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Performance Evaluation of a Centrifugal Peeling System for Pistachio Nuts

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Abstract

In this paper, performance evaluation of the centrifugal peeling system for pistachio nuts was studied as a function of moisture content (in five levels: 4.10, 10.50, 28.50 and 36.10 % d.b) and peripheral speed of separate rotating circular base – plate (in four levels: 35, 40, 45 and 50 m/s) in a factorial design based on completely randomized block. The overall performance was expressed in terms of peeling efficiency and breakage percent. Peeling efficiency and breakage increased with (i) increase in peripheral speed (ii) decrease in the pistachio moisture content. The results of an optimization technique revealed that the best peeling performance could be obtained if the machine is operated at peripheral speed of 50 m/s and moisture content of 4.10 % d.b. Under these conditions, the values of peeling efficiency and breakage percent were 96.5 and 8.7 %, respectively.

KEYWORDS: pistachio, peeling performance, peripheral speed, moisture content

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1. Introduction

Pistachio nuts are mainly produced in Iran, Turkey and the USA. Based on FAO statistics (FOOD and Agriculture Organization, 2005) Iran produced about 275,000 Mt of pistachio nut in 2003, which represents approximately 54.7% of the world's pistachio production. Iran exported 184,946 Mt of its pistachio nut in this year, and the total export revenue from pistachio nuts was about 679,940,000 US$. Therefore, pistachio nut has great economic value for Iran. More than 60 pistachio varieties cultivate in different regions of Iran such as Rafsanjan, Kerman, Feizabad , etc.

Pistachio kernels are a good source of fat (50–60%) and contain unsaturated fatty acids (linoleic, linolenic and oleic acids), essential for human diet (Maskan & Karatas, 1998). It is consumed in confectionery and snack foods. The shell (endocarp) of pistachio nuts split along their sutures which is a desirable trait because pistachio nuts are usually marketed in-shell for eating out of hand as a snack food. Because of the deep green color of pistachio kernels, it is favored in the ice cream and pastry industries (Woodroof, 1979). When pistachios arrive at the processing plant, the following procedures are conducted: (a) dehulling, to separate the soft hull from nuts; (b) trash and blank separation, to remove blank pistachios and trashes such as small branches, remaining shells and leaves; (c) unpeeled pistachios separation, to remove unpeeled and unripe nuts; (d) washing, which involves spraying water at high pressures on the pistachios to clean the nuts; (e) drying, to decrease moisture content of pistachios from 37–40% to the appropriate level; (f) split nuts separation, to separate split nuts from non-split ones; (g) salting; (h) roasting; and (i) packaging (Nakhaeinejad, 1998).

Based on the researches conducted by the specialists, peeling process of pistachio requires more energy consumption compared to above procedures. (Khodabakhshian, 2007; Mahmoodi et al. 2006; Recabi, 2000; Joseph and Benjamin, 1981). Peeling of pistachio can be divided into manual, semi-mechanized and mechanized methods. In manual method, workers peel pistachios by hand or spread them on a clean and smooth surface and smash pistachios by a fail or stick. It is an old method and is not being used anymore. The semi-mechanized method is based on friction; the machine consists of a stationary vertical perforated cylinder with a circular rotating bottom plate. The worker turns a handle and the bottom which has sharp points start to rotate. Centrifugal forces hit pistachios to stationary cylinder and sharp points of the rotating bottom. The skin separate and flow through the cylinder holes. This method is very slow and demands too much energy.

Bolt type peeling machine is the only commercial mechanized method in Iran. The machine are made and designed in local workshops without any attention to mechanical properties of pistachio and many of its parameters

determined experimentally (Mahmoodi et al. 2006). The main part of the machine is a rotating drum covered by the heads of M6 bolts (Shamsi, 1994). The soft skin is detached by vertical and shear stresses produced by these bolts against a fixed blade. Since in bolt type peeling machine pistachio is solely peeled and the subsequent processes, including washing and dehydrating is fulfilled by a long time delay, causing Aflatoxin disease (Hyang et al. 2006). Recabi et al. (2000) investigated performance evaluation of four bolt type peeling machine with capacity of 6 Ton in one of the pistachio preserved terminal in Kerman, Iran. They revealed that in the best condition of machine (when distance between cylinder and frontal blade is 5mm), peeling and breakage rate was 73.8 % and 0.7, respectively. They also reported that 25.5 % of pistachios were remained without any processing.

As it can be found from literature review, bolt type peeling machine has many losses in processing of pistachio. Hence, a centrifugal pistachio peeling machine was designed and manufactured by authors that can do peeling, washing and dehydrating processes simultaneously. As part of the machine development efforts, this study was conducted to evaluate the performance of this machine.

2. Materials and methods

2.1. Preparation of raw material

The O'hadi (or Fandoghi) is one of the major commercial varieties, which was selected for this research work. This cultivar was obtained from Rafsanjan city, Kerman province in Iran during 2007 year. A portion of pistachios equal to eighty kilograms was transported to laboratory. The samples were cleaned to remove all foreign matters as well as broken nuts. From this pile, at random samples of pistachio nuts were drawn for experiment. This methodology was used to ensure the uniform sample size (Joshi et al. 1993). The average initial moisture content of pistachio nut was determined 36.1% d.b. using the standard hot air oven method with a temperature setting of 105±1°C for 24 h (Altuntas and M. Yildiz, 2007; Coskuner and Karababa, 2007). For conditioning, five levels of moisture content (dry basis) ranging from 4.1% to 36.1% were selected that is a usual range since harvesting, transportation, storage and processing operations of pistachio nut. To vary the moisture content of pistachio, the predetermined quantity of samples was dried down to the desired moisture content. To determine the average size of the pistachio, a sample of 100 pistachios was randomly selected. The three linear dimensions of the seeds, namely length (L), width (W) and height (H) were carefully measured using a digital caliper (Diamond, China) with an accuracy ±0.02 mm. Afterwards, some physical properties of pistachio including mass, bulk density, true density and porosity were measured. Mechanical properties including

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tensile strength, bending strength and torsional strength measured by two load cells of one Newton with precision of 0.2. Values of these measurements are shown in Tables 1 and 2.

Table 1- Physical properties of O'hadi variety of pistachio as a function of moisture content (4.1 – 36.10 d.b.)

	Moisture content (%)				
	4.10	10.50	20.10	28.50	36.10
Length (mm)	16.02	16.65	17.12	17.20	17.28
Width (mm)	11.30	11.90	11.98	12.40	12.60
Height (mm)	10.80	11.40	12.02	12.20	12.36
Mass (kg)	0.92	0.98	1.02	1.25	1.32
Bulk density (kg/m3)	561.87	578.26	602.84	624.34	643.79
True density (kg/m3)	858.79	860.64	863.43	865.86	868.07
Porosity (%)	34.32	32.48	30.48	28.46	26.37

Table 2- Mechanical properties of pistachio peel of O'hadi variety

Tensile strength (N)	Bending strength (N)	Torsional strength (N)
0.44	0.35	0.31

2.2. Experimental set-up

Experimental set-up for peeling of pistachio nut as shown in Fig. 1 is developed at Department of Agricultural Machinery Engineering, Ferdowsi University of Mashhad, Mashhad (Iran). Modeling and mechanical analysis of machine is performed using solidworks 2007 software and cosmos 2007 software, respectively. In order to peel pistachio in this machine, centrifugal force is used. The unit consists of two main parts: the peeling set and the power transmission system. The peeling set consists of a rotating drum and a separate rotating circular base – plate. These two parts rotate in opposite directions, employing two separate electrical motors. The power transmission system of machine is mechanically by belt and pulley, so that they convey power of 3 hp between electrical motors and peeling set. The Washing stage in this machine will be immediately performed after peeling process. In this stage, the rotation of drum will be stopped while rotating circular base – plate will rotate and water will be injected into the drum by nozzle simultaneously. In common methods of pistachio process, dehydrating stage follows the washing one. In the machine presented in this paper, the dehydrating stage is performed without any need for transferring the nuts out of machine to another independent dehydrating machine and consequently helps save time and cost. For performing this stage, both of the electrical motors rotate in the same direction. Throughout this method, flow of air through the pile of pistachio nuts which comes from the high rotary speed helps dehydrating. In the

discharging stage, the rotation of the drum will be stopped while rotating circular base – plate will rotate and discharge gate will be opened.

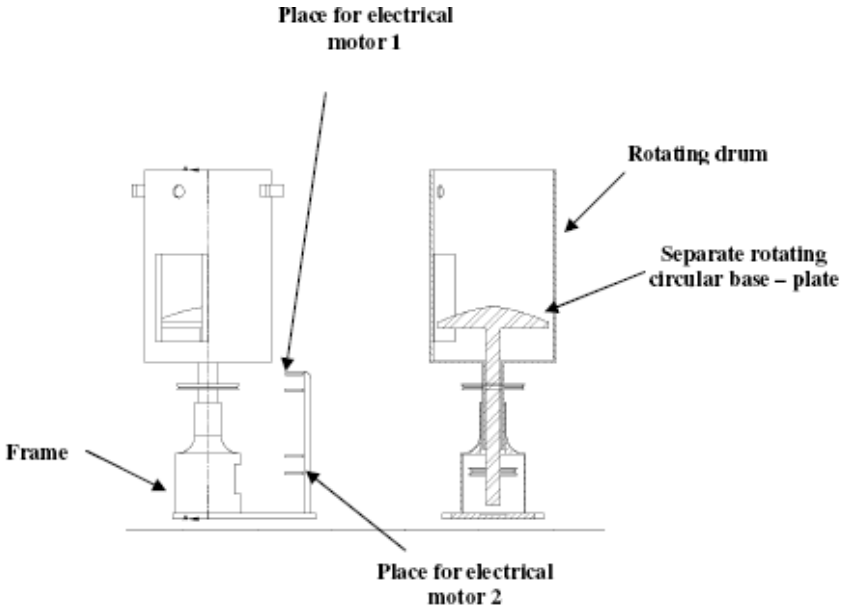

Fig. 1. General view of the proposed machine

2.3. Procedure

Two independent variables including moisture content (in five mentioned levels in Table 1) and peripheral speed of separate rotating circular base – plate (in four levels: 35, 40, 45 and 50 m/s) were chosen based on the performance of the peeling system. The peeling efficiency was sufficiently lower or the loss of fine kernels was more if the system was operated beyond the chosen limits of independent variables. To conduct a performance evaluation, the hopper (rotating drum) was filled with the pile of pistachio nuts at specified moisture content and the total number of nuts (N_t) was determined by counting. Then, the power supply was switched on to run the electric motors and set the working components of the peeler in motion. The number of pistachio nuts that were completely peeled and unbroken (N_1), completely peeled but broken (N_2) and partially peeled and broken (N_3) were determined at the end of each run. The performance of the peeler was evaluated on the basis of the following indices:

1- Peeling efficiency (E_h) in percent is defined as the ratio of the mass of the peeled material to that of the feed, and is expressed as (Atiku et al. 2004),

$$E_h = \frac{(N_1+N_2)*100}{N_t} \qquad (1)$$

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2- Breakage percent (E_c) is expressed as (Atiku et al. 2004),

$$E_c = \frac{(N_2 + N_3) * 100}{N_t} \qquad (2)$$

In order to modify the speed of the rotating circular base – plate during the tests, an inverter with an accuracy 0.01 m/s was used.

2.4. Statistical analysis

The experiments were conducted at least in four replications for each moisture contents and peripheral speed then the average values reported. Non-linear relationship among peeling efficiency and breakage percent to moisture content and peripheral speed of separate rotating circular base – plate were obtained using regression analysis (Microsoft Excel software 2003). The analysis of variance (ANOVA) was carried out on completely randomized design with factorial experiment using SPSS16 software. The F test was used to determine significant effects of each treatment, and significant differences of means were compared using the Duncan's multiple ranges test (LSD) at 5 % significant level.

3. Results and discussion

3.1. Analysis of variance

The results of variance analysis which was carried out to examine the effect of treatments (studied effective factors) on peeling efficiency and breakage percent are shown in Tables 3 and 4. As it can be found from Table 3, the effects of pistachio moisture content and rotating circular base – plate on peeling efficiency are significant at the 1% of probability level. Also, the interaction effects of these parameters were significant at the 1% of probability on peeling efficiency. According to Table 4, each two treatments exhibited a significant effect at the 1% of probability on breakage percent but their interaction had no significant effect on breakage percent.

Table 3- Analysis of the variance of parameters considered on peeling efficiency of pistachio

Variation source	Df	Mean square	$F_{calculate}$
Treatment	15	434.94	89.86**
Peripheral speed of rotating pate	3	2009.8	415.25**
Moisture content	3	119.84	24.76**
Peripheral speed of rotating pate × moisture content	9	15.02	3.10**
Error	48	4.84	-

** Significance at 1% level.

Table 4- Analysis of the variance of parameters considered on breakage percent of pistachio

Variation source	Df	Mean square	$F_{calculate}$
Treatment	15	2.89	20.69^{**}
Peripheral speed of rotating pate	3	10.33	73.78^{**}
Moisture content	3	3.94	28.14^{**}
Peripheral speed of rotating pate × moisture content	9	0.07	0.5^{ns}
Error	48	0.14	-

^{ns} Non – significant

3.2. Effect of peripheral speed and moisture content on peeling performance

3.2.1 Peeling efficiency

Tables 5 – 8 show the results of mean comparison of peeling efficiency and breakage percent in different levels of treatments. According to Table 5, it is apparent that either variation in peripheral speed of rotating circular base – plate had a significant effect on the peeling efficiency of pistachio (p <0.95). Among the studied levels of peripheral speed, the highest efficiency belonged to peripheral speed 50 m/s with peeling of 92.46 %. Mean comparison of peeling efficiency in different levels of moisture content (Table 5) also indicated that except the level of 10.5 % with 28.5 % and level 28.5 % with 36.10 %, another levels had a significant difference with each other. In addition, it can be found that peeling efficiency decreased as the moisture content increased from 4.10 to 36.10 %. This trend was similar at any peripheral speed. Higher peeling efficiency at low moisture content of the pistachio might possibly be due to the brittle or fragile nature of the pistachio peel. At higher moisture content of pistachio nuts, low peeling efficiency might be due to the higher deformation of pistachio at specific load which does not rupture the peel during peeling of pistachio nut in centrifugal peeler. Similar deformation trends with moisture content under compressive loading have been observed for various crops such as melon seed (Makanjuola, 1972), ground nut (Atiku, 2004), sunflower seed (Khodabakhshian et al. 2010) and pumpkin seed (Joshi, 1993) which reflected in their lower peeling efficiency in the process of centrifugal hulling.

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Table 5- Mean comparison of peeling efficiency (%) of pistachio in different levels of peripheral speed of rotating plate and moisture content.

Parameters	Mean
Peripheral speed of rotating pate (m/s)	
35	66.15 a
40	76.64 b
45	84.46 c
50	92.46 d
Moisture content (%)	
4.10	83.88 a
10.50	79.97 b
28.50	78.41 bc
36.10	77.44 c

The means with the same letter is not significant at 5% level according to Duncan's multiple ranges test.

Investigating the interaction effect of peripheral speed of rotating circular base – plate and moisture content on peeling efficiency showed that the treatment of peripheral speed 50 m/s, moisture content of 4.10 % was best treatment. In this treatment, peeling efficiency of the machine was 96.5 % (Table 6). This treatment has a significant difference at the 5% of probability level. Moreover, as it can be seen from Table 4, peeling efficiency of pistachio increases as peripheral speed increases. This may be due to the increasing of the shearing force at the higher peripheral speed.

Table 6- Mean comparison of peeling efficiency (%) of pistachio considering interaction effect of peripheral speed of rotating plate and moisture content.

Moisture content	Peripheral speed of rotating plate			
	35	40	45	50
4.10	78.5 c	83.06 e	87.45 h	96.5 k
10.50	64.47 b	77.45 e	85.47 g	92.77 j
28.50	64.2 ab	75.5 d	82.75 f	90.92 i
36.10	62.85 a	75.1 d	82.17 f	89.65 i

The means with the same letter is not significant at 5% level according to Duncan's multiple ranges test.

3.2.2. Breakage percent

Mean comparison of breakage percent in different levels of peripheral speed of rotating plate (Table 7) indicated that there was a significant difference between peripheral speed of 35 m/s with 50 m/s at the 5% of probability level. As it can be seen from Table 7, the breakage percent of pistachio nuts increased as the peripheral speed increased from 35 to 50 m/s so that the most breakage percent belong to peripheral speed of 50 m/s with breakage of 8.11%. It thus implies that,

higher rotating circular base – plate speed induces larger centrifugal force on the fragile pistachio resulting in more broken and thereby increasing breakage percentage in the peel. Similar observation was also made by Joshi (1993) and Jain (1980) for dehulling of pumpkin seed and paddy, respectively using centrifugal dehuller. Investigating the mean comparison of breakage percent in different levels of moisture content (Table 7) showed that there was no difference between all levels of moisture content with each other. According to this table, it is apparent that breakage percent decreased with increase in moisture content so that moisture content of 4.1 % had the most breakage percent (8.02 %). The higher breakage percentage at low pistachio moisture content was possibly due to the pistachio becoming brittle and thus more brokens and fines are generated.

Table 7- Mean comparison of breakage percent (%) of pistachio in different levels of peripheral speed of rotating plate and moisture content.

Parameters	Mean
Peripheral speed of rotating pate (m/s)	
35	6.3 a
40	7.37 ab
45	7.87 ab
50	8.11 b
Moisture content (%)	
4.10	8.02 a
10.50	7.59 a
28.50	7.15 a
36.10	6.89 a

The means with the same letter is not significant at 5% level according to Duncan's multiple ranges test.

Considering the interaction effect of peripheral speed of rotating circular base – plate and moisture content on breakage percent revealed that breakage percent of pistachio in the studied machine was very low so that the highest value was 8.7% belonged to the treatment of peripheral speed of 50 m/s and moisture content of 4.10% (Table 8). Consequently, the results of Tables 6 and 8 indicated the treatment of peripheral speed of 50 m/s and moisture content of 4.10 % was best treatment. In this treatment, peeling efficiency of the machine was 96.5 %. Recabi et al. (2000) investigated performance evaluation of four bolt type peeling machine (the only existing pistachio peeling machine in Iran) with capacity of 6 Ton in one of the pistachio preserved terminal in Kerman, Iran. They revealed that in the best condition of machine (when distance between cylinder and frontal blade is 5mm), peeling and breakage rate was 73.8 % and 0.7, respectively. They also reported that 25.5 % of pistachios were remained without any processing.

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Table 8- Mean comparison of breakage percent (%) of pistachio considering interaction effect of peripheral speed of rotating plate and moisture content.

Moisture content	Peripheral speed of rotating plate			
	35	40	45	50
4.10	6.82 abc	8.07 bcd	8.47 cd	8.7 d
10.50	6.55 ab	7.72 abcd	7.87 bcd	8.22 bcd
28.50	6 a	7.05 abcd	7.62 abcd	7.92 bcd
36.10	5.82 a	6.65 ab	7.5 abcd	7.6 abcd

The means with the same letter is not significant at 5% level according to Duncan's multiple ranges test.

4. Conclusion

Peeling is the most important process after harvest in pistachio production. Bolt type peeling machine is the only commercial mechanized method in Iran. These machines which made without considering mechanical properties of pistachio crack a lot of amount of pistachio. So for preventing economical losses resulting in processing, a peeling machine designed and made based on physical and mechanical properties of peeling. Finally, the performance of the machine was evaluated and the following are concluded:

1- The peeling efficiency of the pistachio significantly increased with in an increase moisture content while the breakage percent decreased. Also, there was no difference between all levels of moisture content with each other for breakage percent.
2- The peeling efficiency and the breakage percent of the pistachio significantly increased with increasing of moisture content so that highest and the lowest efficiency belonged to peripheral speed of 50 m/s and 4 m/s, respectively.
3- Consequently, by comparing the results of interaction effects of the peripheral speed and the moisture content on peeling efficiency and breakage percent, treatment of peripheral speed of 50 m/s and moisture content of 4.10 % revealed the best results with peeling efficiency of 96.5 %.

References

1- Altuntas, E., & Yildiz, M. (2007). Effect of moisture content on some physical and mechanical properties of faba bean (Vicia faba L.) grains. Journal of Food Engineering Research, 78, 174-183.
2- Atiku, N., Aviara, N.A., & Haque, M. (2004). Performance Evaluating of a Bambara Ground Nut Sheller. Agricultural Engineering International: the CIGR journal of Scientific Research and Development, Manuscript PM 04002.

3- Coskuner, Y, & Karababa, E. (2007). Some physical properties of flaxseed (Linum usitatissimum L.). Journal of Food Engineering Research, 78, 1067-1073.
4- Food and Agriculture Organization (FAO). (2005). www.fao.org
5- Hyang, S.C., Hyun, J.K., & Hyun, E.O. (2006). Determination of Aflatoxin levels in nuts and their products consumed in South Korea. Journal of Food Chemistry, 102, 385-391.
6- Jain, R.K. (1980). Optimisation of operating parameters of centrifugal sheller, M.Tech. thesis. Kharagpur, India: Department of Agricultural and Food Engineering, Indian Institute of Technology.
7- Joseph, V., & Benjamin, V. (1981). Method of hulling pistachio nuts, United States Patent, Patent Number; 4,353,931.
8- Joshi, D.C., Das, S.K., & Mukherjee, R.K. (1993). Physical properties of pumpkin seeds. Journal of Agricultural Engineering Research, 54, 219-229.
9- Joshi, D.C. (1993). Mechanical dehulling and oil expression of pumpkin seed, Ph. D. thesis. Kharagpur, India: Department of Agricultural and Food Engineering, Indian Institute of Technology.
10- Kashaninejad, M., Mortazavi., A. Safekordi, A., & Tabil, L.G. (2005). Some physical properties of pistachio nut and its kernel. Journal of Food Engineering, 72, 30-38.
11- Khodabakhshian, R. (2007). Design, manufacturing and evaluation of the pistachio hulling machine. Bsc. Thesis, Agricultural Engineering Department, Kerman, Iran.
12- Khodabakhshian R., Bagher E., & Abbaspour Fard M.H. (2010) Mechanical Properties of Sunflower Seed and its Kernel, Azargol Variety as a Case Study, under Compressive Loading. Journal of Agricultural Science and Technology, 8, 119–128.
13- Mahmoodi, E., Khojastehnazhade, M., Khazabi, K., & Jafari, A. (2006). Analysis and investigation of the efficient parameters for pistachio peeler Design. The First congress of processing and packaging pistachio in Iran.
14- Makanjuola, G.A. (1972). A study of some of the physical properties of melonseeds. Journal of Agricultural Engineering Research, 12, 128-137.
15- Maskan, M., & Karatas, S. (1998). Fatty acid oxidation of pistachio nuts stored under various atmospheric conditions and different temperatures. Journal of the Science of Food and Agriculture, 77, 334–340.
16- Recabi, M. (2000). Performance evaluation of a bolt type pistachio hulling machine. Bsc. Thesis, Agricultural Engineering Department, Kerman, Iran.
17- Shamsi, M. (1994). Conic centrifugal pistachio huller. Project final report, Ministry of industry and mines, Tehran, Iran.
18- Woodroof, J.G. (1979). Tree nuts: production processing products (2nd ed.). Westport, Conn: AVI.

DOI: 10.2202/1556-3758.2135