IOSR Journal Of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 15, Issue 3 Ser. I (May. – June. 2023), PP 62-71
www.Iosrjournals.Org

Effect Of Climate Change On Post-Harvest Fruits; A Case Study Of Nine (9) Selected Orange Species

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Abstract
The effect of climate change or climate variables such as temperature on post-harvest fruits cannot be overemphasized. Temperature particularly plays a crucial role in the post-harvest handling of fruits. Assessment of the effect of climate change on orange fruits can provide advice on storage conditions and help to improve the physiochemical and physical quality of orange fruits hence, improving its market value. This research was done to determine the effect of Climate change on post-harvest losses in citrus fruits. The studies were done on nine different orange species collected across various location in Benue State. Our result revealed that higher temperature led to increase in weight loss, moisture content and change in the physical properties of orange fruits.
Key words: *Climate change, post-harvest losses, temperature, moisture content, fruits*

Date of Submission: 15-05-2023 Date of Acceptance: 25-05-2023

I. Introduction

The importance of food to humans cannot be overemphasized. Food plays very vital role in maintaining proper health and also helps in prevention and cure of diseases (Raymond, 2022). Foods are categorized into carbohydrate, protein, fats, water, vitamins and minerals (Raymond, 2022). Fruits are not only colorful and flavorful components of our diet, but form part of the food chain and also serve as a major source of energy, vitamins, minerals, and an excellent source of dietetic fiber as well.

Orange is one of the most common fruits grown around the world (FAO, 2012). This is as a result of its importance in nutrition and medicinal attributes. Delicious and juicy orange fruit contains an impressive list of essential nutrients, vitamins, minerals for normal growth, development and overall well-being (Waleed, 2019). Oranges, which are high in vitamins A and C and potassium, are eaten fresh or processed into juice, which can be consumed directly or further processed into concentrate, both used in numerous soda and cocktail drinks, punches, orangeades, and liqueurs. Waleed (2019) noted that orange have the following medicinal attributes; "lower blood pressure, relieves anxiety and depression, serves as mosquito repellant, relieves constipation and lower cholesterol. The rinds produce essential oils used broadly as pharmaceutical components, in supplements and in cosmetic industry and aromatherapy (Raymond, 2013). Orange is equally important in terms of monetary value. Orange fruit production plays an important role in income generation and poverty alleviation of the rural population.

In Nigeria, orange is cultivated in 15 States: Benue, Nasarawa, Osun, Anambra, Ekiti, Imo, Kogi, Ebonyi, Edo, Delta, Oyo, Kwara, Ogun, Taraba and Kaduna (Inienger, 2020). Benue State is the largest producer in the country (Avav, 2015). Despite the huge potential of the orange fruit in terms of yield and value, farmers are unable to realize the expected income on their investment due to post-harvest losses. Orange fruit is one of the most widely used fruit in the world and it is produced globally. However, the post-harvest handling of orange fruit has become a major challenge from the production to the market and consumption ends due to its high moisture content. Consequently, this paper, discusses the need for postharvest handling of orange fruit that reduces postharvest losses. The aim of the study is to investigate the losses in postharvest orange fruits related to temperature and gaps in orange fruits properties data with emphasis on those properties that are important during postharvest handling.

Appropriately, researchers have mad efforts in studying the effects of heat/temperature on post-harvest fruits for example, the effect of heat and cold treatments on post-harvest quality of sweet orange Blood Red cv was examined at the Department of Horticulture, NWFP Agricultural University, Pesha war during 2002-2003.The post-harvest quality of sweet orange was evaluated after 60 days storage at room temperature following different combinations of heat and cold treatments. It was found that both heat and cold treatments and storage

durations have significant effects on various parameters of citrus fruit. There was an initial increase in Total Soluble Solids (TSS) to the storage duration of 45 days but TSS then declined with 60 days storage. Total sugars and organic acids decreased continuously with increasing storage duration and reached the minimum value at day 60 of storage. The juice content increased with increasing storage duration up to 45 days and decreased in some treatments after 60 days storage. Weight loss was maximum in heat treated fruit, while color development, total soluble solids andjuice contents were maximum in cold treated fruits. Organic acids and percent sugars were maximum in control, which decreased with increasing duration of heat treatment (15 minutes at 50°C). Chilling injury increased with increased duration of cold treatment (72hrs at 5°C) (Gohar *et al.,* 2007).

Ali *et al.,* (2012) reported blood orange (*Citrus sinensis*) cv Tarocco, grown in the north of Iran, was harvested at the mature stage and stored at 8, 15 or 22 ºC for various duration. During the storage period, weight loss, total soluble solids (TSS), total titratable acidity (TA), pH, ascorbic acid, total phenols, flavonoids, antioxidant capacity, anthocyanin and L-phenylalanin ammonia-lyase enzyme (PAL) activity were determined. The highest increase in pH, anthocyanins in the pulp and rind, flavonoids and PAL activity after 85 daysof storage at 8ºC were 3.6, 12.4 mg/L, 15. 8 mg/L, 142.6 mg/L and 2.5 μMOL/g FW.min-1, respectively, and TSS, TA, fruit weightand ascorbic acid content decreased for fruit stored at different temperatures. Antioxidant capacity and total phenols increased during the first 45 days of storage at 8ºC by 38% and 631.6 mg/L respectively. The results indicated a significant correlation between antioxidant activity and total phenolic compounds ($P \leq 0.01$).

In their studies on the physiochemical change of orange cultivars stored at different temperature, Habibi et al (2021) using plant material and storage temperature observed that at lower temperature (2ºC) weight loss was reduced. Firmness and peel color also changed. They concluded that lower temperature was efficient to maintain the physical and chemical properties of orange fruits.

Furthermore, Mikasari et al (2021) examined the 'effects of different storage temperature on physical quality change in orange fruit', using plant material, washing treatment and storage conditions and their results revealed that washing treatment with fruit washing solution stored at cold temperature can inhibit the decline in fruit quality more effectively.

Also, Yueming *et al.,* 2022 et al (2022) studied the effects of storage temperature, light illumination and low temperature plasma on fruit rot and change in quality of postharvest orange using storage temperature, light treatment, low temperature plasma and plant materials and found that oranges begin to rot after 90 days of storage at 5ºC and the loss of moisture content of the orange fruits was associated with the physiological activity. They concluded that the application of low temperature plasma reduced rot of orange.

However, none of these studies combined their studies in both controlled and uncontrolled atmospheres. Thus, this paper examines the effects of climate change (temperature and moisture contents) on post-harvest fruits; a case study of nine (9) selected orange species. The experiment was done under controlled and uncontrolled atmospheres to better understand the effect and emphasis were on temperature and moisture contents due the fact the experiment was conducted when other climate variables such as precipitation were out of season.

Oranges

The orange tree is a species of flowering plants. It is one of many types of citrus plants and one of the main crops grown for income globally. The tree grows to 20-30 ft tall and has a crown that spreads out a 15 ft area. The leaves of the trees are shiny and grow to about 4 inches (FAO, 2004). The orange fruit is a reproductive ovary of the tree, the fruit is a modified berry known as a Hesperidium and the flesh is divided into segments called carpel. The usual shape of the orange fruit is round and varies with the types. The fruits of the orange are picked when fully ripe; unlike some deciduous fruits they do not ripen or improve in quality after being picked. The tress bears abundantly from 50 to 80 years. The fruits of the orange tree can be eaten fresh or processed for its juice or fragrant peel. These plants need lots of sun light or shade in order to properly grow (FAO, 2019).

Types of oranges

The types of orange species used in this study include the following:

I. Washington

Washington, also known as acid-less oranges, have a very sweet taste with minimal acidity or tartness. They contain less seeds and light soft skin that can be easily peeled. When ripped, Washington orange fruit appears to be pale yellow mixed with light green in color and the fresh inside is good for juice. The Washington orange fruits are harvested from December to march (Stefafano, 2023).

External in internal view of Washington orange fruit (credit: authors)

II. Navel orange fruit

Navel orange fruit when ripped, are sweet, slightly bitter, and appears to be pale yellow and green in color. They have signatures that resemble a belly button. It has a thick skin that can be easily peeled. This specie of orange contains seeds and is harvested from November to June (Stefafano, 2023).

External and internal view of Navel orange fruits (credit: authors)

III. Valencia orange

Valencia orange fruits have light and tight skin which makes it difficult to peel. When ripped, the fruits have a very sweet taste and good juice. It appears to be pale yellow and light green when ripped. This specie of orange is harvested from March throughout July (Stefafano, 2023).

External and internal view of some Valencia orange fruits (credit: authors)

IV. Lemon

Lemons are sour, round, and bright green citrus fruits. They have a thick rough skin and contain seeds and do not produce asexually like the other species. Lemons fruits are not popular like the other species; they are used for medical and nutritional purposes (de Carvalho, 2011)

External and internal view of lemon orange fruits (credit: authors)

V. Tangelo

Tangelos are classified as mandarin, a species of orange; it is most easily identified by its reddish skin and the protruding nipple like thing at the stem end. It is extremely juicy and sweet, with a very low amount of acid. Tangelo orange fruits when ripped appear to be pale yellow and round in shape with a very smooth skin, very sweet and good aroma. It has a very light and tart skin that is not easy to peel. They can be harvested from December to March (Stefafano, 2023).

External and internal view of tangelo orange fruit (credit: authors)

VI. Tangerine

Tangerine is also classified under mandarin; they have notable nipple that separates them from other citrus fruits. Their skin is light and easy to peel. The fresh inside is juicy and very sweet. When ripped, tangerine fruits appear to bright green mixed with pale yellow. They can be harvested from December to March (Stefafano, 2023).

External and internal view of tangerine orange fruits (credit: authors)

VII. Lime

Limes are small orange fruits. They have a sour and bitter taste. When ripped, they appear to be bright green and have a very light and tight skin that is difficult to peel. Limes are mostly used for medical purposes and are not popular unlike the other species (de Carvalho, 2011).

External and internal view of lime orange fruits (credit: author)

VIII. King orange fruits

King Orange fruits have a very thick rough skin that can easily be peeled off, they are bright green in color when ripped. It is one of the orange species classified under mandarin with tangerine and tangelo. King oranges when ripped have very sweet taste and are very good for juice. They can be harvest from November through March (Stefafano, 2023).

External and internal view of king orange fruits (credit: author)

IX. Grape orange

The grapefruit is a subtropical citrus tree known for its relatively large sour to semi-sweet, somewhat bitter fruit. The interior is segmented and varies in color from pale yellow to dark pink. The fruit when ripped has a sour bitter taste, pale yellow color and a thick sink. This specie of orange is not common like other species. It is harvested from March through June (de Carvalho, 2011).

External and internal view of grape orange fruits (credit: authors)

II. Materials and Method

The microwave oven has a temperature range of the ambient temperature (atmospheric temperature) in degrees Celsius to the maximum temperature of 210 ^{0}C. it was used to vary the temperature during the controlled atmosphere while the measuring scale was calibrated in grams; it ranged from 0 grams to 500 grams. The manual scale was used to measure the weight of the oranges.

Experiment

The experiment was carried out in two atmospheres; in the uncontrolled atmosphere, 5 fruits of each species were collected and exposed under the sun for thirty consecutive days, from 09:00 AM to 05:00 PM daily. The weight measuring scale was used to measure the weight of samples after been exposed for each day under the sun. This process was repeated for thirty consecutive days. The results obtained from the experiment were taken and tabulated. The temperature at which the oranges were exposed was collected on each day. This experiment was carried out under uncontrolled atmosphere.

While in the controlled atmosphere, the microwave oven was used. 5 well picked and sorted oranges were brought per specie. A total of 45 orange fruits were used in this experiment. The orange fruits were kept in the oven under the ambient temperature (atmospheric temperature of the laboratory which was 37^{o}C) and allowed to be heated for a period of one hour. After been heated, they were removed from the oven and measured to determine the weight loss during the heating and how the heat affected the physical properties of the various orange species under that temperature in the given period. The weight was measured three times and the average value was taken to avoid error due to parallax. The fruits were again kept in the oven for another one hour and the oven temperature was varied or increased by +4 (37+4 = 41^{o}C). After been heated for another one hour under 41^{o}C, the fruits were again removed from the oven; they were weighed following the first process.

This process of heating, varying of temperature and measuring of weight was repeated until the temperature of 133^{o}C was recorded. At this point, all the species were completely dried.

Moisture Content

Moisture content refers to the water molecules that become incorporated into fruits. It is also defined as the quantity of water contained in a food material. The moisture content of the various species was determined using the following equation;

$$\mathrm{MC} = \frac{wi - wf}{wi} * 100\% \qquad 1$$

Where MC is the moisture content of the species

Wi = the initial weight of the specie

Wf = the final weight of the specie

III. RESULTS

The results obtained from this experiment are presented in this section. Figure **1a** and **b** shows weight loss as a function of temperature and daily temperature variation for the experiment conducted under an open or uncontrolled atmosphere. Days 1 to 30 on the plot represent days of the month beginning with 27th January, 2023 to 30th February, 2023. While figure 2 **1a** and **b** presents same results for experiment done in a controlled atmosphere.

Table 1 Moisture content of various orange species from uncontrolled atmosphere:

Specie	Initial weight (kg)	Final weight (kg)	Moisture content (MC)
Navel	1.373	0.517	62.35%
Kings	1.157	0.450	61.11%
Tangelo	0.962	0.364	62.16%
Tangerine	0.847	0.291	65.64%
Grapes	2.325	1.462	37.12%
Lime	0.189	0.045	76.19%
Lemon	1.407	0.734	47.83%
Washington	1.397	0.549	60.70%
Valencia	0.783	0.231	70.50%

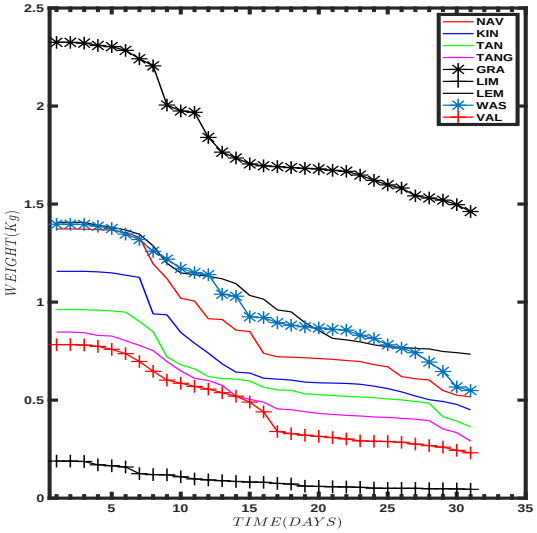
Table 2 Moisture content of various orange species from the controlled atmosphere

Specie	Initial weight (kg)	Final weight (kg)	Moisture content (MC)
Navel	0.708	0.403	43.80%
Kings	0.402	0.179	55.47%
Tangelo	0.241	0.096	60.17%
Tangerine	0.920	0.525	42.94%
Grapes	2.125	0.912	57.08%
Lime	0.346	0.145	58.09%
Lemon	0.652	0.285	56.29%
Washington	0.882	0.557	36.85%
Valencia	0.356	0.188	47.19%

Table 3 Diameter, length and peel thickness of the orange species

s/no	Orange species	Diameter (cm)	Length (cm)	Peel thickness (cm)
1	Navel	7.1	5.8	0.6
2	Kings	7.2	5.4	0.8
3	Grapes	12.7	10.1	1.4
4	Tangerine	5.0	5.6	0.3
5	Tangelo	7.0	6.0	0.4
6	Lime	4.4	4.0	0.2
7	Lemon	6.2	7.6	0.9
8	Valencia	5.4	5.9	0.6
9	Washington	7.9	8.1	0.7

Figure 1a (left) Weight loss for the uncontrolled atmosphere experiment. **b(right):** daily temperature within the period of experiment



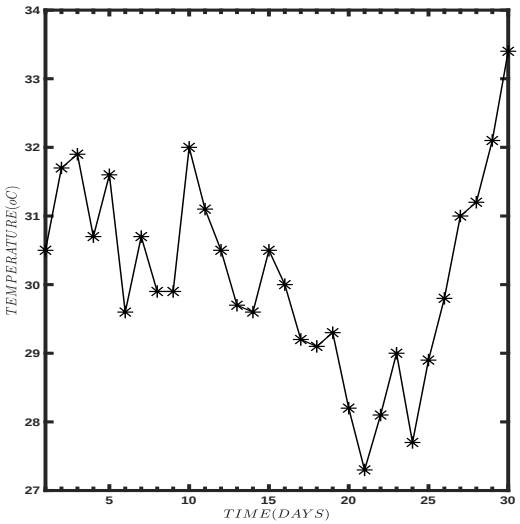
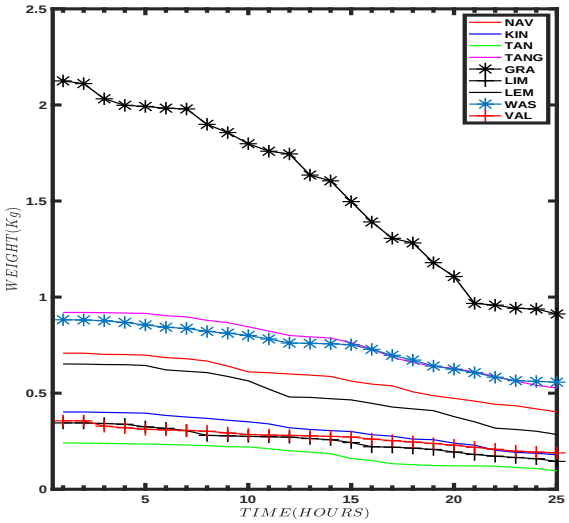
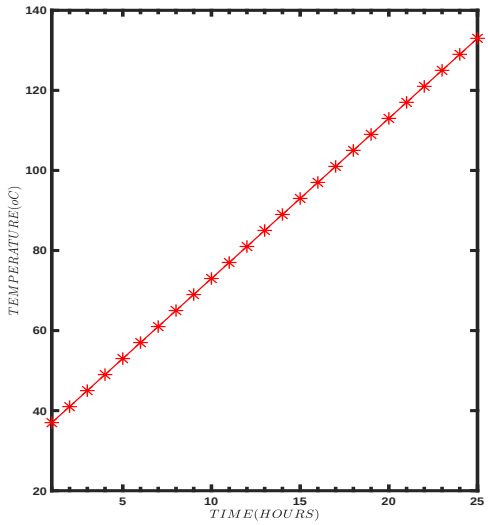


Figure 2a (left) Weight loss for the controlled atmosphere experiment. **b(right):** hourly temperature within the period





IV. Discussion

The physiochemical and physical quality of fruits is known to be affected by different storage conditions (Habibi et al, 2021). Climate variables such as temperature plays a very crucial role in the physiochemical properties and moisture content of fruits: in this case oranges. For example, figure 1 revealed continuous decrease in weight with increasing temperature for all species of oranges, suggesting that oranges exposed under high temperature lose weight resulting to loss in moisture content. This is in line with Habibi et al (2021) which showed that lower temperatures reduced weight loss, and peel color while higher temperature increase weight loss.

The physical properties of the orange species such as color were observed to change at 31.9^0C on the third day of the experiment. For example, Tangerine, Lime and King with peel thickness of 0.3cm, 0.2cm and 0.8cmrespectively started developing rotten spots on the third day. This is in agreement with Mikasari et al (2021) which revealed that temperature affect the physical quality of orange; lower temperature inhibit the decline in fruit quality while fruits exposed to higher temperature would degrade in physical quality.

The initial and final values of weight loss of all the species showed that weight loss is generally increased with prolong exposure to temperature leading to decrease in moisture content. This may be due to the fact that the juice content in orange fruits is affected by heat or higher temperature hence, decreases with storage durations (Gohar et al. 2022).

Generally, all species showed change in the physical properties, loss in weight and moisture content at the end of both experiments with the exception of grape and Lemon with peel thickness of 1.4cm and 0.9cm respectively. This exception may be due to their peel thickness. This is because the rate at which fruits storage loose moisture is dependent on skin structure of the orange (Mukama et al. 2019), while temperature effect may be responsible for the change in properties of the other species. This is in agreement with Emongor et al (2019) and Owoemi et al (2022).

V. Summary

Post-harvest operations play important role in postharvest handling of orange fruits. This can be affected by different factors such as climatic conditions particularly temperature. Here, an experimental approach was used to examine the effect of climate change (temperature and moisture content) on orange fruits (nine selected orange species). Our result revealed that higher temperature led to increase in weight loss, moisture content and change in the physical properties of orange fruits.

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