Investigating the Effects of Shaking Mode, Frequency and Amplitude on Dates Fruit Detachment.

M. Loghavi and M. Abounajmi

Department of Farnl Machinery, College of Agriculture, Shiraz University, I. R. Iran.

ABSTRACT

One of the major problems in date (*Phoenix dactylifera* L.) harvesting is variable maturity. Selective hand-picking of individual ripe fruits from each bunch is the most expensive and time consuming cultural operation. A 2 x 5 x 3 factorial experiment with a completely randomized design in three replications was conducted to investigate the effects of shaking mode, frequency and amplitude on date fruit detachment. Five levels of shaking frequency (200, 300, 450, 600 and 750 cpm) and three levels of shaking amplitude (20, 40 and 60 mm) were investigated at two modes of fruit bunch vibration (vertical and hanging). The experiment was conducted on Shahani dates fruit bunches.

Analysis of variance and mean comparison revealed that the effects of shaking mode, frequency and amplitude were significant on fruit detachment. It was found that at 300 cpm frequency and 60 mm amplitude the most effective detachment of ripe fruits with minimum unripe fruit detachment occurred. Also the results showed that the vertical shaking mode was more effective in detaching ripe fruits than hanging mode and also in the vertical shaking mode the amount of detached fruits with calyx attached was less than the hanging mode. Results also indicated that the amount of detached fruits without calyx attached increased at the higher frequency and amplitude levels. Fruit pull tests showed that the average axial tensile force required to remove ripe fruits was about .35% of that needed for removing unripe fruits. The results of this research indicated that bunch shaker was capable of removing marketable ripe dates from the bunch without imparting any significant rubbing or bruising damage to the fruits.

INTRODUCTION

The date palm (*Phoenix dactylifera* L.) is native to Iran, Iraq, Saudi Arabia and many oases in the desert areas of northern Africa. It has been a staple food in those regions since the first recorded history (Sarig,

1989). For more than 4000 years people have been cultivating date along banks of Karroon and Karkheh, two big rivers in Iran (Eslhampour, 1993). Yearly production of date in Iran is about 900000 tons (Anonymous, 1999).

During the past decades, increasing interest in mechanical harvesting of date fruits has led to the development of date harvesting aids and machines (Perkins & grown, 1964; Al-Suhaibani et al., 1990 and Eslhampour, 1993). Certain fruits such as date do not mature unifonnly, therefore selective harvesting is necessary .The number of hand picking has gradually decreased due to the shortage of available farm labors durimg the harvest season and increasing their wages.

Following the design and development of an experimental bunch shaker (Abounajmi, 2000), the need for detennining the optimum frequency, amplitude and vibration mode for date fruit detachment was recognized. The need for an efficient date harvester that could remove the ripe fruits from the bunch was perceived early by Perkins and Brown (1964). They reported that the vertical shaking mode had the best effect on ripe date detachment. According to these results a rigidly mounted shaker (applying 40 mm stroke at 1400 cpm) and a hand cauied shaker applying 40 mm and 80 mm strokes at 700 cpm, respectively were built and tested (for removing Deglet Noor date fruits). Sarig et al. (1971) designed and developed a hydraulically powered tractor mounted date bunch shaker that delivered a 9.5 cm. stroke vibration at 67 Hz for removing Hiani date fruits. Later sarige used an inertia type shaker for shaking the whole palm (Sarig, 1989). It was consisted of a counter rotating-weight mechanism imparting multi-directional vibration to the palm. The power required for clamping and shaking was provided by an augmented hydraulic system of the prime mover. Clamping the shaker to the lower quadrant of its height (about 2.5-3 m) yielded the optimal rate of fruit removal (about 90%).

The objectives of this research were:

a) Investigation of the effects of shaking mode, frequency and amplitude on date fruit detachment.

b) Determination of the optimum shaking frequency and amplitude for ripe Shahani dates harvesting.

c) Determination of fruit detachment force / weight ratio.

MATERIALS AND METHODS

The experiment was conducted on Shahani date palms in Jahrom, one of the major date growing regions in Fars province. Fifteen Shahani date palms at the same age and growing condition were seJected. The experimental design was a 5 x 3 x 2 factorial experiment with a completely randomized design in three replications. Five levels of shaking frequency (200,300,450,600,750 cpm) and three levels of shaking amplitude (20,40,60 mm) were investigated at two modes of fruit bunch vibration (vertical and hanging) .

Shaking Test

Shahani dates fruit bunches with equal size and maturity were randomly cut from the palms. Each fresh sample was weighed and then attached to the clamping device of the shaker to be shaken either in vertical or hanging mode. Every effort was made to simulate the on-tree orientation of each bunch. In the vertical shaking mode, the base of the fruit bunch stalk was clamped to the shaker frame and the end of the shaker boom was also clamped to the fruit stalk. Then the shaker mechanism was turn on to reciprocate at the preset frequency and amplitude. In the hanging shaking mode, the base of the fruit bunch stalk was attached to the clamping device at the end of the rocking arm of the shaker. Detached fruits at each shaking mode were collected by a special collecting curtain (Fig. 1). Each bunch was shaken at most for ten seconds. After shaking, total detached fruits were weighed and then the number of ripe, unripe, damaged and fruits with their calyx attached were counted. Furthermore, ripe and unripe fruits that remained on the bunch after shaking were counted. After shaking test a sample of 40 dates from each bunch was randomly selected and weighed to find the average fruit weight. Finally the weight of each stripped fruit bunch was measured and recorded. This procedure was repeated for all treatments and their replications in both hanging and vertical shaking modes.

Determination of Fruit Detachment Force /Weight Ratio

In order to measure the detaching force between each fruit and its strand, a spring balance was used (spring scale with 20 N range and 0.1 N resolution). The free end of the spring scale was attached to the randomly selected fruits by a special clamp and a pulling force was applied along the longitudinal axis of the fruit. The pulling force was gradually increased until the fruit was separated from its strand. The maximum force developed was read and recorded as the static detachment force.

This test was done for both ripe and unripe fruits. Finally each fruit was weighed and its dimensions along the three principal axes were measured and recorded.

Estimation of Dynamic Force on Date Fruits

During the shaking tests each fruit is subjected to a dynamic (inertial) force F_d which is proportional to fruit mass, shaking amplitude and frequency, such that:

$Fd = mr\omega^2$ [1]

where:

Fd: Dynamic force, N

m : Fruit mass, kg

r : Shaking amplitude, m

ω: Shaking frequency, rad/s

Assuming that all date fruits along the bunch strands were shaken at the same amplitude and frequency imparted by the shaker boom, the estimated average dynamic force applied on the fruit -stem junction was calculated by using Eq. (1).

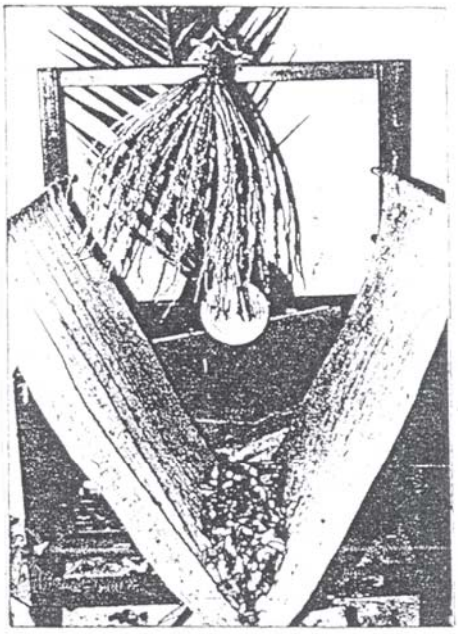

Fig .1 . Collection of detached fruits

RESUL TS AND DISCUSSION

All data collected were analyzed using MSTATC software, and then mean values were compared by DMRT1. Analysis of variance for response of Shahani date fruits to different levels of frequency, amplitude and shaking mode for detaching ripe fruits as shown in Table 1, indicated that there were highly significant differences ($p<0.01$) among these factors for total detached fruits, detached unripe fruits, detached ripe fruits, detached fruits with calyx and remained ripe fruits on the bunch.

Table 1. Analysis of variance of data on Shahani date fruit removal at different levels of amplitude, frequency and shaking mode.

Mean squares						
Source	**Df**	**R_{dt}**	**R_{ut}**	**R_{ret}^2**	**R_{dct}**	**R_{rt}**
F	4	7593^{**}	10514^{**}	0.874^{**}	313^{**}	4909^{**}
A	2	14893^{**}	22380^{**}	2.087^{**}	472^{*}	10854^{**}
S	I	3540^{**}	3044^{**}	0.395^{**}	551^{*}	3730^{*}
FA	8	353^{**}	1552^{*}	0.061^{**}	41^{ns}	471^{**}
FS	4	578^{**}	436ns	0.088^{**}	115^{**}	984^{*}
AS	2	2052	2157^{**}	0.060^{**}	49^{ns}	123^{ns}
FAS	8	429^{**}	452^{**}	0.050^{*}	91^{**}	300^{*}
Residual	60	111	30	0.0130	34	137

* : Significant at P= 0.05
**: Significant at P= 0.01
ns: Non significant
F : Frequency
A : Amplitude
S : Shaking mode
R_{dt}: Ratio of total detached fruits to total fruits on the bunch(%)
R_{ut}: Ratio of detached unripe fruits to total unripe fruits(%)
R_{ret} : Ratio of remained ripe fruits to total ripe fruits (%)
R_{dct} : Ratio of detached ripe fruits with calyx attached to total detached ripe fruits(%)
R_{rt} : Ratio of detached ripe fruits to total ripe fruits (%)

1 -Duncan multiple range test
2- The mean in log transformed value

Effects of Freauencv. AmDlitude and Vibration Mode on Date Fruit Detachment

Fig.2 compares the mean values of the total detached fruits for the frequency-amplitude combinations. Increasing frequency and amplitude both have significant effect on total detached fruits. At the higher frequency and amplitude levels, highest fruit removal has occurred. According to Figs. 3 and 4 it can be concluded that the most suitable frequency and amplitude for ripe fruit detachment has occurred at 300 cpm with 60 mm, respectively. At this treatment, significantly lower unripe fruit removal occurred while detachment of ripe fruits was about the same as the higher frequency treatments. At higher frequency and amplitude levels, detachment of unripe fruits was highly increased which is generally undesirable. Figs. 5 and 6 show that in general, the vertical. shaking mode is more efficient in detaching ripe fruits than the hanging mode, although in some treatments no significant difference was found between the two shaking modes. Fig. 7 shows that significant fruit detachment has occurred at 40 and 60 mm amplitude levels, especially at vertical shaking mode. This is probably attributed to the fact that in the vertical shaking mode, bending moment about the point of fruit attachment to strand are more effective than the axial tensile stresses which are believed to be the main cause of fruit detachment in the hanging mode. The other effective factor may be the whipping motion of the strands in the vertical shaking mode which magnifies the vibration amplitude comparing with the hanging mode.

Static Detachment Force

Table 2 lists the mean values of measured date fruit geometric mean diameters, mass, weight, static detachment force and F /W ratios for ripe and unripe fruits.

F /W ratio is a good indicator of ease of fruit detachment. This ratio decreased from 55 for unripe fruits to 25 for ripe fruits. This is attributed to the fact that under normal rippening process, the strand -calyx junction becomes weaker as the natural abscission layer develops.

Table 3 lists the estimated dynamic forces imparted on an average size ripe fruit at different levels of shaking frequency and amplitude. We may simply expect that fruit detachment occurs as the inertial force due to the imparted vibration and sudden redirection of momentum becomes greater than the static tensile force required to cause fruit detachment. But, the results of Table 3 show that even at the highest shaking amplitude and frequency combination, the estimated dynamic force is smaller than the measured .static force required for fruit detachment. However, almost all of the ripe fruits have been shaken off the bunch at

this and even lower amplitude -frequency combinations as shown in Fig. 3. The reason for this contrariety is that fruit detachment by vibration is a complex phenomenon in which several factors including inertial axial, bending and torsional forces, as well as fatigue failure due to cyclic stresses are involved. Depending on the fruit -stem geometry and physical properties, shaking mode, frequency and amplitude combinations, one of those factors may become dominant.

Table. 2. Physical characteristics and average static forces applied for detaching ripe and unripe fruits.

Fruit Condition	Geometric mean dia.(mm)	Mass (gr).	Weight W(N)	Detachment Force F(N)	F /W
Ripe	27.4	10.3	0.10	2.5	25
Unripe	27.1	13.2	0.13	7.2	55

Table3. Estimated average dynamic force (N) imparted on ripe fruits at different frequency and amplitude levels

Amplitude (mm)	-	Freguency (cpm)			-
	200	300	450	600	750
20	0.045	0.102	0.230	0.409	0.638
40	0.090	0.204	0.460	0.818	1.276
60	0.135	0.306	0.640	1.227	1.914

CONCLUSIONS

1- The results of this study revealed that at 300 cpm and 60mm amplitude the most efficient detachment of Shahani ripe date fruits occurred.
2- The vertical shaking mode had more significant effect on detaching ripe fruits than the hanging mode. Also at the vertical shaking mode the percentages of remained ripe fruits and detached fruits with calyx attached were less than those of the hanging mode.
3- lncreasing shaking time (more than 10 seconds) in hanging mode at high frequencies (600 and 750 cpm) and large amplitudes caused damage to the detached and remained fruits on the bunch (predetachment damage), but at low frequencies (300 and 450 cpm) no fruit damage was encountered.
4- At any specific frequency, increasing amplitude caused higher fruit removal.

5- At any fixed amplitude, increasing frequency caused higher fruit removal.
6- At higher amplitudes and frequencies, the percentage of detached fruits with calyx attached was significantly decreased.
7- F/W ratios for ripe and unripe fruits were found to be 25 and 55, respectively. This means that the force required to remove most ripe fruits is about 35% of that needed to remove unripe fruits.

Suggestions For Further Study

The following suggestions are useful for obtaining further information necessary to develop and improve the performance of the shake harvesting system.

l- Conducting mechanical shaking tests on other major Iranian date varieties such as Kabkab and Mazafti to find the best shaking amplitude and frequency for detaching ripe fruits.
2- Development of a hydraulically-operated clamp in order to facilitate shaking operations.
3- Development of a hydraulically (pneumatically) powered hand carried shaker, for harvesting short palms.
4- Installation of the shaker on the recently developed date towers or hydraulic arms developed earlier to investigate the feasibility of selective fruit harvesting.
5- Utilization of the experimental shaking machine as a part of an integrated harvesting, sorting and packaging system.

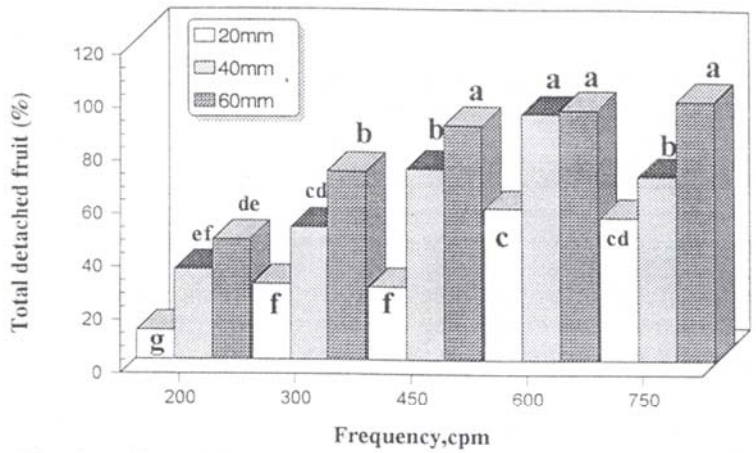

Fig. 2. Effect of frequency on total detached fruits at different amplitude levels.

*: Similar letters indicate no significant difference at 5% probability level.

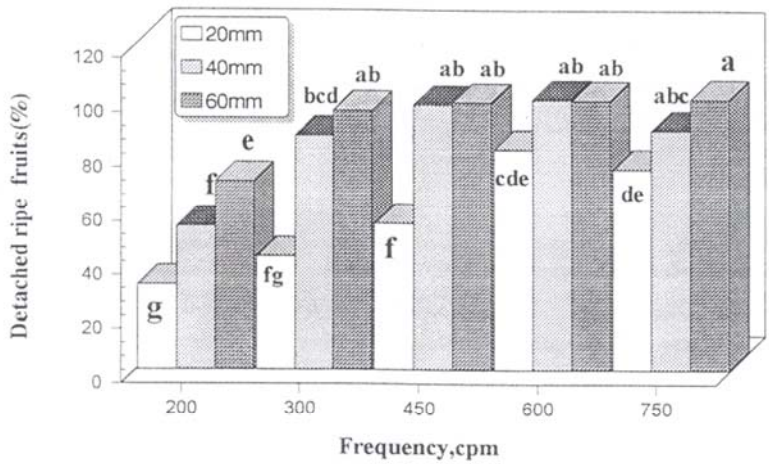

Fig. 3. Effect of frequency on detached ripe fruits at different amplitude levels.

*: Similar letters indicate no significant difference at 5% probability level.

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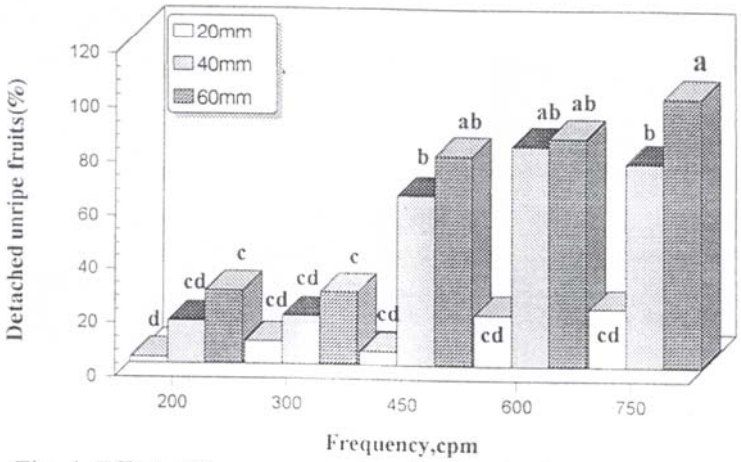

Fig. 4. Effect of frequency on detached unripe fruits at different amplitude levels.

*: Similar letters indicate no significant difference at 5% probability level.

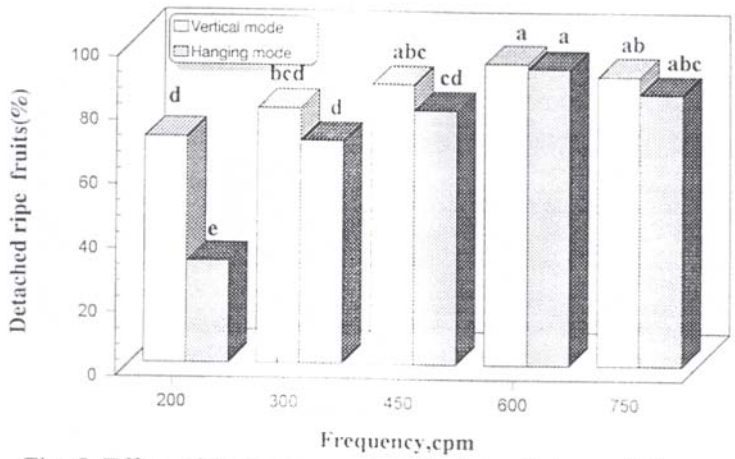

Fig. 5. Effect of frequency on detached ripe fruits at different levels of shaking mode.

*: Similar letters indicate no significant difference at 5% probability level.

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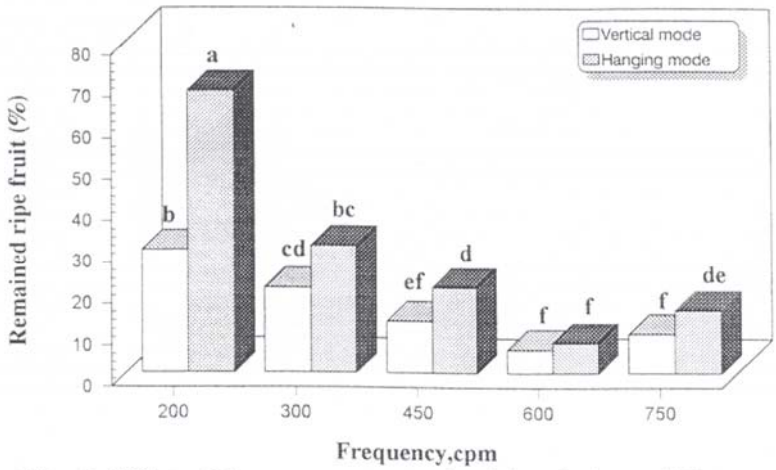

Fig. 6. Effect of frequency on remained ripe fruits at different levels of shaking mode.

*: Similar letters indicate no significant difference at 5% probability level.

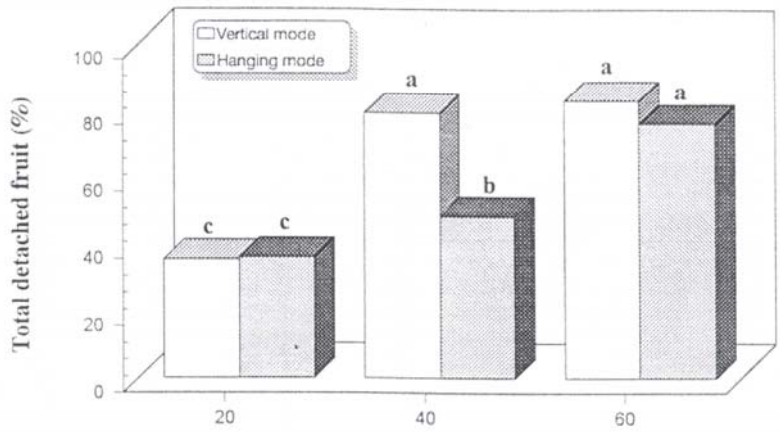

Fig. 7. Effect of amplitude on total detached fruits at different levels of shaking mode.

*: Similar letters indicate no significant difference at 5% probability level.

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