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Interactive Effects of Yeast Coating and Packaging Types on the Postharvest Quality of Local Oranges (Citrus sinensis L.)

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ABSTRACT: Cold storage of orange fruit reduces its respiration rate and metabolic process. This helps to decreasing the postharvest loss in orange fruit. Cold storage efficiently keeps the physicochemical qualities under control such as weight, firmness, total soluble solids and acidity, when coupled with the proper postharvest treatments such as edible coatings or modified packaging. This study was carried out on local orange (Citrus sinensis L.) fruits at the Department of Horticulture and Landscape Design, College of Agricultural Engineering Sciences, Salahaddin University- Erbil, to investigate the influence of yeast coating treatment (10 g. L⁻¹), packaging materials (control, plastic box and foam box), besides storage Durations (7, 14 and 21) days on fruit quality. Likewise (weight loss, total soluble solids (TSS), pH, and commercial value) were among the important factors evaluated.

The findings demonstrated that storage length exerted the most pronounced effect, leading to greater weight loss and TSS, associated by a drop in marketability. Therefore, fruit quality was best preserved by plastic packaging, which was followed by foam packaging. Nevertheless, effects of coating treatments, especially those based on yeast, were inconsistent and often insignificant. While pH and marketable value were less impacted, weight loss and TSS showed significant interactions across treatments. Overall, the results reinforce the crucial role of optimizing storage duration and packaging solutions, while indicating the need for further research to optimize the efficacy of coating treatments.

1 INTRODUCTION

Oranges (*Citrus sinensis* L.) are one of the major fruit crops grown in the world and have a great economic significance in the world citrus industry. Oranges are fruits of the Rutaceae family, which includes commercially important fruits such as lemons, mandarins and grapefruits (Saleem *et al.,* 2024). Oranges mainly cultivate tropical and subtropical regions because of their high consumer demand. The extensive cultivation of eggplant is due to its desirable sensory attributes, nutritional value and excellent suitability for consumption as fresh and for industrial processing (Gupta *et al.,* 2023)

In economic terms, oranges contribute to the juice processing industry since orange juice is one of the most consumed fruit juices in the world. It helps engage in international trade and national agricultural economics (Phaleng *et al.,* 2024).

Consequently, in the botanical classification, oranges are classified as hesperidia, which are non-climacteric fruits that do not have a substantial increase in respiration and ethylene production after harvest. Hence, they require harvest at optimum the maturity for quality (Arista and Ardiningtyas, 2024), and the peel color, TSS, T.A. and sugar/acid ratio are maturity indices. On the other hand, Yeasts are unicellular eukaryotic microbes that belong primarily to the phylum Ascomycota (Liu, 2024). They are universal, found on the surface of plants, fruits, in soil and water.

Yeasts primarily multiply through budding or separation and can grow quickly in favorable at present, due to the biological control potential, besides their traditional applications in baking, brewing and winemaking processes, yeasts are being applied in agriculture and postharvest management (He *et al.,* 2024). Furthermore, the requirement of food is essential for human to get energy for daily activities. Foam packing is widely used in postharvest handling of fresh fruit. Due to its cushioning and protecting properties, usually built of expanded.

Foam boxes manufactured with polystyrene help in the protection of fruits from physical damage during transportation and storage. Thus, restraining bruising, compression and peel injuries (Javed *et al.,* 2018).

In recent decades, there has been a sharp increase in the consumption of packaged food products; plastic packaging protects fruit from mechanical damage and external contamination. If they're used incorrectly, they may form condensation and raise humidity that speeds up spoilage. Choosing suitable plastic packing as well as optimizing storage conditions are useful ways to maintain fruit quality and prolong shelf life (Kan and Miller, 2022).

This present study was aimed to evaluate the impact of yeast-based coatings on the postharvest quality of orange fruit. also to compare the effectiveness of foam and plastic packaging during storage and therefore to monitor quality changes across storage intervals of (7, 14 and 21) days.

2 MATERIALS AND METHODS

2.1 Location of Study

This study was presented in the laboratory of Horticulture and landscape design Department, Collage of Agricultural Engineering Sciences, during December/ 2026. Orange fruits (Baquba Orange) were selected same shapes and sizes, and the fruits with no damages and disease, then the selected ones were washed and dried.

2.2 Preparing Yeast

According to the method that described by Carvalho *et al.,* (2023). A yeast extract solution (10 g. L^{-1}) with (5g. L^{-1}) of sugar was homogenized and prepared overnight at room temperature. Subsequently, after the oranges were immersed in the solution for 3 minutes to allow uniform coating of the fruit surface.

2.3 Packaging Types

The fruits were packaged using plastic and foam box subsequently put in the refrigerator at temperature 4°C (Reque *et al.,* 2014). And the yeast coating concentrations was (control and 10 g. L^{-1}), as well the storage periods were measured after (7, 14 and 21) days.

2.4 Measured Parameters

2.4.1 Total Soluble Solids (TSS):

Total soluble solids of fruits (sugar content) of fruit were determined by using a digital refractometer. The sample plate was cleaned and dried. A few drops of the extracted fruit juice from each fruit after removing the skin and seeds were placed on the plate, which was then closed. The refractometer was held up to a natural light source and the reading was recorded (Burin *et al.*, 2010).

2.4.2 pH Value Determination

The pH of each sample fruit juice was measured using a digital pH meter (HI 2211 pH/ORP meter, China) with a glass electrode. The result was expressed as a percentage of citric acid per 100 g on a fresh-weight basis (AOAC, 2008).

2.4.3 Loss weight

Weight loss of fruits was measured by a digital balance via percentage and using the following formula

Weight loss% = (W b – Wa) /W b *100

Where:

Wb: Weight of before coating, **Wa:** Weight of before coating.

2.4.4 Marketable value (%)

Marketable value was determined following storage by evaluating external quality characteristics of orange fruit, including color retention, texture, physical damage (Karaat, 2019).

Marketable fruits% = Number of marketable fruits /Total number of fruits * 100

Statistical analysis

The statistical analyses were performed using the SPSS (Statistical Package for the Social Sciences, version 22.0) program. The analysis of variance which consisted of univariate analysis was performed followed by Duncan test. One-way analysis of variance (ANOVA) was used to compare means at the significant level $p<0.05$. All analyses were performed with replicates.

3 RESULTS AND DISCUTIONS

The obtained results from the study that displayed in Table 1 demonstrate the principal effects of coating, packaging, and storage time on orange fruit quality. Long-term storage showed a distinct and steady trend in weight loss, which peaked at 21 days (2.3 g) and decreased at 7 days (0.9 g). The main causes of this gradual rise in weight loss are respiratory activity and moisture evaporation during storage.

Similar findings were reported by (Lentzou *et al*., 2021), who demonstrated that prolonged storage leads to higher transpiration rates and subsequent weight reduction in fresh produce. In similar, total soluble solids (TSS) exhibited an increasing pattern over time, with the highest value recorded at 21 days (12.5) and the lowest at 7 days (11.4). This increase may be associated with metabolic activities, including the conversion of complex carbohydrates into simple sugars during ripening, as supported by the findings of (Durán-Soria *et al.,* 2020).

On the other hand, the pH value is slight but an increase was noted. The value at 14 days was 4.2 (maximum) while the lowest was noted at 7 days with a pH of 4.0, which signifies the reduction of acidity of fruit (Mophahlele *et al*., 2020). This finding is consistent with earlier studies (Park et al., 2020), which described comparable changes in acidity. This occurred due to the degradation of organic acid over time. Market value remained stable across treatments, but was slightly reduced in the extended storage, 21 days, (98.4% at 21 days). In no packaging and at 14 days, the marketability at 98.7% was the highest, meaning moderate storage will still keep the fruit quality acceptable.

Regarding treatment effects, yeast coating and foam packaging resulted in relatively higher weight loss compared to the control, whereas plastic packaging demonstrated better preservation of fruit quality, likely due to its ability to reduce moisture loss and gas exchange. According to Duncan's Multiple Range Test, treatments sharing similar letter groupings were not significantly different, indicating that coating and packaging had limited effects on TSS and pH, while storage duration had the most pronounced influence on all measured parameters.

Overall, these findings are in agreement with previous studies, confirming that extended storage adversely affects orange fruit quality, primarily through increased weight loss and reduced marketability. Therefore, optimizing storage duration remains a critical factor in maintaining postharvest quality.

Table 1. Main effects of coating, packaging and storage duration on orange (*Citrus sinensis* L.) fruits.

Factors		Weight Loss	TSS	pH	Marketable Value %
Coating	Control	1.2 [b]	12.0 [a]	4.1 [a]	98.5 [a]
	Yeast	1.9 [a]	11.7[a]	4.1 [a]	98.6 [a]
Packaging Box	Control	1.3 [b]	11.5 [a]	4.1 [a]	98.7 [a]
	foam	1.9[a]	11.9 [a]	4.1 [a]	98.3 [a]
	plastic	1.4 [b]	12.0 [a]	4.1[a]	98.6 [a]
Storage	7 days	0.9[c]	11.4 [b]	4.0 [c]	98.5[a]
	14 days	1.4 [b]	11.5 [b]	4.2 [a]	98.7 [a]
	21 days	2.3 [a]	12.5 [a]	4.1 [b]	98.4[a]

*Means of each factor and their interactions followed by the same letter's are not significantly different from each other, according to Duncan's multiple ranges test at 5% level.

As presented in Table 2, coating treatments, packaging materials, and storage period interact significantly to impact the quality parameters of orange fruits. Duncan's multiple range test at the 5% level confirmed that weight loss, TSS, pH, and marketable value were influenced by these parameters. Yeast-coated fruits kept in foam packaging showed the greatest weight loss (2.3 g), which gradually rose with storage time and reached 2.7 g at 21 days, whereas the control condition with plastic packaging showed the lowest weight loss (0.9 g).

This pattern reflects increased transpiration and respiration rates over time, which are strongly influenced by packaging permeability. Similar findings were reported by Ngure *et al.*, (2009) who highlighted that appropriate packaging significantly reduces moisture loss and extends shelf life.

Total soluble solids (TSS) increased gradually during storage, with the highest value (13.0) recorded under plastic packaging at 21 days and the lowest (11.2) in non-packaged fruits at 7 days. This increase is attributed to metabolic processes such as the conversion of complex carbohydrates into simple sugars during ripening. These findings are consistent with those reported by (Ali *et al.*, (2011), who observed a significant increase in TSS in coated and stored citrus fruits due to ongoing biochemical changes.

The pH values showed only slight fluctuations, with the highest values (approximately 4.0–4.2) recorded in non-packaged fruits at 14 days and the lowest at 7 days. Most variations were statistically non-significant, indicating relatively stable acidity compared to other quality attributes. This observation agrees with Song *et al.,* (2020), who reported that changes in organic acids during storage are gradual and often result in minor pH variations.

Concerning the marketable values the highest value (99.0%) was found under plastic packaging at 7 days while the lowest values (approximately 98.2–98.3%) were produced at 21 days storage showing the decline in commercial quality over time. The use of plastic packaging has been found to effectively maintain fruit quality. As stated by Sogvar *et al.*, (2016), the use of an appropriate packaging material enhances the marketability and storage life of the fresh fruit. In general, the results demonstrate that the use of plastic packaging can maintain fruit quality and the coating treatments especially yeast has a varying effect depending on the type of packaging used and period of storage. All parameters measured are severely impacted by the storage time.

Table 2. Two-way interaction effects of coating, packaging and storage duration on orange (Citrus sinensis L.) fruits.

Coating	Packaging Box	Storage. Days	Weight Loss	TSS	pH	Marketable Value
Control	control		1.3 c	11.5 a	4.1 a	98.7 a
	foam		1.5 c	12.0a	4.1 a	98.4 a
	plastic		0.9 d	12.5 a	4.1 a	98.5 a
Yeast	control		1.3 c	11.5a	4.1 a	98.7 a
	foam		2.3 a	11.9 a	4.1 a	98.3 a
	plastic		2.0 b	11.6 a	4.1 a	98.8 a
Control		7	0.8 d	11.1 b	4.0 c	98.3 a
		14	1.0 cd	11.4 b	4.2 a	98.7 a
		21	2.0 b	13.5 a	4.2 a	98.5a
Yeast		7	1.1 c	11.8 b	4.1 b	98.7 a
		14	1.8 b	11.7 b	4.2a	98.8 a
		21	2.7 a	11.4 b	4.1 b	98.3a
	control	7	0.6c	11.2 c	4.0 c	98.7 a
		14	1.3 b	11.6 bc	4.4 a	98.8a
		21	2.0 b	11.8 bc	4.1 cde	98.8 a
	foam	7	0.8	11.7 bc	4.0 de	98.0 a
		14	2.1b	11.4 c	4.1 bc	98.7 a
		21	2.7 a	12.7 ab	4.2 b	98.4 a
	Plastic	7	1.3 b	11.4 c	4.1 cd	99.0 a
		14	0.7 c	11.7 bc	4.1bc	98.7 a
		21	2.3 b	13.0 a	4.1 bc	98.2 a

*Means of each factor and their interactions followed by the same letter's are not significantly different from each other, according to Duncan's multiple ranges test at 5% level.

Table 3 clearly indicates that coating, packaging, and storage duration interact significantly to influence the postharvest quality attributes of orange fruits. The most pronounced effects were observed in weight loss, TSS, pH, and marketable value.

Similar interaction effects among postharvest factors have been widely reported in recent literature, emphasizing the combined role of storage conditions and handling practices in determining fruit quality, as noted by (Valero *et al.,* 2014).

Regarding weight loss, the lowest values were observed during shorter storage periods, particularly in the control treatment at 7 days (0.6%) and foam packaging at 7 days (0.8%), which were significantly lower than most other treatments. In contrast, the highest weight loss (up to 2.7%) occurred under yeast coating combined with extended storage (21 days), indicating a strong

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effect of storage duration. This increase can be attributed to enhanced transpiration and respiration processes over time. These findings are consistent with those of Sogvar *et al*., (2016), who reported that prolonged storage significantly increases moisture loss, while packaging type plays a crucial role in moderating this effect.

For TSS, the highest value (13.5) was observed in the control treatment at 21 days, while the lowest values (11.1–11.4) were recorded during early storage periods. This indicates a significant increase in TSS with storage duration, likely due to the hydrolysis of complex carbohydrates into simple sugars during ripening. Similar trends were reported by Ali *et al*., (2011), who observed that storage duration enhances TSS accumulation due to ongoing metabolic activities, although some treatment combinations may not differ significantly.

In terms of pH, values ranged from 4.0 to 4.4, with the lowest values recorded at early storage stages and the highest under plastic packaging. However, many treatments shared similar superscript letters, indicating that pH was less affected compared to other parameters. This agrees with findings by Serrano *et al*., (2007), who reported that changes in organic acids during storage are gradual and often result in limited and statistically non-significant pH variation. Marketable value remained relatively stable, ranging between 98.2% and 99%, with the highest value observed under plastic packaging at 7 days and the lowest at 21 days.

The lack of significant differences among most treatments suggests that marketability is less sensitive to treatment interactions within the studied storage period. Similar observations were reported by Opara *et al.,* (2013), who highlighted that visual and market quality attributes often remain stable until advanced stages of storage. In conclusion, the interaction among coating, packaging, and storage duration significantly affected weight loss and TSS, while pH and marketable value were less influenced, showing mostly non-significant differences.

Storage duration emerged as the dominant factor affecting postharvest quality, particularly by increasing weight loss and TSS over time, whereas appropriate packaging especially foam and plastic helped reduce deterioration during shorter storage periods. These findings are consistent with recent postharvest studies emphasizing the importance of integrated handling strategies to maintain fruit quality.

Table 3. Three-way interaction effect of coating, packaging and storage duration on orange (Citrus sinensis L.) fruits.

Coating	Packaging Box	Storage. Days	Weight Loss	TSS	pH	Marketable Value
Control	control	7	0.6^{h}	11.2^{c}	4.0^{cd}	98.7^{a}
		14	1.4^{fg}	11.6^{c}	4.0^{a}	98.8^{a}
		21	2.1^{de}	11.8^{c}	4.1^{bc}	98.8^{a}
	foam	7	0.8^{h}	10.9^{c}	3.9^{d}	97.8^{a}
		14	1.5^{f}	11.4^{c}	4.2^{b}	98.7^{a}
		21	2.3^{cd}	13.8^{ab}	4.4^{a}	98.7^{a}
	Plastic	7	1.0^{gh}	11.3^{c}	4.1^{bc}	98.5^{a}
		14	0.1^{i}	11.2^{c}	4.1^{bc}	98.7^{a}
		21	1.7^{ef}	15.0^{a}	4.2^{b}	98.2^{a}
	control	7	0.6^{h}	11.2^{c}	4.0^{cd}	98.7^{a}
		14	1.3^{fg}	11.6^{c}	4.4^{a}	98.8^{a}
		21	2.0^{de}	11.8^{c}	4.1^{bc}	98.8^{a}

Yeast	foam	7	0.9 gh	12.6 bc	4.1 bc	98.1 a
		14	2.7 bc	11.5c	4.1 bc	98.7 a
		21	3.2 a	11.6 c	4.1 bc	98.0 a
	plastic	7	1.7 ef	11.6c	4.1 bc	99.4 a
		14	1.4 fg	12.2 bc	4.2 b	98.8 a
		21	2.9 ab	11.0 c	4.1bc	98.2 a

*Means of each factor and their interactions followed by the same letter's are not significantly different from each other, according to Duncan's multiple ranges test at 5% level.

4 CONCLUSION

In conclusion, the findings result of this study demonstrate that storage duration had a pronounced negative impact on fruit quality, as evidenced by increased weight loss and a decline in marketable value over time. Among the studied factors, storage period emerged as the most influential variable, significantly contributing to the increase in weight loss and total soluble solids (TSS).

Packaging type played a critical role in qualifying quality worsening. In particular, plastic packaging consistently showed superior performance in preserving fruit quality attributes, including reducing weight loss and maintaining marketability. Nonetheless foam packaging contributed positively, especially during shorter storage periods. In contrast, coating treatments showed variable and, in some cases, statistically non-significant effects. Yeast-based coatings, in particular, demonstrated inconsistent performance depending on their interaction with packaging type and storage duration.

Furthermore, the interaction among coating, packaging, and storage duration significantly influenced weight loss and TSS, whereas pH and marketable value were less affected, often exhibiting non-significant differences. Overall, the results highlight the dominant role of storage duration, with packaging serving as an important mitigating factor.

5 RECOMMENDATIONS

Based on the obtained results, it is recommended to adopt plastic packaging as an effective postharvest strategy to minimize weight loss and preserve fruit quality. Additionally, reducing storage duration is essential to limit quality deterioration and maintain marketable value. The integration of appropriate packaging materials, such as plastic or foam, with coating treatments may enhance preservation outcomes; however, further optimization of coating formulations is required, particularly for yeast-based applications.

Future research should focus on improving the efficacy and consistency of coating treatments and investigating alternative coating materials with more stable performance. Moreover, additional studies are needed to better understand the interactions between coating, packaging, and storage conditions in order to develop more efficient postharvest handling strategies.

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