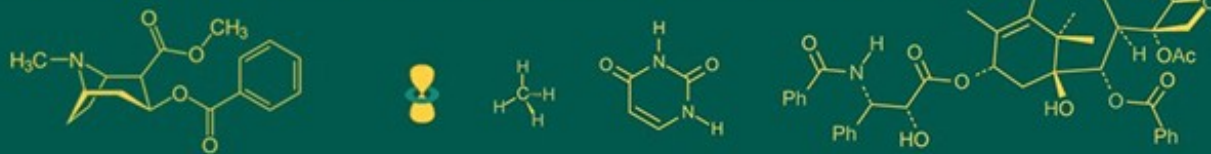


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Chemical changes in Nagpur mandarin (*Citrus reticulata* Blanco) as influenced by storage temperature and duration

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ABSTRACT

Nagpur mandarin (*Citrus Reticulata* Blanco) is an important citrus fruit with limited shelf life due to post-harvest deterioration. This study evaluated the effect of storage temperature and duration on fruit quality. Fruits were stored at $5 \pm 2^\circ\text{C}$, $10 \pm 1^\circ\text{C}$, $15 \pm 1^\circ\text{C}$, and ambient conditions ($25\text{--}30^\circ\text{C}$). TSS and total sugars increased, while titratable acidity and ascorbic acid decreased during storage. Juice pH increased slightly. Storage at 10°C was most suitable for maintaining fruit quality and reducing chilling injury. Therefore, 10°C storage with an appropriate duration is recommended for extending the shelf life of Nagpur mandarin.

Keywords: Nagpur mandarin, Cold storage, Storage temperature, Shelf life, Post-harvest quality, Chilling injury, Total soluble solids, Titratable acidity, Ascorbic acid

Introduction

Mandarin orange is an important citrus fruit widely consumed because of its nutritional and commercial value. It is an evergreen fruit tree belonging to the family Rutaceae and produces attractive orange-coloured fruits. Freshly harvested fruits and vegetables remain physiologically active and continue to respire after harvest, which contributes to progressive changes in quality during storage (Snowdown, 1988).

Mandarin orange is a non-climacteric and highly perishable fruit; therefore, its storage and transportation for extended periods can result in considerable quality deterioration. During post-harvest handling, both external and internal quality attributes, including total soluble solids (TSS) and titratable acidity (TA), may change with storage. Inadequate adoption of improved pre- and post-harvest technologies can further accelerate these changes. Post-harvest treatments are important for extending the shelf life and maintaining the quality of fruits (Deka, 2006, Patil *et al.*, 2024, Patil *et al.*, 2026) [1]. Post-harvest losses can be reduced by controlling transpiration, respiration, microbial infection, and deterioration of cellular membranes (Sahu, 2016).

Therefore, appropriate post-harvest treatments and storage conditions are essential for slowing physiological deterioration, maintaining quality attributes, and extending the shelf life of mandarin orange

Materials and methods

The investigation was carried out in the Food Engineering Laboratory, Department of Agricultural Process Engineering, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. Fresh Nagpur mandarin (*Citrus Reticulata* Blanco) fruits were obtained from the local market at the initial colour-break stage. Fruits free from visible injuries, diseases and physical defects, and having relatively uniform size, were selected for the study. The fruits were cleaned with water, surface-dried and subsequently subjected to storage under controlled temperature conditions of $5 \pm 2^\circ\text{C}$, $10 \pm 1^\circ\text{C}$, $15 \pm 1^\circ\text{C}$, along with an ambient control of $25\text{--}30^\circ\text{C}$. The experiment was conducted using a factorial completely randomized design (FCRD) with three replications.

The biochemical composition of the stored fruits was assessed through total soluble solids, titratable acidity, pH, total sugars and ascorbic acid content. Total soluble solids were measured using a digital refractometer following Jawandha *et al.* (2012). Titratable acidity was estimated by neutralization titration with sodium hydroxide according to Thakur *et al.* (2002) and Patil *et al.*, (2024) [2], while juice pH was determined using a calibrated digital pH meter following Palma *et al.* (2003). Total sugar content was estimated by the volumetric procedure of Lane and Eynon (1923), and ascorbic acid was quantified by the dye-titration method of Tillmans (1932).

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Statistical analysis

During this study, a Factorial design under factorial Completely Randomized Design (FCRD) was used in the experiment. There were four treatments; each cultivar represents a treatment, and each treatment has three replications, and every replication has 30 fruits. The data was analyzed statistically through a 2-way Analysis of Variances (ANOVA). The differences among treatment means were analyzed using the LSD test at a 5% level of significance

Result and Discussion

Total soluble solid (TSS)

Total soluble solids (TSS) were determined using an ATAGO RX-5000 digital refractometer. An aliquot of freshly extracted juice was placed on the prism, and TSS was recorded and expressed as percentage (%). TSS increased during storage, indicating changes in fruit juice composition. The highest value was recorded in the control at 14 days (22.73 °Brix), followed by 5 °C (20.00 °Brix). The lowest TSS was recorded at 10 °C (15.27 °Brix) after 14 days (Table 1). Nagpur

mandarin quality was evaluated at different temperatures. TSS increased over 14 days at 5 °C (8.37 to 20.00 °Brix), 10 °C (10.13 to 15.27 °Brix), and 15 °C (8.20 to 18.63 °Brix). In the control, it rose from 12.37 to 22.73 °Brix by day 7, then declined to 5.00 °Brix at day 14 (fig 1. A)).

Titration acidity (%)

Titration acidity was determined by titrating a diluted fruit juice aliquot with 0.1 N NaOH using phenolphthalein as an indicator. The endpoint was identified by the development of a persistent pink colour, and acidity was expressed as (%) (Patil *et al.*, 2024) [2]. Titration acidity decreased gradually during storage. The highest value was 1.61% in the control at day 0, while the lowest value was 1.47% at 5 °C and 10 °C after 14 days. Acidity decreased during storage due to organic acid utilization in respiration (Table 1). Titration acidity showed a gradual decreasing trend during storage. It decreased from 1.52% to 1.47% at 5 °C, 1.53% to 1.47% at 10 °C, 1.55% to 1.50% at 15 °C, and 1.61% to 1.55% in the control from 0 to 14 days. (fig 1. B))

Titration acidity (%) =

$$\frac{T.V \times N(0.1) \times \text{equivalent weight of citric acid (0.064)}}{\text{volume of sample taken}} \times 100$$

Where,

T.V = Titration volume

N = Normality (0.1)

Equivalent weight of citric acid = 0.064

Juice pH

Freshly extracted fruit juice was analysed for pH using a HANA 8520 pH meter after calibration at pH 7.0. The highest juice pH was recorded at 5 °C (3.57), followed by 10 °C (3.35) and 15 °C (3.31), while the control had the lowest (3.43). Juice pH increased slightly during storage due to reduced organic acid content (Table 1). Juice pH remained nearly stable at 5 °C, 10 °C, and 15 °C, while the control showed a sharp increase to 5.0 at 14 days. (fig 1. C))

Table 1. chemical attributes of Nagpur mandarin as influenced by storage temperature and storage duration

Treatment	Storage Duration (days)	TSS (°Brix)	T.A (%)	Juice pH	A.A (mg/100 g)	T.S (%)
5 °C	0	8.37	1.52	3.55	53.72	5.47
	7	14.58	1.50	3.55	53.04	5.77
	14	20.00	1.47	3.57	51.62	6.57
10 °C	0	10.13	1.53	3.33	54.93	5.67
	7	12.71	1.50	3.33	54.25	5.78
	14	15.27	1.47	3.35	53.57	7.05
15 °C	0	8.20	1.55	3.31	51.40	5.49
	7	9.20	1.53	3.31	50.72	5.82
	14	18.63	1.50	3.33	49.35	6.53
Control (25–30 °C)	0	12.37	1.61	3.43	50.00	5.49
	7	12.80	1.58	3.43	49.32	5.83
	14	22.73	1.55	3.45	47.95	6.76
Mean		15.56	1.51	3.43	51.25	6.15
SE(m) ± Temperature		0.13	0.10	0.07	0.01	0.10
SE(m) ± Storage duration		0.12	0.10	0.06	0.01	0.08
SE(m) ± T × D		0.23	0.10	0.13	0.02	0.17
CD at 5% Temperature		0.39	0.49	0.21	0.03	0.28
CD at 5% Storage duration		0.34	0.49	0.18	0.03	0.24
CD at 5% T × D		0.68	0.97	0.37	0.06	0.48

Note: T × D = interaction between storage temperature and storage duration. The CD values are

(continued on next page)

calculated at the 5% level using the experimental error.

TSS- Total soluble solid, T.A- Titrable acidity, A.A- Ascorbic acid, T.S- Total sugar

* = Significant at 5% level; NS = Non-significant; SE_m = Standard error of mean;

CD = Critical difference at 5% level; $T \times D$ = Interaction between storage temperature and storage duration

Vitamin C (Ascorbic acid mg/100g)

Ascorbic acid concentration was quantified by the 2,6-dichloroindophenol (DCPIP) titrimetric method. The clarified juice extract was titrated against standardized DCPIP using 4% oxalic acid as the extraction medium until a persistent faint-pink endpoint was observed. Results were expressed as mg ascorbic acid per 100 mL of juice. Ascorbic acid decreased during storage, possibly due to oxidation. The highest initial content was recorded at 10 °C (54.93 mg/100 g), while the control recorded the lowest value at 14 days (47.95 mg/100 g). (Table 1). Ascorbic acid decreased slightly during storage at 5 °C, 10 °C, and 15 °C. Ascorbic acid content decreased with increasing storage duration. The highest initial value was 54.93 mg/100 g at 10 °C, whereas the control recorded the lowest value of 47.95 mg/100 g after 14 days. (fig 1. D).

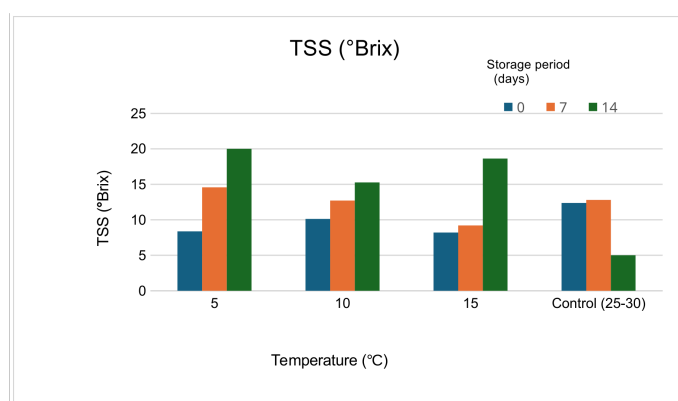
$$\text{Ascorbic acid (mg/100g)} = \frac{0.5 \times v_2 \times 100 \times 100}{v_1 \times w}$$

Where,

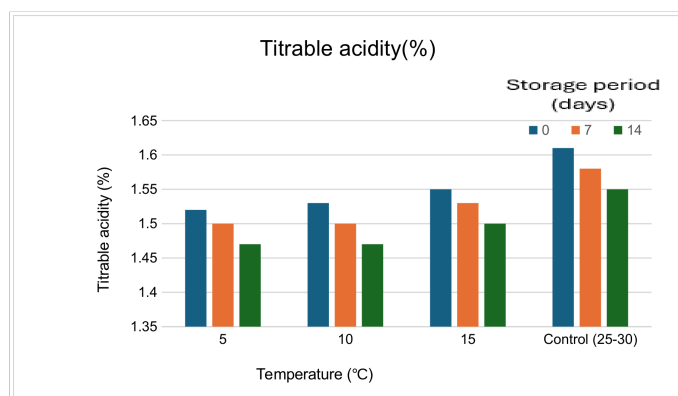
V2 = titration of sample

V1 = titration of working standard

W = weight of sample

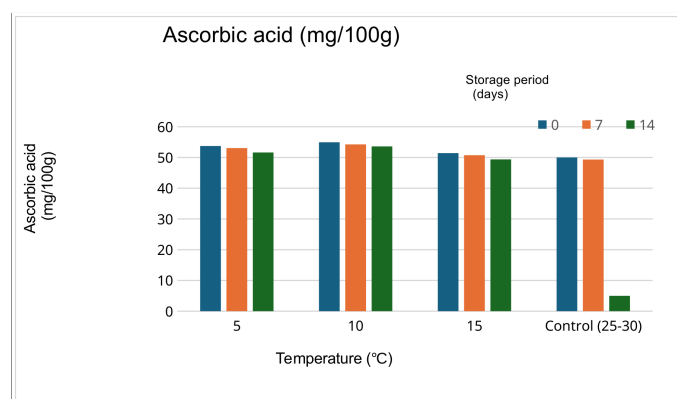
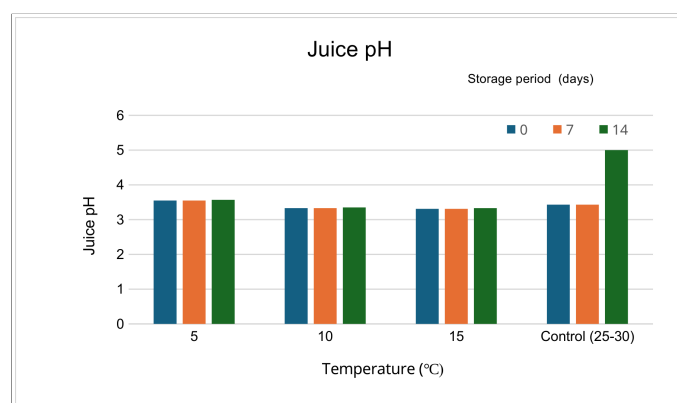


A)



B)

C)



D)

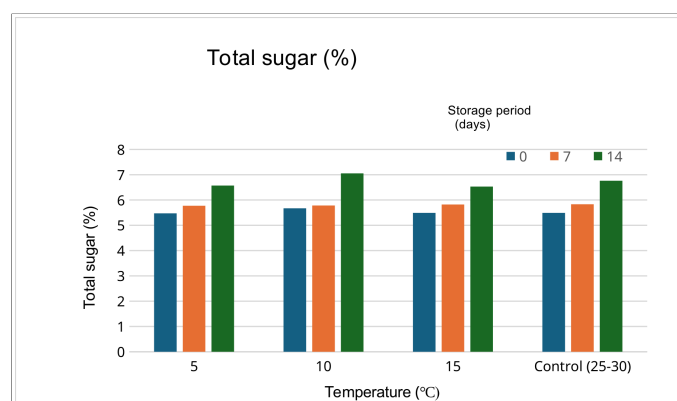


Figure 1. A) represent TSS (°Brix), B) Titrable acidity (%), C) Juice pH, D) Ascorbic acid (mg/100g), E) Total sugar (%) as influenced by storage temperature and storage duration of Nagpur mandarin

E)

Total sugar (%)

Total sugar was determined by the Lane–Eynon titrimetric method using Fehling's solutions and methylene blue indicator. The fruit extract was hydrolysed, neutralized, and titrated with standardized sucrose solution under boiling conditions. Sugar content was calculated from the blank and sample titre values and expressed as percentage. Total sugar increased with storage duration at all temperatures, Total sugar increased with storage duration, possibly due to the conversion of complex carbohydrates into simpler sugars. The highest value was recorded at 10 °C (7.05%) after 14 days, followed by the control (6.76%) (Table 1). Total sugar content increased during storage, reaching the highest value of 7.05% at 10 °C after 14 days. The control also showed an increasing trend, indicating progressive sugar accumulation. (fig 1. E)).

$$\text{Total sugar (\%)} = \frac{(B - S) \times C \times 250 \times 100 \times 100}{w \times v \times 50}$$

Where,

B = Volume of working standard

for blank Titration

S = Volume of working standard for sample titration

C = Sugar working standard concentration

W = Sample weight

V = Volume of final sample solution used during titration

Conclusion

It is concluded that Storage temperature and duration significantly affected the quality and shelf life of Nagpur mandarin. Storage at 10 °C was most suitable for maintaining fruit quality and reducing chilling injury. Prolonged storage increased moisture loss and quality deterioration. Therefore, 10 °C storage is recommended for extending the shelf life and maintaining the marketable quality of Nagpur mandarin fruits.

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