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Study the efficiency of seaweed extract in improving of the storage ability of jujube fruits (*Ziziphus mauritiana* Lam. Cv. Tufahi)

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Abstract:

The present study was carried out on jujube fruits of cultivar Tufahi, planted in a commercial orchard located in the Al-Hartha district of Basrah governorate during the 2022-2023 seasons. Nine trees were chosen for their similarity in terms of growth strength and age, as well as their identical agricultural practices. The experiment included spraying trees with the seaweed extract 'agazone' at concentrations (0, 1, 2) mg.L^{-1} for three times. The fruits were picked when they reached maturity, and those that were undamaged and of comparable bulk were chosen and placed in bags made of perforated polyethylene (8 holes per bag, each hole 4 mm in diameter). The bag held one kilogram of fruits, which were subsequently kept for four weeks at 4°C. In comparison to the control treatment, the most significant findings demonstrated the superiority of the seaweed extract treatment, particularly the concentration of 2 mg.L^{-1}, in lowering the percentage of decay and weight loss while preserving the maximum levels of organic acids and vitamin C. The results revealed that the percentage of decay as well as the fruit content of total soluble solids and total sugars rose with increasing storage duration.

Keywords:

Decay percentage, Jujube fruits, Vitamin C, Weight loss.

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Introduction

Globally, temperate, tropical, and subtropical temperatures are ideal for the more than a hundred species of evergreen trees and shrubs that make up the genus Ziziphus, which is a subfamily of the Rhamanaceae (Williams, 2006). The high concentration of carbs, proteins, organic and amino acids, vitamins, lipids, fibers, and minerals in ziziphus fruits is what gives them their high nutritional value. Ziziphus species in Iraq include Z. jujuba Lam., Z. nummularia L., Z. mauritiana Lam., and Z. spina-christi, with the latter being the most prevalent and economically significant (Al-Rubaai,1988).

The jujube fruit is a drupe resulting from the development of a single ovary. The growth and development of jujube fruit can be divided into four stages: growth, maturation, ripening, and senescence (Pareek, 2001).

Agricultural researchers have turned to finding safe and environmentally friendly materials such as the use of seaweed extracts. Consequently, biostimulant usage has grown recently and is now a regular use in sustainable agriculture. Agazone, a natural liquid extract of the brown seaweed Ascophtllum nodosum, is found on the northern coastlines of Europe and the northeastern coast of North America. It has been employed as an organic fertilizer for a variety of crops for a long time due to its high concentration of micronutrients (S, Cu, Fe, Zn) and critical nutrients (N, P, K).Cytokines, auxins, gibberellins, organic acids, carbohydrates, amino acids, and proteins are also abundant (Taain and Salman, 2018).

Cold storage is one of the important methods at the present time that is used to preserve the quality of fruits for the longest possible period. Cold storage slows down fruit ripening, therefore slowing down their rate of degradation and attaining senescence. This lowers the vital activity of fruits, particularly with regard to respiration and ethylene generation. It also helps to restrict the spread of infections, particularly with those of fungus (Al-sareh & Taain, 2021).

The study was conducted with the aim of improving the storage capacity of the jujube fruits cv.Tufhi, and thus the possibility of extending the display of these fruits in fresh condition in local markets, in addition to improving the qualitative characteristics and reducing the decay of the fruits during storage.

Materials and methods

This study was conducted during the 2022–2023 agricultural season on jujube trees, cultivar Tufahi, in a private orchard located in the Al-Hartha district of Basrah Governorate. Nine trees were selected that were as similar as possible in terms of growth strength and age. The same agricultural operations were carried out on all trees, including irrigation, fertilization, fruit pruning, and pest control. The trees were sprayed three times in the early morning with the extract of the seaweed agazone. The first spray was on 6/4/2022, followed by the second and third sprays, with a time interval of 30 days between each spray using a 5-liter hand sprayer. The spray concentrations were (0, 1, 2) $mg.L^{-1}$.

Tween 20 was added at a concentration of 0.01% as a spreading agent to reduce surface tension. The fruits were harvested at physiological maturity (yellow color) and, after being cleaned of dust, were packaged in perforated polyethylene bags (8 holes per bag, 4 mm diameter). The bag expanded to hold 1 kg of fruits, which were then kept at 4°C for 4 weeks. The following characteristics were estimated:

1. Decy percentage: was estimated as a percentage as follows.

$$\text{Decy percentage} = \frac{\text{Weight of damaged fruits in the package}}{\text{Total weight of fruits in the package}} \times 100$$

4. The weight loss was estimated by monitoring the weight of the produce during the storage period using a weight balance (Taain & Hamza,2019).

2. The hand refractometer was employed to measure the total soluble solids (T.S.S.) and the temperature was set to 20 º C.

3. Total titratable acidity (%) was determined according to A.O.A.C. (1990) by mashing five grams of fresh fruit pulp with 20 ml of distilled water, then filtering and taking 10 ml and titrating with sodium hydroxide NaOH (0.1 N) until reaching the equivalence point using the Phenolphthalein indicator.

5. Total sugars (%) of fruits were determined according to Lane and Eynon method outlined in A.O.A.C. (1990) by taking 0.5 g of dry fruit pulp from each replicate and adding 50 ml of distilled water to it. In order to extract the sugars, the mixture was placed in a water bath at a temperature of 70 °C for half an hour and the extract was filtered. Then, the clearing process was carried out using 3 ml of40% basic lead acetate and 3 ml of potassium oxalate. Then, the reducing sugars were estimated by titrating 50 ml of the filtrate after the clearing process with Fehling's solution A and B in the presence of methylene blue as indicator. Another 50 ml of the cleared filtrate was taken and acid hydrolysis was carried out by adding five ml of concentrated hydrochloric acid and left for 24 hours. Then, the acidified solution was adjusted with 40% sodium hydroxide NaOH until reaching the equivalence point.

6. Vitamin C (mg.100 g^{-1}) was quantified in accordance with A.O.A.C. (1990).

Experiment design

A fully randomized design (CRD) was employed to construct the experiment as a factorial experiment, which consisted of two factors: the storage duration and the seaweed extract agazone. The mean results were compared using the least significant difference (LSD) test at a probability threshold of 0.05 (Al-Rawi and Khalaf Allah, 2000).

Results and Discussion

1. Decay percentage

Table 1 shows the impact of spraying the seaweed extract agazone, storage time, and their interaction on the decay percentage of jujube fruits cv. Tufahi. The study revealed that fruit decay percentage increased with longer storage periods, reaching 5.71%, possibly due to microorganism attacks, specifically fungus and bacteria (Alsareh and Taain, 2018)). The statistical analysis indicated the superiority of the treatment with the 2 mg.L^{-1} seaweed extract agazone in reducing the percentage of decay (0.87%). Regarding the interaction between the two parameters, it is obvious that the control fruits had the greatest percentage of decay after four weeks of storage (8.33%), which differed significantly from the other treatments.

One of the most threatening factors influencing crops after harvest is damage of all types. Fruit damage during storage and packing can be caused by mechanical damage, such as bruises or deformities from pressing fruits, or physiological disorders, such as advancing ripening, or by the fruits advancing in the package. Damage also results from infections with pathogenic microorganisms such as bacteria, fungi and yeasts (Taain, 2011, Taain *et al*.2023).

Agazon seaweed extract may control fruit decay by reducing respiration rates and ethylene production, possibly due to its content of auxins, gibberellins, and cytokinins, thus reducing fruit deterioration. It was well known that auxins work to extend the storage period by preserving the stored food in the fruits, as well as that gibberellins and cytokinins also play a role in reducing the rate of disease infections because of their effectiveness in reducing the rate of respiration and ethylene production and delaying the entry of fruits into the senescence. In addition to that, gibberellin and cytokinin may increase the thickness of cell walls, making them more resistant to the microorganisms that decompose fruit tissues (Hopkins & Muner, 2008).

Basak (2008) indicated that treating apple trees with the sea extract kelpak had a role in inhibiting the growth of fungi and bacteria, extending the storage life and maintaining the qualitative characteristics of fruits.

Table 1. The impact of the application of seaweed extract, the storage period, and their interaction on the degradation percentage of fruits

Seaweed extract (mg.L⁻¹)	Storage period (week)				Means of seaweed extract
	1	2	3	4	
0	0	0	4.12	8.33	3.11
1	0	0	3.3	6.4	2.42
2	0	0	1.1	2.4	0.87
Means of storage period	0	0	2.84	5.71	

RLSD 0.05

- Seaweed extract: 1.51
- Storage period: 2.11
- Interaction: 4.13

2. Weight loss

Table 2 illustrated the effects of applying the seaweed extract, duration of storage, and their interaction on the percentage weight loss of the fruits. The findings showed that weight loss increased with storage time, reaching 1.81% after four weeks. The statistical analysis revealed that spraying with seaweed extract reduced fruit weight loss more effectively than the control treatment, which had the greatest percentage of weight loss (1.32%). The control treatment showed the most weight loss after four weeks of storage (2.87%), indicating a significant difference from other treatments in terms of the interaction between seaweed extract treatment and storage duration.

Crops lose some of their stored food when the respiratory process eats them or when their water content drops (Taain, 2011) as the fruit loses their water by evaporation from their surface and a part of stored food consumed by the respiration process. Fruit water loss is a key issue after harvest that causes withering, wrinkling, and a notable weight loss. The respiration process reduces the amount of food kept, but another possible cause of the weight loss that occurs with longer storage times is the water content loss from fruits (Shirokov, 1988; Taain *et al*.2017).

It is abundantly evident from the foregoing findings that applying the seaweed extract reduced fruit weight loss. The reason for this could be the presence of auxins, cytokinins, and gibberellins, which prevent ethylene gas generation and maintain cell membrane permeability through material transfer (Wang *et al*. 1996). The role of auxins in reducing weight loss is highlighted by reducing the rate of respiration, which is a reason of the consumption of nutrients stored in the fruits, thus their weight decreases. In addition to regulating cell membrane permeability, decreasing respiration rate, and inhibiting ethylene's efficiency, gibberellins and cytokinins slow down the pace of weight loss (Kumar and Gutap, 1987; Hopkins & Muner, 2008).

Table 2. The impact of application seaweed extract, storage duration, and their combination on fruit weight loss percentage

Seaweed extract (mg.L⁻¹)	Storage period (week)				Means of seaweed extract
	1	2	3	4	
0	0.11	0.77	1.54	2.87	1.32
1	0.00	0.16	0.65	1.42	0.56
2	0.00	0.12	0.43	1.13	0.42
Means of storage period	0.04	0.35	0.87	1.81	

RLSD 0.05

- **Seaweed extract: 0.79**
- **Storage period: 1.51**
- **Interaction: 2.67**

3. Total soluble solids

Table 3's findings demonstrated that as the fruits' storage times increased, so did their total soluble solids. This can be the result of the fruits' water content decreasing over time during storage. The water content in fruits is negatively associated with their total soluble solids concentration (Burton, 1982). It is also evident from the aforementioned table that the control treatment (0 mg.L⁻¹) achieved the maximum percentage of the total soluble solids at 16.60%, which was substantially higher than the other treatments. The interaction between seaweed extract and storage period significantly impacted the percentage of total soluble solids in the control treatment after four weeks of storage, with no significant difference after three weeks of storage at 16.80%, and no significant difference from other treatments.

Compared to the fruits in the control treatment, the fruits treated with seaweed extract had the lowest percentage of total soluble solids. This could be because the seaweed extract delays fruit ripening, which is known to increase the percentage of total soluble solids as fruit ripens. Jujue fruits, classified as climatic fruits, experience an increase in total soluble solids accumulation as they ripen, as per Desouki *et al.* (2001) and Fadala *et al.* (2023).

Table 3. The impact of application seaweed extract, storage duration, and their interaction on the total soluble solids of fruits percentage

Seaweed extract ($mg.L^{-1}$)	**Storage period (week)**				**Means of seaweed extract**
	1	2	3	4	
0	16.20	16.50	16.80	17.00	16.60
1	16.00	16.20	16.40	16.50	16.20
2	16.00	16.00	16.20	16.40	16.15
Means of storage period	16.65	16.23	16.46	16.63	

RLSD 0.05

- Seaweed extract: 0.37
- Storage period: 0.22
- Interaction: 0.28

4. Total titratable acidity

Table 4 shows that the total titratable acidity of jujube fruits is influenced by the effect of seaweed extract, storage period, and their interaction. The study found that as storage periods increased, the total titratable acidity in produce decreased, possibly due to increased consumption of organic acids through respiration or conversion into sugars (Alsareh & Taain, 2018). It is also worth noting that the organic acid content of the fruits treated with seaweed extract was greater than that of the control treatment. The combination between seaweed extract treatments and storage duration showed no significant influence on total titratable acidity.

The efficiency of photosynthesis is enhanced by the presence of macro and micro elements, gibberellins, and cytokinins in the seaweed extract. This provides the fruits with the greatest quantity of manufactured food and increases the content of chemical components, including organic acids (Sterm, 2008). This outcome is in accordance with the findings of Taain and Salman (2018), who examined eggplant specimens that were treated with agazone and stored at 13°C.

Table 4. The impact of applying seaweed extract, storage time, and their interaction on the total titratable acidity of fruits percentage

Seaweed extract ($mg.L^{-1}$)	Storage period (week)				Means of seaweed extract
	1	2	3	4	
0	0.062	0.055	0.051	0.045	0.053
1	0.125	0.121	0.115	0.111	0.118
2	0.125	0.121	0.115	0.111	0.118
Means of storage period	0.104	0.099	0.093	0.089	

RLSD 0.05

- Seaweed extract: 0.011
- Storage period: 0.061
- Interaction: NS

5. Total sugars

Table 5 shows that the control fruits had the greatest proportion of total sugars (14.70%), which differed significantly from the other treatments. The treatment with 2 $mg.L^{-1}$ seaweed extract resulted in the lowest percentage of sugars (14.27%), with no significant difference compared to the treatment with 1 $mg.L^{-1}$. The data revealed a rise in total sugar percentage across the storage period, peaking at 14.76% after four weeks.

As it is clear, the pattern of change in total sugar content in fruits aligns with the pattern of change in total soluble solids, with sugars being a significant component. One possible explanation for the decrease in the overall sugar content of the fruits treated with seaweed extract is that these treatments postpone the fruits' development (Taain and Salman ,2018).

Table 5. The impact of applying seaweed extract, storage time, and their interaction on the total sugars of fruits percentage

Seaweed extract ($mg.L^{-1}$)	Storage period (week)				Means of seaweed extract
	1	2	3	4	
0	14.12	14.52	14.82	15.33	14.70
1	14.02	14.22	14.46	14.55	14.31
2	14.11	14.19	14.37	14.41	14.27
Means of storage period	14.08	14.31	14.58	14.76	

RLSD 0.05

- Seaweed extract: 0.32
- Storage period: 0.31
- Interaction: 0.49

6. Vitamin C

The table 6 indicated the superiority of the seaweed extract spray treatments compared to the control treatment in the effect on the fruit content of vitamin C, as the concentration of 2 $mg.L^{-1}$ recorded the highest value 156.30 $mg.100gm^{-1}$ with no significant difference from the concentration of 1 $mg.L^{-1}$, while the concentration of 0 $mg.L^{-1}$ gave the lowest value. The table's findings shown that as storage time increases, vitamin C levels fall until they reach 96.63 mg. 100 gm ^{1}.

The enzymes oxidase and ascorbase may oxidize and turn vitamin C into dehydro ascorbic acid, causing a drop in vitamin C concentration in fruits as the storage time is prolonged. This aligns with the claim of Taain et al. (2017) that the concentration of vitamin C in tomato fruits diminishes with time during storage. Results are also consistent with those of Fadala et al. (2023) in terms of spicy pepper fruits. This suggests that the treatment with seaweed extract is effective in minimizing the oxidation of vitamin C, thereby preserving it, as evidenced by the fact that fruits treated with the extract retained the maximum content of vitamin C compared to the control group (Taain and Salman ,2018).

Table 6. The impact of seaweed extract application, storage duration, and interaction on vitamin C levels in fruits (mg/100g).

Seaweed extract ($mg.L^{-1}$)	**Storage period (week)**				**Means of seaweed extract**
	1	2	3	4	
0	142.32	135.77	122.12	110.05	127.57
1	166.16	157.17	148.87	135.06	151.82
2	168.36	161.66	153.76	141.42	156.30
Means of storage period	158.95	151.53	141.58	96.63	

RLSD 0.05

- Seaweed extract: 19.13
- Storage period: 16.66
- Interaction: 28.35

Conclusions

In conclusion, the results showed that treatment with the seaweed extract, especially at a dose of 2 mg, was adequate, according to the present research. L^{-1} raised the jujube fruit CV's quality index. Tufahi is preserved at the highest levels of organic acids and vitamin C. Simultaneously, the storage treatment reduces the percentage of decomposition and weight loss compared to the control treatment.

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