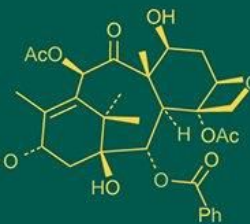
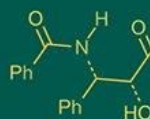


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Pre-harvest bagging of fruits using covering bags for quality fruit production in sweet orange (*Citrus sinensis* L. Osbeck) Cv. Nucellar

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Abstract

Current study was conducted at Sweet Orange Research Station, Badnapur during academic year 2023-24 with an aim to investigate the effect of types of bags on fruit development and quality parameters of sweet orange. The experiment was laid out in Randomised Block Design (RBD) with seven treatments and four replications. The treatments distinguished as T1-control, T2- polypropylene bag (white colour), T3-polypropylene bag (red colour), T4- polypropylene bag (green colour), T5- butter paper bag, T6- polythene bag (black colour), T7- polythene bag (transparent). Among all the treatments, T7 i.e. polythene bag (transparent) appeared to be the most significant treatment showing maximum effect on length of fruit (8.2 cm), diameter of fruit (8.47 cm), fruit weight (264.67 g), juice percentage (64.90%), TSS (11.82° Brix), TSS: Acid ratio (25.99), ascorbic acid (58.92 mg/100g pulp), reducing sugars (4.42%), total sugars (8.32%), non-reducing sugars (3.89%), and shelf life of fruit (30.95 days); while it gave minimum values for other parameters. Highest peel/rind thickness (4.37 mm), peel percentage (17.62%), titrable acidity (0.59%), shelf life of fruit (physical loss in weight) (11.36%), and temperature inside bag (39.5 °C) was observed in T6 i.e. polythene bag (black colour).

Keywords: Sweet orange, bagging, covering bags

Introduction

Citrus is the most widely cultivated tree fruit crop globally, with two distinct markets being the fresh fruit and processed juice sectors. These species are predominantly diploids with a chromosome count of $2n = 2x = 18$. Among the citrus species cultivated globally, *Citrus sinensis* L. Osbeck holds the utmost significance as it notably constitutes the largest group of cultivated citrus worldwide, contributing approximately 70% to the total annual production of citrus varieties.

In India the area and production of citrus during financial year 2023-24 was 1114.47 thousand hectares and 14781.84 thousand MT respectively. Of which area and production of sweet orange was 233 thousand hectares and 3874.63 thousand MT, respectively. (Ministry of Agriculture 2023-24 first advance estimates).

During their growth and development, sweet orange fruits undergo several physical and chemical changes and are susceptible to insect pest infestations, bird attack, and mechanical damage, all of which can reduce their commercial value and thereby cause significant yield and economic losses. To prevent the losses caused by biotic and abiotic factors, several good agricultural practices (GAP) are becoming popular throughout the world (Sharma, 2009) [25].

Among several such alternatives, pre-harvest fruit bagging has emerged as an effective approach in different parts of the World. In this technique, individual fruit or fruit bunches are bagged on the tree for a specific period. Bagging is a physical protection technique, commonly applied to many fruits, which not only improves their visual quality by promoting peel coloration and reducing the incidence of fruit cracking and russeting, but can also change the microenvironment for fruit development (Fan and Mattheis, 1998) [5].

Bagging mainly changes the light levels, temperature, and humidity around the enclosed fruit, resulting in various phytochemical changes in the product (Guo *et al.*, 2019) [6]. In addition, this technique increases the marketable yield, the size and weight of bagged fruit being higher than those that are unbagged (Chonhenchob *et al.*, 2011) [2].

Of course, the benefits of bagging (reduced chemical residues and improved fruit quality) depend on numerous variables, including: (i) the bag material, (ii) the timing of the bagging, (iii) the external environmental conditions, and (iv) the phenological stages during which the bags are applied (Karajeh 2018; Islam *et al.* 2019; Pisciotto *et al.* 2020; Shah *et al.* 2020; Nicolosi *et al.* 2022) [11, 8, 19, 23, 17]. Therefore, considering these points the present research titled, "Studies on use of covering bags for quality fruit production in sweet orange (*Citrus sinensis* L. Osbeck) Cv. Nucellar" was undertaken with following objectives:

1. To study the effect of types of bags on fruit development in sweet orange.
2. To study the effect of types of bags on qualitative parameters of sweet orange.

Materials and Methods

The research investigation was conducted on sixteen years old sweet orange trees of uniform growth. Spacing between trees was 6 meters x 6 meters. The experiment was laid out in Randomised Block Design (RBD) with seven treatments and four replications. Twenty-eight trees that were healthy, bearing a substantial amount of fruit, were carefully chosen. Each tree of the experiment was tagged using a tag for easy identification of treatment given.

The treatments were distinguished as T1-control, T2-polypropylene bag (white colour), T3-polypropylene bag (red colour), T4- polypropylene bag (green colour), T5-butter paper bag, T6- polythene bag (black colour), T7-polythene bag (transparent). The bagging of fruits was done at marble stage in August month. A total of 96 fruits (24 per replication) were covered for each treatment. The fruits of control treatment were kept Un-wrapped. The damaged bags by winds or rainfall were replaced at regular intervals. The physical parameters i.e. length of fruit, diameter of fruit, fruit weight, peel/rind thickness, peel percentage, and juice percentage were recorded. Chemical analysis was done to determine TSS, titrable acidity, ascorbic acid, reducing sugars, non-reducing sugars, total sugars and TSS/acid ratio. Data regarding observation of all parameters was collected at 30 days interval till fruit harvesting at maturity i.e. 180 days after bagging. Temperature inside bag and shelf life of fruit were also recorded.

The length of fruit was measured by taking distance from the base to the apex of the fruit using vernier caliper and expressed in centimeters (cm).

The diameter of the fruit was measured with the help of vernier caliper and expressed in centimeters (cm). Fruit weight was recorded by using monopan electronic balance and determined in grams (g).

Peel thickness of the fruit was taken with the help of screw gauge and expressed in millimeter (mm). For peel percentage fresh fruit peel was removed and weighed using a monopan electronic balance in grams (g), and then converted to a percentage by using following formula:

$$\text{Peel (\%)} = \frac{\text{Peel weight (g)}}{\text{Fruit weight (g)}} \times 100$$

For Juice percentage, the juice of the harvested fruits of each treatment and replication was extracted using electric juice squeezer and strained using muslin cloth. Next the juice was weighed in grams (g) using electric monopan and the weight was converted to percentage using following formula:

$$\text{Juice (\%)} = \frac{\text{Juice weight (g)}}{\text{Fruit weight (g)}} \times 100$$

The TSS was determined with a handheld refractometer (PAL-3, Atago, Japan) calibrated using distilled water as suggested by Ranganna (1999) [20]. The extraction of juice involved the utilization of an electric juice squeezer, followed by straining it through a muslin cloth. Subsequently, two drops of the extracted juice were carefully positioned on a prism, and the corresponding refraction index was observed and calculated based on the temperature of 25°C. Finally, the value was expressed as °Brix.

To determine titratable acidity, juice was extracted. 10ml of juice was measured using a measuring cylinder and put down in big beaker. 40ml of distilled water was added to the beaker to make the solution 50ml. 10ml of aliquot was measured and put in small beaker. Few (2-3) drops of phenolphthalein was added to the solution using a dropper. Fill the burette with 0.1N NaOH and ensure the reading is adjusted accurately by adding or removing a few drops if necessary. Proceed to titrate the solution until a permanent pink color is achieved. Record the reading and put it into the subsequent formula:

$$\text{Acidity (\%)} = \frac{0.1N \text{ NaOH} \times 0.0064}{\text{Volume of weight of sample used}} \times 100$$

Ascorbic acid was determined using DCPIP i.e. 2,6-dichlorophenol-indophenol dye titrimetric method (Jhang *et al.*, (2015)) [9]. Extract the juice. Take 10 ml of juice into a conical flask and add 10 ml of HPO₃ to the flask. Titrate the solution with 2,6-dichlorophenol-indophenol solution from the burette until colour changes from blue to colourless. Take reading of DCPIP Solution used. Put in following formula for ascorbic acid detection:

$$\text{Ascorbic acid (mg/100g pulp)} = \frac{(V1-V2) \times F \times 0.88 \times 1000}{V3}$$

where,

V1 = Volume of DCPIP solution used for the sample titration (ml)

V2 = Volume of DCPIP solution used for the blank titration (ml)

F = factor of DCPIP solution

0.88 = molecular weight of ascorbic acid

V3 = Volume of sample used (ml).

The reducing sugar was estimated by conducting Benedict test. Take test tube in test tube holder and add 5ml of Benedict's Reagent (Complex mixture of Sodium carbonate, sodium citrate and copper (II) sulphate pentahydrate). Add 8 drops of juice sample. Shake the content well and boil for approx. 1 min. Keep shaking little till colour changes from blue to following colours depicting the percentage of reducing sugar. Green (0.5%), Yellow (1%), Orange (1.5%), Red (2%), Brick red (more than 2%).

The total sugars of sweet orange fruit were determined by the method of Lane and Eynon (1923) [13] as described by Ranganna (1977) [21]. In a 250 ml conical flask, 50 ml of lead-free solution was combined with 10 ml of concentrated HCl (1:1) to invert the sucrose, and left for 24 hours. The resulting solution was transferred to a 250 ml volumetric flask and neutralized with 1N NaOH. After adjusting the volume to 250 ml with distilled water, the hydrolysate was

titrated against a boiling mixture of Fehling's solution A and B (5 ml each) using methylene blue as an indicator to determine the total sugars. The total sugar content was calculated using a specific formula and the results were reported as a percentage.

$$\text{Total sugar (\%)} = \frac{100 \times 250 \times 0.05 \times 250}{\text{Titre} \times \text{Weight of samples} \times 50}$$

Non-reducing sugar of the fruit was calculated by subtracting the value of the reducing sugar from total sugar of the juice for each sample individually.

$$\text{Non-reducing sugar (\%)} = \text{Total sugar (\%)} - \text{Reducing sugar (\%)}$$

The TSS: acid ratio represents the proportion of total soluble solids (TSS) to acidity found in each fruit. The data was collected based on replicated treatments and the average value was computed.

Temperature inside bags was measured with the help of specific thermometer used for the purpose. Due to variation in colour and material of bags, temperature inside it also showed varied values in degree Celsius.

Shelf life of fruit (days) was observed when fruits became spoiled and the no. of days fruit survived was noted.

For determining shelf life of fruit (physiological loss in weight%), Two fruits at the same level of maturity were randomly selected from each treatment. The initial weight of

these fruits was measured using a digital balance. Subsequently, they were stored in an open environment at room temperature for a period of thirty days. The weight loss of the fruits was recorded every six days. Finally, the total percentage of physiological weight loss was calculated using the provided formula:

$$\text{Physiological loss in weight (\%)} = \frac{(D_0 - D_1 \text{ or } D_0 - D_2 \text{ or } D_0 - D_3)}{D_0} \times 100$$

Where,

D₀ – Initial weight

D₁ – Weight after x days

D₂ – Weight after y days

D₃ – Weight after z days

Results and Discussion

The findings were systematically organized under relevant headings and subheadings, improving the clarity and understanding of the presented outcomes. The variation observed in values of different parameters may be due to varied colour and material of the bags used which enhances the micro climate inside bag differently giving varied results.

Physical Parameters

The data on the impact of different types of bagging on the physical parameters of sweet orange fruits is shown in Table 1.

Table 1: Effect of bagging on physical parameters of sweet orange fruits after 180 days of bagging

Treatment	Length of fruit (cm)	Diameter of (cm)	Fruit weight (g)	Juice percentage (%)	Peel/Rind thickness (mm)	Peel percentage (%)
T ₁	7.30	7.63	229.08	58.65	3.90	16.85
T ₂	8.18	8.13	267.23	62.50	2.75	15.80
T ₃	7.10	7.48	232.65	56.93	3.53	16.40
T ₄	7.55	7.90	240.50	59.23	4.23	17.13
T ₅	7.83	8.30	252.45	59.95	3.20	16.23
T ₆	6.97	7.12	225.80	55.42	4.37	17.62
T ₇	8.32	8.47	270.67	64.90	2.25	15.52
Mean	7.60	7.86	245.48	59.65	3.46	16.50
S.Em ±	0.05	0.05	0.26	0.02	0.05	0.08
CD at 5%	0.16	0.17	0.77	0.08	0.17	0.24

Length of fruit (cm)

180 days after bagging, at the time of harvest of fruits treatment T₇ significantly gave the utmost value for fruit length (8.32 cm) which was at par with T₂ (8.18 cm) and lowest was noted in T₆ (6.97 cm). Similar results were given by Johns and Scott (1989b)^[10] in banana and Xu *et al.* (2008)^[33] in carambola which validate the current results.

Diameter of (cm)

180 days after bagging, at the time of harvest of fruits treatment T₇ significantly gave the utmost value for fruit diameter (8.47 cm) which was at par with T₅ (8.30 cm) while the minimum value was noted in T₆ (7.12 cm). Yang *et al.* (2009)^[34] in longan, Harhash and Al-Obeed (2010)^[7] in date palm, and Chonhenchob *et al.* (2011)^[2] reported similar results which support the present findings.

Fruit weight (g)

180 days after bagging, after harvesting of fruits treatment T₇ significantly gave the utmost value for fruit weight (264.67 g) while the minimum value was noted in T₆ (222.02 g). The transparent polythene bag and white

polypropylene bag, interchangeably showed the most promising results for weight of fruit compared to other types of bags and control. Researches done by Fallahi *et al.* (2001)^[4] in Apple cultivar 'BC-2 Fuji', Wang *et al.* (2003)^[30] in litchi, reported similar and positive results for fruit weight due to bagging which validate the current data.

Juice percentage (%)

180 days after bagging, after harvesting of fruits treatment T₇ significantly gave the utmost value for juice percentage (64.90%) followed by T₂ (62.50%) while the minimum value was obtained in T₆ (55.42%).

Peel/Rind thickness (mm)

180 days after bagging, utmost decrease in peel thickness was observed than earlier intervals after harvest of fruits and again minimum peel/rind thickness was recorded in treatment T₇ (2.25 mm) followed by T₂ (2.75 mm) while treatment T₆ continued to give maximum value for peel/rind thickness (4.37 mm) which was statistically at par with T₄ (4.24 mm).

Peel percentage (%):

180 days after bagging, post-harvest of fruits lowest peel percentage was observed in T7 (15.52%) which was at par with T2 (15.80%) and treatment T6 significantly gave the utmost value for peel percentage (17.62%). The observed differences in peel percentage may be attributed to the varying colors and materials of the bags, which modify the

microclimate within each bag, resulting in diverse outcomes.

Chemical parameters

The data on the impact of different types of bagging on the chemical parameters of sweet orange fruits is shown in Table 2.

Table 2: Effect of bagging on chemical parameters of sweet orange fruits after 180 days of bagging

Treatment	TSS (°Brix)	Reducing sugars (%)	Non-reducing sugars (%)	Total sugar (%)	Titration acidity (%)	TSS:Acid ratio	Ascorbic acid (mg/100g pulp)
T ₁	10.60	3.53	3.58	7.11	0.54	19.72	52.85
T ₂	11.38	4.03	3.30	7.33	0.47	24.21	55.13
T ₃	10.45	3.68	3.56	7.24	0.57	18.50	54.75
T ₄	10.83	3.93	3.65	7.58	0.51	21.12	55.73
T ₅	10.98	4.39	3.90	8.29	0.48	23.00	58.83
T ₆	9.92	3.40	3.51	6.91	0.59	16.61	51.65
T ₇	11.82	4.42	3.89	8.32	0.45	25.99	58.92
Mean	10.85	3.90	3.62	7.53	0.51	21.30	55.40
S.E.m ±	0.03	0.02	0.02	0.01	0.005	0.28	0.03
CD at 5%	0.09	0.06	0.07	0.03	0.017	0.84	0.10

Table 3: Effect of bagging on temperature inside bag and shelf life of sweet orange fruits after 180 days of bagging

Treatment	Temperature inside bag (°C)	Shelf life of fruit (days)	Shelf life (Physical loss in weight %)
T ₁	33	27.23	10.94
T ₂	34	28.88	9.18
T ₃	36	27.64	10.72
T ₄	35.5	28.82	9.66
T ₅	34.5	29.77	7.45
T ₆	39.5	26.46	11.36
T ₇	36.2	30.95	7.13
Mean	35.6	28.53	9.49
S.E.m ±	0.26	0.02	0.04
CD at 5%	0.77	0.07	0.12

Total soluble solids (°Brix)

180 days after bagging, after harvest of fruits treatment T7 significantly gave the utmost value for fruit TSS (11.82°Brix) which was followed by T2 (11.38°Brix) while the minimum value for fruit TSS was noted in T6 (9.92°Brix). Polythene bag (transparent) and Polypropylene bag (white colour) along with Butter paper bag gave best results for TSS content in sweet orange fruits over all other bagging treatments and control. Equivalent results for increase in TSS due to fruit bagging were also given by Debnath and Mithra (2008) [3] in litchi, Sharma *et al.* (2014) [24] in apple, Lin *et al.* (2012) [14] in pear.

Reducing sugars (%)

180 days after bagging, harvested fruits showed utmost value for reducing sugar percentage in treatment T7 (4.42%) which was statistically at par with T5 (4.39%) while the minimum value was obtained in T6 (3.40%). Results for increase in reducing sugar content was given by Omar *et al.* (2020) [18] in date palm. It reported that the polyethylene coverage caused a significant increase in the percentage of reducing sugars in date palm fruits, being (25.18%) for transparent polythene compared (22.96%) in Control.

Non-reducing sugars (%)

180 days after bagging, after harvesting of fruits treatment T5 significantly gave the utmost value for non-reducing sugar content (3.90%) and was statistically at par with T7

(3.89%) while the lowest value was observed in T2 (3.30%). The Butter paper bag and transparent polythene bag gave the most promising results. Related results were also given by Omar *et al.* (2020) [18] who reported that the bunches coverage significantly affected the percentage of non-reducing sugars in date palm fruits.

Total sugar (%)

180 days after bagging, harvested fruits showed utmost value for total sugar percentage in treatment T7 (8.32%) which was statistically at par with T5 (8.29%) while the minimum value was obtained in T6 (6.91%). The transparent polythene bag and butter paper bag gave the most promising results. Sharma *et al.* (2014) [24] in apple, Lin *et al.* (2012) [14] in pear, Watanawan *et al.* (2008) [31] in mango, and Singh *et al.* (2017) [28] gave similar results about increase in total sugar percentage in bagged fruits.

Titration acidity (%)

180 days after bagging, after harvesting of fruits treatment T7 gave the lowest value for titration acidity percentage (0.45%). Treatment T6 significantly gave the utmost value for titration acidity percentage (0.59%) but at a decreasing rate than earlier intervals and it was statistically at par with T3 (0.57%). Similar results were given by Xie *et al.* (2013) [32] in sweet orange, Meena *et al.* (2016) [15] in guava fruit.

TSS:Acid ratio

180 days after bagging, after final harvesting of fruits treatment T7 significantly gave the utmost value for TSS:Acid ratio (25.99) followed by T2 (24.21) while the minimum value was obtained in T6 (16.61).

Ascorbic acid (mg/100g pulp)

180 days after bagging, after harvesting of fruits treatment T7 significantly gave the utmost value for ascorbic acid content (58.92 mg/100g) and was at par with T5 (58.83 mg/100g) while the lowest value was obtained in T6 (51.65 mg/100g). Transparent Polythene bag and Butter paper bag interchangeably gave the highest values for ascorbic acid content. Tehranifar *et al.* (2010) [29]; Seeram *et al.* (2005) [22] in pomegranate, Sharma *et al.* (2013) [26] in apple, Zhou *et al.* (2019) [35] in pear, Meena *et al.* (2016) [15] in guava, and

Singh *et al.* (2022)^[27] in apple revealed high ascorbic acid content occurred due to bagging of fruits.

Temperature inside bag (°C)

180 days after bagging, at the time of harvesting of fruits treatment T6 significantly gave the utmost value for temperature inside bag (39.5 °C) followed by T7 (36.2 °C) while the minimum value was obtained in T2 (34 °C) and Control (33 °C) respectively. Amarante *et al.* (2002)^[1] in pear, Muchui *et al.* (2010)^[16], and Kutinyu (2014)^[12] reported positive results for temperature inside bag of bagged fruits.

Shelf life of fruit (days)

The data indicates that the difference in fruit shelf life was significant. The longest shelf life was observed in T7 (30.95 days), followed by other treatments and hence it was notably superior to other treatments. In contrast, the shortest shelf life was recorded in T6 (26.46 days). Therefore, it was observed that bagging had a significant impact on the shelf life of sweet oranges. Similar result was given by Debnath and Mithra (2008)^[3] in litchi.

Shelf life (Physical loss in weight%)

After 30 days, T7 consecutively gave the minimum value for physical loss in weight of fruit i.e. (7.13%), with at par value of treatment T5 (7.45%) although the maximum fruit PLW was recorded in T6 (11.36%). Fruits covered with transparent polythene bag and butter paper bag gave the minimum value for physical loss in weight and proved to be the most significant treatments over all other treatments and control. However, Muchui *et al.* (2010)^[16] in banana and Amarante *et al.* (2002)^[1] in pear reported no significant effect of bagging on physical loss of weight of fruits.

Conclusion

The results of this study demonstrate that various treatments significantly impacted the physical parameters, chemical parameters, temperature inside bag, light intensity, mites incidence, shelf life and economic parameters in sweet orange Cv. Nucellar. Thorough analysis of the results suggested that transparent polythene bag, along with butter paper bag and white polypropylene bag proved to give the best results for all the parameters in sweet orange fruit. However, these findings are derived from a single season of experimentation and requires more research for validation.

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