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THEORETICAL AND EXPERIMENTAL STUDY OF THE CRACK FORMATION DEVICE IN THE SHELL OF APRICOT KERNELS

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Abstract: The article conducts research on the analysis of kinetic patterns of crack formation on the shell of apricot kernels. The analysis of various devices for processing fruit kernels is presented, as well as their disadvantages and advantages. Patent data and research works of scientists from far and near abroad on the formation of cracks on the shell and splitting of fruit kernels have been studied. Accordingly, a description of a technological device designed for splitting apricot kernels, operating in continuous operation, is given. On the basis of theoretical and experimental studies, the geometric characteristics of the kernels of various apricot fruits were analyzed and the description of the forces acting on the splitting process was given, as well as the geometric parameters of apricot kernels were studied.

The developed device, based on theoretical and experimental studies, ensures the formation of a small crack in the shell of an apricot kernels, and also contributes to 85-87% of the integrity of the core when splitting in a continuous process.

Keywords: apricot kernels, kernels shell, kernels core, splitting process.

Introduction. In the conditions of Uzbekistan, the processing of fruit products and its export to the world market as a consumer, high-quality and environmentally friendly product is one of the urgent problems. In this regard, there is a great demand for processed products of the split apricot kernels called "shurdanak", which is not produced in other countries by cracking the shell. The development of a device with increased productivity and process continuity based on simple mechanisms that provides a small crack in the shell of an apricot kernels while maintaining the integrity of the core during splitting is problematic [1,2,3,6].

Based on theoretical and experimental studies, a new design of an apricot kernel splitting device with various geometric and strength parameters is proposed, which ensures high performance in continuous operation. The analysis shows that [4,5,6] scientifically based research work on the development of an acceptable variant of the device with periodic or continuous splitting of apricot kernels of various geometric shapes and sizes has not been carried out to the full extent. In addition, manual labor is still used to split apricot kernels or extract its kernel.

Methods. It is known that a number of studies have been conducted aimed at splitting the kernels of hazelnuts, walnuts, almonds, peaches and apricots [3,4]. In particular, the authors proposed a device for splitting apricot kernels, consisting of a complex of mechanisms moving in a horizontal and vertical direction. As a result of the contact of the lower surface of the kernels with the anvil, the shell is split [6].

The disadvantage of this device is that the device is not equipped with a mechanism for transferring apricot kernels to the working chamber according to its geometric dimensions. Since the unit of impact force created in the device is constant, there is a possibility that the kernels of different sizes and degrees of hardness will not be completely split, and the kernels of the apricot kernels with a thin shell will be crushed. In addition, the preparation of working mechanisms and ensuring an accurate trajectory of their movement require accurate calculations.

There is another method in research aimed at the formation of cracks in the shell of apricot kernels, the main working organ of which is the auger. When the width of the screw narrows and the depth of the cut increases, a crack forms on the shell along the flow of the product fed into the working chamber.

The main disadvantage of this complex is the complexity of the preparation of mechanisms, especially the auger element, which is considered the main working body, based on the distance between the shafts of grains of different sizes, and the accuracy of the entire complex depends on the quality of the auger preparation. In addition, this device is designed to form only a crack on the rib part of the kernels shell.

Patent data obtained by Australian scientist Alan Woodhouse Crompton (US 4389927A) was also analyzed, which is close to the principle of operation of a device based on splitting apricot kernels, operating in the proposed single-channel continuous mode and accelerating the technological process. The working body of this device also consists of two rods, along the cross section of which grooves are formed at an angle. As a result of the shrinkage of the grooves, the splitting process is carried out. The design of the device is simple. However, the narrowing of the grooves in the cross section does not ensure uniform crushing of apricot kernels of different sizes. Kernels corresponding to the size of the groove will split, large kernels will slide freely between the shafts. The probability of unbroken kernels increases. In addition, the principle of replacing shafts by kernels size is not taken into account.

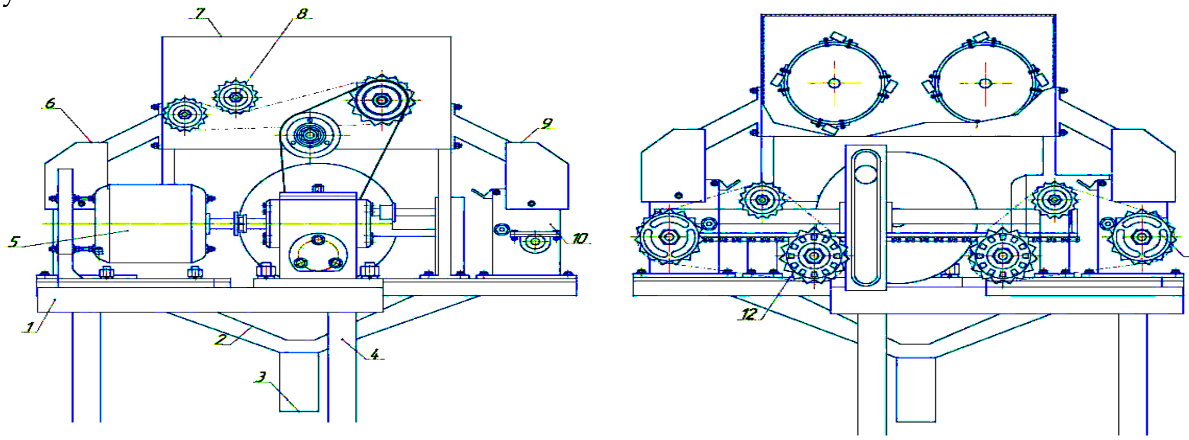

Figure 1. The device for continuous splitting of apricot kernels: 1-bed; 2-channel guiding the crushed kernels; 3-outlet tube; 4-base; 5-electric motor; 6,9-channel providing a normalized flow of kernels into the working chamber; 7-receiving hopper of kernels; 8-a set of gears driving a mechanism providing sequential feeding of bones into the working chamber; 10-the bone splitting chamber (the working organ is a valve, as well as a trailer with a flat surface with sharp corners); 11,12 - a complex of chain gears driving a reciprocating mechanism.

Based on the author's certificates, the analysis of patents for inventions, theoretical, experimental, and practical results on the study of the process of splitting various fruit kernels presented above, a draft device for the formation of cracks and splits in apricot kernels, operating in continuous mode, has been developed (Fig. 1) [9].

The device works as follows. Apricot kernels are loaded into hopper 7. When the device is started, a circular rotation of the disc takes place, transferring the kernels to the working chamber through an improved mechanism using a complex of 8,11 and 12 chain gears, and the kernels are fed piece by piece into the grooves mounted on the discs, perpendicular to the walls of the groove passing through a narrowing channel. The plane passing along the edge of the bone is perpendicular to the axis of the shaft and the kernels entering the working chamber 10 with an edge split between the shafts. The split bones enter the bone receiving hopper through the guide channel 2 through the outlet pipe 3.

Based on this constructive project, a universal semi-industrial device was developed, which, in accordance with the geometric distance of the working bodies (shaft and trailer), creates a crack in the shell of an apricot kernels and performs the splitting process.

Results. On the basis of theoretical and experimental studies, the geometric characteristics of various varieties of apricot kernels were analyzed. Based on a random sample of apricot kernels of the "Shirin Jaupazak" variety, variability curves were constructed on samples of 100 specimens. For this purpose, linear size variability curves were constructed based on random samples of apricot kernels [7,8]. When constructing curves, the ranges of geometric dimensions are separated in the range of 6 by an interval (Figure 2).

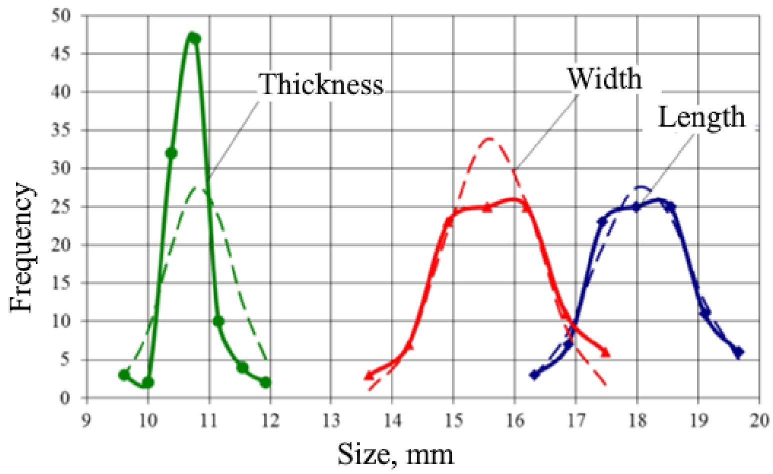

Figure 2. Curves of variability of linear dimensions of apricot kernels

The analysis shows that with a 95% probability it can be argued that the deviation of the shell mass is 5% relative to the kernels core of the normal distribution (Fig. 3).

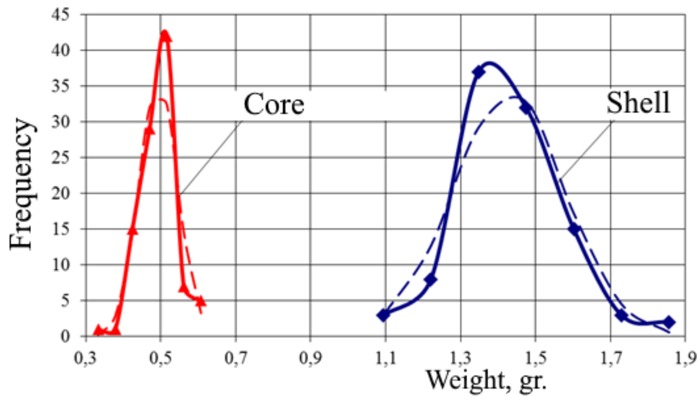

Figure 3. The curve of variability of the shell and kernel of the apricot kernels

The regression equation characterizing the dependence of the unit of force relative to humidity for splitting an apricot kernels has the following form (Fig. 4):

for apricot kernels of humidity 4%: $y = -0{,}415t^2 + 0{,}018t + 3{,}02$

for apricot kernels of humidity 6%: $y = -0{,}415t^2 + 0{,}018t + 5{,}982$ (1)

for apricot kernels of humidity 8%: $y = -0{,}415t^2 + 0{,}018t + 9{,}72$

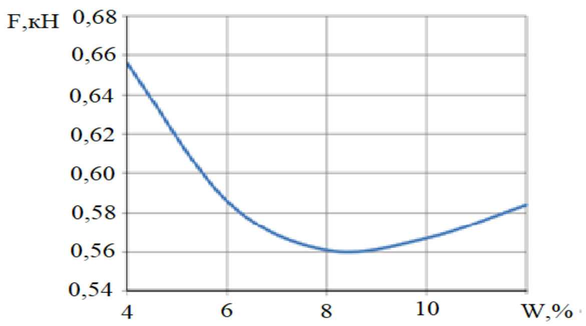

Figure 4. Graph of the dependence of the unit of force on the humidity acting on the splitting of the apricot kernels

As a result of the experiments, a curve of the load value of the splitting process of the apricot kernels was established and obtained, depending on the thickness of the shell (Fig. 5).

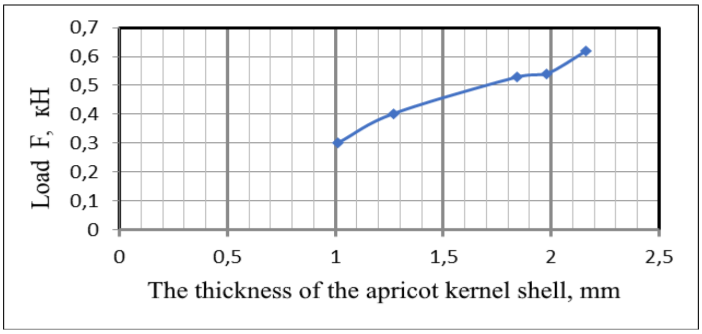

Figure 5. The change in the load value depending on (t) the thickness of the apricot shell

Based on the results of experiments on the process of splitting apricot kernels on a universal WP-300 type device, as well as on a graph expressing the dependence of the load value on changes in shell thickness, we express the change in the load of splitting the bone between the working body and the trailer of the device by the following equation:

$$F = 38{,}1 + 262{,}14 \cdot \delta \tag{2}$$

here: F is the load, H; δ is the thickness of the apricot kernels shell, mm.

It is known that due to the impact of the apricot stone created when splitting the shell, internal stress also acts. Including normal forces *Nx*, *Ny*, displacement force *Nxy*, transverse forces *Qx*, *Qy*, as well as bending moment *Mx*, *My* and rotation moment *Mxy*. We represent the distribution of the acting forces by coordinates as follows:

$$K_x = \frac{d^2z}{dx^2}; \quad K_y = \frac{d^2y}{dy^2}; \quad K_{xy} = \frac{d^2z}{dxdy}; \tag{3}$$

To determine the degree of convexity in relation to the central zone of the apricot stone, taking into account the plane of the shell $\gamma = fa^{-1}$, the thickness of the kernels $e = kf^{-1}$ and the dimensionless intensity of the resultant forces $p = q\sigma_0^{-1}$, we derive the following system of equations based on the plane of the shell $\gamma = 0{,}2y$ and the thickness of the seam of the shell joint $e = 0.0024$ [7,8]:

$$\begin{cases} K_x = \frac{d^2z}{dx^2} = fa^{-2}, \\ K_y = \frac{d^2z}{dy^2} fa^{-2}, \\ K_{xy} = \frac{d^2z}{d_x d_y} = 0 \end{cases} \tag{4}$$

As can be seen from the system of equations, the surface of the apricot kernels does not form a bulge of a certain size. The surface of the shell of the studied apricot kernels is not strictly convex, since there are zones of negative Gaussian curvature near the corners. Therefore, the plane of the apricot kernels is characterized by the ratio of the width of the maximum accessible convex surface to the minimum and is represented by the following equation:

$$Z = f_1 \frac{x^2}{a^2} + f_1 \frac{y^2}{b_2} \tag{5}$$

According to the law of Gaussian curvature, the characteristic surface of an apricot kernels can be considered as a surface having the following shape (Fig. 6):

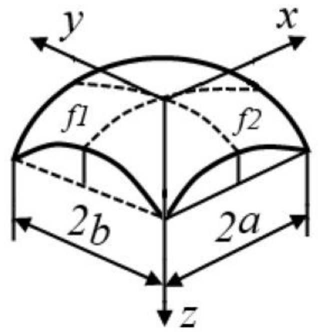

Figure 6. The characteristic surface of the apricot kernels shell

here: $2a, 2b$ - the size of the bone, m; f_1 and f_2 - the width and length of the bulge of the shell of a parabolic shape, m.

Assuming that the total height of the convex surface along the width of the bone shell is the sum of the values f_1 and f_2, then the equation will have the following form [10]:

$$\gamma = (f_1 - f_2) \cdot (2b)^{-1} \quad (6)$$

Considering that the surface of apricot kernels of some varieties has a variable curvature, the following equation is valid for the surface of the central zone of the kernels:

$$Z = f(1 - (xa^2)^2) \cdot \left(1 - (yb^{-1})^2\right) \quad (7)$$

The main geometric value influencing the formation of a crack and also a split in the shell of a kernel is the height of the convex surface relative to the central point along the width of the bone (Fig. 7).

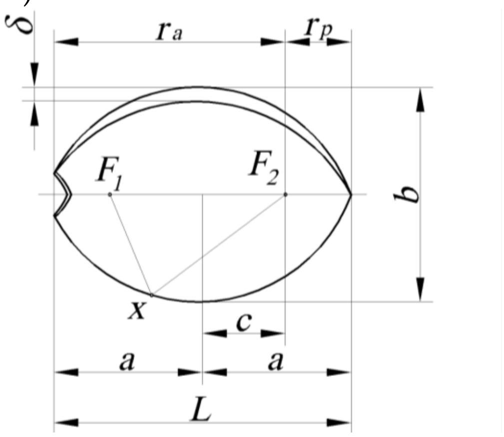

Figure 7. Geometric dimensions of the apricot kernels

The distances r_a and r_p from each of the foci to a given point of the ellipse are the focus radius at that point, and distance C is the focal length: $c = F_1 \cdot F_2 / 2$. The diameter of an apricot kernels is an arbitrary chord passing through its center, according to which the ratio of small and large lengths characterizes the degree of compression $K = b/a$. Then the compression of the kernels on the sides of the rib can be expressed by the following equation [7,8]:

$$(1 - K) = \frac{a - b}{a} \quad (9)$$

If we consider an apricot shell as a segment connecting its radius with a central point, then the length of the shell of the kernels will be expressed by the following equation:

$$L = \frac{a \cdot b}{\sqrt{b^2 \cos^2 \varphi + a^2 \sin^2 \varphi}} = \frac{b}{\sqrt{1 - e^2 \cos^2 \varphi}}, \quad (10)$$

Discussions. Based on experimental studies and analysis of the physico-mechanical properties of the apricot kernels shell, the value of the degrees of compression of the shell thickness in the range of 1.01-2.16 mm is 0.588-0.845 mm. Justifying the dependence of the load value of the split of the apricot kernels sample depending on the humidity level, it was determined that the required load for splitting is 0.656kN at a humidity of 4%, 0.586kN at a humidity of 6%, 0.567kN at a humidity of 8%.

Conclusion. Developed on the basis of theoretical and experimental studies, the device is capable of forming small cracks in the shell and providing 85-87% of the integrity level of the apricot kernel during splitting, and increased productivity has been achieved by implementing a continuous splitting process based on the use of simple mechanisms in the structure.

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