JOURNAL OF HORTICULTURE AND POSTHARVEST RESEARCH
2022, VOL. 5(1), 93-104

Journal of Horticulture and Postharvest Research

Journal homepage: www.jhpr.birjand.ac.ir

University of Birjand

The effect of different treatments on the storage life characteristics of 'Siaverz' local orange (*Citrus sinensis* L.) in storage conditions

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ARTICLE INFO

Original Article

Article history:
Received 9 June 2021
Revised 12 January 2022
Accepted 3 February 2022
Available online 24 February 2022

Keywords:
Post-harvest
Total soluble solids
Wax
Wax paper
Weight loss

DOI: 10.22077/jhpr.2022.4330.1210
P-ISSN: 2588-4883
E-ISSN: 2588-6169

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ABSTRACT

Purpose: The type of pre-storage treatments has a significant effect on the fruit quality at postharvest storage. In this study, the effects of some physical and chemical treatments on the quality and storage properties of 'Siaverz' local orange in the cold storage were investigated. **Research method:** This research was conducted as a factorial experiment with factors of different treatments and storage time. Treatments were wax paper, Rovral-TS fungicide, wax, hot salty solution, Rovral-TS fungicide+wax paper, hot salty solution+wax paper, Rovral-TS fungicide+wax, hot salty solution+wax, and control. The fruits were stored at 8°C and examined monthly. **Findings:** Increasing the storage period for 90 days in control, wax paper, fungicide, fungicide+wax, and hot salty solution+wax treatments resulted in an increase in the soluble solids compared to the 30-day treatment. The increase in the storage period was accompanied by a decrease in titratable acidity. As the storage period progressed, the percentage of weight loss increased constantly. Hot salty solution+wax and wax paper treatments showed the lowest weight loss. The highest taste index was related to the control treatment and then the wax paper. The firmness of fruit tissue was reduced after 90 days of storage. **Research limitations:** No limitations were found. **Originality/Value:** The wax paper treatment and the combination treatment of hot salty solution+wax can be recommended to maintain the quality of 'Siaverz' local orange during the storage period for 90 days.

INTRODUCTION

Orange is one of the most important and popular fruits in subtropical regions. This fruit has vitamin C, folate, fiber, minerals, and phytochemicals (Roussos, 2011). The origin of oranges is from China and Southeast Asia (Zanoni et al., 2005). Usually, during the harvest season, the balance between supply and demand for horticultural yields is upset, and prices reduce due to the high supply of the yield to the market. To prevent this and prolong the supply period of the yield in the market, it is necessary to store some of the harvested yields in the storage and gradually supply them to the market. In this regard, only a part of produced citrus directly enters the consumer market every year and most of it is stored in cold storage for three to four months (Shaabanian et al., 2015).

Although citrus fruits are non-climacteric, the change of compounds in the fruit depending on the storage period (Lester & Hodges, 2007). On the other hand, due to unsuitable conditions in the storage, the waste of the yield is high every year. Integrated treatments, such as hot water treatments and chlorine disinfection, have been successfully used in the global citrus industry (Kassim et al., 2020). To reduce the loss of quality and fruit waste in the storage, the use of some coatings has been considered by researchers (Obenland et al., 2011, Puttongsiri & Haruenkit, 2010). These treatments include fungicides, hot salty solutions, waxes, or a combination of these treatments.

The use of chemical treatments has the most economical effect on controlling citrus fungal rot (Chandra et al., 1995), but the residues of the systemic fungicides for human and environmental health have led researchers to look for new ways to maintain quality and reduce storage waste (Plaza et al., 2004). Healthy compounds such as sodium bicarbonate along with heat treatments are good alternatives to harmful chemical toxins for human health and the environment (Plaza et al., 2004).

Shekari et al. (2012) showed that immersion of fruits in saline solutions of sodium and potassium carbonate and bicarbonate for three minutes reduced more waste than the control treatment. Using electron microscopy scanning, it was found that in 'Fortune' cultivar mandarin fruits immersing in warm water were not create deep gaps in the temperatures of 54-50°C compared to the control fruit (Schirra et al., 2004).

Wax coating is used as one of the common chemical treatments to prevent fruit weight loss. The use of wax coating has been reported to increase the storage period of citrus fruits (Chien et al., 2007) and improve the appearance and reduce weight loss (Chen & Nussinovich, 2001). The results of a research showed that the use of wax and hot water treatment significantly prevented weight loss and tissue firmness (Alemzadeh Ansari & Feridoon, 2007). It was found that treated orange fruits with wax had the lowest weight loss (Marcilla et al., 2009). In another research, wax treated fruits recorded the maximum juice recovery percentage (31.43%) whereas the minimum juice recovery percentage (27.81%) was observed in control fruits (Thapa et al., 2020).

Lo-Scalzo et al. (2004) showed that total soluble solids (TSS) and titratable acidity (TA) decreased at the end of the storage period in all species except 'Valencia' orange, which showed a slight increase. Shoja et al. (2011) reported the reduction of TSS and TA in orange during storage with coating treatments. The use of the coating leads to lower metabolism, preservation of organic acids and reduces the TSS/TA ratio, although relatively low temperatures in storage also play a role in reducing respiration and fruit metabolism (Meng et al., 2008). In another study, TA was significantly preserved at a higher level in wax coatings during the storage period (Shaabanian et al., 2015). Contrary to these results, it has been reported that by covering fruits, the taste index increased due to a decrease in TA (Shen et al., 2012). Lo-Scalzo et al. (2004) reported that fruit weight loss during storage was significantly different in citrus cultivars due to differences in skin thickness with protective coatings on the skin, such as waxes on the cuticle.

The type of cover treatment during storage will have a significant effect on fruit quality, so it is important to study the different methods that lead to preventing fruit quality reduction in storage (Choi et al., 2002). Iranian local orange (*Citrus sinensis* L.Cv. 'Siaverz') is one of the oldest cultivars of oranges in Iran, which have been cultivated in the Hajiabad region of Hormozgan province for many years due to their good quality and suitable climate compatibility with southern Iran. It is necessary to achieve cheap, accessible, and safe treatments for human health and the environment and keep the quality properties of the fruit for a longer period of time.

MATERIALS AND METHODS

Plant material

The flowering period of 'Siaverz' was from March 15 to April 29. 'Siaverz' fruits were harvested from Hormozgan Agricultural and Natural Resources Research Center, Iran in the second half of December after measuring fruit taste index. Ratio of TSS to TA in about 10 fruits was considered at least 8 (Azad Shahraki & Kafashan, 2018). The orchard had geographical coordinates of 55° 54´ east and 28° 18´ north with a height of 931.2 meters above sea level. A total of 810 healthy fruits were selected with uniform size and color and randomly placed in 30 units.

Treatments

Treatments included wax paper (WP), fungicide (F), wax (W), hot salty solution (S), fungicide+wax paper (F+WP), hot salty solution+wax paper (S+WP), fungicide+wax (F+W), hot salty solution+wax (S+W) and control (C) treatments. The hot salty solution treatment involved immersion of the fruits in sodium carbonate solution (EMSURE® Merck) in a ratio of 1.3 weight to the volume (1.3 gr sodium carbonate in 100 ml water) at a temperature of 45°C for 150 seconds. The fungicide treatment involved immersing the fruits in a Rovral-TS fungicide solution at a concentration of one per thousand for two minutes. Rovral-TS, which is Iprodione+Carbendazim fungicides with 52.5% wettable powder, is a systemic contact fungicide. The wax treatment included waxing the surface of the fruit (a common type used by producers in the area) with a wax-soaked sponge. In the wax paper treatment (including kraft paper compositions, glue, 10-micron thick aluminum layer, and paraffin listed in Iranian National Standard No. 1461), the fruits were also placed in wax paper. In the control treatment, the fruits were placed in a plastic box without any treatment.

The fruits were placed in plastic boxes after the treatment so that 30 fruits were included in each box and a total of 27 boxes. The boxes were kept in the cold storage with a temperature of 8 °C and relative humidity of 85% for three months.

Measured traits

The measured quality parameters included total soluble solids (TSS), titratable acid (TA), taste index, fruit firmness and fruit weight loss percentage, which were measured at 30 days' intervals (three times during storage). Each test unit was weighed before and after being transferred to the cold storage. By calculating the difference between primary and secondary weight, the percentage of weight loss was recorded. An Italian-made EFFEGI handheld penetrometer was used to determine tissue firmness. For this, the fruit (without the peel) tissue pressure was measured with a special cap and the incoming force was recorded as kg/cm^2. TSS was measured by an ATAGO N-1α refractometer made in Japan in percentage and using fruit juice. TA was calculated by titration with 0.1 N NaOH and according to citric acid (Varasteh et al., 2012). The taste index was obtained by dividing the TSS by TA (Razzaq et al., 2014).

Data analysis and experimental design

This research was carried out as a factorial experiment based on a randomized complete block design with two factors including storage time at three levels and type of coating at nine levels with three replications and 30 fruits per replication. Data analysis was performed using SAS statistical software (version 9.1) and comparison of means using the LSD method.

RESULTS AND DISCUSSION

According to the results of analysis of variance (Table 1), the interaction between treatment type and storage period on TSS at the 1% level and on the taste index at the 5% level were significant (Table 1). The main effect of the storage period on the percentage of weight loss, TA, and tissue firmness at the 1% level was significant. The type of treatment also had a significant effect on the percentage of weight loss.

With prolonged storage period, the percentage of weight loss increased with a relatively constant slope. This increase in weight loss in the 90-day treatment was 3.53 times that of the 30-day treatment (Fig. 1). Loss of water during storage leads to fruit weight loss and weight loss has a negative effect on the appearance of the fruit (Pasquariello et al., 2013). Fruit weight loss is caused by water loss through skin apertures or biological changes. Rapid reduction of water content in fruit is a good indicator of its aging (Rahemi, 2003). Shaabanian et al. (2015) evaluated the role of different coatings to increase the storage time of 'Valencia' orange at 5-12°C for three months and reported that fruit weight loss was more evident in the third month of storage.

According to the results (Fig. 2), the highest percentage of fruit weight loss belonged to the fungicide+wax treatment with an average of 25.31%. After that, the control treatment showed the highest weight loss with an average of 23.93%. Treatments with the fungicide as well as control treatment showed more weight loss than other treatments. Hot salty solution+wax treatment showed the lowest percentage of weight loss with an average of 11.84%. Similarly, Larrigaudiere et al. (2002) and Willams et al. (1994) reported that 'Valencia' with hot water treatment had less weight loss in storage. It has also been reported that wax coating is more resistant to water vapor passing (Rahmatian et al., 2015). Wax on fruit can reduce moisture and gas exchange, and wax paper can reduce moisture exchange, and thus these coatings have led to less weight loss.

Table 1. Analysis of variance of the effect of treatment type and storage period on the storage life traits measured in 'Siavers' orange cultivar

Source of variation	df	Mean square				
		Weight loss	TSS	TA	Taste index	Tissue firmness
Storage period	2	3344.07**	6.42**	0.13**	28.53**	15.21**
Treatment	8	141.39**	4.35**	0.017^{ns}	1.59^{ns}	0.32^{ns}
Storage period × treatment	16	11.3^{ns}	2.35**	0.01^{ns}	4.06*	0.19^{ns}
Error	54	22.1	0.67	0.015	2.12	0.2
Coefficient of variations	-	23.23	5.62	10.24	11.89	15.39

**,* and ns: Significant at the 1% and 5% probability level and non-significant difference respectively

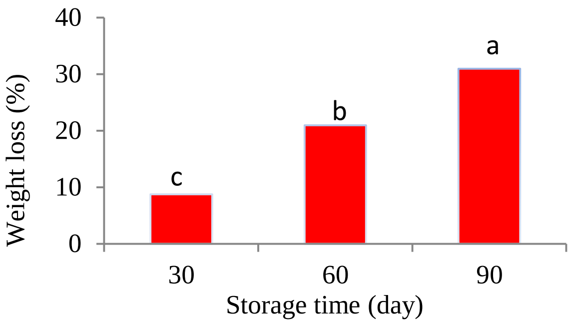

Fig. 1. The effect of storage time on weight loss percentage in 'Siaverz' orange

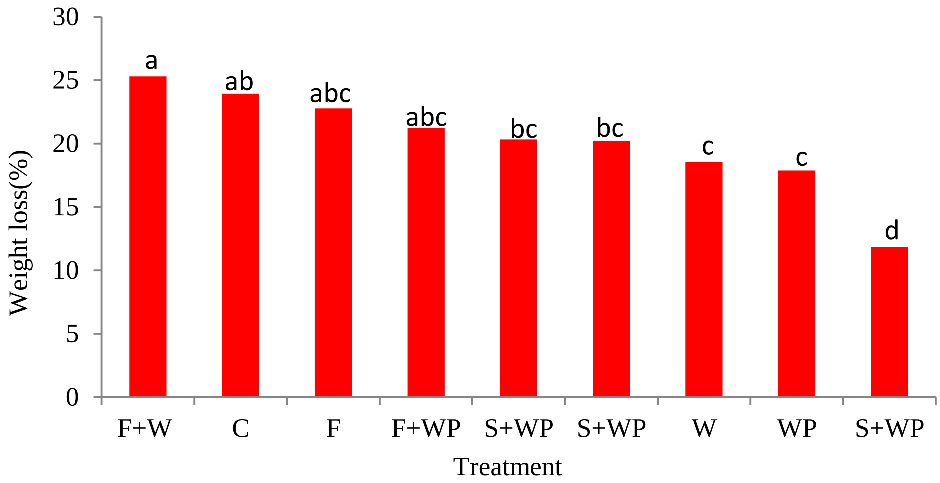

Fig. 2. The effect of treatments on weight loss percentage in 'Siaverz' orange

The interaction of the type of treatment and storage period (Fig. 3) showed that the 90-day storage period in control, wax paper, fungicide, fungicide+wax and also hot salty solution+wax treatments led to an increase of 14.86, 14.4, 15.9, 12.35 and 9.11% in TSS compared to 30-day treatment, respectively. The increase in sugar content in citrus during the storage period occurs due to cell wall hydrolysis with cellulose, hemicellulose and pectase enzymes that convert cellulose, hemicellulose, and pectin into simple sugars and this increase is consistent with the results of Obenland et al. (2011). They reported an increase in TSS by studying 'W. Murcott' mandarin cultivar, which was stored during 0, 3, and 6 weeks at 0, 4, and 8°C. It has been reported that the increase in TSS during storage is not only related to the addition of sugar but also the increase and decrease of other substances such as acids, soluble pectins, and phenolic compounds (Amodio et al., 2007). Similarly, Golshan Tafti & Shahbeig (2004) studied the effects of polyethylene coating, thiabendazole fungicide and heat treatments on 'Valencia', 'Marr's Early' and local Jiroft orange cultivars and reported that the percentage of TSS during storage was 15.7%, 15.9%, and 15.3%, respectively, which was higher than the initial values (9.8%, 15.5%, and 14.4%, respectively). The 90-day storage period in the treatments showed that the control treatment had the highest TSS compared to the other treatments. Wax paper, fungicide, fungicide+wax, fungicide+wax paper, hot salty solution+wax paper, wax, hot salty solution+wax, and hot salty solution treatments showed 1.62, 2.63, 4.45, 7.08, 9.92, 11.74, 12.75 and 17.56% reduction in TSS compared to the control treatment, respectively.

Table 2. Interaction of treatment and storage period on TSS/TA in 'Siaverz' orange

Treatment	Storage period (day)		
	30	60	90
Control	11.56±0.90fgh	11.19±0.78gh	15.48±1.50a
Wax paper	11.33±1.03gh	12.15±0.79defgh	14.04±1.36b
Fungicide	11.64±0.68efgh	11.22±0.49gh	13.94±0.65b
Wax	12.19±0.53defgh	12.46±1.25cdefg	13.13±1.02bcd
Hot salty solution	11.22±1.38gh	12.27±1.49defgh	10.94±0.45h
Fungicide + Wax paper	11.78±0.78efgh	12.95±1.45bcde	13.62±1.70bcd
Hot salty solution + Wax paper	11.37±1.45gh	11.48±1.99gh	12.87±1.06bcdef
Fungicide + Wax	13.26±0.65bcd	12.95±0.77bcde	13.77±0.78bc
Hot salty solution + Wax	11.18±1.85gh	10.95±1.56h	13.12±1.05bcd

The average ± standard error (SD)

TSS in wax, hot salty solution, fungicide+wax paper as well as hot salty solution+wax paper treatments in 60 days storage period, increased (6.42, 3.95, 8.92 and 6.74%, respectively). and then decreased (2.48, 4.5, 1.29, and 6.31%, respectively) (Fig. 3). Similarly, the reduction of TSS was observed at the end of the storage period of 'Jaffa' and 'Sanguino' orange cultivars that treated with sodium bicarbonate and immersion in 53°C water (Sadrnia et al., 2015) and in 'Satsuma' mandarin that treated with hot water 52, 55 and 60°C for 2 minutes, 1 minute and 20 seconds, respectively (Hong et al., 2007). Lo-Piero et al. (2005) stated that the reduction in TSS during storage is due to the consumption of sugar in respiration and energy supply for the endothermic process.

In this study, the highest TSS with an average of 16.46% belonged to the control treatment and storage for 90 days (Fig. 3). Shaabanian et al. (2015) and Thapa et al. (2020) also reported that TSS in control treatment was more than coating treatments. As regards that the control treatment was uncovered, it seems that more water loss has occurred in the fruits of this treatment and the decrease in fruit juice has increased the concentration of TSS. An increase in TSS with increasing storage time has also been reported by Baltazari et al. (2019).

30 and 60 days storage period did not show a significant difference in TA, but further increase in storage period was associated with a decrease in TA by 7.43% (Fig. 4). Organic acids have a high volume of fruit extract at the beginning of fruit development, but as the fruit ripens, most organic acids decompose or convert to other organic acids or sugars, increasing the sweetness of the fruit (Hudian & Stampar, 2004). The reduction of citric acid during the storage of citrus fruits may be due to the use of organic acids for energy production, conversion to sugar, or alcoholic fermentation in fruits (Roongruangsri et al., 2013). TA decrease has also been reported by other researchers (Klimezak & Malecka, 2006). In the present study, the effect of treatment type on TA was not significant.

The relationship between TSS and TA plays an important role in citrus fruit consumption and expresses the sweetness or sourness of citrus fruits (Pehrson & Ivans, 1988). If this ratio for orange is in the range of 8 to 10, the fruit will be sour for most consumers. If this value is in the range above 19 to 20, it will not be welcomed by most consumers due to the excessive sweetness (Ladaniya, 2008). With the prolongation of the storage time, the taste index showed an increasing trend (Table 2). An increase in TSS/TA with an increase in storage period has been reported by other researchers in citrus fruit (Marcilla et al., 2009). At the end of the third month, the taste index only in the hot salty solution treatment was lower than the second month. It has been reported that heat treatment on 'Satsuma' mandarin reduced the taste index during the five-week storage period at 5°C due to the continuous consumption of sugar and organic acids for metabolism (Hong et al., 2007).

The highest taste index by an average of 15.48 was belonged to control treatment that was stored for 90 days. It seems that the high TSS in this treatment has led to an increase in the taste index. After the control treatment, the wax paper treatment had the highest taste index. It seems that the ability to transfer oxygen in this treatment prevents fermentation and decreases the taste index (Rahmatian et al., 2015). According to the results, hot salty solution+wax treatment at the end of the second month had the lowest taste index (10.33). In this treatment, it seems that gas exchange has decreased and fermentation has taken place in the fruit. In these conditions, the percentage of weight loss also decreased (Rahemi, 2003).

According to Figure 5, fruit firmness decreased 90 days after storage, but there was no significant difference between the storage period of 30 and 60 days. The firmness of the fruit depends on the structure and composition of the cell wall (Valero & Serrno, 2010). Fruit maturation and aging lead to the dissolution of the middle blade and loss of cell wall cohesion, and it leads to increased activity of hydrolyzing enzymes and reduced firmness of fruit tissue (Raese & Drake, 2000). Decreased firmness of fruit tissue with the prolongation of the storage period was according to the results of Fidelibus et al. (2002).

In the present study, the type of treatment did not affect fruit firmness, which was consistent with the results of some researchers (Lydakis & Aked, 2003, Hong et al., 2007). In contrast, other researchers (Willams et al., 1994; Schirra et al., 2004) found that the texture of the fruits under heat treatment remained firmer after the end of the storage period. They attributed the increase in fruit firmness to the loss of fruit juice due to heat treatment.

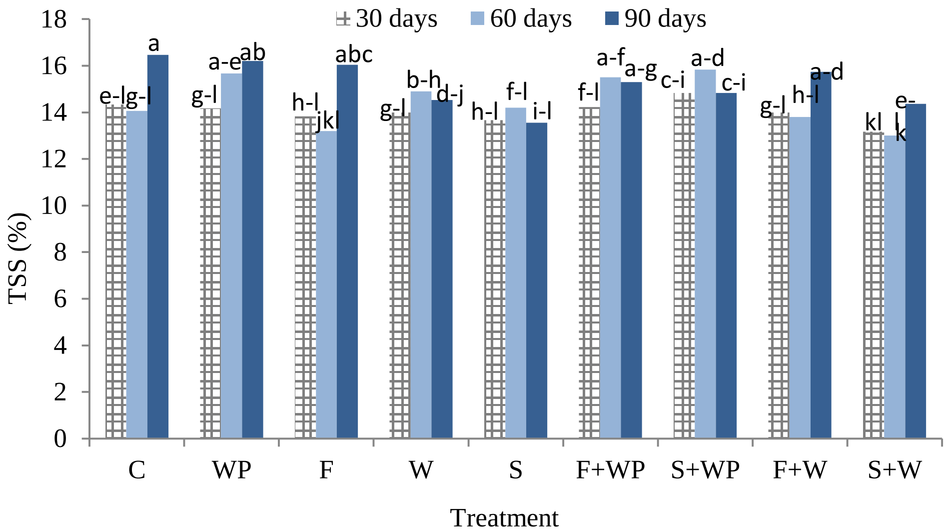

Fig. 3. Interaction of treatment and storage period on TSS percentage in 'Siaverz' orange

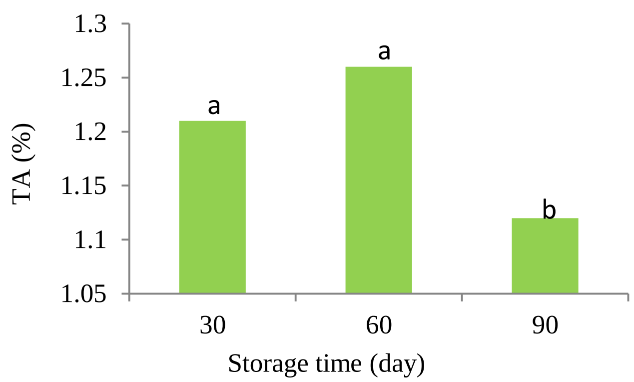

Fig. 4. The effect of storage time on TA in 'Siaverz' orange

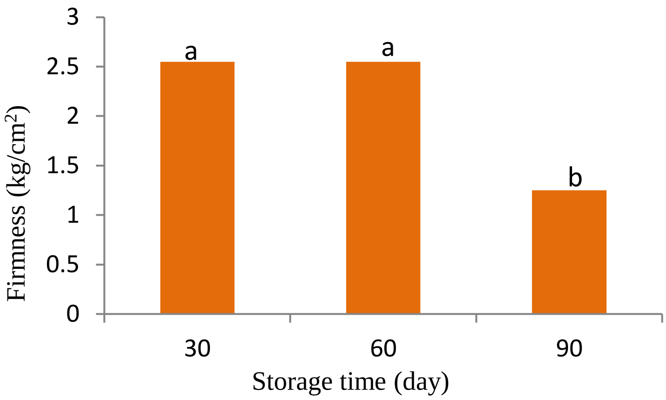

Fig. 5. The effect of storage time on fruit firmness in 'Siaverz' orange

CONCLUSION

In general, the wax paper treatment and its combination with hot salty treatment were more effective in maintaining storage properties. These treatments showed the lowest percentage of fruit weight loss. Wax paper prevents fermentation in fruit due to its ability to transfer oxygen. Also, due to the prevention of water vapor leakage in this treatment, lower weight loss observed. Treatment of hot salty solution+wax also reduced gas exchange and resulted in less weight loss than other treatments. As regards the used coating to store the fruit in the cold storage must be cheap, available, safe for human health and the environment, and also maintain the fruit quality at the desired level, with the least weight loss, the results of this study showed that wax paper and hot salty solution+wax treatments are suitable for 'Siaverz' local orange.

Conflict of interest

The authors declare that they have no competing interests.

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