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Study of the Strength Properties of Pistachio Nuts and Cluster Stem Joints for the Design and Development of a Harvesting Machine

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ABSTRACT

A consideration of the design and development of any harvesting machine is required to determine the physical and biomechanical properties of the tree and its fruit. Biomechanical properties such as pull, bending and torsion strengths must be determined. In the field experiments, trees were selected from an orchard in Rafsanjan, Kerman Province, Iran. Parameters related to fruit properties were measured using load cells. In Rafsanjan's Pistachio Research Institute laboratory, subsequent measurements were made using similar instrumentation. In a randomized design layout, 18 tree cultivars with five replications were selected. The maximum pull, bending, and torsion strengths were found respectively for Badami Ravar, Momtaze Tajabadi and Italiaee cultivar clusters. Minimum pull, bending, and torsional strengths were obtained for Ghazvini, Louk and Kalleh Ghoochi clusters. The cultivars Kalleh Ghoochi, Rezaee Zoodras and Khanjari Damghan were found to have fruit with the highest pull, bending, and torsional strengths, with the lowest strengths belonging to the Italiaee cultivar.

Keywords: Bending, Harvest, Pistachio, Pull, Strength, Torsion.

INTRODUCTION

Pistachio is a high-value nutritive nut popular in European Union (EU) countries, South East Asia, the United States and Japan. In Iran, it is the second most important non-oil export after hand woven carpets. About forty varieties of pistachios are produced in Iran, and Iran's pistachio is known to be of the highest quality and taste. The export of pistachios has increased in recent years and this has led to higher production [5, 8, 9]. Iran, the United States, Turkey, Syria, Greece and Italy are the largest producers of pistachios. The first three account for 50, 25, and 12 percent of total world annual production, respectively. The production figures for these three countries were reported to be 200, 100 and 48 thousand tons in 1995 [5,7,10].

The important export markets for Iran's pistachio nuts are Germany, the United Arab Emirates, Japan and the United Kingdom. More than 70 percent of Iran's export goes to EU countries, in particular Germany. The export market is expanding in East Asia, particularly in Japan. Production increased from 200 to 250 thousand tons from 1995 to 1999, with exports exceeding above 200 thousand tons annually [3, 7, 10].

Studies have revealed that at least ten percent of a grower's income goes to harvesting. Reducing harvesting costs would decrease production costs. This will lower consumer costs, which can encourage domestic consumption and give farmer a competitive edge in export markets [5]. Afghanis and

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Pakistanis comprise the majority of the harvest labor force in most pistachio producing areas of Iran, particularly in Kerman Province. Following a recent visit of the WHO and their investigation into hygiene in the harvesting process of pistachios, all workers are now required to have hygiene permits. This has led to an increase in labor costs.

The pistachio export market is not saturated. An increase in cultivation would further raise labor and harvesting costs. These points highlight the importance of mechanization, particularly during harvest. Prior to the design and development of a harvesting machine, data on the physical and mechanical properties of the nut are required [2, 4, 6].

In 1976, Alper and Foux studied the strength properties of orange fruit joints attached to stems [1]. The parameters studied were pull, bending moment, torsion, pull along with deflection of the fruit stem and a pull-torsion combination. It was concluded that pull speed and angle of pull are factors that affect detachment. Detachment was not much affected by torsion and bending strengths. Not much difference was observed between pull-torsion combinations and the pull case. A stronger pull was needed for detachment at the start of the harvest season. During the middle and end of the season, little difference was observed among the strengths with which fruits are attached to their stems. Equal average pull strengths of about 60 N were recorded.

Barnes studied in 1969 the strength with which lemons were attached to their stems. He used pull, torsion, pull at angle, and shake resistance [2]. He used a special type of load cell to make his measurements. No significant difference was observed between pull and pull at angle for different varieties and in different climates. Detachment of fruit occurred when subjected to torsion or vibration forces.

It is evident that, prior to the design and development of any fruit harvesting machine, the physical and mechanical properties of the fruit must thoroughly be studied. The purpose of the present study is the evaluation of physical and mechanical properties of pistachio to present the most efficient way of mechanically harvesting the fruit.

MATERIALS AND METHODS

Two load cells with an accuracy of ± 0.2 N and ±1.0 N were used to measure the pull, bending and torsional strength of pistachio nuts and clusters. To determine the pull strength, the cluster was pulled along its main stem. Instrument readings at the moment of detachment indicated the pull strength. To find the bending strength, normal force was measured at a distance from the end point of cluster attachment to the tree. Bending strength, thus, would be the distance times the force.

A wooden clamp was used together with a ± 0.2 N accuracy load cell to measure the torsional strength of the cluster. The main stem end of the cluster was normally clamped. The end point of the clamp was pulled using a load cell to measure the torsional detachment force. Readings were taken at the moment of sudden downfall of the force.

As for the fruit, measurements (pull, bending and torsional strength) were made in the field and laboratory using a ±0.01 N accuracy load cell with display. Data obtained from the load cell readings were displayed by load cell indicator.

For pull strength measurements, the nut was fastened to a string that was pulled along the cluster stem by a load cell of ± 0.01 N in accuracy. The fruit's bending strength was measured by fastening the string to the fruit stem at a point about 5 mm from the point of attachment to the cluster stem. During the process, the fruit acted as a cantilever beam, the bending strength being force times the distance. For fruit torsional strength measurements the string was wrapped around the fruit rind while being fastened to the rind using a thumbtack. The other end of the string was pulled and a load cell measured the force. The torsional

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Table 1. Mean[a] pull, bending and torsional strengths for clusters of different varieties of pistachio.

No.	Variety	Pull (N.)		Bending (N.cm)		Torsion (N.cm.)	
1	Ghazvini	29.98	D	11.95	ABCD	10.24	CD
2	Italiaee	68.12	ABC	10.06	ABCD	30.45	A
3	Khanjari Damghn	51.20	BCD	17.70	ABCD	12.59	CD
4	Ravar 3	42.72	CD	11.69	ABCD	17.72	BCD
5	Ohade	55.00	BCD	9.16	BCD	12.62	CD
6	Badami Ravar	89.60	A	15.98	ABCD	16.80	BCD
7	Ravar 2	52.60	BCD	10.85	ABCD	13.42	CD
8	Badmi Khodmadeh	33.00	D	12.04	ABCD	11.82	CD
9	Cherookkhordeh	34.40	D	10.03	ABCD	15.26	BCD
10	Kalleh Ghoochi	77.00	AB	7.918	CD	6.60	D
11	Louk	31.00	D	7.10	D	12.40	CD
12	Musaabadi	42.00	CD	19.35	ABCD	13.05	CD
13	Amiri	49.40	BCD	9.20	BCD	14.79	BCD
14	Momtaz Tajabadi	45.00	CD	21.80	A	12.16	CD
15	Ahmadaghi	52.40	BCD	18.08	ABCD	15.96	BCD
16	Shahpasand	60.40	BCD	20.80	AB	25.05	AB
17	Khanjari Ravar	45.40	CD	19.88	ABC	18.59	BC
18	Rezaee Zoodras	37.00	D	14.50	ABCD	16.71	BCD

[a] Similar letters are indicative of no significant difference between the means (Duncan test α= 1%).

strength was the force times radius of the nut.

RESULTS

Pull, bending and torsional strengths were measured for pistachio cluster and nut. Eighteen cultivars, each with five replications, were used in a completely randomized design experiment. The results are as follows:

Cluster Strength

Table 1 shows the average and comparison

Table 2. Mean[a] pull, bending and torsional strengths for nuts of different varieties of pistachio.

No.	Variety	Pull (N)		Bending (N.cm.)		Torsion (N.cm)	
1	Ghazvini	0.27	D	0.20	D	0.22	C
2	Italiaee	0.25	D	0.14	D	0.15	C
3	Khanjari Damghan	4.40	AB	2.20	A	2.40	A
4	Ravar 3	0.96	D	0.42	BCD	0.50	C
5	Ohade	0.44	D	0.35	D	0.31	C
6	Badami Ravar	0.56	D	0.44	BCD	0.53	C
7	Ravar 2	0.54	D	0.38	CD	0.20	C
8	Badmi Khodmadeh	0.80	D	0.25	D	0.44	C
9	Cherookkhordeh	0.200	CD	1.20	BC	1.30	B
10	Kalleh Ghoochi	5.08	A	1.24	B	1.232	B
11	Louk	0.45	D	0.32	D	0.20	C
12	Musaabadi	0.30	D	0.29	D	0.29	C
13	Amiri	1.66	CD	0.32	D	0.38	C
14	Momtaz Tajabadi	1.36	CD	0.51	BCD	0.60	C
15	Ahmadaghi	0.44	D	0.23	D	0.364	C
16	Shahpasand	0.62	D	0.45	BCD	0.44	C
17	Khanjari Ravar	0.79	D	0.72	BCD	0.602	C
18	Rezaee Zoodras	3.10	BC	2.30	A	2.18	A

[a] Similar letters are indicative of no significant difference between the means (Duncan test α= 1%).

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Table 3. Highest and lowest pull, bending and torsional strengths for clusters and nuts for different varieties of pistachio.

Property	Cluster Type	
	Highest	Lowest
Pull:	Badmi Ravar	Ghazvini
	Kalleh Ghoochi	Louk
	Italiaee	Badami Khodmadeh
Bending:	Momtaz Tajabadi	Louk
	Shahpasand	Kalleh Ghoochi
	Khanjari Ravar	Ohadi
Torsion:	Italiaee	Kalleh Ghoochi
	Shahpasand	Ghazvini
	Khanjari Ravar	Badami Khodmadeh
Property	Nut Type	
Pull:	Kalleh Ghoochi	Italiaee
	Khanjari Damghan	Ghazvini
	Rezaee Zoodras	Musaabadi
Bending:	Rezaee Zoodras	Italiaee
	Khanjari Damghan	Ghazvini
	Kalleh Ghoochi	Ahmadghai
Torsion:	Khanjari Damghan	Italiaee
	Rezaee Zoodras	Louk
	Cherookkhordeh	Rovar2

between pull, bending and torsional strengths for different pistachio cultivar clusters.

Pull As observed from Table 1, there are six groups of pull strength. The highest strength, 89.60 N, belongs to the Badami Ravar cultivar while the lowest strength recorded was 29.98 N for Ghazvini cultivar.

Bending Bending strength for 11 out of 18 cultivars was grouped as one for those that showed no significant difference ($p<0.0l$). The highest records, 21.80, 20.80, and 19.88 N.cm. were obtained for Momtaze Tajabadi, Shah Pasand and Khanjari Ravar, respectively. The lowest values, 7.10, 7.92, 9.16 and 9.20 N.cm. were obtained for Louk, Kalleh Ghoochi, Ohadi and Amiri cultivars, respectively.

Torsion The torsional strengths for 14 out of 18 cultivars were separated into two groups. There was not much difference between the torsional strengths of the two groups. The lowest recording of 6.60 N.cm. was for Kalleh Ghoochi, while the highest records, 30.54, 25.05, and 18.59 N.cm. were for Italiaee, Shah Pasand and Khanjari Ravar, respectively.

Nut Strength

Pull The pull strengths for 12 of the 18 cultivars were combined into one group (Table 2), the lowest value of 0.25 N was for the Italiaee cultivar. The highest record of 5.08 N. was for Kalleh Ghoochi.

Bending The highest and lowest figures recorded were 2.30 and 0.14 N.cm. for Rezaee Zoodras and Italiaee, respectively.

Torsion The first out of three groups recorded the highest figures of 2.40 and 2.18 N.cm. for Khanjari Damghan and Rezaee Zoodras, respectively. Lowest torsional strengths were observed in the third group with a low of 0.15 N.cm. recorded for Italiaee.

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Table 4. Correlation coefficient between different parameters of pistachio strengths for clusters and nuts.

		Cluster			Nut	
		Pull	Bending	Torsion	Pull	Bending
Cluster:	Bending	0.486				
	Torsion	0.174	0.121			
	Pull	0.541	-0.219	-0.491		
Nut:	Bending	0.338	0.208	-0.307	0.721	
	Torsion	0.334	0.229	-0.315	0.715	0.999

DISCUSSION

To study the detachment of pistachio nuts and clusters from the tree, the related pull, bending and torsional strengths were determined for 18 varieties in Rafsanjan, Iran. In a study of strength properties of orange fruit stem joints, Alper and Foux in 1976 concluded that pull was more effective in detachment of orange from stem than either bending or torsional strength [1]. In the present study of pistachios, the reverse was evident. At the same time, not much difference was observed between torsional and bending strengths.

In 1997, Mobli [5] in studying the biomechanical properties of mechanized pistachio harvests concluded that an indirect relationship exists between the pull, torsional and bending strength of the nut and cluster versus percent of detachment. The present study found the Italiaee variety had a weak attachment of fruit to stem (Table 3); a detachment of 97.17 percent for ripe and 90 percent for a mixture of ripe and unripe nuts [5]. The strength (pull, bending and torsional) was lowest in this variety. For cluster, a zero percent detachment was observed because of the strength being too high. In the Khangari Damghan variety, with high figures for pull, torsional and bending strengths with respect to Italiaee, percent detachment for ripe nuts was only 55.67[5].

Strength properties for nuts compared with clusters are shown in Table 4. Pull in fruit is positively and significantly correlated with torsion and bending, rendering the latter two effective in fruit detachment. A close relationship was also observed (r=0.99 p<0.0l) between torsion and bending in the nut.

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مطالعه و بررسي خواص بيومكانيكي ميوه و خوشه پسته به منظور طراحي ماشين برداشت پسته

ح. مبلي, ت. توكلي هشجين, هـ . عقابي و ر. عليمرداني

چكيده

پيش از اقدام به طراحي و سپس ساخت هر ماشين برداشتي از جمله ماشين برداشت ميوه نياز است ابتدا خواص فيزيكي و بيو مكانيكي درخت و ميوه آن مورد بررسي قرار گيرد. در مورد پسته نيز كه قصد، طراحي و ساخت ماشيني براي برداشت مكانيزه آن است لازم بود پاره اي از خواص بيومكانيكي شامل مقاومت كششي خمشي و پيچشي ميوه و همچنين خوشه مورد بررسي قرار گيرد. براي انجام آزمايشات صحرايي در جهت پيدا كردن مقاومتهاي مورد نظر درختان موجود باغي در رفسنجان انتخاب شدند. مقاومتهاي مربوط به ميوه با استفاده از نيروسنجي با دقت ۲/. ± نيوتن اندازه گيري و براي پيدا كردن اعداد مربوط به خوشه، علاوه بر استفاده از اين نيرو سنج از نيرو سنج ديگري با دقت يك نيوتن نيز استفاده شد. در تحقيقات آزمايشگاهي كه به دنبال بررسي هاي صحرايي فوق در آزمايشگاه موسسه تحقيقات پسته رفسنجان صورت گرفت سنجش ها با استفاده از ابزار اندازه گيري مجهز به لودسل و صفحه نمايش با دقت ۰/۰۱ ± نيوتن صورت گرفت. در طرح آماري كاملا تصادفي كه براي تحقيق انتخاب شده بود از ۱۸ رقم پسته هر يك در پنج تكرار استفاده شد. در اين طرح بالاترين مقادير مقاومت كششي، خمشي و پيچشي به ترتيب متعلق به خوشه ارقام بادامي راور، ممتاز تاج آبادي و ايتاليايي و در مقابل كمترين مقادير مقاومتهاي كششي، خمشي و پيچشي به ترتيب به خوشه ارقام قزويني، لوك و كله قوچي تعلق گرفتند. در مورد ميوه، ارقام كله قوچي، رضايي زودرس و خنجري دامغان به ترتيب بيشترين مقاومتهاي كششي، خمشي و پيچشي را دارا و كمترين مقاومتهاي سه گانه فوق به ميوه رقم ايتاليايي تعلق يافت.

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