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Design, Construction and Performance Evaluation of the Walnut Cracking Machine

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Abstract: The traditional method in Iran of cracking walnut manually, using harmer or knife cutter is labor-intensive, slow and tedious; besides, most mechanical crackers do not give satisfactory results in terms of kernel extraction quality. A prototype machine was developed to crack walnut. A walnut cracker was designed, constructed and tested to evaluate its performance. The cracker, which consists of a hopper fitted with a flow rate control device, a cracking unit, a sorter and power system, operates on the principle of attrition using crushing force from a cylinder and helix. The percentage of whole kernels produced was 66.66 %. The capacity of the machine was estimated to be about 25.2 kg/hr. A device of this nature can be manufactured for small entrepreneurs and industrial-level applications in the developing countries where bulk of the world walnut is produced. This paper describes the design and performance evaluation of the cracker as well as the implication of the results obtained.

Key words: Walnut % Helix % Cracker % Kernel % Industrial-level % Iran

INTRODUCTION

Iran is ranked fourth in the world (FAO, 2007) with 170,000 tones of walnut (*Juglans regia* L.) production. This production is mostly obtained from seedling trees. Cultivation of new cultivars resulting from a selective breeding programmed in Iran is leading to standard production of walnuts. Walnut harvesting and cracking are still carried out manually in Iran, which results in increased cost and processing time for kernel extraction. Therefore, a mechanized cracking and handling unit should be developed based on the physical characteristics and mechanical properties of walnuts. Since the cracking process is the most critical and delicate step for achieving high-quality kernels, mechanical properties of walnut cultivars is a pre-requisite for the design and development of a cracking machine (Guzel *at al.*, 1999). Xavier (1992) emphasized that size, shape, shell thickness and texture were the most important parameters affecting the kernel extraction quality in macadamia nuts. Many researchers (Liang, 1977; Tang *et al.*, 1982; Liang *et al.*, 1984; Sen, 1985; Özdemir & Özilgen, 1997) stated that the kernel extraction quality depended on shell moisture content, shell thickness, nut size and loading positions in nuts. Dursun (1997) found that the compression position influenced the amount of force applied to crack walnuts and other nuts. In this study, the maximum force required to crack walnuts occurred at right angles to the longitudinal axis while the minimum force occurred when the force was applied along the suture line. Similarly, both Braga *et al.*, (1999) and Aydın (2002) found that the maximum force required to crack nuts was measured when nuts were placed at right angles to the longitudinal axis whereas the minimum force required to crack nuts occurred when the force was applied along the longitudinal axis. Additionally, Ôen (1986), Dursun (1997) Özdemir and Özilgen (1997) and Akça (2001) reported that the cracking position had an important effect on extracting the kernel for both nuts and stone fruits.

The knowledge of the physical and mechanical properties of the agricultural products is of fundamental importance for the correct storage procedure and for design, dimensioning, manufacturing and operating different equipments used in post harvesting and main processing operations of these products (Correˆa *et al.*, 2007). In recent years, physical and mechanical properties have been studied for various nut crops such as macadamia nut (Braga *et al.*, 1999) castor nut

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(Olaoye, 2000); raw cashew nut (Balasubramanian, 2001); hazelnuts (Aydin, 2002; Güner, Dursun & Dursun, 2003), areca nut kernel (Kaleemullah & Gunasekar, 2002); groundnut kernel (Olajide & Igbeka, 2003); almond nut and kernel (Aydin, 2003); shea nut (Olaniyan & Oje, 2002); and pine nuts (Özgüven & Vursavu, 2005).

The objective of this study was to examine same physical and mechanical properties of walnut for design, construction and performance evaluation of the walnut cracking machine.

MATERIALS AND METHODS

Philosophy of Design: A number of points were considered during the design. Such points include the cost of construction, power requirement of the machine and labour requirement in operating the machine. Also considered in the design was the ease of replacement of component parts in case of damage or failure. The machine was conceived as a laboratory-level, simple-to-operate and easy-to-fabricate Automatic - operated device capable of cracking many walnuts at a time.

Physical Characteristics: The shape of the walnut was found to be a sphere with three major perpendicular dimensions, length (L), width (W) and thickness (T). The physical dimensions were determined randomly measuring the length, width and thickness of 100 nuts. The dimensions of the walnut were measured by a digital-micrometer to an accuracy of 0.01 mm. To obtain the unit mass, each nut was weighed with an electronic balance to an accuracy of 0.001g.

The equivalent diameter as the geometric mean of the three dimensions was calculated using the following expression (Mohsenin, 1978):

$$D_g = (LWT)^{1/3}, \quad (1)$$

The criteria used to describe the shape of the nuts are the sphericity and aspect ratio. Thus, the sphericity (S_p) was accordingly computed (Mohsenin, 1970): as:

$$f = \left[\frac{D_g}{L}\right] \times 100, \quad (2)$$

All the above experiments were replicated and the average values were reported.

Prototype Machine Description: The machine is a simple device, it comprises of six major components assembled together. The cracker, which consists of the Stand, a hopper fitted with a flow rate control device, a cracking unit, Reservoir and power system, operates on the principle of attrition using crushing force from a cylinder and helix.

The outer cylinder is made of polyethylene, 200 mm long and 125 mm in diameter. The hopper is also made of polyethylene, 300 mm long and 140 mm in diameter.

The Stand: The cracking unit and electro gearbox motor were bolted firmly to the stand. The stand was made from 20×40×3.2 mm rectangle iron, 400 mm wide, 800 mm long and 800 mm high. The entire surface of the machine was painted to prevent corrosion and rusting.

The Hopper: The hopper, which is conical in shape, is mounted on the stand and held in place by a hopper support frame. It is connected to the cracking unit by the nut feed flow channel inclined from the hopper base to the top of the cracking unit at the nut's angle of repose.

The Flow Rate Control Device: A nut flow rate control device is located between the hopper and the cracking unit. By this means, the quantity of walnut entering into the cracking unit per unit time can be regulated and varying feed rates achieved.

The Cracking Unit: The cracking unit consists of a cylindrical shell and helix that cracked walnut with standing between them. The helix can rotate freely inside the stationary outer cylinder when powered through the shaft via a chain arrangement. The helix is mounted to give a clearance that is lesser than walnut size with cracking cylinder surface. The gap between the helix and cylinder is variable and this is enough to crack the walnuts whose average diameter is about 30-40 mm.

The Reservoir: The cracked walnuts falling and banked at this part.

The Power System: The helix is driven by its vertical shaft, which is powered through the shaft via a chain arrangement. The mild steel solid shaft for power transmission is 20 mm in diameter and 700 mm long. It is supported at both ends by roll bearings, which are in turn bolted to the stand. The vertical shaft is driven by an electromotor through a system of chain.

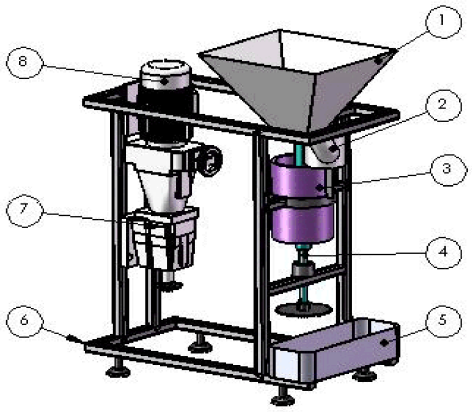

Fig. 1: Schematic of a complete assembly of the walnut cracker (1.hopper, 2.flow divider, 3.Cylinder, 4.Helix, 5. Reservoir, 6. Stand, 7.Gearbox, 8.Electro-motor)

The complete machine assembly is shown in Figure 1.

Power Requirement: The power requirement, P, can be divided into two parts; (1) power required in cracking, Ph and (2) power required to drive the helix, Pc.

The power required in cracking was obtained from the following equations

$P_h = T\omega$ (3)

$T = Fd$ (4)

Where,

P_h = Power needed to crack [W]
T = Torque [N.m]
d = Radius of applying force = 0.1 [m]
ω = Angular speed; it is given by
$\omega = 2\pi N/60$

Where,

N = Speed in revolutions/minute.

Using the above equations and for a helix speed of 50 rpm, Ph was found to be 389.36 W.

For the power needed to drive the helix, P_C, torque was first obtained using Equation 3.

$T = W_c R$ (5)

Where,

W_C = Weight of helix = 50 [N]
R = Radius of helix = 0.05 [m]

Therefore, Pc was found to be 2.5 W.

The total power P was then found as:

$P = P_h + P_c = 391.86$ W.

To account for friction and other losses, a 746 W motor was selected for the machine.

Cracker Throughput (*Tp*): The throughput of the cracker (Tp) was evaluated using the following equation:

$$T_p = \frac{3.6M_c}{t_D} \quad \text{(kg/h)} \qquad (6)$$

Where

t_D = Time used in cracking (s)
M_t = Mass of sample before cracking (g)

Preliminary Investigation: In this research, nuts of walnuts (Juglans regia L.) Chandler, Hartley and Pedro varieties that are cultivated in the Karaj of Iran were used for the tests Nuts harvested in the 2008 season were dried in the sun. The resulting shell moisture content were 10.5%, 15% and 20% wet basis (w.b.). The moisture contents of the shells (taken from 10 nuts) were determined using an oven set at 105±1C for 24 h (three replicates). The dried nuts were stored at 0 C and 60-65% relative humidity in plastic bags (moisture tight) during the tests. Before the cracking test, nuts were visually inspected and those with damaged shells were discarded.

RESULTS AND DISCUSSION

Dimensional Properties, Mass and Volume: Physical characteristics of walnut for three varieties (Chandler, Hartley and Pedro) are demonstrated in Table 1. The mean of length, width and thickness for Chandler variety were 37.12, 33.12 and 31.68(mm), respectively. These values were 38.17, 31.88 and 31.59(mm) for Hartley and also 38.58, 33.87 and 32.78(mm) for Pedro, respectively. The results showed that the domain of their length for about 89% of Chandler variety and 75% of Hartley and 78% of Pedro variety were about 35-40(mm). The mean of mass for Pedro variety was 12.59(mm) and for Hartley was 10.16(mm); so they were the heaviest and the lightest of all, respectively. The biggest and smallest varieties were Pedro (volume mean: 22.54cm3) and Hartley (volume mean: 20.27cm3),

Table 1: Results of physical properties of varieties of Chandler, Hartley and Pedro

Variety		Length (mm)	Width (mm)	Thickness (mm)	Mass (gr)	Volume (cm3)	Geometric mean diameter (mm)	Sphericity
Chandler	Range	14.54	8.59	12.43	9.43	12.72	7.38	0.220
	Mean	37.12	33.12	31.68	11.50	20.50	33.88	0.910
	Standard Deviation	2.50	1.52	1.60	1.76	2.83	1.62	0.032
Hartley	Range	12.22	8.60	9.29	8.05	15.24	8.68	0.150
	Mean	38.17	31.88	31.59	10.16	20.27	33.74	0.880
	Standard Deviation	2.48	1.62	1.79	1.70	3.17	1.80	0.024
Pedro	Range	14.00	9.53	9.24	28.12	16.40	9.23	0.230
	Mean	38.58	33.87	32.78	12.59	22.54	34.98	0.910
	Standard Deviation	2.42	1.65	1.62	2.29	3.02	1.62	0.032

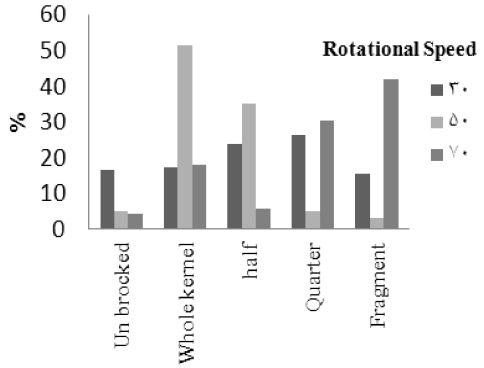

Fig. 2: Test results in three rotational speed machine 30, 50 and 70 rpm with Chandler variety

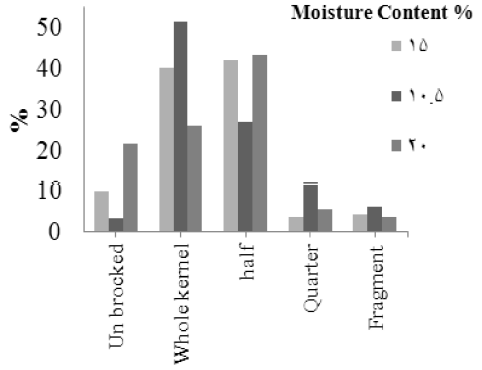

Fig. 3: Testing machine at three levels of moisture content of 10.5, 15 and 20% (w.b.)

respectively. Sphericity coefficient For Chandler, Hartley and Pedro were 0.91, 0.88 and 0.91, respectively; this parameter is important to design the reservoirs and drying systems for walnut. Cracker Throughput was 25.2 kg/hr for dry walnut. In Table 1.

Cracker's Evaluation: For evaluating of the cracker three parameters such as moisture content (three levels 10.5%, 15% and 20 % wet base (w.b.)) and Helix velocity (30, 50 and 70 rpm) were considered.

Effect of Rotational Speed on Kernel Extraction Quality of Walnut: To estimate optimum velocity for cracker, three levels of velocity considered experimentally (as showed in picture 2). The best results were obtained on velocity was 50 rpm. On lower speed almost most of them were not broken and they passed helix without breaking and also it needed long time. So higher speeds are more suitable, in the other hand in higher velocities the percent of damaged walnut's kernel were higher too and because of sudden stresses forced on walnut the kernels were crushed and broke.

Effect of Moisture Content of Walnut Shell on Kernel Extraction Quality: Relevant experiments were done with walnut cracker machines in three levels of moisture content (10.5, 15 and 20 %) at 50 rpm with Chandler variety. As can be seen in Fig. 3 Any shell moisture content of walnut increased, amount of unbroken kernel decreased, but amount of half kernel increased, Because of this phenomenon was that with rising shell moisture content, Walnut shell resistance with increasing humidity, increased and walnut from its suture was broken, This makes that walnut half into two piece and thus the value kernels more than half in the high moisture content was increased.

CONCLUSION

The domain of their length for about 89% of Chandler variety and 75% of Hartley and 78% of Pedro variety were about 35-40(mm). The biggest and smallest varieties were Pedro and Hartley, respectively. The best results were obtained on velocity was 50 rpm.

With increasing shell moisture content of walnut, amount of unbroken kernel decreased, but amount of half kernel increased. The percentage of whole kernels produced was 66.66 % of chandler variety. The capacity of the machine was estimated to be about 25.2 kg/hr.

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