modal distribution, temperature of 24.7oC - 36.4oC and a relative humidity of 88.5%. The 8-year old sweet orange (cv Agege 1) trees were budded on Cleopatra mandarin rootstock and

cultivated under standard organic practices. The trees were spaced at 9.5cm between rows and 3.5cm within rows. Sweet orange fruits at physiologically mature green stage were collected at the point of harvest in the early season harvests of May-June 2015 and April-May in 2016.

Sample preparation

The experiment was carried out in the Laboratory of the Department of Horticulture, Federal University of Agriculture, Abeokuta. The mature green sweet orange fruits collected at harvest were sorted based on size and the damaged fruits removed. The fruits were washed with clean water, air dried and weighed individually.

Degreening medium

The degreening medium was made up of a total of fifteen plastic containers of 9 liters capacity. Each plastic container was perforated with 8 holes (r=0.2cm) with a soldering iron for gaseous exchange to enhance ethylene formation and degreening process (Kumar and Purohit, 2010). The plastic buckets were thereafter washed, disinfected in a solution of 10% sodium hypochlorite and air dried.

Treatments

Ten sweet orange fruits of similar weight were selected randomly and placed in each plastic container. Degreening was induced with climacteric fruits: Apple (Malus domestica), Avocado fruit (Persea americana Mill) and African bush mango fruits (Irvingia gabonesis) while the un-induced sweet orange fruits served as the control treatment. The climacteric fruits were collected at full mature stage, applied at 10% of fruits weight, washed and air dried prior to placement in the plastic containers (Suman et al., 2012). The climacteric fruits were suspended internally to the lid of the plastic containers and the lid was tightly covered and kept under ambient condition for 7 days. A temperature range of 27-29 °C and a relative humidity range of 75-80% were observed in the degreening media (Table 1). The experiment was laid in a completely randomized design, replicated four times. Data were collected on the physical attributes and biochemical composition of the sweet orange fruits prior degreening (pre-degreening) and after degreening in the early season harvests of 2015 and 2016.

Table 1: Average temperature and relative humidity observed in the degreening medium

Degreening materials /Early season fruits	Temperature (^oC)		Relative humidity (%)	
	2015	**2016**	**2015**	**2016**
Apple	28.90	27.90	77.2	80.2
ABM	29.15	28.10	75.6	80.0
Avocado	29.0	27.35	77.0	79.3
Un-induced fruits	28.85	27.15	78.2	78.5

Parameters observed

Physiological Weight Loss (%): This was calculated as the difference between the initial fresh weight of fruit (on day -0) and the fresh weight of fruit at the time of sampling, expressed as a percentage of the initial fresh weight.

Rind and Juice color: Color was evaluated using a colorimeter (Model CR-400/410, Konica Minolta, Netherlands) to measure colour coordinates in hunter's L*, a*, b* units. The L* represents the lightness of the fruit colour (0–100, black to white), a* indicates the redness (+a*) or greenness (-a*), and b* indicates the yellow (+b*) or blue (-b*) colour of the rind.

Number of days to full colour development on peel: This was determined by counting the number of days through visual assessment of the rind of the sweet orange to attain full yellow colour from green.

Fruit firmness: The firmness of individual fruits was measured using a hand-held penetrometer. Three independent force measurements were made at three equatorial points on each fruit, 90° from each other, and the results expressed in Newton (N) (Barman et al., 2014)

Total Soluble Solids: Juice extracted from fresh samples was placed on the reading surface of a hand-held Brix Refractometer (Model Atago, 1140, Japan) Readings were taken in Degrees Brix.

Titratable acidity: 10 mL of freshly-prepared un-diluted juice was titrated with 0.1N sodium hydroxide in a beaker, using 2-3 drops of phenolphthalein as indicator to a pink colour end point. The titratable acidity was expressed as percentage citric acid.

Determination of Vitamin C (mg/100ml): The vitamin C content of sweet orange fruits was determined using the titration method with the indicator dye 2,6-dichloroindophenol to a faint pink end point.

Juice volume (ml): The individual fruits were peeled and sliced into two portions. The juice content of both portions was squeezed out using a juice extractor. The juice was filtered to remove the seeds and pulp. The juice volume was determined in a measuring cylinder calibrated in milliliters (ml).

pH: The pH from juice samples were determined using a pH meter (Jenway, Model 3310, UK) previously standardized with buffers 4 and 7.

Sensory Evaluation: This was determined by twenty trained panelists who compared coded samples of some specified characteristics such appearance, taste, aroma and overall acceptability on a hedonic scale of 1 to 9.

Statistical analysis

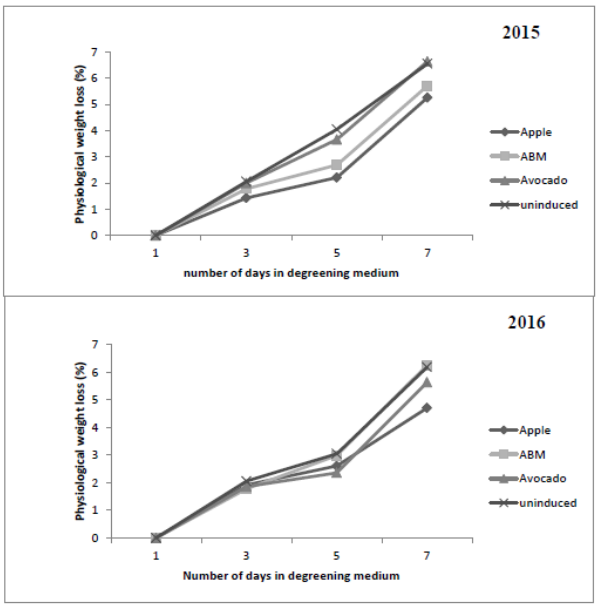
Data collected were subjected to Analysis of Variance (ANOVA) using GenStat Discovery Statistical package (GenStat, 2011). Means were separated using Least Significant Difference at $p<0.05$.

RESULTS

Physiological weight loss

There was reduction in the physiological weight of all the fruit samples as the day progressed with the degreening. Sweet orange fruits degreened with apple, avocado, African bush mango fruits and from the un-induced sweet orange fruits had comparable physiological weight loss in both years (Figure 1).

Figure 1. Physiological weight loss in sweet orange fruits degreened with climacteric fruits



Rind colour

Colour development on sweet orange before and after degreening at 5 days revealed that fruits degreened with apple and African bush mango fruits were lighter, with significant less green and more yellow colour on the rind when compared with rind colour of sweet orange fruits at pre-degreening and from the un-induced fruits at 5 days after degreening. Results were not consistent on the rind colour of fruits degreened with avocado fruits as colour development were only comparable to fruits degreened with apple and avocado fruits in 2016 only (Table 2).

Table 2: Colour development on sweet orange rind during degreening with climacteric fruits

	2015			2016		
Treatments/Early seasons	**L***	**a***	**b***	**L***	**a***	**b***
Pre-degreened	43.4	-9.24	22.5	41.6	-9.62	18.9
Apple	60.3	-0.01	43.9	59.1	-0.22	44.4
ABM	51.1	-3.55	32.2	58.2	-3.70	40.5
Avocado	44.2	-0.67	21.5	49.1	-2.47	34.0
Un-induced fruits	43.9	-4.00	21.4	48.8	-6.26	27.1
Lsd (0.05)	12.62	5.14	17.98	13.99	4.80	12.71

African bush mango –ABM

L*=lightness (0=maximum darkness, 100=maximum lightness) a= (+a* redness/ -a* greenness) b= (+b* yellowness/ -b* blueness)

Juice colour

In the early season of 2015, sweet orange fruit juice samples at pre-degreening and after degreening with apple, avocado and African bush mango fruits as well as fruits from un- induced sweet orange fruits had comparable juice colour values. However, the juice colour of fruits harvested in the early season of 2016 at pre-degreening were lighter in colour and had green when compared with the juice colour extracted from fruits degreened with apple, African bush mango, avocado fruits and the un-

induced sweet orange fruits after 5 days in storage (Table 3).

Table 3: Colour development in sweet orange juice during degreening with climacteric fruits

Treatments/Early seasons	2015			2016		
	L*	a*	b*	L*	a*	b*
Pre-degreened	50.4	-2.50	19.6	56.2	-4.28	24.3
Apple	53.8	-2.42	13.2	46.5	-2.72	18.1
ABM	47.0	-2.42	17.2	39,5	-2.78	14.4
Avocado	60.1	-3.19	22.7	34.5	-2.02	9.9
Un-induced fruits	52.1	-2.75	15.6	38.6	-1.66	10.9
Lsd (0.05)	8.47	1.29	11.42	13.99	1.16	12.05

ABM- African bush mango,

L*=lightness (0=maximum darkness, 100=maximum lightness) a= (a* redness/ -a* greenness) b= (+b* yellowness/ -b* blueness)

Number of days to full colour development on rind

Sweet orange fruits degreened with apple fruits developed full colour from green to yellow on the rind after 3 days of exposure while fruits degreened with African bush mango attained full yellow colour at 5 days of exposure. Fruits degreened with avocado pear attained full colour after 7 days of exposure. However, the un-induced sweet orange fruits still had visible green colour after 7 days of degreening. Colour change from green to full yellow was earliest in sweet orange fruits degreened with apple fruits (Table 4).

Table 4: Number of days to full color change in sweet orange fruit rind degreened with climacteric fruits.

Treatments	no of days to full yellow
Apple	3
ABM	5
Avocado	7
Un-induced	green colour still visible at 7 days

Table 5: Fruit firmness and juice content of sweet orange degreened with climacteric fruits

Treatments/Early seasons	Fruit firmness (kg)		Juice content (ml)	
	2015	2016	2015	2016
Pre-degreened	5.80	6.20	47.7	49.9
Apple	4.10	4.00	49.4	51.2
ABM	4.25	4.20	47.2	51.6
Avocado	5.10	5.20	48.3	48.6
Un-induced fruits	5.40	5.25	49.0	50.5
Lsd (0.05)	1.20	1.44	ns	ns

ABM –African Bush Mango

Firmness

Sweet orange fruits degreened with apple and African bush mango fruits were less firm ($p<0.05$) when compared with sweet orange fruits at pre-degreening, the un-induced sweet orange fruits and those exposed to ethylene produced from avocado fruits (Table 5).

Juice content

Degreening of sweet orange fruits with apple, avocado pear and African bush mango did not produce a significant effect on the juice content of the fruits. Sweet orange fruits pre- degreened and un-induced sweet orange fruits had similar juice contents (Table 5) Biochemical composition of degreened sweet orange fruits degreening with sweet orange fruits with apple fruits improved the quantity of vitamin C contents at 39.65 mg/100ml and 38.38 mg/100ml in 2015 and 2016 early harvests respectively when compared with sweet orange at pre-degreening and those that were degreened with avocado, African bush mango fruits and the un-induced sweet orange fruits. The titratable acidity, pH and total soluble solids of the sweet orange fruits before and after degreening with the climacteric fruits and the un-induced sweet orange fruits had comparable values in 2015 and 2016 early season harvests (Table 6).

Table 6: Biochemical composition of sweet orange degreened with different materials.

Treatments/Early season	pH		Titratable acidity (%)		Total soluble solids (brix)		Vitamin C mg/100ml	
	2015	2016	2015	2016	2015	2016	2015	2016
Pre-degreened	3.57	3.57	0.40	0.41	9.80	9.00	32.50	31.53
Apple	3.69	3.60	0.34	0.44	9.40	9.62	39.65	38.38
ABM	3.97	3.90	0.35	0.39	9.53	9.43	31.25	32.72
Avocado	3.63	3.55	0.39	0.40	9.47	9.10	32.54	32.54
Un-induced fruits	3.78	3.69	0.45	0.39	9.83	9.12	31.46	32.49
Lsd (0.05)	ns	Ns	ns	ns	ns	ns	6.57	5.14

ABM- Africa bush mango

Table 7: Sensory evaluation of sweet orange fruits degreened with climacteric fruits

Treatments	Appearance	Taste	Aroma	Overall acceptability
Apple	8.2	8.05	7.55	8.05
ABM	7.2	4.75	5.05	6.15
Avocado	6.75	6.45	6.65	7.00
Un-induced fruits	5.25	5.9	6.10	6.25

ABM –African bush mango

Hedonic scale: 1- dislike extremely, 2-disliked very much, disliked moderately, 4,- disliked mildly, 5-neither disliked nor liked, 6-liked slightly, 7-liked moderately, 8-liked very much, 9–liked extremely.

Sensory evaluation

The appearance, taste and aroma of sweet orange fruits degreened with apple fruits were liked very much by the panelists when compared with other sweet orange fruits degreened with the African bush mango, avocado fruits and the un-induced sweet orange fruits at 3 days after exposure. The appearance of African bush mango-degreened fruits was liked moderately. The avocado degreened sweet orange fruits were liked slightly, while the un-induced sweet orange fruits were neither disliked nor liked by the panelist. Overall, sweet orange fruits degreened with apple fruits were highly acceptable to the panellist (Table 7).

DISCUSSION

The physiological weight loss observed during the degreening of the sweet orange fruits with increase in storage days was due to water loss. The rate of water loss from a produce is determined mainly by packaging, temperature, relative humidity and airflow (Cantwell, 2013). The high temperature of the degreening medium could have increased the rate of water loss from the degreened sweet orange fruits as stomata increase in aperture with increase in temperature up to about 30°C. High temperature is also required to hasten the release of ethylene from the climacteric fruits. Ahrens and Barmore, (1987) suggested a high temperature of 29.4^{o}C for degreening to be effective in citrus. The relative humidity of the degreening medium was high. Cohens, (1978) stated that different levels of relative humidity do not affect colour development during degreening in citrus. However, high relative humidity is recommended to avoid shriveling. The degreening medium was perforated to allow airflow as gaseous concentration, particularly O_2 affects degreening. According to Ladaniya (2008), 50% O_2 alone increased the rate of degreening but higher value did not produce further degreening response in both Hamlin and Washington navel oranges.

Generally, fruits are known to produce different quantities of ethylene during development. The rate of ethylene formation varies in different organs and tissues and this depends on the growth and developmental stages of an organism (Kumar and Purohit, 2011). Climacteric fruits are known to produce much higher amount of ethylene especially during the ripening stage than non-climacteric fruits. Apple, avocado and African bush mango fruits produce an estimated 25-2500µl/l, 28.9-74.2µl/l and 25-250µl/l internal ethylene concentration, respectively, as reported by Current Science (2003). Citrus fruits have the ability to respond to exogenous ethylene in terms of chlorophyll degradation (Bouzayen, *et al,* 2016). Colour change from green to full yellow was therefore earliest in sweet orange fruits degreened with apple fruits probably due to the huge amount of ethylene that is released from the apple fruits. The loss of green colour from the degreened sweet orange fruits when exposed to climacteric fruits was due to the degradation of the chlorophyll to reveal the yellow carotenoids as a result of ethylene given off from these climacteric fruits. Non climacteric fruits when treated with ethylene show increased respiration. This degradation, according to Wills (2016), is due to changes in pH, oxidative systems and chlorophyllases. Loss of colour depends on one or all of these factors acting in sequence to destroy the chlorophyll structure to unmask the hidden carotenoids.

Firmness of fruits of sweet orange decreased with colour change from green to full yellow over time due to textural change as a result of enzymatic degradation of the components responsible for structural rigidity of the fruit. According to Malik (2014), during ripening, there is breakdown of insoluble protopectin into soluble pectic compounds which results into softening in tissues. Furthermore, sweet orange fruits degreened with apple fruits had the best overall acceptability in terms of taste, aroma and appearance probably because consumer's perception is highly influenced by external quality in fruits. Full yellow coloured sweet orange fruits looked more appealing to consumers than fruits with mature green colour and those with mixture

of green and yellow. Green colour in fruits is often associated with immaturity and poor quality. Ripening in fruits also brings about increase in aroma and flavour (Malik, 2014). This is due to the volatile chemical compounds that are enzymatically-synthesized and emitted (Malik, 2014). Sdiri *et al.* (2017), in their study concluded that degreening of early season citrus varieties with ethylene produced reproducible and variety- specific changes in the levels of fruit volatiles.

CONCLUSION

Sweet orange fruits responded to degreening when exposed to exogenous ethylene released from fruits that are climacteric in nature, producing uniform and attractive fruits. Colour change from green to full yellow of sweet orange fruits rind degreened with apple fruits was earliest at 3 days after exposure and the vitamin C contents increased with degreening. Sweet orange fruits degreened with apple fruits had the overall best consumer's acceptability in terms of appearance, taste and aroma. In conclusion, use of apple fruits could be a source of ethylene to degreen sweet orange fruits on a small scale.

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