PITS TRANSPORTING SYSTEM FROM PITTER FRUIT MACHINE - CASE STUDY

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Resume

The paper presents the construction and technological aspects of a device for pitting fruit, especially cherries, on an industrial scale.
The presented work includes design solutions related to the transport of pits removed from pitted fruit, as well as a gravity chute, with an indication of potential operational problems related to the machine design. The authors proposed the use of a screw conveyor, especially in the case of longer drums, to optimize the process. Some analyses are also presented, including friction occurring during the transport of pits. Ultimately, a specific design concept is presented that integrates the screw conveyor with the pitting drum. The presented conclusions point to practical technological and engineering aspects related to fruit processing, suggesting the potential for innovative solutions in the design of pitters.

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1 Introduction

Removing the pit (stone[1]) from the fruit is necessary when preparing preserves, jams or compotes, and in the production of e.g. candied fruit, for decorating baked goods, etc. [1-2]. Initially, this activity was performed manually using simple and generally available tools. Currently, this activity is performed using specialized equipment for industrial scale applications. A pitter is a device used to remove pits from drupes (those with pits) such as cherries, sweet cherries, Mirabelle plums, plums, olives and others. Unlike pulpers, the pitter minimally damages the fruit, leaving it whole. Generally, devices of this type can be divided into manual, semi-automatic and automatic. In addition, pitting machines can be devices for home-use and industrial-use. In the case of home-use pitters, we distinguish between manual and mechanical pitters. They generally have a simple structure and are characterized by low efficiency. Industrial pitters are automated devices with high efficiency of up to 300 kg/h - some devices offered on the market have a capacity of up to 1200 kg/h. Such devices can be generally divided into drum pitters (the element with slots for fruit is a drum) and belt pitters (the element with slots for fruit is a belt or ribbon) [3-5].

The system for transporting pits from pitters should be designed in such a way as to minimize losses, ensure the efficiency of the process and maintain high quality pits (used in further processing, e.g. for planting or as an intermediate product for pellet production). Adapting the system to the specific needs and pit type is key to achieving optimal results.

Currently used solutions for the system of transporting pits from a fruit pitting device in the form of a pitter, especially a drum pitter, use a chute (inclined plane). After pitting the fruit, the pit falls into the chute, which has a ramp set at an appropriate angle, allowing the pit to move by gravity and thus evacuate it from the pitting machine. A diagram of the current solution is shown in Figure 1.

This solution is very simple and effective. However, a problem occurs when the drum used has more than

1 *Pit fruit (stone fruit) - the seed or stone in the middle of various foods such as: olives, peaches, cherries, apricots, avocados, and plums*. The authors of this paper decided to use the name "pit", but it is an equal name "stone".

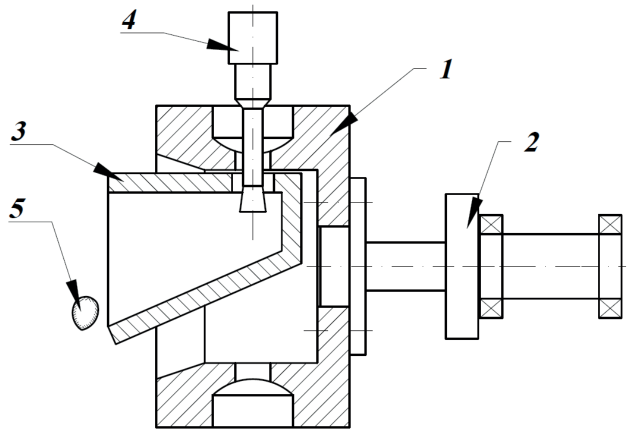

***Figure 1** Scheme of the solution for evacuating a cherry pit using a gravity chute. 1 - pitter drum with fruit slots, 2 - drum drive shaft, 3 – gravity chute, 4 – pitter tip, 5 – evacuated pits*

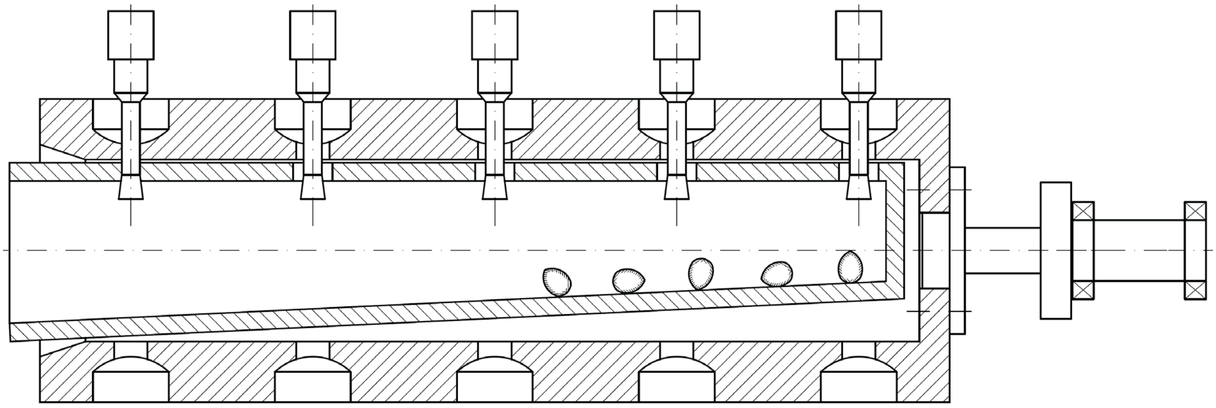

***Figure 2** Chute for a longer drum. The angle of discharge decreases significantly*

one row of slots located around its circumference. In this case, the length of the entire drum increases and, as a result, the angle of inclination of the chute decreases. This is schematically shown in Figure 2.

If the internal diameter of the drum is (standard) 60 mm (which allows for the arrangement of eight sockets around the circumference) and its length, determining the length of the chute, is 300 mm, the angle of the chute is reduced below 1.5°. It is assumed that the minimum effective angle of gravity chute should be 5° to 8° (typically, due to the most reliable evacuation of the pits, the angle is between 30° to 60°). At an angle of 1.5° and less, there is a high probability that the pits will not slide down the chute by gravity and will get stuck on its surface. This state of affairs is determined by the fact that the pit itself is covered with juice and fruit remains, which gives it certain adhesive properties and increases the possibility of "sticking" to the surface of the chute with too small an angle of inclination.

One of the ways to improve the efficiency of the pits' evacuation from the chute is to increase the angle of inclination, which requires increasing the internal diameter of the drum for a given length of the chute. Due to design reasons, this solution is not always possible, as it would significantly increase the overall dimensions of the entire device. The second solution used in such a case is a water jet, whose task is to rinse the pits. The disadvantage of this solution is the need to use clean water, which must be discharged into the sewage system or subjected to a purification process. Therefore, the authors of this article propose to use a screw conveyor for the process of transporting pits, which is driven directly from the stoner drum.

2 Materials and methods

The material for research and analysis were the cherry pits, the dimensions and properties of which are presented in Figure 3 and Table 1. The research was carried out on 100 cherry pits. The measurements were calculated according to the following relationships [6-7]:

$$d_g = \sqrt[3]{a \cdot b \cdot c}\,, \tag{1}$$

$$S = \frac{d_g}{b} \cdot 100\,, \tag{2}$$

$$\upsilon = \frac{a \cdot b \cdot c}{6} \cdot \pi, \tag{3}$$

where: d_g is a geometric mean diameter, mm,
a, b, c are main dimensions of the pit, mm (see: Figure 3),
S is a sphericity, %,
υ is a volume, kg/m^3.

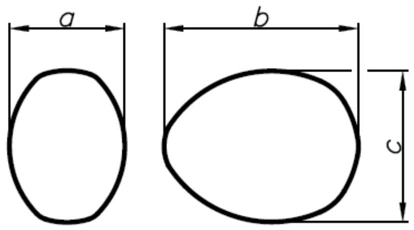

Figure 3 Schematic presentation of the dimensions of the cherry pit being the subject of the analysis

Table 1 Geometrical properties, mass and friction coefficient of cherry pits (averaged results) [7-10]

Physical properties		Value
Dimensions, mm	a	9.00
	b	12.00
	c	10.00
Geometric mean diameter d_g, mm		7.00
Sphericity S, %		60.00
Mass m, g		0.45
Friction coefficient f, - (for galvanized mild steel surface)		0.70

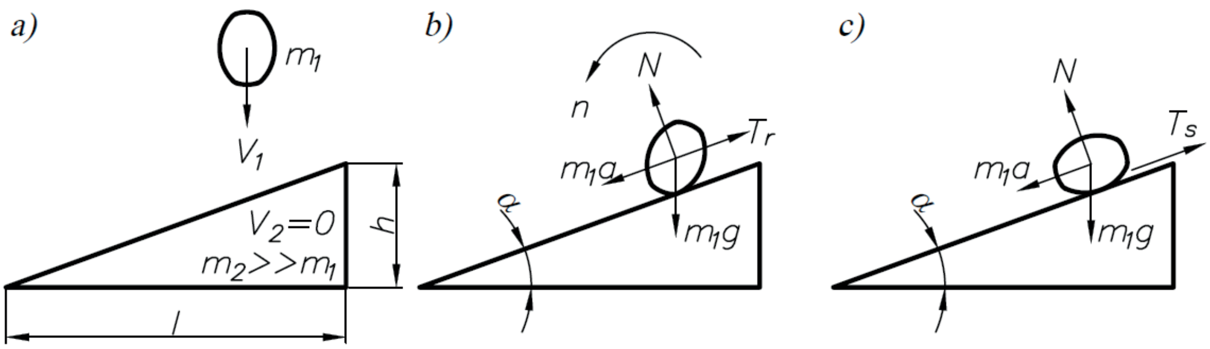

Figure 4 Diagram of the considered possibilities: a) elastic/inelastic collision, b) rolling friction, c) sliding friction

2.1 Analysis of transport efficiency using a gravity chute

A gravity chute can be treated as a classic inclined plane. Analyzing the efficiency of pits transport along an inclined plane is possible after introducing the following aspects - Figure 4.

a) elastic/inelastic collision of pit with an inclined plane,

b) transport on an inclined plane using the rolling friction,

c) transport on an inclined plane using the sliding friction.

When reviewing the structure of the stone pitters, it can be concluded that the standard devices of this type, i.e. pitters with a short drum, have an inclined plane installed with an angle of inclination of at least $\alpha = 30°$, i.e., $tg\alpha \approx 0.6$. This corresponds to the height of the inclined plane h to its length l in the ratio 1.0/1.5 and is the maximum percentage of the radius of the inner diameter of the drum:

$$tg\alpha = \frac{h}{l} \tag{4}$$

where: h is the inclined plane height, mm,
l is the inclined plane length, mm.

Such proportions ensure sufficient geometric parameters of the device for transporting pits outside the pitter and placing such a chute inside the pitter drum. It was also observed that during the transportation of the pits, in the first phase it bounces off the surface of the chute at least once, and finally "rolls" out of it. Due to the irregular shape of the pit and its surface covered with pulp remnants, it is very difficult to model how the pits behave during transport. The first problem is to determine whether the collision of the pit (which has a certain initial velocity after the pitting V_1) with the surface of the chute is an elastic or inelastic collision. Regardless of the type of collision, in both cases, it should be considered that it is a collision of a body (pit, m_1) with a stationary body (inclined plane, m_2) having a very large mass $m_2 >> m_1$ and velocity equal V_2 = 0. According to the principle of conservation of momentum and energy, the velocities of both bodies can be determined from the following relationship:

$$m_1 \cdot V_1 + m_2 \cdot V_2 = m_1 \cdot V_1' + m_2 \cdot V_2', \tag{5}$$

$$\frac{1}{2} m_1 \cdot V_1^2 + \frac{1}{2} m_2 \cdot V_2^2 = \frac{1}{2} m_1 \cdot V'^2_1 + \frac{1}{2} m_2 \cdot V'^2_2, \tag{6}$$

where: V_1, V_2 are the velocities of the pit and inclined plane, respectively, before the collision, m/s,
V'_1, V'_2 are the velocities of the pit and inclined plane, respectively, after the collision, m/s
m_1, m_2 are the masses of the pit and inclined plane, respectively, kg.

For elastic collisions, when determining $m_2 >> m_1$ and $V_2 = 0$:

$$V_1' \approx - V_1, \tag{7}$$

$$V_2' \approx 0. \tag{8}$$

For inelastic collisions, when determining $m_2 >> m_1$ and $V_2 = 0$:

$$V_1' + V_2' \approx 0 \tag{9}$$

In the first case, the velocity of the pit after the collision will have the same value, but in the opposite direction. In the second case, the pit's velocity will be "suppressed" by the mass of the plane. In fact, the rebound of the pit is "between" elastic and inelastic collision. The irregular shape and adhesive properties of the pulp remaining on the pit complicate the calculations.

Let us now consider the case of the possibility of the pit rolling with a rotational motion. According to the law of dynamics for progressive motion:

$$m_1 \cdot a = m_1 \cdot g \cdot \sin\alpha - T_r, \tag{10}$$

where: a is an acceleration, m/s^2,
g is an acceleration of gravity, m/s^2,
T_r is the rolling friction force without slipping, N.

According to the law of dynamics for rotational motion:

$$I \cdot \varepsilon = r \cdot T_r, \tag{11}$$

$$a = \varepsilon \cdot r, \tag{12}$$

where: I is a moment of inertia (we assume for a sphere), kgm^2,
ε is an angular acceleration, rad/s^2,
r is a pit (sphere) radius, m.

After solving the above equations, assuming that the pit is a sphere and assuming no slip, the translational motion of the body is uniformly accelerated, then the linear velocity can be written:

$$V = \sqrt{g \cdot h}. \tag{13}$$

Analogously, for the case of a pit sliding off an inclined plane without slipping (T_s is a sliding friction force), using Equation (11) and making the appropriate transformations, one obtains:

$$V = \sqrt{2 \cdot g \cdot h \cdot (1 - ctg\alpha)}, \tag{14}$$

Analyzing Equations (13) and (14) one can see that for h → 0, V → 0 aswell.

2.2 Analysis of transport efficiency using a screw conveyor

Of course, the above considerations are very simplified and do not fully reflect the real conditions. However, based on the above relationships and the engineering intuition, one can assume that for the small plane angles, transport of the pits outside the pitter will not be possible.

Therefore, the authors proposed a solution consisting in transporting the pits using a screw conveyor. The movement of the working element of the conveyor (spiral) can be carried out using a separate drive or integrated (connected via a clutch) with the main drive of the pitting machine drum.

To calculate such a conveyor, the relationships presented in sources [11-15] can be used. We assume that, for the purposes of the solution, the conveyor operates at an angle of inclination α = 0. The velocity of pits' movement in the trough can be found from the relationship:

$$V = \frac{p \cdot \omega}{2\pi}, \tag{15}$$

where: p is a screw pitch, m,
$\omega = 2\pi n$ is an angular speed of the screw, rad/s,
n is a rotational speed, rps.

The volumetric efficiency Q_v, m^3/h, and the mass efficiency of the horizontal conveyor Q_m, t/h are calculated from the relationships:

$$Q_v = 450 \cdot [(D + 2\delta)^2 - d^2] \cdot p \cdot \omega \cdot \lambda, \tag{16}$$

$$Q_m = 450 \cdot [(D + 2\delta)^2 - d^2] \cdot p \cdot \omega \cdot \lambda \cdot \rho_s, \tag{17}$$

where: D is an external diameter of the screw, m,
d is an internal diameter of the screw, m,
δ is a radial clearance between the screw and the trough housing, m,
λ is a trough filling factor (see: Table 2),
ρ_s is a bulk density, t/m^3.

Traction force on the drive shaft F_H, N, is:

$$F_H = q \cdot l \cdot k \,, \tag{18}$$

where: q is a unit load of the conveyor, N/m,
l is a length of the conveyor, m,
k is a motion resistance coefficient (see: Table 2).

Conveyor driving power, P, W, is:

$$P = \frac{Q_v \cdot l \cdot \rho_s \cdot g}{3600} \cdot k \,. \tag{19}$$

Based on the above assumptions and calculations, a solution involving the mechanical transport of pits was presented. It was decided to use a screw conveyor in the form of a spiral made of steel wire with a square cross-section, which is integrated with the pitting machine drum and rotates simultaneously with it. The operation diagram is presented in Figure 5. A cross-section of the proposed solution is shown in Figure 6.

The principle of operation is as follows. The pitting machine drum 1 is driven directly by the drive shaft 2 (the drum and the shaft are connected with a prismatic key). The conveyor screw 3 is connected to the drive shaft 2 via a clutch. The conveyor screw is mounted on a slide bearing installed in the evacuation channel 4. The evacuation channel 4 is attached to the frame of the device - the pitting machine (not shown in the diagram) in such a way that it is immobilized. The pitting machine drum 1 and the conveyor screw 3 rotate simultaneously using a motor connected to the drive shaft 2. With each revolution of the drum and screw, the pitted pit is moved towards the outlet until it is completely evacuated.

3 Conclusions

In the fruit processing, an effective method of evacuating pits from pitted fruit, e.g. cherries, plays a key role in maintaining high efficiency of the production process. The issue of transporting pits, especially in the context of the construction of pitters with drums of increased length, is quite important due to the possibility of material blocking in the form of pits from pitted cherries. For that reason, the screw conveyors become a promising solution to these problems while eliminating the need to increase the angle of inclination of the chute. An innovative approach to the design of pitters has the potential to significantly improve both the efficiency and quality of the pit transport.

The proposed new design solution, supported by the field tests, is crucial for the safe handling of pitted pits, minimizing the risk of their blocking. The authors focused on improving the transport technology and

***Table 2** Calculation parameters for various types of transported materials [12]*

Material	λ	k
Light, free-flowing and non-abrasive materials, e.g. grain, rapeseed, groats, ground coal	0.45 ÷ 0.50	1.25
Medium-weight, non-abrasive, fine-grained materials, e.g. beans, soybeans, gravel, coal dust	0.38 ÷ 0.40	1.45 ÷ 1.85
Low-abrasion, fine-grained materials, e.g. coal, walnut, ash, lime, salt	0.30	2.10 ÷ 2.60
Medium abrasive materials, e.g.: cement, gypsum, fine limestone, foundry sand, sulfur, sodium acid phosphate	0.25	3.20 ÷ 4.00

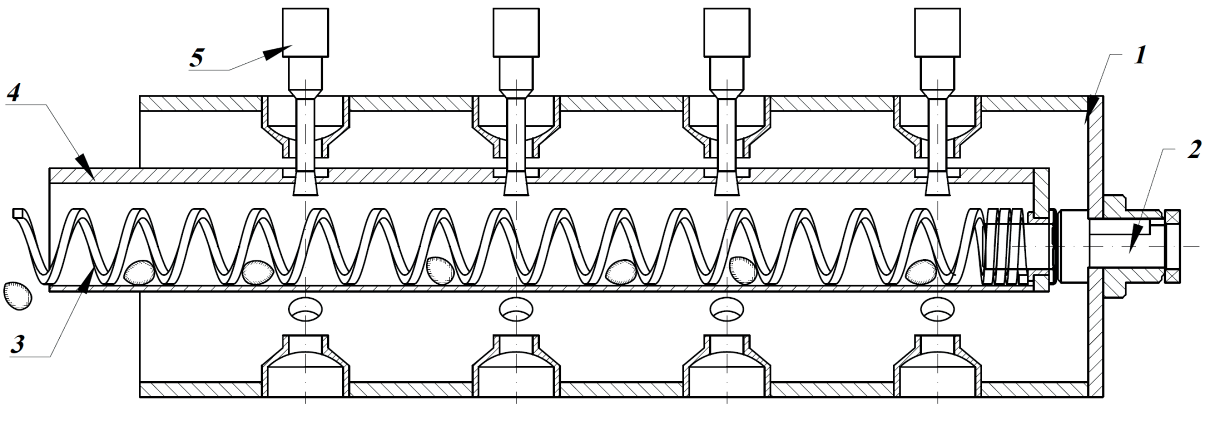

***Figure 5** Operational diagram of the pit evacuation system from the fruit pitting device.
1 - pitter drum with slots for cherries, 2 - drum drive shaft with clutch,
3 – conveyor screw, 4 – escape channel, 5 – pitter tips*

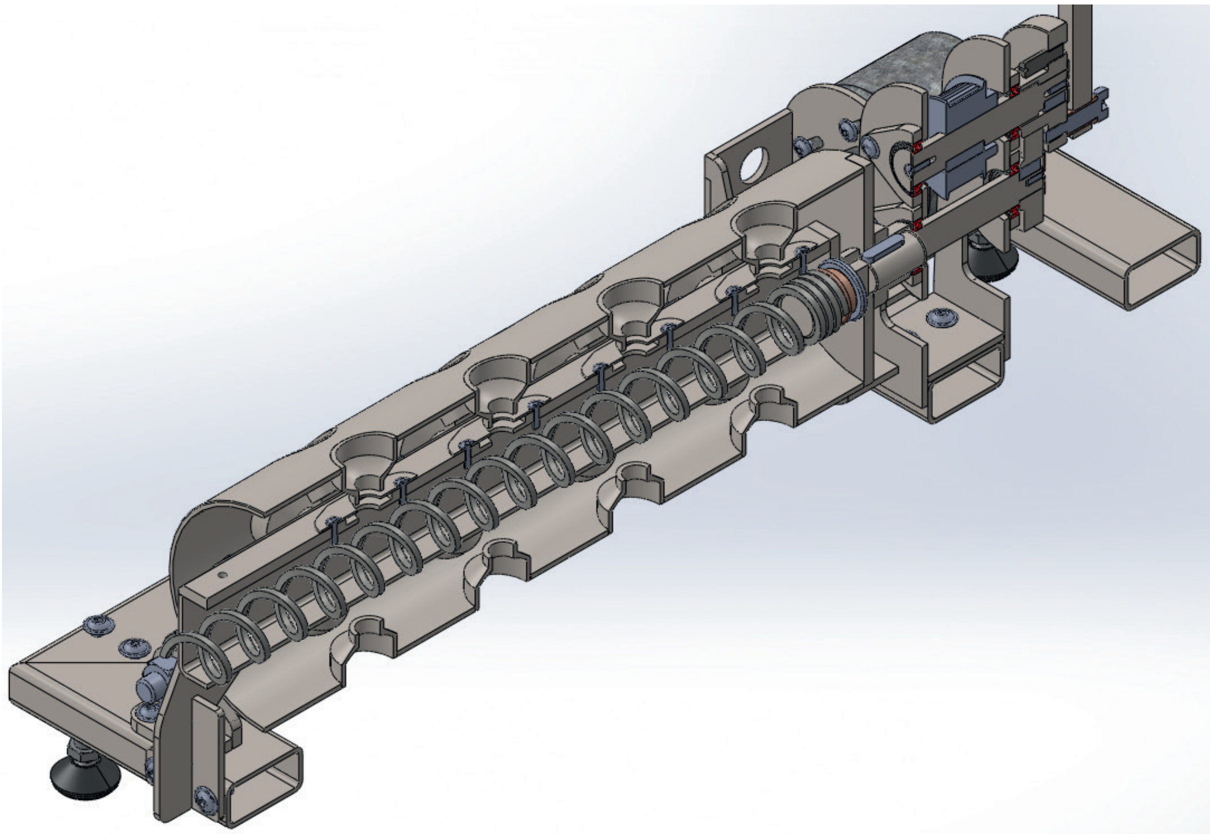

Figure 6 *Cross-section of the proposed solution for a ready-made drum pitter design*

designing a new chute to increase the reliability of the entire process, while eliminating the potential problems related to blocking of the evacuated pits. Another very important aspect of the developed structure is ease of use and hygiene maintenance, which is so important in all the fruit treatment processes.

The next step in improving the efficiency of pitting may be the introduction of automation and monitoring of the entire process, which will translate into an additional increase in efficiency, quality and reliability of the pitting process.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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