Moisture Loss of Semidry Libyan Dates at 'Rutab' Stage Evaluated Under Simulated Handling and Transportation Conditions

Mohamed A. Fennir [1*] and Mohamed T. Morghem[2]

Abstract—This study investigated moisture loss and water activity changes in dates subjected to simulated transportation and handling conditions. Samples of date cultivar 'Bronsi' at 'Rutab' stage with 39% moisture content wet basis were subjected to temperature treatments simulating handling conditions at 30, 45 and 55°C, these were made possible using a temperature controlled chamber. Moisture loss (ML) and water activity (a_w) were measured throughout the experiment. ML rates and behavior in relation with time and a_w were obtained and modeled. ML behavior exhibited linear relations with time, temperature and a_w. Mean moisture content dropped from 39 to 35, 31 and 27% after 24 hours for 30, 45 and 55°C treatments, respectively. After 72 hours however, mean moisture contents dropped to 30, 21 and 15% for the same temperatures. a_w was also linearly reduced from initial mean value of 0.82 to 0.67, 0.5 and 0.35 after 72 hours for temperature 30, 45 and 55°C, respectively. a_w, ML, and temperature relations were presented by linear regression models at good agreements with the experimental data with R^2 values ranged between 0.94 and 0.98.

Keywords—Dates, handling, modeling, moisture, transportation, water activity

I. Introduction

DATE palm (*Phoenix dactylifera* L.) is a monocotyledon belongs to the Palmae family. Date fruit is a berry consisting of a single seed surrounded by a fibrous tissue as an endocarp, fleshy mesocarp and a skin as pericarp. It is the most important fruit tree in dry and semidry regions, mainly North Africa and Middle East countries. World production of dates is estimated at nearly 7 million metric tons per year, major producers are Egypt, Saudi Arabia, Iran, Iraq, United Arab Emirates, Pakistan, Algeria, Sudan, Oman, Tunisia, and Libya [1]. In fact, more than 67% of the world production of dates comes from Arab countries [2]. According to FAO statistical data, Libya arrives at the tenth place among date producing countries, with annual production at 170 thousand metric tons [3]. For its large area at nearly1.75 million square kilometers, extending from Chad and Niger boarders to the Mediterranean sea, Libya is considered as geographically vast area suitable for growing dates. More than 400 cultivars are cultivated between latitudes 24:57˚N and 30˚N [4].

Dates are generally classified into three groups, based on fruit moisture content at full ripening: (a) soft dates, contain moisture as high as 70%; those are grown in the fertile coastal Mediterranean plain around latitude 30˚N, (b) semidry dates, contain (20-40% moisture), grown in desert oases around 29˚N, and (c) dry dates contain less that 20% moisture grown in oases located between 24:57˚N and 27˚N [5]. It is evident that temperature and relative humidity of the growing location greatly affect the type of dates. The three important development stages of date fruit itself are "Balah", "Rutab" and "Tamr". At "Balah" stage fruit becomes yellow, firm contain high moisture content, and astringent, with exception of few cultivars, it is unpalatable. At "Rutab" stage the fruit become sweet, soft, diminished astringency, yet still contains high moisture content. In dry regions, when the crop at "Rutab" stage is left on the tree, fruits loose moisture and become "Tamr"; gaining firmer structure, dark color and exhibits gummy chewing mouth feel [1].

In Libya, although most dates are produced in the southern region, the produce is transported to the most populated coastal northern cities. Commonly, dates are packed in perforated PVC boxes with about 20kg capacity, stacked in trucks and covered with a special fabric for protecting the produce from dust and rain. Means of transportation are light, medium and heavy trucks, however, no mechanical refrigeration is implemented. The transportation process including packing, loading, on road, and unloading may take up to three days, wherein the produce is subjected to heat stress that may affect its moisture content. For merchants however, moisture loss is quite important, not only affects their profit but also affects date quality marketing attributes.

Investigations of the impact of handling and transportation conditions on fruits and vegetables under real and simulated conditions have been reported in several references. For instance, impact of road conditions as source of mechanical injuries, temperature and relative humidity are commonly recorded in shipped commodities [6, [7], [8], [9]. For dates though, no such investigations have been found in the literature. Apart from moisture loss during handling, several authors have studied drying behavior of dates under several conditions. Solar and convective drying have been extensively investigated by several authors [10], 11], [12]. However, in such studied drying parameters are temperature and relative humidity of the drying medium as well as air velocity are considered the most important variables. Nonetheless, It is quite important to carry out an investigation that addresses moisture loss behavior of transported dates. The current work aimed at investigating moisture loss under simulated transportation conditions, targeting dates of 'Bronsi' cultivar at Rutab stage grown in a semidry zone.

Mohamed A. Fennir[1], Assistant professor, Department of Agricultural Engineering, Faculty of Agriculture, Tripoli, Libya.

Mohamed T. Morgham[2], Research Assistants, Department of Agricultural Engineering, Faculty of Agriculture, Tripoli, Libya.

II. Materials And Methods

A. Plant Materials

Date fruits of the cultivar 'Bronsi' grown in Wadan area, located at about 750km south east of the capital Tripoli were collected from a storage facility frozen at 'Rutab' stage and packed in perforated PVC box. Dates were transported frozen in an insulated container at the same day to the postharvest laboratory at the department of Agricultural Engineering, Faculty of Agriculture in Tripoli, wherein was kept in a freezer at -18ºC until experimental procedures were carried out, similar to procedures reported in Ref. [12]. The 'Bronsi' cultivar is commonly grown in the coastal region wherein its fruits are considered as a soft dates as they are consumed at Rutab stage. Lately it is planted in a semidry date zone, it is well adapted in Wadan region, where other semidry cultivars such as Degla and Tagyat are commonly grown. Additionally it was targeted in the current investigation for its large fruit size compared with other cultivars.

Fruit physical properties such as weight and dimensions were determined, mean weight was 23g, fruit mean length was 5.5cm and mean diameter was 3.9cm, dark in color, soft structure as fruits contain relatively high moisture content.

B. Simulated Transportation and Handling Conditions

Prior to implementing the experimental study, real road conditions were determined by measuring temperature on the top of a vehicle in a trip from Tripoli to Wadan, temperature was recorded using remote data logger model (USB-503-TC, Measuring Computing Corporation, Norton, MA, USA). Fig. 1 shows temperature profile during real time measurement extended for nearly sixty hours. Based on the trip recorded temperature, three temperatures were selected, 30, 45 and 55°C and were applied in the experimental investigation. Low relative humidity was assumed since the region is dry and relative humidity is normally below 50%.

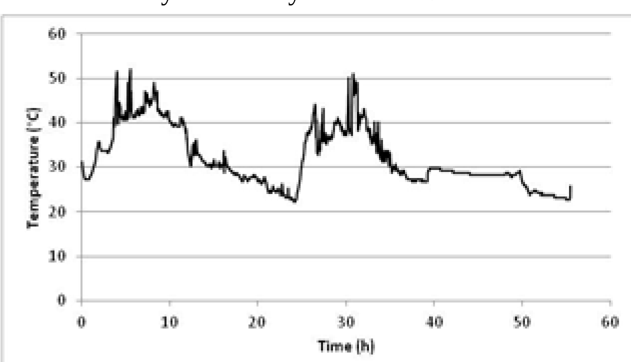

Fig. 1. Real time temperature profile

C. Sample preparation and temperature treatments application

Before carrying out every experiment, samples were removed from the freezer and left overnight at room temperature for thawing, then were sorted; only intact fruits with similar size and maturity stage were selected. Moisture content was determined using the oven method. Random number from previously thawed and sorted fruits were weighed and dried at an oven sat at 100 ºC for 24 hours following standard drying methodology. Moisture content was calculated using equation 1 and expressed in wet basis. The stage moisture loss was calculated using equation 2.

$$M = \frac{W_w - W_d}{W_w} \quad (1)$$

Where: M is the moisture content of the sample (wet basis), W_w is the wet weight, W_d is the dry weight.

$$ML = \frac{W_i - W_t}{W_i} \quad (2)$$

Where: ML is moisture loss at anytime of the simulated condition, W_i is the initial sample weight, W_t is the sample weight at anytime.

Similarly, water activity was determined using water activity meter model (ART: HP: 23 AW-A, Rotronic AG, Bassersdorf, Switzerland). Initial moisture content and water activity were used for developing moisture loss and water activity changes and trends. All measurements were made in triplicates.

A controlled temperature and air flow chamber (Model XB112, France Etuves, Chelles, France) was used for assuring constant temperature and keeping air circulation at its minimum rates. Before the start of every run, the chamber was adjusted to the targeted temperature and given enough time to reach temperature set point. Samples were placed on perforated stainless steel tray and arranged on the chamber racks. A digital scale with three decimal displays weight in gram was used for measuring mass loss 24 hour intervals. Also, water activity was measured using the same instrument described earlier. All runs were again carried out in triplicates.

III. Results And Discussions

A. Moisture Loss- Time Relation

Fig. 2 shows stage moisture loss; that is the moisture loss between two consecutive measurement (24 hour intervals) for the three temperatures treatments, while Fig. 2 shows accumulated moisture loss versus time for the three temperature treatments. Moisture loss at anytime of the simulated conditions was determined using equation 1.

Initial moisture content on wet basis was determined for the date samples using equation 1, and it was 39.66% (±1.47). Moisture loss at every measurement time was calculated starting from the initial moisture content, thus moisture loss trend and behavior were obtained.

Moisture loss rate was high in the first 24 hours, reaching as high as 12, 8 and 4% for 50, 45 and 35 ºC temperature, respectively. In the second day, moisture loss dropped to about 7, 6 and 4% for the three temperatures, and in the third day moisture loss percentage was even less; reaching 5, 4 and 2% for temperatures 50, 45 and 30, respectively. This indicates that moisture loss exhibited almost linear dropping trend, also, such behavior shows that moisture loss took place at high rates in the first day of exposure to high temperature followed by lower rates at the second and third day. Accumulated moisture loss shown in Fig. 3 exhibited linear descending relation with time for the three temperatures. The higher moisture loss was for 55°C treatment followed by 45 and 30°C. Samples subjected to 55°C condition lost more than 50% of their moisture, reaching final moisture content 16%. On the other hand, those subjected to 45°C and 30°C treatments reached final moisture content of 20 and 30%, respectively.

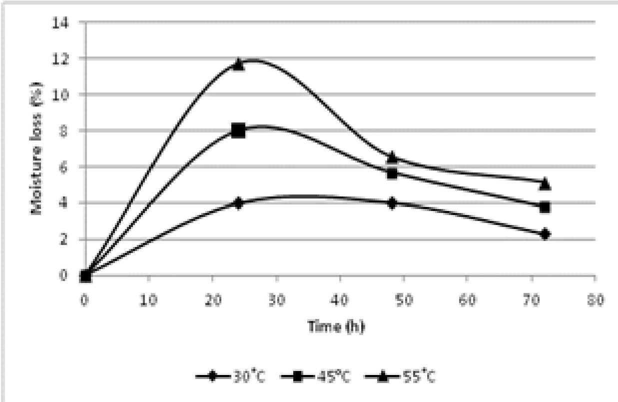

Fig. 2 Stage moisture loss versus time

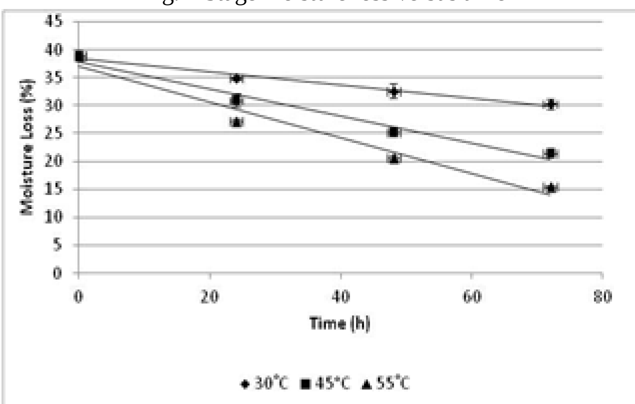

Fig. 3 Accumulated moisture loss versus time

Comparable behavior was reported by several authors for other agricultural commodities, however such produces contain higher moisture content than dates and had different tissue characteristics, in addition to effects of applying different drying conditions such as air flow, fruit surface chemicals treatments [13], [14]. Though, such dissimilarity may affect moisture loss curves in their steepness, in this study however, the moisture loss trends were less steep, long time elapsed before samples reached close to steady state conditions obtained by other authors. This also may be attributed to the nature of date tissue as they are more dense and contain moisture content less than other fresh products. Date samples used here had moisture content less than those found in other agricultural products reported in the literature. Also, in the current study, getting the steady state of low moisture content was not targeted, instead, the aim was to subject samples to the three temperature for a predetermined period of time. However, an agreement with the finding of this work was found in a convective date drying and modeling study, a linear relations between moisture loss and time was reported in [15]. Also, a linear relation between moisture loss and time was reported for drying several other agricultural commodities [16]. In this study, temperature was kept virtually stable, air exchange was kept minimum, and mean relative humidity was less than 20%.

Regression analysis was made on moisture loss versus time relation as shown in Table 1 (left). Moisture loss was described by three linear regression relations with fairly good R^2.

TABLE I
MOISTURE LOSS AND WATER ACTIVITY REGRESSION MODELS

Temp.	Model	R^2	Model	R^2
30°C	ML = 38.387- 0.117t	0.98	aw = 0.8021 - 0.002t	0.94
45°C	ML = 37.825 - 0.242t	0.97	aw = 0.8129- 0.0042t	0.97
50°C	ML = 37.066 - 0.320t	0.96	aw = 0.7972-0.0058t	0.98

ML = moisture loss (%), aw = water activity, t = time.

B. Water Activity - Time Relation

Fig 4 shows water activity measured in the same manner as moisture loss. Water activity followed similar trends as moisture loss. The initial mean water activity of dates was 0.816, it can be noticed that water activities after 24 hours were in close range for the three temperature treatments, however a quite clear gap can be noticed after 48 and 72 hours. This may be attributed to the evaporation rate from dates at 30°C was quite low compared with the other two temperatures. The three temperatures treatments lowered moisture contents from their initial mean value following linear descending trends as presented in Table 2 (right). The final water activity for the three temperature treatments were 0.38, 0.50, and 0.67, for the three temperatures, 30, 45 and 55°C, respectively. This indicates that high temperatures during transportation and handling may lead to the excessive dryness of the dates. The lower moisture loss rate was recorded for 30°C and accordingly water activity reached its lowest value at 0.68, which equivalent to moisture content of 30%, while a moisture content of 25% gave water activity around 0.63.

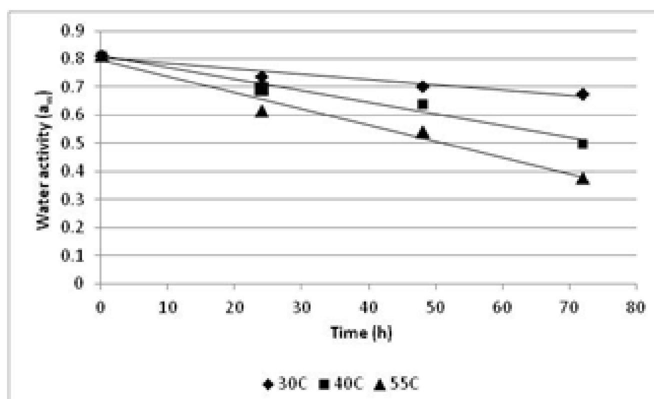

Fig. 4. Water activity versus time

C. Water Activity- Moisture Loss Relations

Fig. 5 shows moisture loss in relation to water activity. The three time point water activities were plotted versus moisture loss of the three temperature treatments. It is well known fact that moisture loss and water activity are inversely related. For this investigation however, the relation was described by a linear regression model with R^2 = 0.93. Relation followed similar trend as moisture loss, and by using the regression relation water activity of the sample can be determined at any moisture content within the tested range. Apart from dates, linear relations between water activity of honey and its moisture content were reported [17]. In this study however, the relations were derived between water activity and moisture loss and presented by linear model. Thus, water activity can be determined at any moisture loss regardless of the temperature applied.

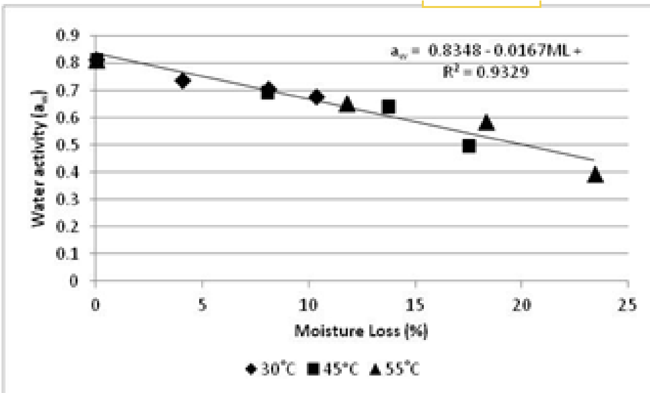

Fig. 5. Water activity versus moisture loss

IV. Conclusion

Moisture loss from semidry Libya dates cultivar 'Bronsi' was investigated under simulated transportation and handling conditions. Moisture loss exhibited descending linear trend with time, fruits lost the highest moisture in the first day of exposure to 30, 45 and 55°C, followed by the second and third days. Dates lost more than50% of its moisture content at 55°C, near 50% at 45° and 20% at 30°C, while water activity followed similar trends. The moisture loss versus time, water activity versus time and water activity versus moisture loss were fitted to regression models with high R^2 values.

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Mohamed A. Fennir was born in 1963, received his Bachelor's degree in Agricultural Engineering from the Faculty of Agriculture, Tripoli University in 1985, a Master's degree in 1997 and a PhD in 2002 from McGill University, Montreal Canada. He joined the Department Agricultural Engineering, Faculty of Agriculture, Tripoli University, Libya in 2002.

Dr Fennir teaches several undergraduate courses; Strength of Materials, Mechanics, Farm Tractors, Advanced Topics, Principals of Environment. At the graduate level he teaches Postharvest Technologies, Ventilation of Agricultural Structure and Instrumentation and Control.

Dr Fennir served as an acting departmental chair several times, also appointed as departmental chair for two years, and has been the Graduate Studies Coordinator since 2012. Also, he was member of the Graduate program development committee of his department, member of improving the undergraduate program committee, and worked on developing curriculum of the Libyan Agriculture Technical Higher Institutes guided by the UNESCO.

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. Morghem was born in 1951 earned his technical degree in Engineering and technology in 1971. He also has attended several training and vocational programs. Mr. Morghem 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. Morghem employed his technical and farming experiences in developing a patented date pollination device, also he patented date ripening method.

Mr Morghem is an active member of the Libyan Inventors Association (LIA). He joined the date postharvest research team in 2013 at the department of Agricultural Engineering, and ever since has been in charge of the technical aspects of the laboratory.