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EFFECT OF OZONE TREATMENT AND STORAGE TEMPERATURE ON THE STORAGE ABILITY OF DATE PALM FRUITS (*PHOENIX DACTYLIFERA* L.) CV. MEDJOOL

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تأثير المعاملة بالأوزون ودرجة حرارة الخزن في القابلية الخزنية لثمار النخيل صنف مجهول

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***Keywords**: Date palm fruits, Medjool cultivar, storage, decay percentage, water content*

ABSTRACT

This study was conducted during the agricultural season 2021-2022 on the fruits of date palm, Medjool cultivar, where the fruits were brought from one of the private orchards belonging to the Shatt Al-Arab district in Basrah Governorate, on 9/3/2021, and the experiment was carried out as a factorial experiment according to the Complete Randomized Design (CRD), with three replicates for each treatment .The experiment included three factors, the first was the evaporation with ozone gas at concentrations of 0, 2.500 and 5000 ppm, the second factor was the storage of fruits at three temperatures (5°C, 10 °C and 25°C), while the third factor was the storage period which extended six months .Fruits were packed in plastic containers with a capacity of 250 g before storage and the obtained results showed that the treatment with ozone at a concentration of 5000 ppm was superior in reducing the percentage of decay and retaining the water content, the percentage of total soluble solids, and the total acidity of the fruits. The results also showed that fruits stored at 5°C were the best in reducing decay and retained the water content, the percentage of total soluble solids compared to 10°C and 25°C. Stored fruits retained most of their studied characteristics despite the advanced storage period, which reached six months.

ملخص

أجريت هذه الدراسة خلال الموسم الزراعي 2021-2022 على ثمار نخيل التمر صنف المجهول حيث تم جلب الثمار من أحد البساتين الخاصة التابعة بواقع ثلاث مكررات (CRD) نفذت التجربة كتجربة عاملية وفق التصميم العشوائي الكامل . لقضاء شط العرب في محافظة البصرة بتاريخ 2021/3/9 جزء في المليون، أما العامل الثاني فكان تخزين لكل معاملة. وتضمنت التجربة ثلاثة عوامل أولها التبخير بغاز الأوزون بتراكيز 0 و 2.500 و 5000 الثمار عند ثلاث درجات حرارة (5 درجات مئوية، 10 درجات مئوية، 25 درجة مئوية)، أما العامل الثالث فهو مدة التخزين التي امتدت لستة أشهر. وتم وأظهرت النتائج المتحصل عليها تفوق المعاملة بالأوزون بتركيز 5000 جزء بالمليون في .غم قبل التخزين 250 تعبئة الثمار في عبوات بلاستيكية سعة كما أظهرت النتائج أن الثمار المخزنة عند .خفض نسبة التلف والاحتفاظ بالمحتوى المائي، ونسبة المواد الصلبة الذائبة الكلية، والحموضة الكلية للثمار احتفظت الثمار المخزنة .درجة 5 °م كانت الأفضل في تقليل التلف واحتفاظها بالمحتوى المائي والمواد الصلبة الذائبة مقارنة بدرجتي 10°م و 25°م بمعظم صفاتها بالرغم من وصول مدة التخزين الى ستة أشهر

INTRODUCTION

The date palm (*phoenix dactylifera* L.) is considered an evergreen fruit tree, belongs to the family Arecaceae and to the order Arecales. It is one of the monocotyledonous fruit trees and the Arabian Gulf region is considered one of the largest and most important areas of date palm trees in the world. Among them, the cultivation of date palm trees spread to all regions with suitable weather (*Al-Jubouri, 2002*).

In view of the importance of Medjool cultivar, which is one of the Moroccan cultivars, that entered Iraq recently through tissue culture technique, and is characterized by good taste and the large fleshy layer compared to the small seed, which makes it a desirable for the consumer.

Storing fruits at low temperatures is a good way used to reduce or delay the decay percentage of fruits. As low temperatures work to inhibit the activity of microorganisms that cause damage to the fruits and reduce the vital activities in the climacteric fruits, especially the rate of respiration and the production of ethylene and thus delay ripening processes (*Taain, 2005; 2014, Al-Amiri, 2010*).

Ozone (O3) is a natural substance in the atmosphere and one of the powerful disinfectants against a wide range of microorganisms (*Khadre and Yousef, 2001*). Applied either as a gas or dissolved in water, it can destroy chemical residues on the surface of the fruit and effectively reduce post-harvest losses during storage for several crops (*Taain et al., 2019*).

The aim of the current study is to improve the storage ability of date palm fruits Cv. Medjool by treating them with ozone and stored at different temperatures.

MATERIALS AND METHODS

This study was conducted during the agricultural season 2021-2022 on the fruits of date palm, Medjool cultivar. The fruits in the tamir stage were brought from one of the private orchards belonging to the Shatt Al-Arab district in Basrah Governorate, on 9/3/2021, then transferred in the morning to a laboratory of storage technologies in the Department of Horticulture and Landscape Design. The small and damaged fruits were excluded while the selected fruits were evaporated with ozone at concentrations of 0, 2.500, 5000 ppm, then packed in plastic containers of 250g, then divided into three parts. The first was stored in a cold incubator at a temperature of 5°C, the second stored at 10° C. and the third was stored at a room temperature of 25°C for a period of six months from the date of 9/3/2021 until 3/3/2022**.**

Studied parameters

1. The percentage of decay was calculated as a percentage during storage according to the following formula

$$\text{Percentage of decay} = \frac{\text{Weight of damaged fruits per package}}{\text{Total weight of damaged fruits per package}} \times 100$$

2. Water content of fruits was calculated as a percentage as follows

$$\text{Water content \%} = \frac{\text{Fresh weight of the sample (gm)} - \text{Dry weight of the sample (gm)}}{\text{Fresh weight of the sample (gm)}} \times 100$$

3. Total soluble solids (T.S.S.) of fruit pulps were determined by using hand refractometer and the results were corrected to 20º C (*Shirokov, 1968*).

4. Total titratable acidity (%) determined according to A.O.A.C. (1992).

Complete Randomized Design (CRD) was used with three replicates. The results were analyzed by the analysis of variance and mean values were compared using the Revised Least Significant Difference Test at 0.05 probability level. (*Al-Rawi and Khalf Allah, 1980*).

RESULTS AND DISCUSSION

The percentage of decay

The results of table .1 showed the effect of ozone treatment, temperature, storage period and the interaction among them on the percentage of decay of date palm fruits cv. Medjool. Where it is noted that the ozone treatment had a significant effect in reducing the percentage of decay, as the lowest percentage was 1.33% for fruits treated with 5000 ppm ozone, while the highest percentage of decay was 5.74% for fruits treated with 0ppm ozone. The treatment maintained the quality of the date palm fruits and significantly reduced the percentage of decay, compared to the fruits of 0 ppm concentration. Ozone gas reduces the percentage of post-harvest decay and reduces the loss of the quality and nutritional value of the fruits during cold storage due to the role of ozone in inhibiting the growth of pathogenic fungi that cause fruit decay (*Amiri, 2016, Taain, 2014*).

The lowest percentage of decay was 1.95% for the fruits stored at a temperature of 5°C, with a significant difference from the rest of the treatments, while the highest percentage of total damage was 5.51% for the fruits stored at a temperature of 25°C. The decrease in the percentage of decay to the fruits stored at a temperature of 5°C, was due to the fact that the low temperatures work to preserve fruit quality compared to storage at room temperature, and the results are consistent with (*Taain, 2005; Al-Amri, 2010; Taain, 2011*). The duration of storage had a significant effect, as it was noted from the table that the percentage of decay increased with the length of the storage period, as the highest percentage reached 11.80% for fruits after six months of storage. As for the effect of the interaction between ozone treatment and temperature, the results indicated that the fruits treated with ozone at a concentration of 5000 ppm and stored at a temperature of 5°C had excelled in reducing the percentage of percentage of decay and recorded the lowest percentage which was 0.55%. As for the percentage of decay for the fruits treated with a concentration of 5000 ppm and stored at a temperature of 10°C recorded 0.88%, while the percentage of decay was 9.31% for fruits treated with ozone at a concentration of 0 ppm and stored at a temperature of 25°C.

The results also showed that the interaction between the ozone treatment and the storage period had a significant effect, as the lowest percentage of decay was 0.00% for the fruits treated with ozone at a concentration of 2.500, 5000 ppm after four months of storage. The highest percentage of decay was 16.64% for fruits treated with 0ppm ozone after six months of storage. As for the interaction between the temperature and the storage period, that had a significant effect on the percentage of decay, as the lowest percentage of decay fruits was 0.00% for the fruits stored at a temperature of 5°C after four months of storage, whereas the highest percentage of decay, which was 5.51% recorded in fruits stored at a temperature of 25 °C after six months of storage. The effect of the interaction between the three studied factors had significant effect on percentage of decay, the highest percentage of decay, for fruits treated with 0 ppm ozone, stored at a temperature of 25°C, after six months of storage, which reached 25.31 %.

Table 1

Effect of ozone treatment, storage temperature and storage period on the percentage of decay of Medjool date palm fruits.

Ozone	storage temperature	Storage period (month)						Ozone x temperature
		1	2	3	4	5	6	
0 ppm	5° C	0.00	0.00	0.00	0.00	7.26	9.29	2.76
	10° C	0.00	0.00	0.00	5.37	10.27	15.33	5.16
	25° C	0.00	0.00	5.18	10.14	15.22	25.31	9.31
2.500 ppm	5° C	0.00	0.00	0.00	0.00	6.14	9.20	2.55
	10° C	0.00	0.00	0.00	0.00	8.18	12.58	3.46
	25° C	0.00	0.00	0.00	0.00	12.36	15.68	4.67
5000 ppm	5° C	0.00	0.00	0.00	0.00	0.00	3.32	0.55
	10° C	0.00	0.00	0.00	0.00	0.00	5.31	0.88
	25° C	0.00	0.00	0.00	0.00	5.14	10.23	2.56
								Mean values of ozone
Ozone x Storage period	0 ppm	0.00	1.72	0.00	5.17	10.92	16.64	5.74
	2.500ppm	0.00	0.00	0.00	0.00	8.89	12.48	3.56
	5000ppm	0.00	0.00	0.00	0.00	1.71	6.28	1.33
								Mean values of temperature
temperature x Storage period	5° C	0.00	0.00	0.00	0.00	4.47	7.27	1.95
	10° C	0.00	0.00	0.00	1.79	6.15	11.07	3.17
	25° C	0.00	1.72	0.00	3.38	10.91	17.07	5.51
Mean values of storage period		0.00	0.00	0.57	1.72	7.17	11.80	

L.S.D. (0.05)

Ozone	storage temperature	Storage period	Ozone x temperature	Ozone x Storage period	temperature x Storage period	Ozone x temperature x Storage period
0.03	0.03	0.05	0.06	0.09	0.09	0.15

The percentage of water content

Table. 2 showed the effect of ozone treatment, storage temperature, storage period and their interactions on the percentage of water content of Medjool date palm fruits. The results indicated that the ozone treatment had a significant effect on retaining water content in fruits, as the concentration of 5000 ppm gave the highest percentage of water content reached 64.00%, while the lowest percentage of water content

was 60.13% recorded in fruits treated with 0 ppm ozone. The ozone treatment retained the water content of date palm fruits.

As for the effect of storage temperature, the highest percentage of water content was 70.33% for fruits stored at a temperature of 5°C, while the lowest percentage was 52.2% for fruits stored at 25°C. It is clear that the percentage of water content decreased with the elongation of the storage period, reaching the lowest percentage of 60.69% after six months of storage, This is due to the fact that the water content of the fruits decreases due to the evaporation of water from the fruits as a result of the difference in vapor pressure between the moisture of the fruits and the humidity of the storage atmosphere (*Taain, 2014*). The result of this study agreed with (*Al-Barrak, 2009; Attaha and Taain, 2009; Taain, 2011*).

The table also showed the effect of the interaction between ozone treatment and storage temperature, as the fruits treated with ozone at a concentration of 5000 ppm and stored at a temperature of 5°C significantly excelled in retaining the percentage of water content, reaching 71.14% as compared to the lowest percentage that was recorded in fruits of 0 ppm ozone stored at 25°C that reaching 49.36%.

The interaction between the ozone treatment and the storage period was significant, where the highest percentage of water content was 65.68% for fruits treated with 5000 ppm ozone after one month of storage, while the lowest percentage of water content was 57.90% for fruits treated with 0 ppm ozone after six months of storage. Regarding to the interaction between the storage temperature and the storage period, the highest percentage of water content was in fruits stored at5°C after a month of storage which was 72.25%, while the lowest percentage was in fruits stored at 25°C after six months of storage which was 50.74%.

As for the interaction among the three factors, the highest percentage of water content was 72.90% for fruits treated with ozone at a concentration of 5000 ppm after one month of storage at a temperature of 5°C, while the lowest percentage of water content was 50.03% for fruits treated with 0 ppm ozone after six months of storage at 25°C.

Table 2

Effect of ozone treatment, storage temperature and storage period on the percentage of water content of Medjool date palm fruits.

Ozone	storage temperature	Storage period (month)						Ozon x temperature
		1	2	3	4	5	6	
0 ppm	5° C	71.16	70.96	68.43	68.06	67.33	66.43	68.73
	10° C	65.66	64.10	62.40	62.30	60.16	59.23	62.31
	25° C	51.20	50.23	49.26	49.10	48.36	48.03	49.36
2.500 ppm	5° C	72.70	71.76	71.10	71.13	70.63	69.46	71.13
	10° C	69.20	68.13	67.40	66.66	65.23	64.73	66.89
	25° C	54.76	54.13	54.10	53.16	52.80	51.86	53.47
5000 ppm	5° C	72.90	71.96	71.13	70.80	70.13	69.93	71.14
	10° C	69.06	68.93	67.53	66.50	65.16	64.20	66.90
	25° C	55.10	55.00	54.60	53.70	53.06	52.33	53.96
								Mean values of ozone
Ozone x Storage period	0 ppm	62.67	61.76	60.03	59.82	58.62	57.90	60.13
	2.500ppm	65.55	64.67	64.20	63.65	62.88	62.02	63.83
	5000ppm	65.68	65.30	64.42	63.66	62.78	62.15	64.00
								Mean values of temperature
temperature x Storage period	5° C	72.25	71.56	70.22	70.00	69.36	68.61	70.33
	10° C	67.97	67.05	65.77	65.15	63.52	62.72	65.36
	25° C	53.68	53.12	52.65	51.98	51.41	50.74	52.26

Mean values of storage period		64.64	63.91	62.88	62.38	61.43	60.69	
L.S.D. (0.05)								
Ozone	storage temperature	Storage period	Ozone x temperature	Ozone x Storage period	temperature x Storage period		Ozone x temperature x Storage period	
0.10	0.10	0.15	0.18	0.26	0.26		0.46	

The percentage of total soluble solids

It is clear from table. 3 that ozone treatment had a significant effect on the percentage of total soluble solids, as the lowest percentage was recorded at 40.27% at a concentration of 5000 ppm, while the highest one was 43.18% at a concentration of 0 ppm. This results indicate the role of ozone treatment in reducing the loss of the water content of the fruits, as it was negatively reflected on the total soluble solids (*Burton, 1982, Taain, 2005*).

The temperature significantly affected the percentage of total soluble solids, as the lowest percentage was recorded for the fruits stored at 5° C which was 39.41%, while the highest percentage for fruits stored at a temperature of 25° C which reached 45.26%. Studies have shown that the percentage of total soluble solids started to increment gradually until the end of the storage period (*Al-Amri, 2010; Taain, 2011; Taain et al., 2019*). Results indicate that the percentage of total soluble solids increased with the increment of a storage period reached 43.95% after six months of storage. The results are in the same line with (*Benjamin et al., 1985; Youssef and Abu Ali, 1993; Taain, 2010; 2011; 2014; Al-Amri, 2010*), where the results of storage experiments for different cultivars of date palm fruits showed that the total soluble solids in the fruits increased with the elongation of storage period, that mainly due to the reduction of water content and the increment of sugars with the progression of fruits towards ripening.

The interaction between ozone and the storage temperature had a significant effect, as the lowest percentage of total soluble solids was recorded at 44.72% for fruits treated with ozone at a concentration of 5000 ppm and stored at a temperature of 5°C, while the highest percentage was for fruits treated with ozone at a concentration of 0 ppm and stored at a temperature 25°C. As for the interaction between ozone and the storage period, date of the same table showed that the lowest percentage of total soluble solids was 38.81% for fruits treated with 5000 ppm ozone after one month of storage, while the highest percentage reached 44.62% for fruits treated with ozone at a concentration of 0 ppm after six months of storage. The interaction between the storage temperature and the storage period significantly affected the percentage of total soluble solids, as the lowest percentage of total soluble solids was recorded at 37.42% after a month of storage at a temperature of 5° C, while the highest percentage of total soluble solids was 47.26 after six months of storage at temperature 25° C. The effect of the triple interaction was significant, where the lowest percentage of total soluble solids was 35.92% for fruits treated with ozone at a concentration of 5000 ppm after a month of storage at a temperature of 5°C. The highest percentage of total soluble solids was 52.13% for fruits treated with ozone at a concentration of 0 ppm, after six months of storage at 25°C.

Table 3

Effect of ozone treatment, storage temperature and storage period on the percentage of total soluble solids of Medjool date palm fruits.

Ozone	storage temperature	Storage period (month)						Ozone x temperature
		1	2	3	4	5	6	
0 ppm	5° C	37.31	38.42	39.44	40.17	41.03	42.91	39.88
	10° C	38.26	39.67	40.31	41.22	42.98	44.72	41.19
	25° C	40.52	41.11	43.25	45.21	46.14	52.13	44.72
2.500 ppm	5° C	36.81	37.21	38.14	39.76	40.23	41.23	38.87
	10° C	37.23	38.02	39.72	40.02	41.10	42.93	39.84
	25° C	40.10	41.33	42.43	42.86	43.33	44.23	42.38
5000	5° C	35.92	36.56	37.53	38.72	39.43	40.92	38.18

ppm	10° C	36.71	37.33	39.22	39.91	40.44	41.02	39.11
	25° C	39.22	40.03	40.55	42.23	43.53	44.06	41.60
								Mean values of ozone
Ozone x Storage period	0 ppm	41.32	42.13	43.03	43.85	44.14	44.62	43.18
	2.500ppm	40.09	40.71	41.39	42.12	42.95	43.13	41.73
	5000ppm	38.81	39.35	39.92	40.56	41.05	41.95	40.27
								Mean values of temperature
temperature x Storage period	5° C	37.42	38.21	39.14	39.99	40.46	41.23	39.41
	10° C	39.10	40.26	41.45	42.42	43.65	44.74	41.94
	25° C	42.22	43.45	45.66	46.20	46.78	47.26	45.26
Mean values of storage period		38.74	39.59	40.75	41.68	42.48	43.81	

L.S.D. (0.05)						
Ozone	storage temperature	Storage period	Ozone x temperature	Ozone x Storage period	temperature x Storage period	Ozone x temperature x Storage period
0.09	0.09	0.13	0.16	0.23	0.23	0.40

The percentage of total titratable acidity

The results of the table. 4 showed the effect of ozone treatment, storage temperature, storage period and the interaction among them on the percentage of total titratable acidity of Medjool date palm fruits.

The results showed that the highest percentage of total titratable acidity was 0.259% for fruits treated with ozone at a concentration of 5000 ppm, while the lowest percentage was for fruits treated with ozone at a concentration of 0 ppm which reached 0.208%.

The effect of storage temperature was significant, as the highest percentage of total titratable acidity was recorded at 0.281% for fruits stored at a temperature of 5° C, while the lowest percentage of total titratable acidity was 0.233% for fruits stored at a temperature of 25° C, and this is may be a result of the progress of fruit ripening which is faster with the temperature rise which results in a higher rate of respiration and, consequently, a greater consumption of organic acids, as well as their conversion into sugars (*Burton, 1982; Al-Ani, 1985*).

The storage period had a clear effect, as it was noted from the same table that the percentage of total titratable acidity decreased with the elongation of the storage period, reaching the percentage of 0.215% at the end of the storage period. The reason for the decrease in the total acidity content of the fruits with the elongation of the storage period may be due to the consumption by the respiration process or converted into sugars *(Dessouki et al., 2011).*

The use of ozone led to the preservation of the total titratable acidity during the cold storage period and the results are consistent with Jassim *et al*., (2016) and Taain *et al*., (2019).

As the table showed the effect of the interaction between the ozone treatment and the storage temperature, the results indicated that fruits treated with 5000 ppm ozone and stored at a temperature of 5° C, had a significant increase of total acidity, reached 0.312%, while the lowest percentage of the total acidity was in the treated fruits with 0 ppm ozone and stored at a temperature of 25°C, reached 0.185%.

The results of the table also showed the effect of the interaction between the ozone treatment and the storage period, where the highest percentage of total acidity reached 0.288% for fruits treated with ozone at a concentration of 5000 ppm after a month of storage, while the lowest percentage reached 0.191% for the treated fruits with 0 ppm ozone after six months of storage.

The table also shows the interaction between the storage temperature and the storage period, as the highest percentage of the total acidity reached 0.312% after a month of storage at a temperature of 5°C, while

the lowest percentage of the total acidity reached 0.196% at the end of the storage period at a temperature of 25°C.

As for the interaction between the three factors, it was noted that the highest percentage of total acidity was 0.343% for fruits treated with ozone at a concentration of 5000 ppm after a month of storage at a temperature of 5° C. While the lowest percentage of total acidity was 0.167% for fruits treated with 0 ppm ozone, after six months of storage at a temperature of 25°C.

Table 4

Effect of ozone treatment, storage temperature and storage period on the percentage of total titratable acidity of Medjool date palm fruits.

Ozone	storage temperature	Storage period (month)						Ozon x temperature
		1	2	3	4	5	6	
0 ppm	5° C	0.273	0.256	0.253	0.250	0.240	0.233	0.251
	10° C	0.242	0.235	0.227	0.213	0.202	0.197	0.219
	25° C	0.201	0.198	0.182	0.189	0.175	0.167	0.185
2.500 ppm	5° C	0.320	0.320	0.286	0.276	0.240	0.216	0.276
	10° C	0.270	0.240	0.226	0.210	0.203	0.193	0.223
	25° C	0.240	0.232	0.224	0.214	0.203	0.192	0.217
5000 ppm	5° C	0.343	0.330	0.313	0.300	0.300	0.283	0.312
	10° C	0.303	0.286	0.270	0.250	0.250	0.240	0.267
	25° C	0.231	0.227	0.217	0.210	0.209	0.199	0.215
								Mean values of ozone
Ozone x Storage period	0 ppm	0.227	0.216	0.211	0.205	0.200	0.191	0.208
	2.500 ppm	0.266	0.256	0.235	0.223	0.214	0.200	0.232
	5000 ppm	0.288	0.276	0.262	0.250	0.244	0.234	0.259
								Mean values of temperature
temperature x Storage period	5°C	0.312	0.302	0.284	0.275	0.260	0.251	0.281
	10°C	0.285	0.276	0.266	0.257	0.243	0.232	0.260
	25°C	0.267	0.253	0.241	0.228	0.213	0.196	0.233
Mean values of storage period		0.271	0.26	0.246	0.237	0.226	0.215	

L.S.D. (0.05)

Ozone	storage temperature	Storage period	Ozone x temperature	Ozone x Storage period	temperature x Storage period	Ozone x temperature x Storage period
0.003	0.003	0.004	0.005	0.008	0.008	0.014

CONCLUSION

It is concluded from the current study that the treatment with ozone at a concentration of 5000 ppm was superior in improving qualitative characteristics of date palm fruits Cv. Medjool during storage at 5°C.

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