Effects of Controlled Atmosphere Conditions on Storability of Libyan 'Hurra' Soft Date Cultivar

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***Abstract*—Libyan 'Hurra' soft dates at 'Khalal' (Balah) stage were stored at 1°C and four controlled atmosphere (CA) treatments; O_2-CO_2 percentages named as CA1 (7.33-4.23), CA2 (10.75-5.95), CA3 (12.08-3.38), and CA4 (15.05-2.70). CA treatments were compared with Regular Atmosphere (RA) (21-0.03) in storage duration. Quality related attributes such as mass loss, color, fruit firmness, Total Soluble Solids (TSS) and respiration rate were also measured at the start and the end of the storage duration. The four CA treatments led to extending fruit storability up to 23 weeks, compared with RA treatment which lasted for 7 weeks. Mass losses were about 5, 5, 6 and 8% for CA1 to CA4 treatments, respectively, while mass loss in RA treatment reached 38%. Color, firmness, TSS were all significantly lower than those measured at the start of the experiment, yet their ranges were in good agreement with values reported in the literature and fell within acceptable ranges. CA treatments also affected respiration, its mean rate was (<0.5ml^{-1}.kg^{-1}.h^{-1}), compared with (2.2ml^{-1}.kg^{-1}.h^{-1}) measured at RA.**

***Index Terms*—soft dates, controlled atmosphere, storability**

I. Introduction

Date palm (*Phoenix dactylifera* L.) is an important tree in most North Africa and Middle East countries, nearly 7 million metric tons of dates are produced annually, top producers are: Egypt, Saudi Arabia, Iran, United Arab Emirates, Pakistan, Algeria, Sudan, Oman, Tunisia, and Libya [1], [2]. In fact, Libya attains the tenth place among date producers; and for its location and large area, it has a unique diversity in date cultivars. The three date cultivar groups; soft, semidry and dry are cultivated between latitudes 24:57°N and 32:75°N. Soft date cultivars are grown in the coastal regions, while dry and semidry cultivars are cultivated in desert oasis's in the southern regions of 'Jufra', 'Wahat' and 'Fezzan'. An extensive review on Libyan date cultivars, their development stages, some characteristics and growing regions has been previously reported in Ref. [3]. Soft date cultivars themselves are divided into two subgroups. Based on palatability at development stage, they are divided into cultivars that consumed at 'Balah' stage and others palatable at 'Rutab' stage. Cultivars such as 'Hellawi' and 'Hurra' are edible at their 'Balah' stage due to lower tannin, high sugar content and less astringency, yet contain high moisture content (>60%) [4]. On the other hand, cultivars such as 'Bronsi', 'Ammi', 'Bekrari', 'Bayothi' and 'Taboni' exceed the 'Khalal' stage and become palatable in their 'Rutab' stage. At this stage fruits become soft, less moisture (<50%), sweet and not astringent. Nonetheless, both groups contain high moisture content, and generally are consumed fresh, and susceptible to fast quality deterioration.

Soft date production is subjected to low prices due to short harvesting season wherein production exceeds demand. Also, high losses are common due to fruit high moisture content, and reaching their ripening stage in Autumn, wherein conditions of high temperature, relative humidity and chances of rainfall are common.

Soft dates are generally sold at public markets, and no means of refrigeration are applied. However, some consumers and producers keep 'Rutab' frozen, yet such method is quite limited, and virtually has no commercial applications. Despite keeping soft dates frozen for an extended period of time, freezing is still energy consuming preservation method, and has negative effects on quality; such as fruit softening and tissue collapse after defrosting, leading to fast quality deterioration and shorter shelf life.

'Hurra' cultivar is well known in the coastal region as one of best quality soft dates. At 'Balah' stage, the fruit is yellow, long, weighs nearly 30g, sweet at above 30% sugar content, crunchy, with diminished astringency, and exhibits very slow rate of conversion to 'Rutab'. Generally, fruits are consumed at 'Balah' stage, yet some customers prefer it in a ripening stage of 'Balah' and 'Rutab' mix, a ripening stage of spotted fruits of about 30% is quite preferred.

Harvesting in the western coastal region starts in late September and extends to mid October. Once fully ripe at 'Rutab' stage, fruits are susceptible to fast deterioration, become soft, skin cracking occur; leading to undesirable taste due to yeast and fungal infection. Cooling retards deterioration for few days, while freezing leads to tissue collapse and browning after exposure to air.

Controlled Atmosphere (CA) methods combined with low temperature are widely used with vast agriculture commodities and foods [5]-[7], for dates however, CA applications still very much limited [8]. Yet, positive effects of CA on preserving quality and improving storability of dates have been reported [2], [9]. It has been reported that 'Berhi' dates benefited from CA condition

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of carbon dioxide percentages of 5, 10 and 20% in better quality and prolonged storage duration [8], [10]. Also, in another investigation, high CO_2 treatments were reported to diminish astringency and improve edibility of 'Barhi' dates [11]. Nonetheless, no work dealt with storing Libyan date cultivars has been reported in the literature.

This paper reports the application of four controlled atmosphere treatments at 1 °C (±0.5 °C) with the aim of extending storability of 'Hurra' Libyan soft date cultivar at 'Balah' stage.

II. Materials and Methods

A. Plant Materials

'Hurra' soft date cultivar bunches were harvested early in the morning on September 29th, 2014 from an orchard near Tripoli, and brought to the postharvest laboratory at the department of Agricultural Engineering, Faculty of Agriculture, Tripoli, they were mostly in a maturity stage of 'Balah' and some fruits at their early stage of turning into 'Rutab'. Fruits were sorted, fruits at 'Rutab' stage were removed from strands, while fruits at 'Balah' stage were kept attached, washed with water containing (0.01%) Sodium hypochlorite, rinsed, weighed attached to strands, about 2kg were used in each replicate of the targeted treatments.

B. Storage Enclosures

Five liter glass jars equipped with threaded plastic lid were used as storage enclosures, for securing 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 0.3bar. On the lid a squared (2.5×2.5cm) opening was made, on which a squared polyethylene sheet with unknown permeability was glued, and septa for drawing air samples by syringe was installed. For reaching several air compositions, membrane areas were partially closed with aluminum tape, facilitating active membrane areas of $50mm^2$, $100mm^2$, $150mm^2$, and $200mm^2$ for treatments CA1, CA2, CA3, and CA4, respectively. For the active membrane areas used, O_2-CO_2 combinations obtained are shown in Table I. For the regular atmosphere known as control treatment on the other hand, jars were covered with fabric, facilitating RA conditions and high relative humidity. In each jar about 2kg of 'Balah' were placed, and for reaching the desired CA condition fast, jars were flushed with Nitrogen, tightly closed and placed in a walk in cold room sat at 1 °C (±0.5 °C). Treatments were carried out in triplicates.

TABLE I. Combinations of Carbon Dioxide and Oxygen Percentage Used

Treatment code	CA combinations	
	O_2 (%)	CO_2 (%)
Control (C)	21	0.0
CA1	7.33 (±0.997)	4.23 (±0.65)
CA2	10.75 (±2.19)	5.95 (±1.23)
CA3	12.08 (±0.48)	3.38 (±0.45)
CA4	15.05 (±2.28)	2.70 (±0.26)

C. Air Analysis

Air analysis for O_2 and CO_2 percentages in the enclosures were periodically 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 air volume sample, analyze it, and displays its O_2 and CO_2 percentage on an LCD screen.

D. Color Assessment

Surface color of fruits was measured at the beginning of storage and at its end using handheld Tristimulus reflectance colorimeter (Minolta CR400, Minolta Corp., New Jersey, USA). Color was recorded using CIE L*, a* and b* color spaces, with L* indicates lightness, a* indicates chromaticity from green (-) to red (+), while b* represents chromaticity from blue (-) to yellow (+).

E. Total Soluable Solids (TSS) Measurment

Sugar content of samples were measured as TSS using digital handheld refractmeter (Model PAL-α, ATAGO Co, Ltd, Tokyo, Japan). Degrees of Brix (°Bx) measured by the instrument indicates sugar content of an aqueous solution. One degree Brix is equivalent to 1 gram of sucrose in 100 grams of solution, and represents the strength of the solution as mass percentage. 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 for measuring sample Brix. TSS was measured for all treatments at the beginning and at the end of the experiment.

F. Fruit Firmness

Fruit firmness was tested at the start and the end of the storage duration 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 into halves, surface skin and seed were removed, and the samples were tested against solid surface. A tip size of 11.1mm in diameter was used to penetrate fruit tissue, instrument was held vertically and a uniform force was applied by hand until the tip penetrated fruit tissue and ruptured it, then maximum breaking force was recorded.

G. Respiration Rate Measuremen

Respiration rates were measured under RA and CA conditions. For the four CA treatments CO_2 and O_2 accumulation was obtained by closing the membrane window for several hours and respiration rate was calculated as reported in earlier investigation Ref. [3]. Respiration rate was expressed as carbon dioxide produced ($ml.kg^{-1}.h^{-1}$).

H. Visual Inspection of Treatments

CA treatments shown in Table I were kept at 1 °C (±0.5) and were compared with a regular atmosphere treatment that used as a control (C). All treatments were kept in glass jars, facilitating easy visual inspections. Visual inspection was made periodically, changes such as shriveling, fungus infections, ripening (conversion to 'Rutab') and skin cracking. Occurrence of any of such defects was considered as strong evidence for quality deterioration, and led to terminating the treatment.

I. Statistical Analysis

Analysis if variance was carried out using SAS statistical software, significance level was declared at ($p < 0.05$) and comparisons among treatments were made applying Duncan Multiple Range Test (MRT). Four different air compositions defined as Controlled Atmosphere (CA) conditions as independent variables, while dependant variable were; Total Soluble Solids (TSS), firmness, fruit surface color, mass loss and respiration rate. All quality related measures were tested at the start of the experiment and at its end and were carried out in triplicates.

III. Results And Discussions

Effect of Controlled Atmosphere (CA) conditions on fruit quality attributes at 1 ℃ storage temperature.

TABLE II. Fruit Surface Color Analysis at the Start and the End of the Storage Duration

Parameter	0-time	CA2	CA1	CA3	CA4
Brightness (L*)	41.58^a	16.99^b	18.12^b	16.07^b	15.60^b
Redness (a*)	5.12^a	3.02^b	5.22^a	2.77^b	5.40^a
Yellowness (b*)	22.21^c	34.07^a	35.85^a	29.73^b	27.91^b

Means in the same raw with different letters are statistically different at ($p<0.05$).

A. Chromaticity Attributes

Table II shows chromaticity measured attributes (L*, a* and b*) at the end of the experiment as compared with their values measured at its beginning. In general, fruits maintained their yellow color and no signs of shriveling and decay were observed. Chromaticity attributes however showed significantly lower lightness (L*) and no significant changes in redness attribute (a*), while the four CA treatments exhibited significantly high yellowness (b*). Reduced lightness after an extended period of time is quite anticipated because fruit lost some moisture, sugar contents, and subjected to aging (senescence). However, the redness attribute (a*) showed no significant changes in CA1 and CA4 treatments, while CA2 and CA3 exhibited lower values. This may not be considered as sign of important color changes since these values were quite low, also red and yellow color attributes at such values may not give clear indication of important color change. The yellowness attribute (b*) however exhibited significant improvement. This in a good agreement with results reported in Ref. [12], wherein improved strawberries color attributes were recorded. This may indicates that CA treatments have color improving effects. By the end of the experiment however, some fruits developed ripening spots and started conversion to 'Rutab'. This may be an indication of approaching senescence as fruits began losing their brightness (lower L* values). For the regular atmosphere treatment on the other hand, fruits lost most of their quality by 7 weeks in storage; fruits shriveled, experienced sever mass losses as reached their peak at 38%, and therefore treatment was discarded much earlier than the four CA treatments.

B. Storage Duration

CA treatments maintained good appearance up to 23 weeks in storage, while regular atmosphere treatments lasted for 7 weeks. Indeed, shorten storage period at RA was mainly due to high rates of metabolic activities. Despite keeping samples in glass jars covered with a fabric for maintaining RA and high relative humidity, fruits were subjected to relatively high mass losses (38%), separated from strands, while some fruits noticeably shriveled, others turned into Rutab. Similar results were reported by other authors Ref. [8] and Ref. [10]. On the other hand, the four controlled atmosphere treatments (CA1, CA2, CA3, and CA4) did not show noticeable signs of deterioration for 23 weeks, such storage period at CA conditions agreed to some extent with results reported in both earlier mentioned references. However, in this study combinations of CO_2 and O_2 were applied as shown in Table I, while in Ref [8] and Ref. [10] no specific O_2 percentage was presented. Comparing storage duration of this study with what was reported in the two mentioned reference with CO_2 percentages less than 10%, the CA combinations used in our study extended storability of 'Hurra' dates by nearly 6 weeks more as compared with 'Berhi' dates stored under 10% CO_2. This may be attributed to the presence of CO_2 combined with low O_2 and their role in reducing metabolic activities in addition to supposed cultivar differences. When a comparison among treatments was made, CA1 exhibited the lowest mass loss followed by CA2, CA3 and CA4 as shown in Table III. This indicates that the tested combination of lower O_2 and high CO_2 led to reduced mass losses. Accordingly, such lower mass losses led to positive implications on quality attributes and storability 'Hurra' date fruits at 'Balah' stage.

TABLE III. Tested Quality Parameters at the Start and the End of the Storage Duration

Parameter	0-time	CA1	CA2	CA3	CA4
Mass loss (%)		4.87^e	5.87^d	6.43^c	7.55^b
Firmness (kgf)	13.36^a	11.27^b	11.0^{bc}	11.6^b	9.5^c
TSS (°Brix)	36.13^a	34.90^{ab}	33.27^b	30.77^c	28.16^d
RR ($ml^{-1}.kg^{-1}.h^{-1}$)	2.19^a	0.44^b	0.36^b	0.36^b	0.54^b

Means in the same raw with different letters are statistically different at ($p < 0.05$). RR= respiration rate, TSS= total soluble solids.

C. Total Soluble Solids (TSS)

Table III shows means of TTS of the four CA treatments after 23 weeks in storage as compared with those measured at the start of the experiment. TSS values measured at time zero and after 23 weeks were significantly different from those measured at the beginning of the experiment. All CA treatments exhibited significantly lower TSS compared with those measured at the beginning of the experiment. TSS measured as °Brix values were reduced by 3%, 8%, 14% and 22% for treatments from CA1 to CA4, respectively. This disagreed with results reported in Ref. [8] and Ref. [10], as they reported increase in TSS or little reduction. In this study however, lower TSS was recorded after 23 weeks in storage. This may be due to metabolic activities, approaching senescence or cultivar related behavior. However, for the 'Hurra' cultivar the normal Brix values range between 25 and 40%, taking that into consideration the results obtained in this study can be considered as values that fall within normal ranges. Since 'Hurra' fruits contain high percentage of sugars, losing a small sugar content after 23 weeks in storage can be considered as quite acceptable. Among treatments, CA1 and CA2 showed less sugar loss.

D. Fruit Firmness

'Hurra' fruits contain high moisture content and are known as the fruit with high turgidity, also the cultivar is known of its non-uniform ripening and fast deterioration. It has been reported by researchers that CA conditions may improve fruit firmness and turgidity [13], [14]. In both studies improved firmness of strawberries was reported. However, no investigation addressed the relation between storage duration and date fruit firmness has been found in the literature. Nonetheless, an important sign of breaching ripening of date fruit is losing firmness. Table III shows that firmness values of the four treatments were significantly lower than those recorded at the beginning of the storage period. This may be due to the extended storage duration of 23 weeks and its effects on fruit aging and approaching ripening and senescence. However CA1 maintained the highest firmness followed by CA2 and CA3 and CA4. This may be attributed to the fact that the first treatment had lowest O_2 and the highest CO_2 percentages. In general, CA1, CA2, CA3 and CA4 treatment tissues showed loss in firmness by 13%, 15%, 18% and 28%, respectively. In fact, CA4 was the treatment with the highest O_2 level combined with the lowest CO_2 level. Giving considerations to mass loss, which ranged between 4 and 7% for all CA treatments, the loss in firmness is quite evident to be attributed to mass loss, physiological and metabolic activities.

E. Respiration Rate

Table III shows respiration rates measured under CA conditions were significantly lower than those measured in the RA conditions. Respiration rates under the four CA treatments were quite similar and all were more than 75% less than those measured under RA conditions. However, rates were reduced in a manner similar to rates reported for papaya fruits measured under CA conditions [15]. Also, such significant reduction in respiration rate indicates that lowering metabolic activities by controlled atmosphere was a key element in extending storage duration of date fruit. This also in a good agreement with results reported in Ref. [16], wherein reduced mass loss of 'Fuyu' persimmon fruits was found to be associated with reduced respiration rate under controlled atmosphere treatment. In the current study however, the four CA combinations led to significantly low respiration rates from ($2.2 ml^{-1}.kg^{-1}.h^{-1}$) at regular atmosphere to ($<0.5 ml^{-1}.kg^{-1}.h^{-1}$) for the four CA treatments. It is quite evident that such decrease led to less metabolic activity and mass loss, and hence extended storability of 'Hurra' dates.

IV. Conclusions

Fruits of Libyan 'Hurra' date cultivar at their 'Balah' stage were stored under four controlled atmosphere conditions for 23 weeks compared with that stored under regular atmosphere condition which lasted for 7 weeks. Quality parameters were measured at the start and the end of the storage duration; color, total soluble solids, mass loss, fruit firmness and respiration rate, they exhibited different means from those measured at the start of the experiment, however, the tested four CA conditions showed maintaining acceptable fruit quality and prolonged storability.

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Dr. Fennir is active in research, he has been granted a research project funded by the Libyan Authority for Research, Science and Technology aiming at the application of controlled atmosphere on improving quality and storability of dates. His research team consists of four graduate students, two research assistants and a technician. In addition to his work in postharvest technologies, Dr. Fennir has carried out an ongoing research project on olive oil mill solid waste utilization to pellets and briquettes and their uses for heating, also olive mill solid waste composting.

Mohamed T. Morgham was born in 1951. He earned his technical degree in Engineering and technology in 1971. He also has attended several training and vocational programs. Mr. Morgham began his work as a farmer growing mainly dates and olive trees in his farm near Tripoli. Currently, he is an expert in date cultivation; he shares his experience with farmers all over Libya, also very passionate with improving date production. Mr. Morgham employed his technical and farming experiences in developing a patented date pollination device, also he patented date ripening method.

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