World Applied Sciences Journal 11 (8): 930-937, 2010
ISSN 1818-4952

Design and Manufacture of a Pistachio Peeling Machine

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Abstract: Pistachio is one of the important horticulture crops and second exportable non-crude oil product after carpet. Generally, in Iran pistachio is peeled by bolt type peeling machines and the subsequent processes, including washing and dehydrating is fulfilled by a another machines. These peeling machines are made without any attention to mechanical properties of pistachio that this causes to break considerable percentage of pistachio when peeling. Therefore, it is essential to design a peeling machine with high efficiency that can carry out washing and dehydrating processes, too. So, a pistachio peeling machine designed and developed that can do peeling, washing and dehydrating processes simultaneously. The machine is designed on the basis of physical and mechanical properties of pistachio and all calculations related to strength of material done. 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.

Key words: Pistachio · Mechanical properties · Peeling machine · Centrifugal force

INTRODUCTION

Pistachio is one of the important horticulture crops in Iran. Most of the pistachio nuts are exported to countries around the world. For the first time in year of 2003, after petroleum and carpet, pistachio with 72 thousands tones gained the first score in export goods, bringing 272 million dollars to the country. Iran owns about 48 percent of the pistachio world production, United State, Turkey and Syria are other main producers [1]. Within the seventy years ago, pistachio specially has gained a commercial and economical value and Iran reputed as the first and main exporter in the world. From that time, the area cultivation of this product is increasing more and more. Developing this product in many regions is not practical because of weather condition limitation. So, for taking a good ranking at the world production of this strategic product, we should increase it's yield [2].

Pistachio is one of the products which can not be entered to market directly after harvest. It should follow stages for rendering to market. In fact, these stages are processes that call retention and preservation. These processes are (1) hulling, to separate the soft hull from nuts; (2) trash and blank separation, to remove blank pistachios and trashes such as small branches, remaining shells and leaves; (3) unpeeled pistachios separation, to remove unpeeled and unripe nuts; (4) washing, which involves spraying water at high pressure on the pistachios to clean the nuts; (5) drying, to decrease moisture content of pistachios from 37% to 4% to appropriate level; (6) split nuts separation, to separate split nuts from non-split ones; (7) roasting; and (8) packaging [3].

In production process of pistachio, peeling is the most important process after harvest. In Iran, peeling of pistachio is different according to softness or hardness of it. Those which have soft skin are peeled by bolt type peeling machine and pistachio with hard skin are peeled by another machine that name unripe peeler. Bolt type peeling machine is the only commercial mechanized method in Iran. The machine has been developed and improved during the last 50 years. The main part of the machine is a rotating drum covered by the heads of M6 bolts. The soft skin is detached by vertical and shear stresses produced by these bolts

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against a fixed blade. This machine are made and designed in local workshops without any attention to mechanical properties of pistachio and many of its parameters determined experimentally [4]. In addition, bolt type peeling machine pistachio only peel pistachio and the subsequent processes, including washing and dehydrating is fulfilled by a long time delay, causing Aflatoxin disease [5].

Recabi [6] 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. Shamsi [7] investigated pistachio peeling by using centrifugal force with method of up-side down cone, in a project that was done for ministry of industry and mine in Iran. They also made this peeling machine that its efficiency was not analyzed.

As it can be found from literature review, despite an extensive research on pistachio nuts, there was not a precise statistical survey from existing losses in processing of pistachio. One of these machines in processing of pistachio that has many losses is bolt type peeling machine. According to experts, 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, this study was conducted to design a pistachio peeling machine that can do hulling, washing and dehydrating processes simultaneously.

MATERIALS AND METHODS

In order to choose suitable system for peeling of pistachio, we need to determine some physical and mechanical properties of pistachio. So, a mass of eighty kilograms of o'hadi variety of pistachio from Rafsanjan city, Kerman province in Iran was supplied and transferred to laboratory. The samples were cleaned to get rid of all foreign matters as well as broken nuts. Then random samples of pistachio nuts were drawn for experiment. This methodology was used to ensure the uniform sample size [8]. 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 [9, 10]. 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 calliper (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 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 (%)				
Parameters	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/m^3)	561.87	578.26	602.84	624.34	643.79
True density (kg/m^3)	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

RESULTS AND DISCUSSION

Machine Description: A general view of machine is shown in Fig. 1. In order to peel pistachio in this machine, centrifugal force is used. The machine consists of two main parts including 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.

Calculations

Electromotor: Required power for peeling of pistachio was calculated by subtracting the power needed for rotation of the axis of electromotor in the pile of pistachio nuts and in free condition. First, electricity current calculated in each above condition. Then with knowing the constant value of voltage, the power for each condition was calculated from Eq (1). Finally, subtracting the two powers gained a value of 2.208 kw as required power for peeling of pistachio [11].

$$P = VI \tag{1}$$

In order to determine torque which is transmitted by electromotor, T_a, round axis of electromotor assigned 250 rev/min by a light photometer. Then with substituting this value in Eq (3), the torque resulted in 84.37 N.m [12].

$$P = T_a\omega \tag{2}$$

$$\omega = \frac{2\pi n}{60} \tag{3}$$

Transmitted torque for rotating drum was 105.44 (N/m) with consideration of speed of 200 rev/min of rotating d rum electromotor and Eq. (2) and (3). In order to analyze the force of peeling resulting from electromotor torque and compare with mechanical properties of pistachio, force which exist in rotating circular base - plate calculated by substituting radius of plate and torque in Eq. (4).

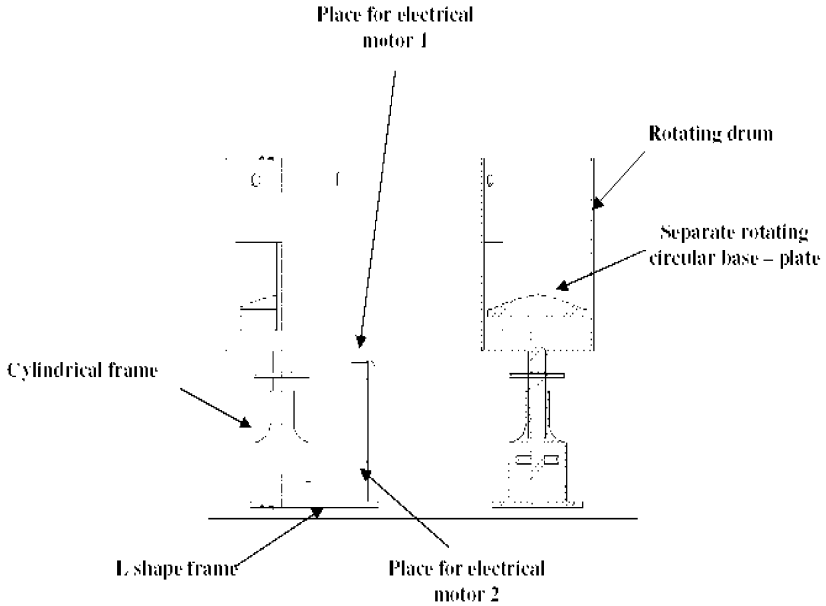

Fig. 1: General view of the proposed machine.

$$F = \frac{T_a}{R} = \frac{84.3}{0.25} = 337.2N \quad (4)$$

Required force for peeling one pistachio gained 0.56 N by considering porosity, geometric mean diameter of studied variety, area of the circular base - plate and dividing force to number of pistachio on the circular base - plate. As it can be seen from Table 2, the force calculated (0.56 N) is more than strength of pistachio peel. So it is suitable for peeling.

Rotating Shafts of Circular Base - Plate and Rotating Drum: As it can be said in the description of the machine, the peeling set of the machine consists of a rotating drum and a separate rotating circular base - plate with a separate shaft for each of them. In the operational stages of the machine, shafts of circular base - plate and rotating drum are affected by torsional stress. So these shafts designed based on their strength against shearing stress resulting from torsion by Eq. (5):

$$Z_p = \frac{T}{\tau_d} \quad (5)$$

Where τ_d is shearing stress, Mpa, Z_p is Shaft polar section modulus, mm^3 and T is torsional torque on the shaft, N.m.

So, for computing Zp in this Eq. (5), first we should calculate torsional torque and shearing stress on the shafts. The torsional torque on shaft of rotating circular base - plate was measured by substituting of torque transferred, T_a and the proportion of diameter of pulley of shaft to diameter of pulley of electromotor in Eq. (6).

$$T = T_a * \frac{d}{d_a} \quad (6)$$

The torsional torque on shaft of rotating drum was calculated by the same method. The shearing stress of shafts (designing stress) was computed using the following equation [12]:

$$\tau_d = 0.577 * \frac{S_y}{N} \quad (7)$$

Where S_y is yield strength, Mpa and N is factor of safety. The variation of the factor of safety is from 2 to 4. In this study, the factor of safety was equal to 4. Due to existence of water in machine (in the washing stage), each two shafts were made from stainless still. By considering yield strength of this kind of steel (Table 3), factor of safety and Eq (7), the shearing stress of each two shafts were as following:

Table 3: The properties of stainless still

Parameters	Value
Yield strength (Mpa)	206.00
Bulk density (Kg/m^3)	8000.00
Modulus of rigidity (Gpa)	79.00
Poisson's ratio	0.27
Elastic modulus (Gpa)	200.00

Table 4: The properties of nozzle used in the machine

Patter of scattering	Angle of scattering (degree)	Amount of scattering (Lit/min)
Cone type	120	8.39

$$\tau_d = 0.577 * \frac{206}{4} = 29.72 \text{ Mpa}$$

Consequently, Shaft polar section modulus, Z_p, was as following:

$$Z_p = \frac{84370}{29.72} = 2838.82 \text{ mm}^3$$

By consideration of a value of 1.4 for concentration coefficient of stress, Shaft polar section modulus for shaft of rotating circular base - plate was equal to 3974.35 mm^3. Referring to table of physical properties of steel shaft, it was found that shaft with external diameter of 60 mm and thickness of 5 mm has bigger shaft polar section modulus than allowable value. Hence, with substituting of this value for Zp in this Eq. (5), the value gained for shearing stress is less than allowable value of designing stress. In the same way, by consideration of a value of 1.4 for concentration coefficient of stress, Shaft polar section modulus for shaft of rotating drum was equal to 3547.80 mm^3. Referring to table of physical properties of steel shaft, shaft with external diameter of 90 mm and thickness of 5 mm was selected. Length of shafts was computed with attention to Eq. (8) and considering this point that two shafts should have the same angle of twist.

$$\phi = \frac{TL}{GJ} \quad (8)$$

Consequently length of shaft of rotating circular base - plate and shaft of rotating drum resulted in 600 and 400 mm, respectively (Figs. 2 and 3).

Hopper (Rotating Circular Base - Plate and Rotating Drum): Hopper of machine is an another main part of peeling unit which its volume was gained 1055 mm^3 based on bulk density of pistachio in the moisture content of 36.10 % and in the capacity of 1 ton of pistachio.

Fig. 2: Shaft of rotating drum

Fig. 3: Shaft of rotating plate

Fig. 4: Rotating circular base - plate

The hopper designed with notice to torque of 105.44 N.m and equations 5 to 7. Because of the water in water in machine (in the washing stage), the material of hopper was selected from stainless still. As a result, a hopper with height of 1250 mm, thickness of 4 mm and external diameter of 500 mm from stainless steel was made. For better peeling of pistachio in the machine, rotating circular base - plate and rotating drum were covered by jagged surface. The rotating circular base - plate designed by considering required torque for peeling, needed tolerance (3 mm) between plate and rotating drum for guiding litter and water to exit port, equations 5 to 7 and existence of a stress concentration in junction point between shaft and plate. So a plate with thickness of 50 mm and diameter of 484 mm from stainless steel was made (Fig. 4). A hole with diameter of 100 mm at the bottom of hopper was arranged for exiting of water and litter from the machine. Also, for arriving peeled pistachios to discharging stage, a hinge gate with the length of 400 mm and width of 300 mm on rotating drum was prepared.

Fig. 5: Thrust bearing of shaft of rotating circular base- plate

Fig. 6: Thrust bearing of shaft of rotating drum

Bearings: In Order to Transmit Axial Loads When Machine Is Operating, Two Thrust Bearings Were Placed in Following Locations:

- In the supporting place of shaft of rotating circular base - plate on frame.

In order to transmit axial loads resulting from weight of rotating circular base - plate (about 35 Kg) and weight of existing pistachio nuts in the hopper (1000 Kg), a thrust bearing was used which can tolerate axial loads up to 2000 Kg (Fig. 5).

- In the supporting place of shaft of rotating drum on frame for transmitting axial loads resulting from weight of hopper, pistachio nuts in the hopper, water in washing stage and nozzle. Similar to last position, a thrust bearing which has capacity of axial loads up to 2 ton was used (Fig. 6).

Also for helping to easy rotation of shafts, two ball bearings were placed in following locations:

- In the supporting place of shaft of rotating drum for tolerating radial loads resulting from rotation of shaft (Fig. 7).
- In the supporting place of shaft of rotating circular base - plate for tolerating radial loads resulting from rotation of plate in the pile of pistachio nuts (Fig. 8).

Fig. 7: Ball bearing of shaft of rotating drum

Fig. 8: Ball bearing of shaft of rotating circular base - plate

Fig. 9: Bottom part of cylindrical frame

Fig. 10: Upper part of cylindrical frame

Frame: In order to locate electromotor, hopper, shafts and bearings used a frame in L shape and two parts cylindrical frame (Figs. 1, 9 and 10). Frame in L shape consist of two vertical and horizontal parts (Fig. 1).

Fig. 11: Nozzle used

Fig. 12: Pulley of electromotor

Fig. 13: Pulley of shafts

Vertical part which electromotor stands on it, was made from girder of 18 and horizontal or bottom part of frame which cylindrical frame and girder sit on was made from iron profile with dimension of 100*100.

Nozzle: In washing stage, sprinkling of water into the hopper starts to wash losses and get rid of pill remained on rotating drum and rotating plate. So we used existing nozzle in potato peeling machines with following properties (Fig. 11).

Belt and Pulley: As it was mentioned, the power transmission system of machine is mechanically by two v shape belts and tow pair of pulleys. Designing of pulleys was done on the basis of system power and required power for peeling. It is apparent from two powers that for conveying power of 3 hp between electrical motors and peeling set, a proportion 1 to 6 is needed. So, a pulley with diameter of 60 mm for electrical motors and another pulley

with diameter of 360mm for shafts were made from cast iron (Figs. 12 and 13). Then, length and type of belts were calculated with placing of central distance of pulleys on the frame (1000 mm), diameters of pulleys and properties of seating place of pulleys in following equations and using standard tables of belts.

$$C = \frac{1}{4}\left[H + \sqrt{H^2 - 8(R_2 - R_1)^2}\right] \quad (9)$$

$$H = L - \pi(R_2 + R_1) \quad (10)$$

Therefore, H coefficient was computed from Eq. (9) at first and then length of belt was calculated with substituting of this coefficient in Eq (10) [13]. Also, arc angle of belt was calculated by Eq. (11).

$$COS\psi = \frac{R_2 - R_1}{C} \quad (11)$$

Finally, length and arc angle of belt were computed 2788.67 and 81.37°, respectively. Consequently by consideration these numbers and standard tables of belts, v belts (type of c) with length of 2790mm were selected.

CONCLUSION

As we know, pistachio process is a costly operation for the producers. If these costs are reduced, not only the pistachio consumption but also the competitions of producers in world scale increases. All the expenses of the whole pistachio process include the followings: the costs of machineries used, production wastes, workers wages, transportation and the time consumed during the process. Among those, the first two constitute the highest portion. Consequently, performing some operations of process only in one machine seem beneficial from several aspects. First of all, the expenses for maintenance and repair of one machine are remarkably lower than a number of machines involved. Secondly, expenses due to the transportation are approximately omitted and eventually, automation of the machine for the automatically continuous fulfilment of the steps of the process increases. Regarding the simple mechanism of belt and pulley for the power transmission, easy and simple assemblage, capability of being equipped with automatic systems for the process and other predicted advantages for the machine, it can reduce a lot the total expenses. Present innovative mechanism can be used for hulling other nuts such as walnut or hazelnut, but with some modification and adaptation in design. Any way researcher can study this proposal for other nuts and after that design and fabricate suitable machine with different capacity. Also waste material discharged from these machines (green hull), can be used for colors industry or others industry.

Nomenclature

C	Length of belt, m
d	Diameter of pulley (pulley of shaft), mm
F	Force, N
G	Modulus of rigidity, Mpa
H	Length of belt coefficient
I	Electricity current, A
J	Polar moment of inertia, mm^2
L	Length of shaft, mm
N	Factor of safety
P	Power, Kw
R	Radius of rotating circular base–plate, m
T,	torque needed for rotation of the shafts, N.m
ϕ	Angle of twist, degree
R_1	Radius of small pulley, mm
φ	Arc angle of belt, degree
T_a,	torque conveyed by electromotor, N.m
d_a	Diameter of pulley (pulley of electromotor), mm
n	Revolution of electromotor, rev/min
ω	Angular speed, rad/sec
Z_p	Shaft polar section modulus, mm^3
S_Y	Yield strength, Mpa
τ_d	Sheering stress, Mpa

ACKNOWLEDGMENTS

The authors would like to thank Ferdowsi University of Mashhad for providing the laboratory facilities and financial support.

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