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THE MECHANICAL PROPERTIES OF DIFFERENT CULTIVARS DATES AT THREE MATURITY STAGES

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ABSTRACT

The present study investigated the effect of three maturity stages on the basic mechanical properties of four date cultivars.

Higher hardness values for the four cultivars were found at the *Tamer* stage relative to the *Rutab* stage for all basic mechanical properties. Higher hardness values for the four cultivars at the *Khalal* stage relative to the *Rutab* and *Tamer* stages were found using the compression test. Higher hardness values for the cultivars at the *Khalal* stage relative to the *Rutab* and *Tamer* stages, except for the *Saqie* cultivar at the *Tamer* stage, were found using the penetration test.

According to the compression test, the elasticity modulus and rupture point values for the cultivars at the *Khalal* stage were higher than the values at the *Rutab* stage. The compression test also indicated that the elasticity modulus and rupture point values were higher for the cultivars at the *Khalal* stage than at the *Rutab* and *Tamer* stages.

The longitudinal hardness values for the cultivars at the *Khalal* stage were higher than the values at the *Rutab* and *Tamer* stages. Moreover, the diametrical hardness values were higher for the cultivars at the *Khalal* stage than the cultivars at the *Rutab* and *Tamer* stages.

KEYWORDS: Dates, Maturity, Cultivars, Mechanical, Elasticity Modulus

INTRODUCTION

The date fruit of date palm trees *(Phoenix datylifera L.)* is the most important fruit in Saudi Arabia, which produces 1,008,105 tons of date fruit. The area cultivated for date palm trees in Saudi Arabiais 156,023 ha, with approximately 24.37 million trees in different regions of the country *(Ministry of Agriculture and Water, 2012).* Exporting agricultural products to all countries, especially Europe, is one of the main goals of the current policy. Dates must be well sorted, graded and backed. To achieve such operations, information regarding the physical and mechanical properties of dates is required *(Bahnasawy, 2004).* Consumers are increasingly demanding fruit of consistently high quality. Mechanical damage, which can occur during harvesting, handling and transport, represents a serious hazard for quality. Undoubtedly, dynamic forces incurred during fruit transport and handling cause the most bruise damage *(Zeebroeck et al., 2007).*

Fully mature dates in all stages are fragile and subject to mechanical damage through a series of static and dynamic loads. Such loads cause significant loss by decreasing the quality during storage *(Bargale et al. 1994).* The mechanical injury may be the most important cause of defects and disease. *(Knee and Miller 2002).* Mechanical properties mainly include rupture force, penetration force, deformation at rupture, deformation at penetration, firmness and

modulus of elasticity. All of these fruit properties are necessary for the design of equipment for harvesting, transporting, cleaning, packing, storing and processing *(Kilickan and Guner 2008).* The firmness of dates as a function of maturity has been studied *(Myhara et al, 2000).* At 103 days after pollination, the force required to penetrate dates is 186×10^4Pa. As dates mature, this firmness decreases to 53.6×10^4 Pa at 152 days after pollination (corresponding to the *Rutab* stage of maturity). Immediately after the *Rutab* stage, the firmness temporarily increases to 89.8×10^4 Pa before reaching a minimum of 28.2×10^4 Pa at 170 days after pollination. The knowledge of various mechanical properties of date fruit, provides essential engineering data required for the design of various processing machines, structures and controls. This knowledge is also important in the analysis and determination of the efficiency of a machine or an operation and in the development a new consumer product, particularly for evaluating the quality of the final product. The aim of this study was to investigate the effect of maturity stages on basic mechanical properties off our date cultivars.

MATERIALS AND METHODS

Sample Preparation

In the present study, four cultivars of Saudi dates, namely *Barhi, Khudari, Sukkari and Saqie*, were investigated at three stages of maturity [*Khalal, Rutab and Tamer*]. During the *Khalal* stage of maturity, the fruit color changes from green to yellow or red in some cultivars, and the moisture content decreases to 55% on a wet basis. Moreover, tannins begin to precipitate and lose their astringency in the *Khalal* stage. The *Rutab* stage follows the *Khalal* stage of maturity. During this stage, the moisture content of some cultivars decreases to approximately 20% on a wet basis. The *Tamer* stage follows the *Rutab* stage of maturity. During this stage, the moisture content of some cultivars decreases to approximately 7% on a wet basis. The dates used in the present study were obtained from Riyadh, Saudi Arabia. Dates were sorted to discard damaged fruits and kept for less than 24 hin cold storage at 5^oC. The moisture content of the flesh of the dates was determined using AOAC procedures *(AOAC, 2010).* Samples were dried at 70^oC for 48 h under a vacuum at 200 mm Hg (Vacutherm model VT 6025, Heraeus Instruments, D-63450, Hanauer, Germany). Water activity was measured using an Aqua Labmeter (Model CX-2T with a readability of 1mg; Decagon Devices Inc., Washington).

INSTRUMENTATION

A texture analyzer (TA-HDi, Model HD3128, Stable Micro Systems, Surrey, England) together with a 75-mm-diameter disk plunger (# P 75) was used to conduct uniaxial compression tests. The texture analyzer was interfaced with an IBM-compatible PC and Texture Expert Exceed software (version 2.05), which allowed data acquisition in an Excel format. This software can determine the gradient of the curve between any two specified locations and the area under the curve. All experiments were conducted at room temperature (23^oC). The instrument was calibrated with a 50–100 kN force and a linearity better than 1%. The contact area between the plunger disk surface and each tested fruit surface was determined experimentally. The plunger disk surface was covered with white paper. The horizontally oriented upper longitudinal fruit surface was then gently pressed in an ink stamp, and the plunger was allowed to contact the fruit surface. The resulting contact area traced on the white paper was scanned, and specially developed software that accurately estimates the scanned surface area was used to determine the contact area.

Tests

For the compression tests, the experiments were conducted using individual date fruits of the four cultivars. The fruits were oriented parallel to the compression surfaces during loading at across-head speed of 1.5 mm s^{-1}. Before the

tested force or stress was applied, the deformation rate was set at 10 mm for the compression test. For the penetration test, a cylinder probe (P/2) with a diameter of 2 mm was used. The penetration depth was 5mm from the rind of the fruit.

For the shear test, the fruit was first cut into halves, and the nucleus was removed. A craft knife was then used to cut the fruit into two parts longitudinally and diametrically, where the penetration force was measured at a distance of 15 mm with a speed of 1.5mm s^{-1}. The speed of disarmament was 1.5 mm s^{-1}. Ten random fruits from each cultivar at each maturity stage were used for these tests with a total number of runs equal to 360.

RESULTS AND DISCUSSIONS

Moisture Content

The mean moisture contents of the four date cultivars are shown in Figure 1. Date fruits pass through several separate stages of maturity, traditionally described by changes in colour, texture, moisture content and taste/flavor. The moisture content at the *Khalal* stage was higher than the moisture content at the *Rutab* and *Tamer* stages. The moisture content at the *Khalal* stage varied from 72.4% (w.b.) for *Saqie* to 62.6% for *Sukkari*. The moisture content at the *Rutab* stage varied from 31.6% (w.b.) for *Sukkari* to 19.1% for *Saqie*, and the moisture content varied from 12.5% (w.b.) for *Sukkari* to 7% for *Barhi* at the *Khalal* stage.

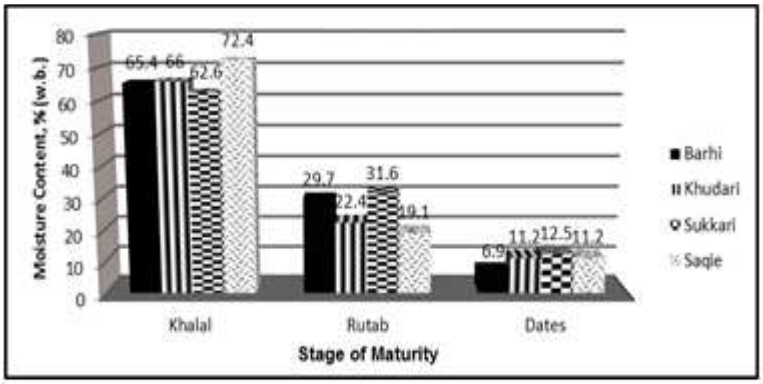

Figure 1: The Effect of Maturity Stages on Moisture Content of Four Date Cultivars

COMPRESSION TEST

Modulus of Elasticity

Figure 2 shows the modulus of elasticity values for the four date cultivars at the three maturity stages. The modulus of elasticity values at the *Khalal* stage were higher than the modulus of elasticity values at the *Rutab* stage, with values ranging from 60.23 Nmm^{-1} for *Khudari* to 32.5 Nmm^{-1} for *Barhi* at the *Khalal* stage, and values ranging from 2.17 Nmm^{-1} for *Saqie* to 0.21 Nmm^{-1} for *Barhi* at the *Rutab* stage. The difference in maturity stages has been attributed to changes in chemical composition.

In the *Rutab* stage the loss of moisture is accelerated, the fruits become softer in texture (Sawaya, 1983). These data demonstrate the importance of greater care for *Barhi* dates at the *Khalal* stage during handling, packaging and processing because they are more sensitive to deformations at this stage. Moreover, the modulus of elasticity values at the *Rutab* stage were lower than the modulus of elasticity values at the *Tamer* stage, with values ranging from 2.17 Nmm^{-1} for *Saqie* to 0.21 Nmm^{-1} for *Barhi* at the *Rutab* stage and values ranging from 5.64 Nmm^{-1} for *Saqie* to 2.76 Nmm^{-1} for *Barhi* at the *Tamer* stage.

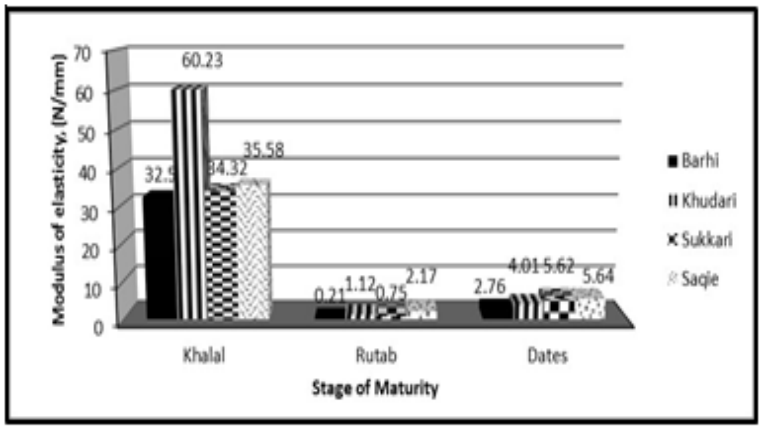

Figure 2: The Effect of Maturity Stages on Modulus of Elasticity of Four Data Cultivars

Rupture Point

Figure 3 shows the rupture point values for the four date cultivars at the three maturity stages. The rupture point values at the *Khalal* stage were higher than the rupture point values at the *Rutab* stage, with values ranging from 263.5 N for *Khudari* to 137 N for *Barhi* at the *Khalal* stage and values ranging from 32.64 N for *Saqie* to 2.97 N for *Barhi* at the *Rutab* stage. Moreover, the rupture points at the *Rutab* stage were lower than the rupture points at the *Tamer* stage, with values ranging from 32.64 N for *Saqie* to 2.97 N for *Barhi* at the *Rutab* stage, and values ranging from 121.49 N for *Barhi* to 47.3 N for *Sukkari* at the *Tamer* stage.

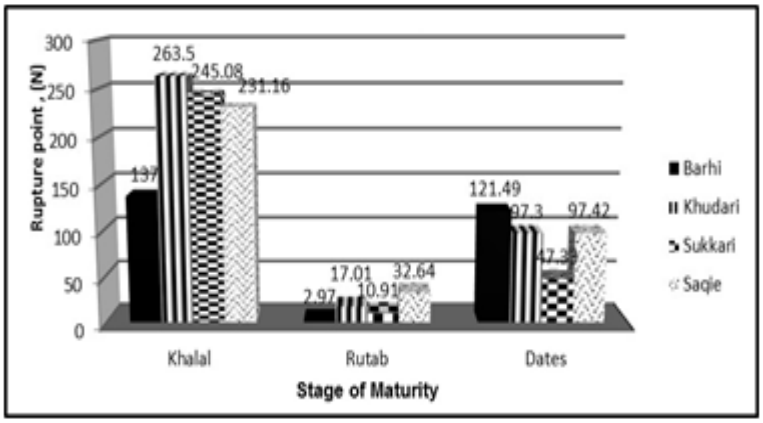

Figure 3: The Effect of Maturity Stages on Rupture Point of Four Data Cultivars

Hardness

Figure 4 shows the hardness values for the four date cultivars at the three maturity stages. The hardness values at the *Khalal* stage were higher than the hardness values at the *Rutab* stage with values ranging from 913.94N mm for *Saqie* to 636.8N mm for *Barhi* at the *Khalal* stage, and values ranging from75.02N mm for *Saqie* to 7.89N mm for *Barhi* at the *Rutab* stage. Moreover, the hardness values at the *Rutab* stage were lower than the hardness values at the *Tamer* stage, with values ranging from 75.02N mm for *Saqie* to 7.89N mm for *Barhi* at the *Rutab* stage, and values ranging from 213.65 N mm for *Saqie* to 145.43 N mm for *Khudari* at the *Tamer* stage. These results is related to decreasing the tannin with the maturity progressed. As dates mature, they become softer in texture. This change in texture is normally associated with progressive changes in the composition of the dates fiber (Sawaya et al, 1982 and 1983).

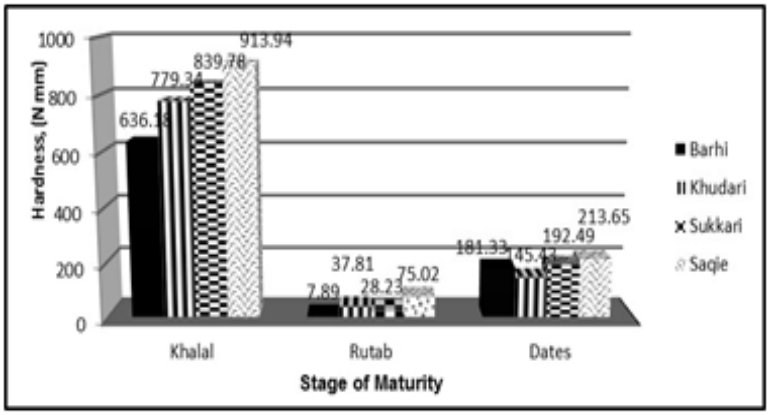

Figure 4: The Effect of Maturity Stage on Hardness of Four Data Cultivars

Bio Yield Point

Figure 5 shows the bio yield points of the four date cultivars at the three maturity stages. The bio yield points at the *Khalal* stage were higher than the bio yield points at the *Rutab* stage, with values ranging from 248.65 N for *Sukkari* to 71.6 N for *Barhi* at the *Khalal* stage, and values ranging from18.00 N for *Saqie* to 2.06 N for *Barhi* at the *Rutab* stage.

Moreover, the bio yield point values at the *Rutab* stage were lower than the values at the Tamer stage, with values ranging from 18.00 N for Saqie to 2.06 N for *Barhi* at the *Rutab* stage, and values ranging from 116.16N for *Barhi* to 30.63 N for *Sukkari* at the *Tamer* stage. These results is related to decreased polygalacturonic acid (Pectin) with dates matured and this results is agreed with El-Zoghbi (1994)

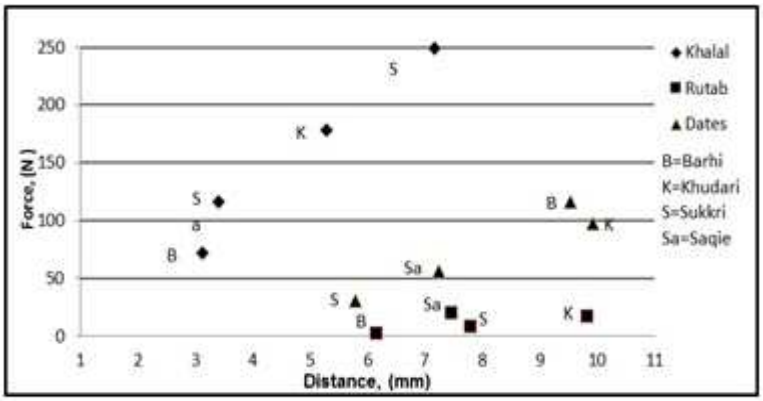

Figure 5: The Effect of Maturity Stages on Bio Yield Point of Four Data Cultivars

Maximum Point

Figure 6 shows the maximum point values for the four date cultivars at the three maturity stages. The maximum point values at the *Khalal* stage were higher than the maximum point values at the *Rutab* stage, with values ranging from 275.1 N for *Khudari* to 172.46N for *Barhi* at the *Khalal* stage, and values ranging from31.59 N for *Saqie* to 3.9 N for *Barhi* at the *Rutab* stage.

The maximum point values at the *Rutab* stage were lower than the maximum point values at the *Tamer* stage, with values ranging from 31.59 N for *Saqie* to 3.9 N for *Barhi* at the *Rutab* stage, and values ranging from121.49 N for *Barhi* to 47.39 N for *Sukkari* at the *Tamer* stage.

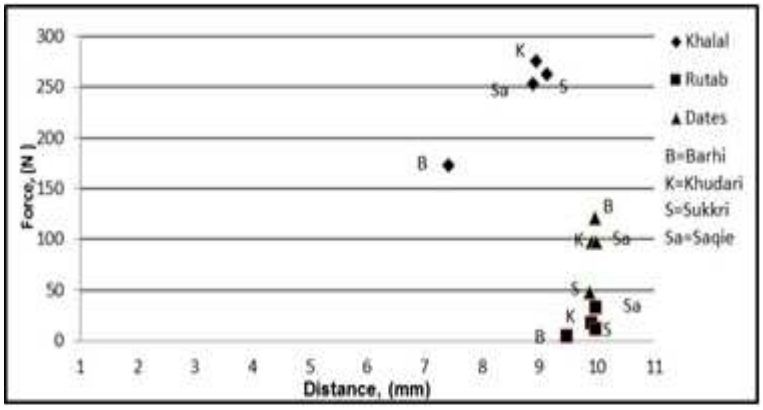

Figure 6: The Effect of Maturity Stages on Maximum Point of Four Data Cultivars

PENETRATION TESTS

Modulus of Penetration

Figure 7 shows the modulus of penetration values for the four date cultivars at the three stages of maturity. The maximum point values at the *Khalal* stage were higher than the values at the *Rutab* stage, with values ranging from 10.24 Nmm^{-1} for *Saqie* to 5.7 Nmm^{-1} for *Barhi* at the *Khalal* stage, and values ranging from1.7 Nmm-1 for *Saqie* to 0.1 Nmm^{-1} for *Barhi* at the *Rutab* stage.

Although, the modulus of penetration values at the *Rutab* stage were lower than the values at the *Tamer* stage, with values ranging from 1.7 Nmm^{-1} for *Saqie* to 0.1 Nmm^{-1} for *Barhi* at the *Rutab* stage, and values ranging from 3.93 Nmm^{-1} for Saqie to 0.82 Nmm^{-1} for *Khudari* at the *Tamer* stage.

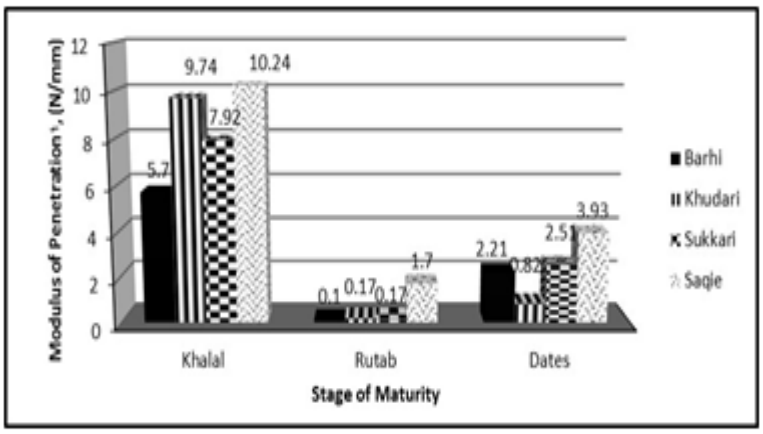

Figure 7: The Effect of Maturity Stages on Modulus of Penetration of Four Data Cultivars

Hardness

Figure 8 shows the hardness values for the four date cultivars at the three stages of maturity. The hardness values at the *Khalal* stage were higher than the hardness values at the *Rutab* stage, with values ranging from 44.06 Nmm for *Khudari* to 31.32 Nmm for *Saqie* at the *Khalal* stage, and values ranging from 14.46 Nmm for *Saqie* to 1.54 Nmm for *Barhi* at the *Rutab* stage. While, the hardness values at the *Rutab* stage were lower than the hardness values at the *Tamer* stage, with values ranging from 14.46 N mm for *Saqie* to 1.54 N mm for *Barhi* at the *Rutab* stage, and values ranging from 22.95 Nmm for *Saqie* to 5.64 Nmm for *Khudari* at the *Tamer* stage.

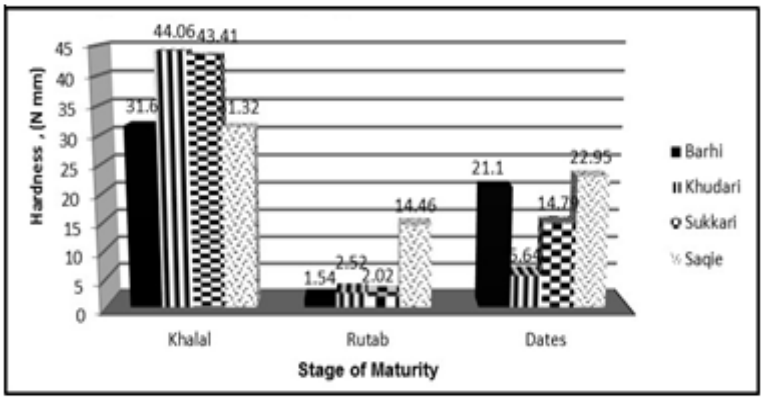

Figure 8: Effect of Maturity Stages on the Hardness of Four Data Cultivars

SHEARING TEST

Longitudinal Modulus of Shearing

Figure 9 shows the longitudinal modulus of shearing values for the four date cultivars at the three stages of maturity. The longitudinal modulus of shearing values at the *Khalal* stage were higher than the values at the *Rutab* stage, with values ranging from 26.26 Nmm^{-1} for *Saqie* to 14.7 Nmm^{-1} for *Barhi* at the *Khalal* stage, and values ranging from 2.01 Nmm^{-1} for *Saqie* to 0.56 Nmm^{-1} for *Sukkari* at the *Rutab* stage. The longitudinal modulus of shearing values at the *Rutab* stage were lower than the values at the *Tamer* stage, with values ranging from 2.01 Nmm for *Saqie* to 0.56 Nmm^{-1} for *Sukkari*at the *Rutab* stage, and values ranging from8.31 Nmm^{-1} for *Saqie* to 1.57 Nmm^{-1} for *Khudari* at the *Tamer* stage.

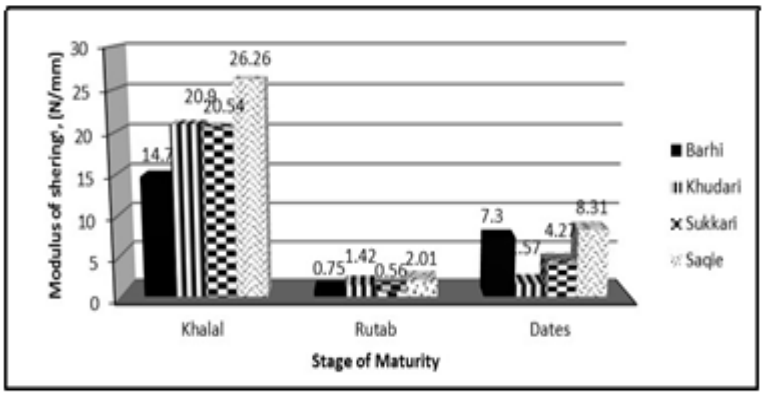

Figure 9: The Effect of Maturity Stages on Longitudinal Modulus of Shearing at Four Data Cultivars

Diametrical Modulus of Shearing

Figure 10 shows the diametrical modulus of shearing values for the four date cultivars at the three stages of maturity. The diametrical modulus of shearing values at the *Khalal* stage were higher than the values at the *Rutab* stage, with values ranging from 20.21 N/mm for *Saqie* to 14.67 Nmm^{-1} for *Barhi* at the *Khalal* stage, and values ranging from 1.31 Nmm^{-1} for *Barhi* to 0.62 Nmm^{-1} for *Khudari* at the *Rutab* stage. The diametrical modulus of shearing values at the *Rutab* stage were lower than the values at the *Tamer* stage, with values ranging from 1.31 Nmm^{-1} for *Barhi* to 0.62 Nmm^{-1} for *Khudari* at the *Rutab* stage, and values ranging from5.41 Nmm^{-1} for *Saqie* to 1.8 Nmm^{-1} for *Khudari* at the *Tamer* stage.

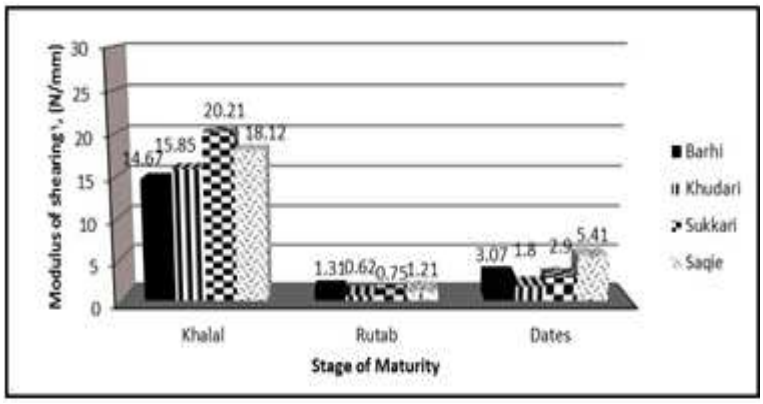

Figure 10: The Effect of Maturity Stage on Diametrical Modulus of Shearing at Four Data Cultivars

Longitudinal Hardness

Figure 11 shows the longitudinal hardness values for the four date cultivars at the three stages of maturity. The longitudinal hardness values at the *Khalal* stage were higher than the longitudinal hardness values at the *Rutab* stage, with values ranging from 283.4 N mm for *Saqie* to 123.4 N mm for *Sukkari* at the *Khalal* stage, and values ranging from 147.34 N mm for *Saqie* to 72.12 N mm for *Barhi* at the *Rutab* stage. These is related to acceleration of the loss of moisture in Rutab Stage. The longitudinal hardness values at the *Rutab* stage were lower than the longitudinal values at the *Tamer* stage, with values ranging from 147.34 N mm for *Saqie* to 72.12 N mm for *Barhi* at the *Rutab* stage, and values ranging from309.72 N mm for *Sukkari* to 138.44 N mm for *Khudari* at the *Tamer* stage.

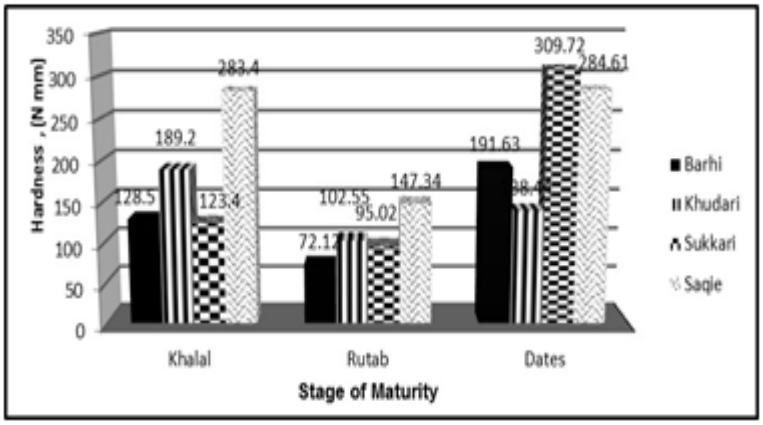

Figure 11: The Effect of Maturity Stages on Longitudinal Hardness at Four Data Cultivars

Diametrical Hardness

Figure 12 shows the diametrical hardness values for the four date cultivars at the three stages of maturity. The diametrical hardness at the *Khalal* stage was higher than that at the *Rutab* stage, with values ranging from 577.52 N mm for *Sukkari* to 236.66 N mm for *Barhi* at the *Khalal* stage, and values ranging from 120.87 Nmm for *Saqie* to 75.37 N mm for *Barhi* at the *Rutab* stage. On the other hand, the diametrical hardness at the *Rutab* stage was lower than that at the *Tamer* stage, with values ranging from 120.87 Nmm for *Saqie* to 75.37 Nmm for *Barhi* at the *Rutab* stage, and values ranging from607.14 Nmm for *Saqie* to 96.31 Nmm for *Khudari* at the *Tamer* stage.

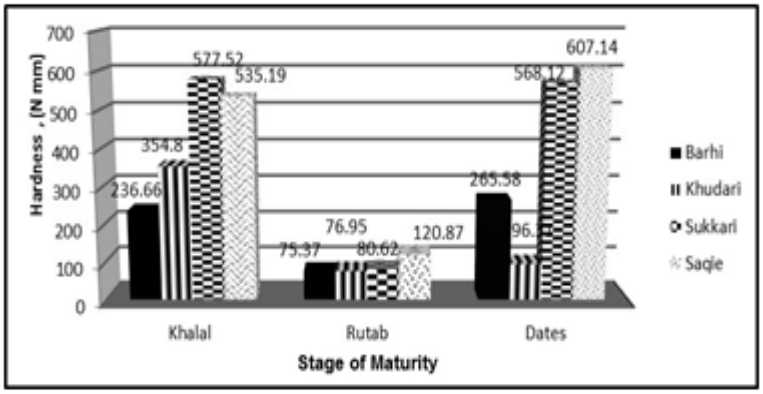

Figure 12: The Effect of Maturity Stages on Diametrical Hardness at Four Data Cultivars

CONCLUSIONS

The results indicate higher values of hardness for the four cultivars, namely *Barhi, Khudari, Sukkari and Saqie*, at the *Tamer* stage than the *Rutab* stage for all basic mechanical properties, and the results indicate higher values of hardness for the four cultivars at the *Khalal* stage thanat the *Rutab* stage according to the compression test. In addition, the penetration test indicated higher values of hardness for the cultivars at the *Khalal* stage than at the *Rutab* and *Tamer* stages, except for *Saqie* at the *Tamer* stage.

According to the compression test, the elasticity modulus and rupture point values for the four cultivars at the *Khalal* stage were higher than the values at the *Rutab* stage. Moreover, the elasticity modulus and rupture point values obtained with the compression test indicated higher elasticity modulus and rupture point values for the cultivars at the *Khalal* stage than at the *Rutab* and *Tamer* stages. The longitudinal hardness values for the cultivars at the *Khalal* stage were higher than the values at the *Rutab* stage, except for *Barhi* and *Sukkari* at the *Tamer* stage. In addition, the diametrical hardness values were higher for the cultivars at the *Khalal* stage than at the *Rutab* and *Tamer* stages, except for the *Barhi* and *Saqie* cultivars at the *Tamer* stage.

The shearing test indicated higher values of longitudinal shearing modulus and diametrical shearing modulus for the four cultivars at the *Khalal* stage than at the *Rutab* stage. Moreover, the shearing test indicated higher values of longitudinal shearing modulus and diametrical shearing modulus for the cultivars at the *Khalal* stage than at the *Rutab* and *Tamer* stages.

The results indicated higher values of penetration modulus for the four cultivars at the *Khalal* stage than at the *Rutab* stage. Furthermore, the penetration modulus values for the cultivars at the *Khalal* stage were higher than the values at the *Rutab* and *Tamer* stages.

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REFERENCES

1. Bahnasawy, A. H., El-Haddad, Z.A., El-Ansary, M.Y. and Sorour, H.M. (2004). Physical and mechanical properties of some Egyptian onion cultivars. Journal of Food Engineering 62, 255–261.

2. Bargale, P.C., Irudayaraj, J. and Marquis, B.(1994). Some mechanical properties and stress relaxation characteristics of lentils. Canadian Journal of Agricultural Engin. 36(4):247-254.
3. El-Zoghbi M, (1994). Biochemical changes in some tropical fruits during ripening. Food Chem 49:33-37.
4. Kilickan, A. and Guner, M. (2008). Physical properties and mechanical behavior of olive fruits under compression loading. Journal of Food Engineering 87 (2), 222–228.
5. Knee, M., A.R. Miller (2002). Mechanical injury. In: Knee, M. (Ed.), Fruit Quality and its Biological Basis. Sheffield Academic press, Sheffield, pp. 157–179.
6. Ministry of Agriculture and Water (2012). Agriculture statistical yearbook. Fourteenth Issue. Department of Economics Studies and Statistics, Riyadh, Saudi Arabia.
7. Myhara, R., Al-Alawi, A., Karkalas, A. and Taylor, M.(2000) Sensory and textural changes in maturing Omani dates. J. Sci. Food Agric., 80:2181–2185.
8. Sawaya, W. N., Khalil, J.K., Safi, W. N. and Al-Shalhat, A. (1983). Physical and chemical characterization of three Saudi date cultivars at various stages of development. Can Inst Food Sci Technol 16:87-91.
9. Sawaya, W. N., Khatchadourian, H. A., Khalil, J. K., Safi, W. M. and Al-Shalhat, A. (1982). Growth and compositional changes during various developmental stages of some Saudi Arabian date cultivars. J Food Sci 47:489-1492, 1497.
10. Zeebroeck, M. V., linden, V. V., Ramon, H., Baerdemaeker, J. D., Nicola, B. M., and Tijskens, E. (2007). Impact damage of apples during transport and handling. Postharvest Biology and Technology, 45, 157–167.