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Development and justification of the parameters of a destemmer for dried grapes

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Abstract. The article discusses the design features of a destemmer for dried grapes in order to remove the ridges and stalks from them. A series of experiments were carried out on the destemmer design developed by the author, as a result of which the patterns of interaction of various working bodies with dried grapes were established. The most effective operating modes of the destemmer and the optimal parameters of the working parts have been established. Based on the results of a serial industrial test, it was established that this design has a high degree of crushing of bunches and cleaning of dried grapes.

1 Introduction

Uzbekistan is carrying out large-scale measures to reduce labor and energy costs, save resources in the production of environmentally friendly dried fruits using advanced processing technologies, in particular, special attention is paid to the development of resource-saving technologies and technical means for cleaning grapes and fruits and vegetables with high productivity, while preserving all natural and healthy elements. The Development Strategy of the New Uzbekistan for 2022-2026 provides for “increasing the incomes of farmers and farmers at least twice, ensuring annual growth in agricultural volumes of at least 5% through intensive development of agriculture and the application of advanced scientific achievements” [1].

When performing these tasks, it is important to obtain high-quality products from grapes, fruits and vegetables and other agricultural raw materials with the maximum preserved natural and beneficial elements, as well as vitamins, carbohydrates, minerals and reduce their cost through technical and technological modernization of drying and cleaning equipment [2-4].

2 Materials and methods

The object of the study is a mechanized drum-type impact-centrifugal destemmer developed by the authors. It is presented in Figures 1-3 [4-10]. Some varieties of dried sultana and raisin grapes were used as the test product.

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The research methodology is based on the principles of theoretical mechanics, dynamics and mathematical physics.

The destemmer contains a hopper (1) with a feed dispenser (2) and a screw conveyor (3), an inclined rotating cylinder (4), inside which blades (5) are radially fixed around the circumference and two pairs of slats (7) and brush (8) drums are mounted eccentrically on axes (6). The latter are driven by an electric motor (9) and a belt drive (10). The main cylinder rotates due to the friction transmission of support wheels (11), a worm gearbox (12) and a drive (13). In the head part of the cylinder (4) in its loading zone, a rotor is coaxially mounted, which is a dismembrator consisting of an internal a fixed disk (14) and an external disk (15), installed for rotation from an electric motor (16).

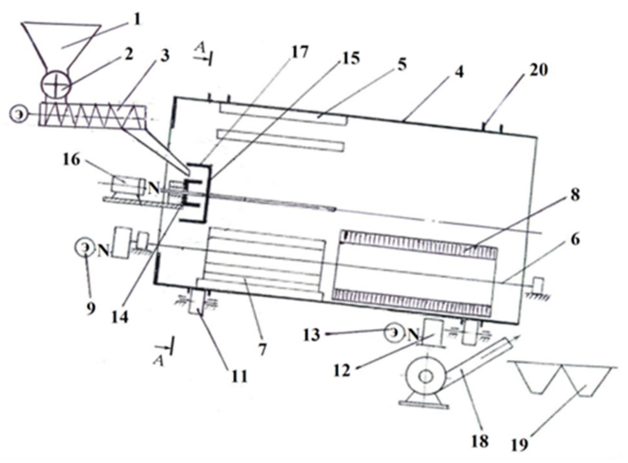

Fig. 1. Centrifugal impact destemmer for dried grapes.

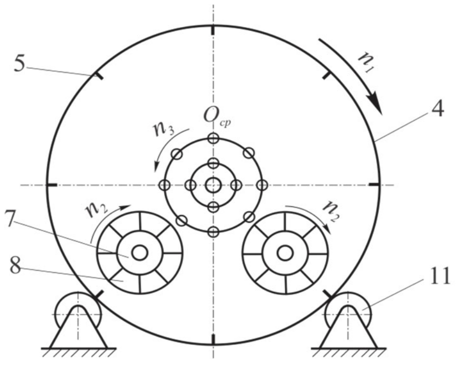

Fig. 2. Cross section of destemmer.

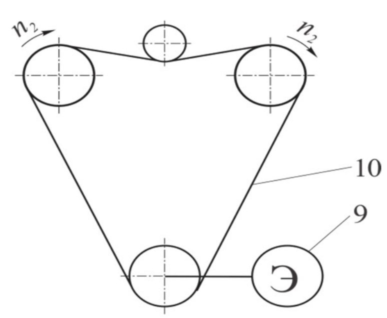

Fig. 3. Kinematic diagram of the drive of slatted and brush drums.

Along the periphery of the disks in concentric circles, fingers (17) are installed in rows, made of an elastic-deformable material, for example, rubber. Both disks form an annular gap, where the feed conveyor tray (3) is directed. Under the output end of the cylinder (4) there is a pneumatic separator (18) and two bins (19): one for cleaned sultanas, the second for collecting waste.

The device is equipped with a control panel (not shown in the figure). The support wheels (11) are placed in two circular tires (20) made of channel No. 10.

Bunches of dried grapes with a moisture content of 18-21% enter through hopper (1) into dispenser (2), where they are pre-crushed into smaller brushes and then through conveyor tray (3) and the tray enter the loading zone of cylinder (4), where a rotating dismembrator is installed. Entering the annular gap formed by the internal fixed disk (14) and the external rotating disk (15), lumps and small tassels of dried grapes collide with the fingers (17) of the dismembrator and are crushed into individual berries and ridges. Further, under the influence of the angle of inclination and centrifugal force, the product moves along the cylinder (4), the blades (5) lift individual grapes (sultanas) and half-hulled tassels to a certain height (lifting angle α>90º), from where, falling, they fall on the surface of both slatted drums (7), rotating at a frequency of 290-370 rpm in the same direction with cylinder (4), the rotation speed of which is 20-24 rpm. In this case, the clusters (tassels) of grapes are crushed into individual berries and ridges, both when they hit the slats of the drums (7), and when they hit the blades (5) and the walls of the cylinder (4). This process is repeated many times until the end of the section of the slatted drums (7) and thereby ensures the separation of the berries from the ridges of dried grapes. At the exit from the drum, the mixture of ridges and fruits undergoes aerodynamic separation.

3 Theoretical research

The raisin mass is heterogeneous in composition and contains impurities in the form of dry ridges and stalks. To crush bunches of dried grapes and remove impurities, it is necessary to apply some kinetic and force action, which would create a regime that ensures the integrity of the sultana berries. To reveal the features of the process, it is necessary to consider the physical essence of the process of interaction of the working fingers of the dismembrator with a bunch of dried grapes.

The working fingers of the rotating disk of the dismembrator drag bunches of dried grapes through the gaps between the fingers of the stationary disk, during which the bunches receive blows from them. The completeness or degree of crushing of the bunches, i.e. the separation of berries from the ridges depends on the force of the impact of the dismembrator fingers on them and their physical and mechanical properties. Studying the process of destruction of bunches allows us to establish certain operating and design parameters of the elements of the dismembrator part of the destemmer (Fig. 4 and 5) [4-7].

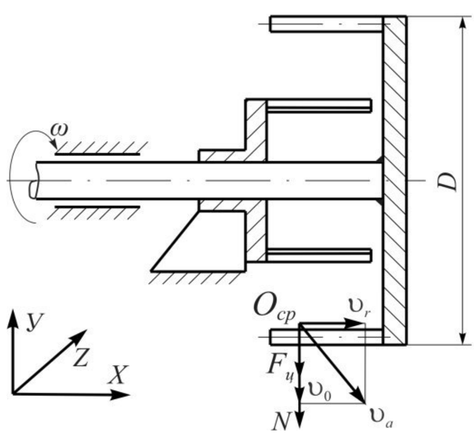

Fig. 4. The process of interaction of the working fingers of the dismembrator with a bunch of dried grapes.

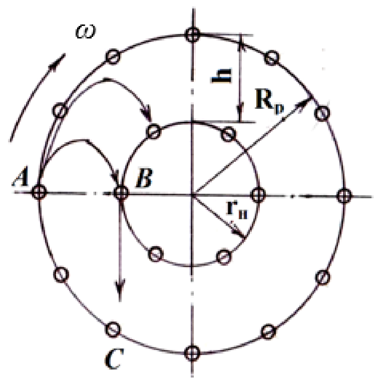

Fig. 5. Analysis of the interaction of a bunch of dried grapes with fingers.

After impact with the fingers at the O_{cp} point, the bunches of dried grapes will have a speed equal to the speed of the fingers of the rotating disk of the dismembrator. In this case, the work of deformation during an inelastic impact is equal to [4].

$$A_d = 0{,}5[m(\upsilon - \upsilon_o)^2 + M \cdot \upsilon_0{}^2] \,, \qquad (1)$$

where A_d – work of deformation, J; m – weight of bunches of dried grapes, kg; M – mass of dismembrator fingers, kg; υ – speed of grapes and fingers after impact, m/s; υ_0 – speed of grape bunches before impact, m/s.

The point of impact with the material can be taken as the point O_{cp} and at this point the finger has a speed

$$\upsilon = \omega r_{cp}, \qquad (2)$$

where r_{cp}– radius of the rotating disc of the dismembrator, m, ω– angular velocity of the pin, rad/s.

The force impulse in this case is determined as follows:

$$S = m\upsilon = m\omega r_{cp} \,, \qquad (3)$$

where m – weight of bunches of dried grapes, kg.

Critical force impulse at which dried grapes are damaged:

$$S_{кр} = m \cdot \upsilon_{dop} \,, \qquad (4)$$

where υ_{dop}– permissible speed of the dismembrator at the moment of impact, at which the sultanas do not burst or become deformed, m/s.

Solving equations (3) and (4) together, proceeding from the condition $S < S_{кр}$, we determine the rotation frequency of the movable disk of the dismembrator if the condition is met:

$$m\omega r_{cp} < m\upsilon_{dop}, \qquad (5)$$

as $\omega = \frac{\pi n}{30}$, we will get from (5):

$$n < \frac{30}{\pi} \cdot \frac{\upsilon_{dop}}{r_{cp}}. \qquad (6)$$

where n - disk rotation speed, min^{-1}.

Then, by experimentally determining υ_{dop}, it is possible to establish a rational rotation frequency of the movable disk of the dismembrator np, which ensures complete crushing of bunches of dried grapes.

When the particle (berries) leaves the fingers of the dismembrator, its absolute speed υ_a is equal to the geometric sum of the circumferential speed υ_o and the relative speed υ_r of the particle moving along the axis of the fingers, i.e.:

$$\overline{\upsilon_a} = \overline{\upsilon_o} + \overline{\upsilon_r}. \qquad (7)$$

Since the fingers are located along the radius of the movable disk, the absolute speed is equal to:

$$v_a = \sqrt{v_o^2 + v_r^2}. \tag{8}$$

To a first approximation, we can assume that the particles move along a parabola, the equation of which is described by the system:

$$\left.\begin{aligned} x &= v_a t \\ y &= 0{,}5gt^2 \end{aligned}\right\}. \tag{9}$$

The fall of the bunches after being struck by the fingers occurs in a vertical plane along the trajectory described by equation (9). In this case, it will be carried out under the action of gravity *mg* and air resistance.

$$R_p = m \cdot k_n \cdot {v_a}^2, \tag{10}$$

where k_n – proportionality coefficient depending on the particle shape.

Figure 5 shows that a bunch of dried grapes, including its individual berries, at the moment of impact at point A, fly out along a parabolic trajectory until they collide with a fixed finger at point B, and then, under the influence of gravity, fall vertically to meeting with the next finger at point C. Since the movable disk of the dismembrator is constantly in rotation, the collision of the grape bunches with the fingers occurs repeatedly in a continuous mode until they are completely or partially separated.

To determine the flight range of particles or the comparable probability of collision frequency with stationary and rotating fingers, which depends on the flight path, taking $y = h = (R_p - r_н)$ and solving the second equation (9) for t and substituting into the first, we obtain:

$$X = v_a \sqrt{\frac{2(R_p - r_н)}{g}}. \tag{11}$$

From (11) it turns out that the smaller the distance h between the moving and fixed fingers, the more often the collision of a particle of a bunch of dried grapes with the fingers.

In addition, the crushing of bunches depends on the density of the brushes, the physical and mechanical properties of the ridges, the degree of withering, humidity, the nature of the impact and processing conditions, the number of fixed and rotating fingers and the material from which they are made. The influence of these parameters on the completeness of crushing is not theoretically possible to determine and they are determined experimentally: in a specific case, for each variety of dried grapes.

4 Results and discussion

Experimental studies have shown that the rational parameters of the destemmer dismembrator for dried grapes (raisin varieties) are the rotation speed of the movable disk n_p=400–500 min^{-1} with its diameter D_p=420 *mm* and the number of fingers *Z=12 pcs*. In this case, the length of the fingers is *l*=100 mm and they are made of elastically deformable material (the rod is made of steel St. 3, and the outer shell is made of rubber). The internal fixed disk is equipped with six fingers fixed with a radius $r_н$=105 *mm*. With these parameters, the degree of fragmentation was experimentally 90-92% [4].

The proposed destemmer has undergone pilot and industrial tests, which have shown that the device provides high-quality cleaning of dried grapes from ridges, debris and stalks due to the free interaction of the product with the active working parts of the device.

The test results were compared with the indicators of the existing grape cleaning technology installed at the Turakurgan dried fruit plant. They are presented in the table. The proposed development passed successful semi-industrial tests on the farm of Zhemchuzhina Gulistan MH LLC in the Syrdarya region and showed a high degree of readiness and suitability for widespread implementation in specialized dried fruit factories of the Republic of Uzbekistan.

Table 1. Results of economic tests of a prototype for cleaning grapes.

Indicators	**Unit**	**Variants**	
		prototype (implemented)	**existing technology (basic)**
Equipment productivity for finished product	kg/h	4-5	4-5
Shift time utilization rate	-	0.76 -0.78	0.60-0.71
Process reliability	-	0.87	0.63
Number of service personnel	people	1	6
Electricity consumption	kWh	88	130
Amount of work per season of use	T	50	50
Seasonal loading per installation	-	40	310

5 Conclusion

Thus, based on the experimental studies carried out, we can conclude that the recommended design of the shock-centrifugal destemmer ensures high-quality cleaning of sultanas from litter, stems and ridges due to the free interaction of grapefruits with certain active elastically deformable fingers of the dismembrator, which do not damage the sultanas fruits and maintain their integrity. The introduced analytical dependencies will make it possible to determine the parameters and operating modes of the destemmer.

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