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Research Article

INFLUENCE OF RIPENING AGENTS ON THE PHYSICOCHEMICAL QUALITIES OF STORED ORANGES IN SOUTH EAST NIGERIA

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ABSTRACT

The objective of this study is to evaluate the influence of ripening agents on the physicochemical qualities of stored oranges. The different ripening agents, such as calcium carbide and tomatoes (ethylene-producing fruits) with different packaging materials (sack, polythene, and envelope) were introduced to the orange samples. The study employs analytical techniques and tools to assess the effects of ripening agents and packaging materials on the orange samples. The overall observation on the ripening agents was that both the organic and inorganic agents had good results and better oranges than the control sample. However, the results showed that organic ripening agents with sac as the packaging material had the best outcome. Hence, recommended to be used for the ripening of oranges.

Keywords: Oranges, Organic ripening, Inorganic ripening, Fruit storage, and packaging materials.

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INTRODUCTION

Ripening marks the final stage in fruit development during which various physiological and biochemical changes occur. These changes influence the fruit's color, flavor, texture, and aroma, making it more appealing and palatable (Gapper *et al*., 2015; Saquet *et al*., 2016). During ripening, starch in the fruit is converted to sugar (becomes sweeter) and its skin often changes color (green to yellow or bright red in the case of papaya). However, some fruits such as oranges, may not show noticeable skin color changes when they ripen (Rodov *et al*., 2003; Dahlken *et al*., 2018). The process of fruit ripening involves the coordination of multiple metabolic changes that involve the activation and inactivation of the genes causing these changes within the fruit's tissues (Gapper, 2013; Riquelme-Navarrete *et al*., 2018). The developmental process referred to as embryology, is a complex phenomenon and the early stages of embryonic development are also important to ensure the fitness of the organism, these processes require a lot of essential care to produce a better outcome (Seymour *et al*., 2013). Fruits and vegetables contain essential nutrients that are crucial to the body due to their vital roles in aiding good sight, embryonic development, cellular differentiation, reproduction, and growth (Sivakumar *et al*., 2019). Fruit maturity naturally plays a critical function in human nutrition hence the demand for mature fruits. However, synthetic substances such as calcium carbide (CaC2) and ethylene glycol are frequently used illegally for fruit ripening. When harvested, the majority of these fruits have a short shelf life (perishable), and with the decline in quality handling, there has been a considerable post-harvest loss of up to 50% losses (Zhou *et al*., 2017). As a result, commercial growers now harvest fruits when they are mature but still green because of the substantial post-harvest loss.

Most times, the collected fruits are subsequently artificially ripened in stores before being sold to consumers with the help of artificial ripening agents (Paliyath *et al*., 2019). Fruits must be stored and transported from the farm to retailers, a procedure that might take several days (Valero *et al*., 2010). The fruits may ripen too much during this period, become inedible, and lose their appeal to customers. During transit, some fruits may potentially sustain damage or even be destroyed. Fruit vendors intentionally induce artificial ripening before selling their products to avoid financial loss (Watada *et al*., 2003). According to reports, wholesalers offer fruits that have been calcium carbide-treated to ripen them and prevent financial loss and there are specified allowed limits for the use of several post-harvest ripening agents. Although, it takes a small amount of ethylene (1 ppm) in the air to accelerate the ripening of fruit (Seymour *et al*., 2013). Due to the high cost of getting these agents in areas with limited resources, fruit vendors in these areas have resorted to using calcium carbide and another inexpensive artificial ripening agent that is readily available. In addition, it has been noted that the majority of ripening agents used by fruit vendors are of industrial grade and frequently obtained from unlicensed sources (Sethi *et al*., 2014). The use of calcium carbide has been shown to affect the color of unripe fruits and also lengthen their shelf life. In addition, it has the ability to keep the ripened color for a long time. While naturally ripened fruits are part of a healthy diet and important for growth and development (Rodov *et al*., 2003; Meher *et al*., 2020), the increasing demand for ripe fruits in Nigeria has led to the use of artificial ripening methods. Artificial ripening often involves chemicals such as calcium carbide which is the most commonly used agent due to its affordability (Sethi *et al*., 2014). The objective of this study is to evaluate the influence of ripening agents on the physicochemical qualities of stored oranges.

MATERIALS AND METHODS

Materials sourcing and equipment

Thirty-five oranges were collected from the Ndoru market in Umuahia. Five for each replica of the treatments and then the control. The oranges were cleaned and taken to the laboratory for further treatment. Five oranges were packaged in a well-tied sack with four fresh tomatoes as organic/natural ripening agents and labeled batch A. The other five oranges were selected and treated with calcium carbide powder and then packaged in a well-tied sack and labeled batch B. Another five oranges were selected and packaged in a well-tied polythene bag with four fresh tomatoes as organic/natural ripening agent and labeled batch C. More, five oranges were selected and treated with calcium carbide powder then packaged in a well-tied polythene bag and labeled D. Then more five oranges were selected and packaged using a well-tied envelope as packaging material with four fresh tomatoes as a natural ripening agent and labeled batch E whereas other five oranges treated with calcium carbide powder were packaged in a well-tied envelope and labeled batch F. Finally, the other remaining five were left to self-ripen at room temperature without any ripening agent or packaging material but to ripen naturally and was labeled G. The samples were checked at intervals and the ripeness was determined by the change in skin color and texture. The data collection process for the study involves assessing various properties of oranges at different stages. During ripening, controlled conditions such as temperature, humidity, and lighting are monitored and adjusted as necessary. The different ripening agents, such as calcium carbide and tomatoes (ethylene-producing fruits) with different packaging materials (sack, polythene, and envelope) were introduced to the orange samples.

Methods

The study employs Dahlken *et al*., (2018) analytical techniques and tools to assess the effects of ripening agents and packaging materials on the orange samples. The following dimensions were determined:

(i) The diameter of an orange refers to the measurement of the cross-section, which is the distance from one side of the fruit to the other, passing through its center. Measurement was taken with a vernier caliper

(ii) Weight refers to the measurement of how heavy these oranges are and is typically expressed in grams or kilograms. Measurement was taken with a weighing balance

(iii) Volume is the amount of space occupied by an orange in three dimensions. For oranges, it can be determined by measuring the space the fruit occupies in cubic centimeters.

Calculation: $$V = \frac{4}{3}\pi abc \quad (1)$$

Where V is the volume, a is the radius of the maximum diameter, b is the radius of the intermediate diameter, and c is the radius of the minimum diameter.

(iv) Bulk density is the mass of a material per unit volume. It is a measure of how tightly packed the oranges are, often expressed in grams per cubic millimeter or kilograms per cubic meter. Bulk density can be calculated by:

$$\text{Bulk density} = \frac{mass}{volume} \quad (2)$$

(v) Firmness: Firmness is a measure of how resistant a fruit is to deformation when pressure is applied. It is typically measured in newton or pounds-force and is used to assess the ripeness and texture of the fruit. It is measured using a penetrometer model FHP-802. The firmness was measured using a digital fruit firmness-tested penetrometer (dual tip) model FPH 802. Each of the samples was peeled and the penetrometer was used to probe the samples, this was done repeatedly on different points of the samples and the mean was taken to ensure accurate reading. This test was carried out on the samples before the application of ripening agents and after the application when they were ripened

(vi) Surface Area: The surface area is the total area of an object's outer surface, such as the skin or peel of a fruit. It is typically measured in square units such as square centimeters or millimeters. The formula for surface area is:

$$A = 2\pi b^2 + \frac{4}{3}\pi \times \left(\frac{a^2 - b^2}{e}\right) \times \ln\left(\frac{1+e}{1-e}\right) \quad (3)$$

Where A is the surface area, a is the radius of the maximum diameter, b is the radius of the intermediate diameter, and c is the radius of the minimum diameter.

(vii) Sphericity measures how closely an object resembles a perfect sphere. For fruits such as plantains and bananas, this refers to their roundness or curvature. The formula for sphericity is:

$$S = \frac{GMD}{a} \quad (4)$$

Where S is the sphericity, GMD is the geometric mean diameter, and (a) is the radius of the maximum diameter. The data collected for this study were analyzed using a one-way analysis of variance, and the Duncan multiple range test was used to compare the experimental data at a 95% confidence level. All statistical analyses were performed using Statistical Package for the Social Sciences software (version 21). Results are expressed as mean ± standard deviation. Physical measurements of the fruits, such as maximum, intermediate, and minimum dimensions, as well as volume and bulk density, were obtained using a vernier caliper and a weighing balance.

(viii) Titratable acidity (TA) is the number of protons recovered during titration with a strong base to a definite endpoint. It is expressed based on the percentage (%). TA measures the acidity of a sample and is expressed as a percentage. The following procedure was used: 5 g of the fruit sample was soaked in 50 mL of distilled water for 1 h. The mixture was filtered using filter paper, and 10 mL of the filtrate was measured into a 250 mL conical flask. Three drops of phenolphthalein were added as an indicator, and the sample was titrated with 0.1N sodium hydroxide (NaOH) until a faint pink color appeared. The titration was repeated 3 times, including a blank, and the average reading was used to calculate the acidity percentage

(ix) The pH (hydrogen ion concentration) was determined by a digital pH meter. A 5 g of sample was soaked in 50 ml of distilled water for 1 h. It was filtered into a beaker using filter paper. The electrode of the pH meter was directly inserted into the solution. When the first reading was completed, the electrode was wiped with distilled water and dried up with tissue paper. Similarly, as a continuous series, all other samples were determined accordingly

(x) The total soluble solids (TSS) were determined using a Digital-Bench Refractometer. Before use, the instrument was cleaned and adjusted to zero at 20°C using distilled water. 5 g of sample was dissolved in distilled water and left for 1 h. The solution was filtered into a beaker and the refractometer was placed in it to obtain a reading. For each sample, the instrument was calibrated using distilled water. The reading that appeared on the screen was directly recorded as TSS as brix. In order to assess the quality parameters of the samples in each experimental group, samples were collected and examined every 24 h to study the daily changes.

RESULTS AND DISCUSSION

The influence of ripening agents and packaging materials on the oranges can vary depending on the ripening agent used. Table 1 shows the firmness of the orange samples.

The firmness of fruits during ripening changes due to the breakdown of insoluble protopectin into soluble pectin, accompanied by cellular breakdown and increased membrane permeability. Organically ripened fruits (e.g., apples) demonstrated the highest firmness, followed by inorganically ripened fruits, with the control group showing the least firmness (Mahak *et al*., 2019). Ado and Josephine (2022) observed that naturally ripened bananas undergo firmness changes at a higher rate than artificially ripened ones. This highlights the impact of natural ripening processes on fruit texture and quality. The selected chemical properties of the stored oranges are shown in Table 2.

Table 2 shows the measurements of TTA of orange samples. Batch A had the highest TTA of (0.31±0.01%), whereas batch E and G had the lowest TTA with the lowest TTA of 0.15%, which are more suitable for those who prefer a sweeter taste, whereas samples A and F have slightly higher acidity, suitable for a balance of tartness and sweetness. However, batch E was the most acceptable. Furthermore, from Table 2 the TSS is a measure of the overall concentration of dissolved solids, primarily sugars and other soluble compounds in a liquid or solution. The TSS values in oBrix indicate the sugar content in these orange

Table 1: The firmness of stored orange samples

Batches	Firmness
A	5.33^c 0.21
B	10.98^a 0.59
C	8.12^b 0.99
D	3.60^d 0.41
E	2.08^e 0.04
F	4.88^c 0.28
G	3.55^d 0.26

a-e value is the mean standard deviation of replicate determination. Mean values in the same column with different superscripts are significantly different (p<0.05). Key: A=control orange, B=orange with organic (tomatoes) ripening agent in envelope, C=orange with inorganic (carbide) ripening agent in envelope, D=orange with organic (tomatoes) ripening agent in sack, E=orange with inorganic (carbide) ripening agent in sack, F=orange with organic (tomatoes) ripening agent in polythene, and G=orange with inorganic (carbide) ripening agent in polythene. Table 1 shows the mean firmness in orange samples among the batches. With batch B has the highest mean firmness (10.98a 0.59), whereas batch E has the lowest mean firmness value (2.08e 0.04). Now batch B is more significantly different in firmness than the rest of the packaging conditions based on the statistical test conducted at a significance level of (p<0.05)

Table 2: Chemical properties of stored orange samples

Sample code	pH	Total titratable acidity (%)	Total soluble solids (oBrix)
A	3.73g±0.03	0.31^a±0.01	11.57^f±0.01
B	3.98^f±0.01	0.23^b±0.02	12.71^d±0.01
C	4.46^b±0.01	0.21^{bc}±0.01	12.14^e±0.01
D	4.12^d±0.01	0.19^c±0.01	12.97^b±0.01
E	4.81^a±0.01	0.15^d±0.01	13.28^a±0.01
F	4.07^e±0.01	0.22^{bc}±0.01	12.82^c±0.02
G	4.17^c±0.01	0.15^d±0.01	12.96^b±0.03

a-g values are the mean standard deviation of duplicate determination, mean values in the same column with different subscripts are significantly different (p<0.05). Key: A=control oranges, B=oranges with organic (tomatoes) in an envelope, C=oranges with inorganic (carbide) in an envelope, D=oranges with organic (tomatoes) in a sack, E=Oranges with inorganic (carbide) in a sack, F=orange with organic (tomatoes) in polythene, and G=orange with inorganic (carbide) in polythene. The acidity level of the stored oranges is shown in their pH values. From Table 2, batch E has the highest pH (4.81±0.01) making it the most acidic among samples whereas batch A has the lowest pH level (3.73±0.03). Batch E (pH 4.81±0.01) falls on the higher end of acidity and might be a sweeter choice. The choice depends on your taste preference and the specific application. Thus, batch E was most acceptable and the difference was statically significant among batches. For the total titratable acidity, this is a measure of the acidity in a substance, often expressed as a percentage. Sample A has a Total Titratable Acidity of 0.31±0.01%. Sample B has a TTA of 0.23±0.02%. Sample C has a TTA of 0.21±0.01%. Sample D has a TTA of 0.19±0.01%. Sample E has a TTA of 0.15±0.01%. Sample F has a TTA of 0.22±0.01%. Sample G has a TTA of 0.15±0.01%. The TTA values represent the total acid content in these orange samples. a-g values are the mean standard deviation of duplicate determination, mean values in the same column with different subscripts are significantly different (p<0.05)

samples. Batch A has the lowest number of sugar content (11.57 oBrix±0.01) whereas batch E has the highest number of sugar content (13.28^a±0.01). Fig. 1 shows the physical characteristics of organically ripened oranges stored in an envelope.

The organically ripened oranges exhibited a gradual color change from green to pure yellow reflecting a very slow ripening process whereas GMD shows a decrease in trend with its maximum from day 5 to 7. The weight showed a slight decrease whereas sphericity remains relatively constant from day 1 to day 7. The bulk increased through the days whereas volume decreased from day 1 to day 7. Fig. 2 shows the physical characteristics of organically ripened oranges stored in sacks.

The organically ripened oranges exhibited a gradual color change from green on day 1 to pure yellow on day 5 reflecting a very slow ripening process. GMD and sphericity decreased from day 3 to 5. The bulk increased through the days whereas volume decreased from day 1 to day 5. The surface area shows a slight decrease over the 5 days. Fig. 3 shows the physical characteristics of organically ripened oranges stored in polythene.

The organic ripened exhibited a gradual color change from green on day 1 to pure yellow on day 6 reflecting a very slow ripening process. GMD showed much increase on day 3 and remained constant on other days whereas weight showed a slight decrease over the days. Sphericity remains relatively constant from day 1 to day 6 whereas bulk density increased from day 3 to day 6. Volume decreased from day 1 to day 6 whereas surface area shows a slight decrease over the days. Fig. 4 shows the physical characteristics of inorganically ripened oranges stored in an envelope.

The inorganically (calcium carbide) ripened oranges showed the color transition from green to yellow which occurred over 8 days indicating a slower and halfway ripening process compared to the organic treatment. Similar to the organic treatment, the GMD was observed to have decreased from day 1 to day 8 whereas the weight remained constant along the trend. Sphericity decreased slightly over the days whereas bulk density increased over time indicating denser fruit. The volume gradually decreased and the surface area also experienced a drastic decrease over the days which indicates a decrease in size. Fig. 5 shows the physical characteristics of inorganically ripened oranges stored in sacks.

The inorganically ripened oranges showed color transition from green to yellow occurred over 5 days indicating a fast ripening process compared to other inorganically treated samples. Similar to others, the GMD decreased from day 1 to day 5 whereas the weight remained constant over the days. Furthermore, sphericity decreased from day 1 to day 5 while bulk density increased over the days indicating denser fruit. The volume gradually decreased and the surface area also decreased over the days indicating a decrease in size. Fig. 6 shows the physical characteristics of inorganically ripened oranges stored in polythene.

The inorganically ripened oranges showed that the color transition from green to yellow occurred over a period of 7 days indicating a slower and halfway ripening process compared to the organic treatment. Similar to other inorganic treatments, the GMD was observed to have decreased from day 1 to day 7 whereas the weight remained constant over the days. Sphericity also decreased over the days while bulk density was increasing which indicates a denser fruit. The volume and surface area gradually decreased over the days which indicates a decrease in size. Fig. 7 shows the physical characteristics of the untreated (control) oranges stored in the laboratory with no packaging.

The control oranges had a slow color transition which took 6 days to go from green to yellow, the GMD and weight showed a gradual decrease over the 6 days. Sphericity decreases throughout the 6 days whereas bulk density increases along the days. However, volume had a gradual decrease from day 1 to day 6 and the surface area experienced a much decrease on the 5th day. It was observed that oranges in batch A took 6 days to ripen whereas batch B and C took seven and 8 days respectively. Batch F and G took 6 and 7 days respectively. Ripening was similar in batches D and E. Analysis of the influence of ripening agents on ripening efficiency of the stored oranges is shown in Table 3.

Both the organic (use of tomatoes) and inorganic (use of calcium carbide) ripening agents have different ripening periods based on the different ripening agents and packaging materials used. The organic ripening agent (use of tomatoes) with different packaging materials

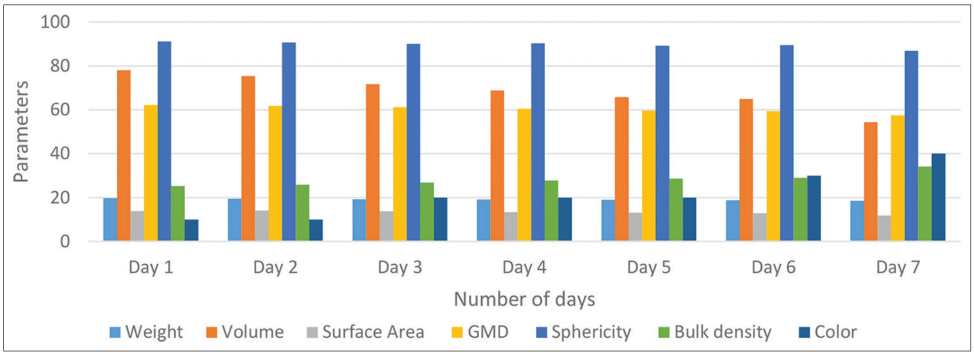

Fig. 1: Organically ripened oranges in an envelope

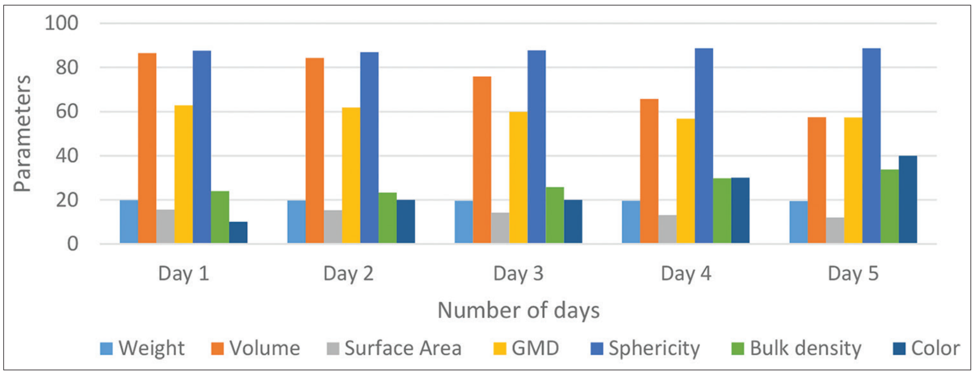

Fig. 2: Organically ripened oranges in sack

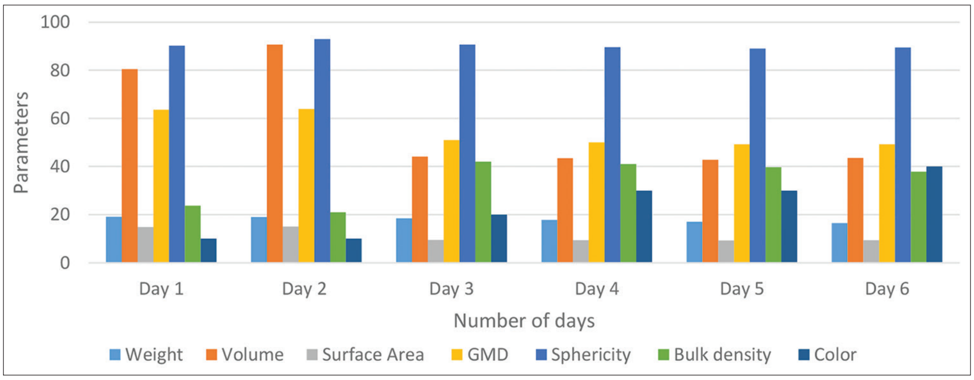

Fig. 3: Organically ripened oranges in polythene

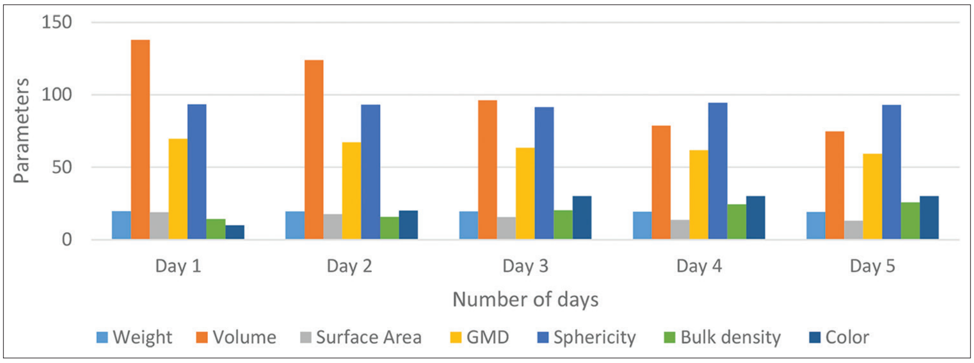

Fig. 4: Inorganically ripened oranges in the envelope

was notably efficient based on the physicochemical characteristics exhibited by the stored oranges. The oranges packaged in sack achieved good ripening in 5 days thereby producing a stable orange with good qualities.

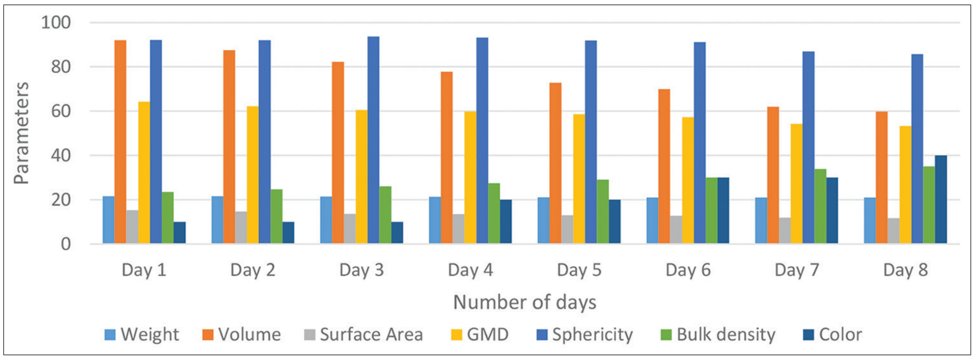

Fig. 5: Inorganically ripened oranges in sack

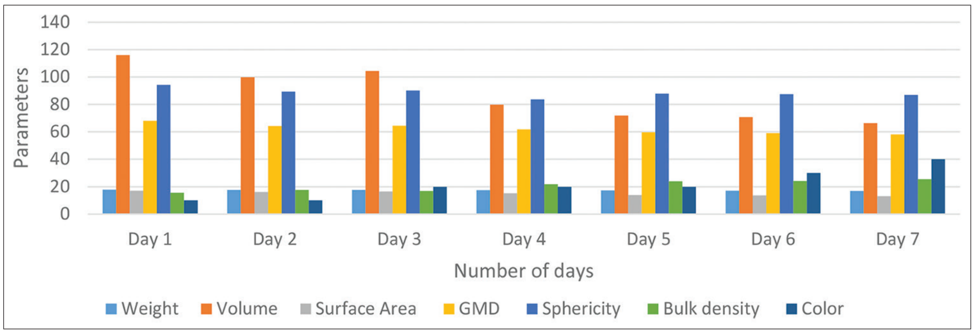

Fig. 6: Inorganic orange, polythene bag

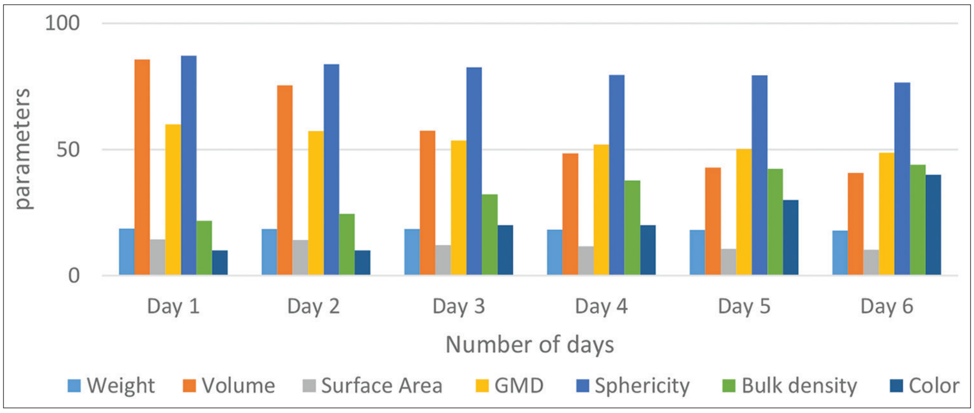

Fig. 7: Control oranges with no ripening and packaging

Table 3: Analysis of the influence of ripening agents on ripening of packaged oranges

Treatment	Package	MD (mm)	ID (mm)	Md (mm)	W (10g)	V (10^4mm^3)	SA (10^5mm^2)	GMD (mm)	Sph (10^{-2})	BD (10^{-5}g/mm^3)	Days
Organic (tomatoes)	Envelope	66.2	64.9	44.3	18.6	54.4	11.8	57.5	86.9	34.2	7
	Sack	64.5	63.2	46.1	19.4	57.4	12.0	57.3	88.8	33.8	5
	Polythene	55.1	50.2	43.4	16.5	43.5	9.4	49.3	89.5	37.9	6
Inorganic (calcium carbide)	Envelope	62.2	50.1	47.9	20.9	59.8	11.6	53.3	85.7	35.0	7
	Sack	63.7	61.9	52.9	19.2	74.7	13.2	53.3	93.1	25.7	8
	Polythene	67.0	60.4	48.6	19.9	66.3	13.1	59.3	86.9	25.5	7
Control		61.3	47.2	39.8	17.9	40.7	10.3	48.7	76.5	44.0	6

CONCLUSION

The overall observation on the ripening agents was that both the organic and inorganic agents had good results and better oranges than the control sample. However, the results showed that organic ripening agents with sac as the packaging material had the best outcome. Hence, recommended to be used for the ripening of oranges.

CONFLICTS OF INTEREST

There was no conflict of interest among the authors or with anyone in this publication.

AUTHOR'S CONTRIBUTIONS

Paul came up with the research conceptualization and first draft development.

Sunmola carried out the data gathering and second draft development.

Okosa carried out the experimental and laboratory experiments and analysis.

Umunna did the proofreading and assisted with the literature review.

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