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Original Article

Response of Libyan Soft Date Cultivars "Hellawi" and "Hurra" at "Balah" Stage to Controlled Atmosphere Conditions.

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Abstract

The current study investigated effects of controlled atmosphere (CA) conditions applied at near zero temperature on quality attributes of two Libyan important soft date cultivars that were consumed at "Balah" ("Kalal") stage. Samples of "Hellawi" and "Hurra" were collected from Tripoli region in the 2015 harvest season. An experimental setup consisted of 3L airtight glass jars equipped with two-valve ports was used; periodical measurement of air constituents was carried out throughout the study duration. CA treatments applied were 10%, 15%, and 20% CO_2 combined with 5% O_2, and regular air as a control treatment. CO_2 and O_2 percentages were measured twice a week, and were adjusted to set point whenever a ±2% deviation was recorded using a gas mixer connected to cylinders containing CO_2, O_2 and N_2. Quality attributes mainly, total soluble solids (TSS), fruit firmness, and fruit skin color properties (L, a and b) were determined three times during the experiment; its beginning, the middle, and its end. Similarly, sensory evaluation and weight loss were made. After 12 weeks, results showed no significant changes in TSS, firmness, taste and weigh loss. However, color was significantly affected by the three CO_2 treatments; fruits significantly lost their yellow color and became dark (light brown), the intensity of color change was very much related to CO_2 concentration. The study showed that unlike cultivars reported in the literature that benefited from high CO_2 levels, the two cultivars studied herein exhibited sensitivity to CO_2 levels ≥10%, giving a solid ground for testing lower CO_2 treatments.

Key words: controlled atmosphere, CO_2, O_2, soft dates, storage.

Introduction

Date palm (*Phoenix dactylifera* L.) is the most important tree in arid and semiarid regions, mainly Arabian Peninsula, North Africa, and the Middle East (Chao and Krueger, 2007). In fact it is considered as a symbol of desert life; also dates are

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invaluable fruits; rich in sugars and other nutritional constituents, an excellent food source since the ancient civilizations (Alhamdan *et al.*, 2014, El-Juhany, 2010). Physiologically, dates are classified as climacteric fruits, as they exhibit ethylene production behavior similar to other climacterics, thus they may continue their ripening even after harvesting from mother tree (Serrano *et al.*, 2001). They have four important development stages, "khimri", ("Balah"), "Rutab" and "Tamr". Most cultivars are astringent at "Balah" stage, but become palatable at both "Rutab" and "Tamr" stages (Kader and Hussein 2009). Nonetheless, quite few cultivars are consumable at "Balah" stage, palatability at this stage is merely cultivar related, and fruits lose their astringency, yet still firm and crunchy (Fennir *et al.*, 2014). In North Africa, "Hellawi", "Hurra" and "Lemsy" are among soft dates they are palatable at "Balah" stage. Nonetheless, "Hellawi" extends even east; it has been reported as a common cultivar in Palestine (El Kichaoui *et al.*, 2013). In Libya, amongst nearly 400 cultivars exist in the country (Racchi *et al.*, 2014), dates marketed "Balah" are ("Hellawi", "Hurra" and "Lemsy"). The third cultivar however is not widely spread in Libya but it is common in Gabes region of the neighboring Tunisia (Kearney, 1906). They are grown in the coastal plains of the Mediterranean around latitude 32:57°N. It is believed that the three cultivars require mild temperature and high relative humidity conditions. In Libya, however they are cultivated in a coastal strip not exceeding 50km inland, beyond that the fruits are subjected to dryness and shrinkage at early "Balah" stage. It has been reported that in early 80s that nearly 1.2 million of productive soft cultivars date palms existed in this region, representing 40% of the national palm trees at that time (Al-Sharafa, 1982). Generally, "Hellawi" and "Hurra" cultivars have excellent market potential; "Hellawi" is an early harvested cultivar, entering the market in August, while "Hurra" is a late cultivar that is harvested late September. Locally, the two cultivars are consumed fresh at "Balah" stage, and they are less appealing to consumers at "Rutab" stage.

In Libya, dates in general and soft cultivars in particular encounter several difficulties such as; produce surplus in a short harvest season, early rainfall in fall, and susceptibility to postharvest diseases. Low temperature indeed extends shelf life, since dates are not chilling and freezing sensitive (Kader and Hussien, 2009). Controlled atmosphere (CA) storage systems certainly add advantages to low temperature, by maintaining quality and extending marketability, reducing physiological activity and retarding microbial growth for most fruits (Kader, 1992). However, few CA methods have been tested and applied for storing dates. Application of CA for preserving some quality attributes and extending shelf life of "Barhi" dates has been reported (Alhamdan *et al.*, 2014, El-Rayes, 2009, Al-Redhaiman, 2005). However, for soft date cultivars in general and Libyan cultivars in particular there is scarce information on feasibility of applying controlled atmosphere, its benefits and optimum conditions.

This work investigated the effects of applying CA conditions with elevated CO_2 at 10, 15 and 20% combined with O_2 level near 5% on storage duration and quality attributes of "Hellawi" and "Hurra" Libyan soft dates.

Materials and Methods

Plant materials:

"Hellawi" is an early maturing cultivar; it is the first type of dates enters the market in the coastal region of Libya. Bunches were harvested in early morning on September 2nd, 2015 from an orchard located in the suburb of Tripoli. Fruits at their "Balah" stage were brought to the Postharvest Laboratory (PL) at the Department of Agricultural Engineering, Faculty of Agriculture, University of Tripoli. They were inspected, undesirable dates were removed, strands were cut and fruits were washed with water containing (0.01%) Sodium hypochlorite and rinsed, samples were weighed (about 350g) and filled in the storage enclosures. For the "Hurra" cultivar, because it is a late cultivar, bunches were harvested on September 29th, 2015 from another orchard near Tripoli. CA treatments for both cultivars were: regular atmosphere (RA), (10% CO_2+ 5%O_2), (15% CO_2 + 5%O_2), and (20% + 5% O_2). All treatments were applied in triplicate.

Storage Enclosures:

Three liter glass jars equipped with threaded plastic lid were used. For ensuring air tightness, O-ring gasket was placed between the inner edge of the lid and the jar mouth. Jars were also tested for air tightness using pressured air at 0.3 bar. On the lid, two brass valves that are used in tires were installed; facilitating air tightness, air sampling and adjusting air constituents. For the regular atmosphere (RA) on the other hand, jars were covered with fabric, facilitating RA conditions and high relative humidity (> 90%). In each jar about 350g of "Balah" were placed, the assigned CA treatment was applied using an air mixing valve system. Jars were tightly closed and placed in a walking- in cold room set at 1ºC ± 0.5. Samples were kept at their assigned CA conditions for 12 weeks. Samples were taken and analyzed at 0 time, after 8 and 12 weeks.

Air Analysis and maintaining set point:

The desired gas composition was achieved using a valve-based air mixing setup developed at the PL. It is consisted of N_2, O_2 and CO_2 cylinders pipe connected to a set of three pressure regulators, each of them attached to a liver valve that selectively opens gas flow from a cylinder to a small air room. The air room is equipped with another pressure regulator and it is connected to a hose, on which a female connection fits the jar valve. The setup was facilitated manually obtaining the desired CA condition and adjusting it to the set point.

Air analysis for O_2 and CO_2 percentage in the enclosures was performed using portable gas analyzer (Model CANAL120 O_2 & CO_2 Gas Analyzer, EMCO Packaging Systems Ltd, Kent, CT14 0BD UK). The analyzer draws small volume air sample, analyzes it, and displays O_2 and CO_2 percentage on an LCD screen. Sample analysis was carried out twice a week, and corrections to set

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points were made manually whenever a deviation of ±2% of O_2 and CO_2 was recorded. Also, respiration rate was measured under CA and RA conditions using a method reported by the current authors in a previous investigation (Fennir *et al.*, 2014). Under CA conditions respiration rate was measured three times within the 12 week storage duration.

Color assessment:

Fruit surface color was measured three times, at the beginning of the experiment, midway and at its end using handheld Tristimulus reflectance colorimeter (Minolta CR 400, Minolta Corp., New Jersey, USA). Color was recorded using (Lab color spaces), with (L) indicates lightness, (a) for chromaticity from green (-) to red (+), while (b) represents chromaticity from blue (-) to yellow (+).

Total soluble solids (TSS) measurement:

TSS was measured as degrees of Brix (°Bx) using digital handheld refractometer (Model PAL-α, ATAGO Co, Ltd, Tokyo, Japan). Considering that most TSS of date fruit is sugar; thus TSS was used as an indication to sugar content of fruit juice. One degree Brix is equivalent to 1 gram of sugar in 100 grams of solution. The instrument was zeroed at every measurement using distilled water. Ten fruits were blended and pressed for juice extraction using a special pressing tool, then juice was filtered and few drops were used in the measurements.

Fruit firmness:

Fruit firmness was tested using handheld penetrometer (Model FHT 803, General Tools & Instruments™, New York, NY, 10013, USA). Although no procedures using such instrument for measuring date fruit firmness were found in the literature, fruit was divided longitudinally, surface skin and seed were removed, and the sample was placed against solid surface. A 7.9 mm dimaeter tip size was used to penetrate fruit tissue, instrument was held vertically and a hand force was applied until the tip penetrated fruit flesh and maximum breaking force was recorded in Newtons (N).

Visual inspection and sensory evalutions:

CA and RA treatments were kept in transparent glass jars, facilitating easy visual inspections. Visual inspection was made periodically, changes such as shrivelling, fungal infections, ripening (conversion to "Rutab") and cracking were considered as sings for quality deterioration, leading to terminating the treatment. Also, periodical weight loss was performed, and treatments were discarded when loss reached 15%.

At the end of the storage duration, sensory evaluation was made by PL members. Few dates from the treatments were randomly coded, introduced to four members as non trained panellist, a taste scale was given ranged from 1 to 4, using a 4- point hedonic rating scale, assigned

as poor, good, very good and excellent, respectively.

Statistical Analysis:

Analysis of variance was carried out using SPSS statistics software ver. 20, significance level was declared at ($p < 0.05$) and comparisons among treatments were made using Tukey-Kramer pair wise comparisons. Three air compositions defined as CA treatments and one RA treatment as a control. Independent variables were CA treatment at (3 levels) and time elapsed between two consecutive analyses (3 levels), time zero, after 4 weeks and 12 weeks. Dependant variable were, total soluble solids (TSS), firmness, respiration rate and fruit surface color spaces (L, a and b). All quality related measures were tested at the start of the experiment, after 4 weeks and after 12 weeks, and they were carried out in triplicates. All dependent variables were compared with the control and time zero measurements.

Results and Discussion

Performance of the CA treatments:

Table 1 shows CO_2 and O_2 means inside jars for all treatments during the 12 weeks of the study. Generally, CO_2 and O_2 percentages were maintained close to their pre-assigned values with minor deviations. For dates, because they contain high sugars, O_2 percentage above 5% was maintained for avoiding possible yeast fermentation and anaerobic reactions. Respiration rate under RA conditions was measured at the beginning, while under CA was measured after 4, 8, and 12 weeks, and compared with its rate under RA. Respiration measurements were carried out according to the methodology used by the authors in a previous study (Fennir *et al.*, 2014). It can be observed in Table 2 that respiration rate was significantly reduced by CA treatments; rates were lowered almost four folds, considering the fact that O_2 was kept nearly stable for the three CA treatments, it is quite evident that CO_2 exhibited a significant effect on respiration rate.

Table 1. CA storage setup performance during 12 weeks (means ± standard deviation)

CA conditions				
CA trt.	*"Hurra"*		*Hellawi*	
	CO_2%	O_2%	CO_2%	O_2%
10% CO_2	12.1 (±0.84)	5.52 (±0.37)	10.45 (±0.12)	5.65 (±0.87)
15% CO_2	16.2 (±1.18)	6.55 (±0.50)	15.83 (±0.91)	6.97 (±0.35)
20% CO_2	20.23 (±0.65)	7.22 (±0.10)	21.53 (±0.50)	6.95 (±0.15)

Table 2. Mean respiration rates under CA and RA conditions.

Treatment	Respiration rate ($ml.CO_2.kg^{-1}.h^{-1}$)		
	4 weeks	8 weeks	12 weeks
	"Hurra" cultivar		
RA 8.12[a]			
10% CO_2	2.40[b]	2.97[b]	2.67[b]
15% CO_2	2.21[b]	1.69[c]	1.82[c]
20% CO_2	1.98[c]	1.74[c]	1.62[c]
	"Hellawi" cultivar		
RA 8.42[a]			
10% CO_2	1.98[b]	1.75[b]	2.19[b]
15% CO_2	1.96[b]	2.03[c]	1.63[c]
20% CO_2	1.84[b]	2.34[c]	1.98[c]

Means with the same letters on the same column are not statistically different at 0.05 level.

Effect of CA treatments on quality attributes:

Total soluble solids:

Table 3 shows ANOVA results of the effect of CA treatments and storage duration on TSS and firmness. They were considered in the study as the most important quality attributes of dates at "Balah" stage. Both cultivars maintained their TSS content for the entire storage duration, no significant difference ($P > 0.05$) between TSS measured at the beginning, after 4 weeks and 12 weeks. TSS was maintained at 39.6 Brix for "Hellawi" and 33.0 Brix for "Hurra", and both were not significantly different throughout the 12 week duration ($P > 0.05$). Nonetheless, TSS of the two cultivars was different among each other, because "Hellawi" dates are generally sweeter than "Hurra" dates. Indeed, respiration rate can be reduced under CA conditions for most fruits and vegetables, yet the level of reduction is very much produce related. Martins *et al.,* (2013) reported a reduction in respiration rate of papaya by 2.9 times less than respiration rate under normal conditions, giving the present study good agreement with it. Moreover, respiration rate was significantly affected by CO_2 levels applied, exhibiting linear relation for the two cultivars. Knowing that respiration is the major physiological activity that continues under storage conditions, thus lower respiration rate is responsible for low losses, showing good agreement with results reported by Brackmann *et al.*, (2014) on their quantifying of losses related to respiration rate of 'Fuyu' persimmon fruit stored in CA conditions. Respiration rate of dates under CA conditions is very scarce, yet respiration rate of several Libyan cultivars has been previously reported (Fennir *et*

al., 2014). Respiration rate under RA conditions reported in the current study were in a good agreement with those reported by the current authors in the previous study.

"Hellawi" dates under RA treatment lasted for 4 weeks, weight loss exceeded 15%; wherein the control treatment was discarded. For the "Hurra" cultivar on the other hand, the RA treatment was discarded after two weeks, fruits showed signs of deterioration, cracking and fungus infection. "Hurra" dates are characterized as very sensitive with quite short shelf life; not exceeding few days under RA conditions, also susceptible to cracking, rotting and off flavour (souring). However, under CA conditions, fruits lasted for 12 weeks, yet some fruits exhibited cracking may be due to physiological reasons. The sensory evaluation at the end of the storage duration showed acceptable taste for all treatment ranged from good to very good. Taking into consideration variations in fruit taste, generally fruit taste was not affected by the applied treatments.

Maintaining TSS indeed was attributed to low respiration rate, in addition to low temperature and high relative humidity effects that were maintained inside enclosures. Among the three CA treatments applied, there was no significant difference, giving good agreements with studies on the application of CA on fruits and vegetables (Kader, 1992, Thosmpson, 2003). For dates however, the use of CA treatments led to stable sugar contents of "Barhi" cultivar dates at "Balah" stage (Al-Redhaiman, 2005), giving the current study fair agreement with results reported in the literature.

Fruit firmness

"Hellawi" dates retained their firmness, no significant differences were observed between measurements made at the beginning and those made after 4 and 12 weeks. It can be observed in Table 3 that neither duration nor CA treatment did have significant effect firmness to be recorded. Generally, mean breaking force was recorded at 94.3N. For "Hurra" dates however, significant effect of time on firmness was observed. Force applied for breaking fruit tissue increased significantly by time, its mean was 72.4 N at the beginning, rose to 104.8N after 4 weeks then to 106.3N after 12 weeks. This indicated that elevated CO_2 may result in improving firmness of "Hurra" dates.

Firmness is an important physical quality attribute for most fruits. Al-Rhedhaiman (2005) reported maintaining firmness of "Barhi" dates under CA conditions. Apart from dates, Harker *et al.*, (2000), Smith and Skog (1992) reported improved firmness of strawberries subjected to elevated CO_2 conditions. For the current study however, effect of CA treatment on firmness of "Hurra" dates may be cultivar related, since similar effect was not observed with "Hellawi". Nonetheless, maintaining firmness of dates at "Balah" stage is an indication of turgidity and freshness. Therefore, the two cultivars indeed benefited from the applied CA treatments. Indeed, CA treatments improve firmness of many fruits, but for these two date cultivars, it seems that

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"Hurra" dates responded positively to CA conditions, firmness increased by nearly 47%.

Table 3. Analysis of variance of TSS and firmness

Source	SS	Df	MS	F	Sig	SS	Df	MS	F	Sig.
	"Hellawi"					*"Hurra"*				
					TSS					
Time	25.8	2	12.91	3.05	0.06	60.2	2	30.1	3.12	.052
Error	237.4	56	4.24			538.6	56	9.6		
CA trt	26.3	3	8.77	2.07	0.12	17.2	3	5.7	0.6	.620
Error	237.4	56	4.24			538.6	56	9.6		
					Firmness					
Time	175.9	2	87.9	0.21	0.81	8518.8	2	4259.4	7.0	.002
Error	23421.4	56	418.2			34015.1	56	607.4		
CA trt	563.1	3	187.7	0.45	0.72	8673.7	2	2891.2	4.8	.005
Error	23421.4	56	418.2			34015.1	56	607.4		

Effect of CA treatments on color:

Table (4) shows effects of CA treatments and time on the three color space values (L, a and b). It is worth mentioning that dates palatable at "Balah" stage are commonly preferred yellow. For "Hellawi" and "Hurra" cultivars a bright yellow color is preferred. It can be seen that color was subjected to significant change, especially in the (L) and (b) space values (lightness and redness). After harvesting, (L), (a) and (b) represented coordinates that gave normal yellow color of dates at "Balah" stage. However, as time elapsed, color began to darken, losing its yellowness and became brown. This change was recorded after 2 weeks for "Hellawi" and after one week for "Hurra".

Color can be considered as the major quality attribute for most fruits and vegetables. It is always intended to be maintained for keeping the produce appealing to the consumer. Dates consumed at "Balah" stage are preferred to be yellow. In the current study however, considerable color changes were recorded for both cultivars. Such changes gave dissimilarity with color attributes of "Barhi" dates at "Balah" stage were reported by Al-Redhaiman (2005), wherein CO_2 treatment was reported as significantly improved quality attributes of "Barhi" dates, and 20% CO_2 gave best results. Also, elevated CO_2 levels have been suggested as an effective tool for extending shelf life of many fruits without affecting quality (Al-Rayes, 2009, Kader 1992). Additionally, it has been reported that CO_2 has significant effect on dates by reducing tannins content (Alsmsairat *et al.,* 2013),

leading to improving edibility of "Barhi" dates at "Balah" stage. For fruits other than dates, high CO_2 combined with low temperature was also reported having negative effects on tomato tissue (Deltsidis *et al.,* 2011), physiological disorder on apples known as (scald) was also linked to high CO_2 levels (Sitton and Patterson 1991). From a physiological point of view, effect of elevated CO_2 on fruit tissue is also somehow related to O_2 level, temperature and other factors (Kader 1992). It has been reported that molecular changes related to the development of CO_2 injury are not well explained (Johnson and Zhu, 2015). Therefore, developing concrete explanation of the changes reported in this study is quite premature. Thus, elevated CO_2 at and above 10% can be considered as a cause of such color change in "Hellawi" and "Hurra" cultivars. The present study demonstrated that "Hellawi" and "Hurra" dates at "Balah" stage are quite sensitive to CO_2 treatments within the applied range. It is indeed very much cultivar related, therefore further investigations may be recommended.

Table 4. Effects of CA and time on three color space (L, a and b).

Time	**CO_2 percentage**					
	10%	**15%**	**20%**	**10%**	**15%**	**20%**
	"Hellawi"			*"Hurra"*		
			L			
Time (0)*	43.21[a]			38.15[a]		
4 weeks	33.25[b]	31.20[b]	27.24[b]	33.7[b]	27.70[b]	24.40[b]
12 weeks	23.5[c]	16.50[c]	15.40[c]	19.4[c]	16.83[c]	14.78[c]
			a			
Time (0)*	6.01[a]			5.46[a]		
4 weeks	5.97[a]	6.27[a]	6.64[a]	5.01[a]	5.82[a]	5.59[a]
8 weeks	5.99[a]	5.32[a]	5.24[a]	5.4[a]	5.53[a]	5.10[a]
			b			
Time (0)*	29.19[a]			17.77[a]		
4 weeks	22.2[b]	16.37[b]	17.70[b]	17.6[b]	17.57[a]	15.52[a]
12 weeks	19.83[c]	13.15[c]	10.41[c]	13.5[c]	12.18[b]	10.96[b]

(*) dependant variable at time (0) was compared with (8 weeks and 12 weeks. Means with the same letters column-wise are not statistically different at 0.05 level.

Figure (1) shows that (L) and (b) color spaces numerical change trends. It is quite evident that both color space values (L and b) were linearly reduced as time elapsed. Such changes were also virtually linear with CO_2 increase. Such values indicate that fruit surface color lost its bright yellow and turned to light brown. Indeed, such changes are not preferred by consumers. However, samples kept under RA treatment did not show such color changes, though lasted shorter storage duration, but color was not affected contrary to CA treatments.

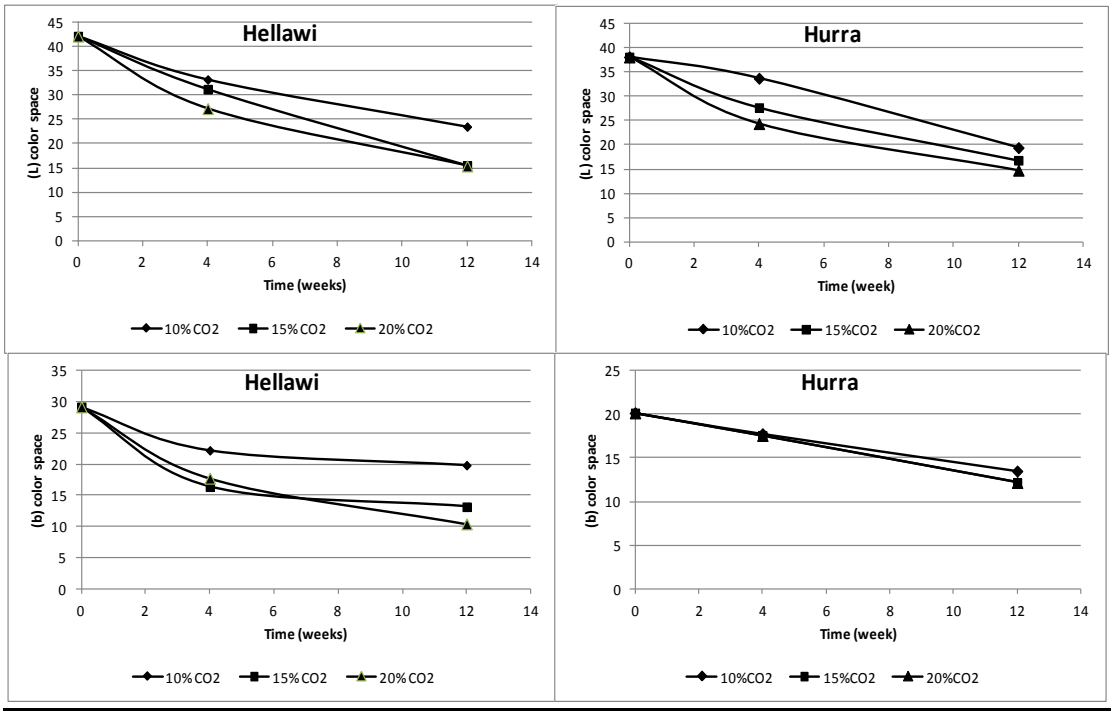

Figure1. (L) and (b) color space change in relation with time and CO_2 level.

CONCLUSIONS

"Hellawi" and "Hurra" soft date cultivars of Libya were investigated in their response to CA conditions at elevated CO_2 at 10, 15 and 20% combined with O_2 level about 5% and were compared with an RA treatment. Dates were kept under CA condition for 12 weeks. Experiment showed that controlled atmosphere treatments lasted for 12 weeks and maintained some quality attributes such as TSS and fruit firmness, taste, but color was significantly affected. Dates of both cultivars lost their bright yellow color, (L) and (b) color spaces were reduced, giving light brown appearance. The study demonstrated that the two investigated cultivars are sensitive to CA conditions with CO_2 levels at and above 10%. Further investigations are recommended.

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استجابة صنفين من التمور الرطبة الليبية، الحلاوي والحرة في طور البلح لظروف الجو المتحكم فيه.

محمد أبوصاع فنير، محمد الطاهر مرغم، سمية اشتيوي رحيل
قسم الهندسة الزراعية- كلية الزراعة- جامعة طرابلس

المستخلص

تناولت الدراسة تأثير ظروف الجو المتحكم فيه عند درجات حرارة قريبة من الصفر المئوي على بعض مؤشرات الجودة لصنفين من أصناف التمور الليبية الرطبة، وال لذان يستهلكان محلياً في طور البلح . عينات لصنفي الحلاوي والحرة جُمعت من منطقة طرابلس في موسم الحصا د من العام 2015. لضمان ظروف الجو المعدل وإحكام الغلق، استخدمت برطمانات زجاجية سعة 3 لتر، ثُبت على غطاء كل منها صمامين محكمين، استخدما لقياس وتعديل مكونات الهواء، وقيست مكونات الهواء دورياً خلال فترة الدراسة. تركيبة معاملات الهواء المتحكم فيه المستخدمة تكونت من ثاني أكسيد الكربون (ك أ$_2$) عند ثلاث مستويات 10%، 15% و 20% كل منها مع 5% أكسجين (أ$_2$) إضافة إلى الهواء العادي كشاهد. قيست المكونات الهوائية من (ك أ$_2$) و (أ$_2$) داخل البرطمانات بواقع مرتين أسبوعيا، وعُدلت النسب كلما انحرفت عن تلك المستهدفة بمقدار ± 2%، استُخدمت في ذلك منظومة خلط غازات متصلة باسطوانات بها (أ$_2$)، (ك أ$_2$) و نيتروجين (ن$_2$). حُفظت الثمار لمدة 12 أسبوعاً، قيست المواد الصلبة الذائبة الكلية ، صلابة الثمار، وخصائص لون القشرة الخارجية (L, a, b) ثلاث مرات، عند بداية التجربة و منتصفها و عند نهايتها، كما قيست مؤشرات الجودة الحسية (الطعم) و قيس كذلك فقد الوزن عند نهاية التجربة . أشارت النتائج إلى أنه بعد أربعة أسابيع من المعاملة، لم تسجل فروق معنوية في المواد الصلبة الذائبة، الصلابة، الطعم و فقد الوزن عند مستوي معنوية 0.05، بينما سُجلت فروق معنوية في مؤشرات اللون المقاسة للمعاملات الثلاثة مقارنة بتلك التي قيست في بداية التجربة . تأثرت مؤشرات اللون الثلاثة (L, a, b) مسجلة تغير لون الثمار من اللون الأصفر إلى اللون البني الفاتح، و قد كان للتغير علاقة طردية مع معاملة (ك أ$_2$). أظهرت نتائج الدراسة أن الصنفين موضوع الدراسة (الحلاوي و الحرة) يختلفان في استجابتهما لظروف الجو المعدل عن أصناف أخرى تناولتها دراسات سابقة منشورة . إذ اظهر الصنفان حساسية لثاني أكسيد الكربون عند نسب أعلى من 10%. مهدت الدراسة لاختبار معاملات أخرى عند مستويات (ك أ$_2$) أقل.

الكلمات الدالة: الهواء المتحكم فيه، ك أ $_2$ ، أ$_2$ ، التمور الرطبة، التخزين.

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