UDC: 631.1: 635.1/.8: 634
DOI: 10.56407/bs.agrarian/3.2025.09

**Ukrainian Black Sea Region Agrarian Science**
**Vol. 29, No. 3**

# Justification of the design parameters of improved equipment for tomato processing

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**Abstract.** The implementation of a full-cycle tomato processing operation is a complex technological task that requires precise control of various parameters to ensure the high quality of the final product. The main stages of the process include raw material preparation, mechanical crushing of tomatoes, separation of juice from pulp and skin, as well as additional treatment to enhance the organoleptic and nutritional properties of the juice. The objective of this study was to investigate the relationship between processing performance and the optimal parameters of improved tomato processing equipment, specifically: the clearance between beaters and sieve, the rotational speed of the perforated drum, and the feed rate of the crushed mass. The article presented an improved structural solution for tomato processing equipment, characterised by the integration of crushing and pulping operations, which reduces both the metal intensity of the design and the energy consumption of the process. The study involved determining the percentage content of components in the crushed tomato mass by weighing each fraction. Based on the collected data, an a priori ranking of influencing factors was performed using expert evaluation. The most significant factors affecting the technological process were identified. Through mathematical modelling and experimental studies, the optimal operating modes of the equipment were established to achieve maximum juice yield with minimal energy consumption. Special attention was given to the consideration of design and operational parameters such as angular drum speed, productivity, and equipment power. The analysis of constructive and technological factors influencing the process showed that the optimal configuration includes a beater-sieve clearance of 2 mm, a pulp feed rate of up to 80%, and a drum rotational speed of up to 25 m/s, which ensures a pulping efficiency of approximately 90%. The obtained results can be used for upgrading existing tomato processing lines and developing new production facilities in accordance with current market demands

**Keywords:** tomato crusher; raw material pulping; pulp; agro-industrial sector; mechanical processing

***Article's History***:
Received: 21.05.2025
Revised: 09.08.2025
Accepted: 30.09.2025

***Suggested Citation***:
Babenko, D., Dotsenko, N., & Gorbenko, O. (2025). Justification of the design parameters of improved equipment for tomato processing. *Ukrainian Black Sea Region Agrarian Science*, 29(3), 9-22. doi: 10.56407/bs.agrarian/3.2025.9.

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## INTRODUCTION

To develop and improve tomato processing equipment, several key factors need to be considered: the type of product to be processed, technological requirements, productivity and economic aspects. Tomato sorting and washing lines must ensure that tomatoes are thoroughly cleaned and sorted by quality and size. Capacity depends on the needs of the enterprise and can vary from several hundred kilograms to several tonnes of tomatoes per hour. The technological processes of processing companies require high accuracy of technological operations, but the design of food production lines faces the problem of excessive energy and metal consumption and the need to adapt equipment to the mechanical and technological properties of a particular product. A classic variant of the tomato processing scheme is to perform the crushing and mashing stages separately. Insufficient attention is paid to the study of the design and technological parameters of tomato processing equipment that affect the productivity of the production line. Therefore, determining the optimal parameters of the equipment for wiping tomato pulp is a key issue in the implementation of the technological process of tomato juice production. Improvement of tomato processing equipment should be aimed at increasing efficiency, quality of the final product and reducing operating costs.

According to K. Mukhopadhyay *et al*. (2021), it is important to consider materials, performance, automation, and environmental aspects when designing, which will allow creating equipment that meets the modern requirements of the food industry and meets the needs of both small and large businesses. To justify the design parameters of advanced tomato processing equipment, several key aspects should be taken into account: production requirements, raw material properties, technological processes, and final product quality requirements. In the study by V. Shebanin *et al*. (2019) noted that production requirements are determined by the required volume of tomato processing per unit of time. It depends on the scale of production and the planned volume of output. Tomatoes contain a large amount of water, which must be taken into account when choosing methods of processing them. The design parameters of cutting and chopping machines should ensure product homogeneity and minimal loss of raw materials.

The analysis of tomato processing machines focuses on machines for wiping and crushing raw materials. These include: crushers with toothed rollers, disc grinders equipped with a centrifuge for grinding and further separation, and wiping machines for separating juice from pulp. In the work of Z. Kaliniewicz *et al*. (2021) noted that the size of the crushed particles and the ratio of the average size before and after deformation is key to the process. However, despite the variety of crusher designs, it should be noted that the main design requirement is the easy replacement of working bodies and parts. Researchers B. Kotov *et al*. (2019) noted that the crushed product requires pieces of the same size in each fraction. When designing a structure, it is also important to take into account the lowest permissible metal consumption of the structure and the presence of elements that prevent clogging of the working bodies, which can lead to an accident. Shredding machines can be divided into impact, crushing, splitting, and abrasion based on the nature of the applied force. In the context of practical use of machines, it is advisable to combine different types of deformation. The choice of deformation type directly depends on the type and characteristics of the material to be processed (DSTU 8439:2015, 2015; DSTU 7160:2020, 2020).

Z. Despotovic *et al*. (2019) argued that determining the amount of work to break the mutual adhesion of particles is one of the key aspects in the theory of grinding. G. Kaletnik *et al*. (2020) noted that volumetric deformation and heat generation are the main components of the deformation work of grinding machines. Researchers E. Eslami *et al*. (2025) studied the effect of tomato packaging on different types of processed tomato products in terms of the requirements for sustainable production of different categories of processed tomatoes. C. Sena *et al*. (2025) presented algorithms for efficient sowing of tomatoes for industrial processing in arid regions. E. Eslami *et al*. (2024) identified resource conservation strategies in tomato processing that led to significant savings in water (23.4%), electricity (14.7%) and methane (28.7%) and, as a result, to 16 and 19% reduction in global warming potential in peeled tomato and tomato puree production lines, respectively.

Research in the field of tomato processing has presented such key aspects of the issue as the study of the mechanical and technological properties of raw materials, production requirements for tomato processing, and general requirements for the technological process. However, the analysis of scientific sources did not reveal numerous studies on the improvement of tomato processing equipment, so the justification of the design parameters of improved tomato processing equipment is an important subject of research. The aim of the study was to substantiate the methodology for determining the angular velocity, determining the productivity and determining the power consumption of the proposed design solution for tomato processing, to determine the optimal parameters, and to study their impact on the technological process performance.

## MATERIALS AND METHODS

Studies involving experimental work with plants, including the collection of plant material, were carried out in accordance with the established norms and requirements of the institutional, national or international level. The authors followed the standards of the Convention on Biological Diversity (1992). The mass obtained after grinding, consisting of juice, pulp and crushed peel, was of the greatest interest for the study. Therefore, in the course of laboratory research, two types of objects were investigated: the mass after the grinding device and the tomato fruit. The study was conducted at a temperature of 20-22 °C and relative humidity of 60-70%. For weighing the samples, we used laboratory scales with an accuracy of 0.01 g Ohaus Pioneer PX 3202 (Minebea Intec, Germany), measuring cylinders SBP-1, a set of sieves LS-20 with holes of different diameters. The methodology is based on well-known recommendations (Bortz & Schuster, 2010), as well as the specific conditions of experiments with the development and manufacture (Bezusov & Totsenko, 2017). The average value of the set of obtained values $X_a$ was determined by the formula for the statistical mean:

$$X_a = \sum_{k=1}^{N} X_{av \cdot k} \cdot P_k, \tag{1}$$

where $P_k$ is relative frequency or weight of the $k$-th group/variant in the total amount of data; $X_{av \cdot k}$ – is the average value for the $k$-th group.

The formula for the mean square of the deviation $S$ was used to estimate the divergence of the values of the random variable $X$ around the average value $X_a$:

$$S = \sum_{k=1}^{N} (X_{av \cdot k} - X_a)^2 \cdot P_k. \tag{2}$$

The standard deviation $\sigma$ demonstrates a comparison of the spread of values near the centre of the distribution and a random variable:

$$\sigma = \sqrt{S}, \tag{3}$$

where $S$ is the variance.

The coefficient of variation was also found $v$:

$$v = \left(\frac{\sigma}{X_{av}}\right) \cdot 100\%. \tag{4}$$

The error rate (error) of the experiment $p$, should not exceed 4.0%:

$$p = \pm \frac{\sigma}{X_a \cdot \sqrt{n}} \cdot 100\%, \tag{5}$$

where $n$ is the number of experiments.

Determination of the percentage of components of the crushed mass of fruit $C_{ps}$ was carried out by weighing each fraction according to the formula:

$$C_{ps} = \left(\frac{m_i}{\sum_{Ci=1}^{n} m_i}\right) \cdot 100\%, \tag{6}$$

where $Ci\,m_i$ is percentage of both the mass and the $i$-th fraction.

The relationship for determining the ratio between the components is as follows:

$$C_{ps} = \left(\frac{m_j}{\sum_{Cj=1}^{n} m_i}\right) \cdot 100\%, \tag{7}$$

where $Cj\,m_j$ is respectively, the percentage ratio of both the mass and the $i$-th component.

Determine the dynamic and kinematic parameters, it is necessary to investigate the dependence of fetal deformation on the applied static and dynamic load. For this purpose, the least squares method was used, followed by an adequacy test using Fisher's criterion. The determination of the functional dependence $y = f(x)$ of the trait under study was carried out at j fixed argument values, with $j \geqslant 4$. The repetition of the experiment at each point of the fixed argument value was $n = 5$. Also, to check the uniformity of the results obtained, the average value of the function at each point was calculated, i.e:

$$Y_j = \frac{1}{n} \cdot \sum_{s=1}^{n} Y_{ij}, \tag{8}$$

where $Y_{ij}$ is the average value of the function at the $j$-th point.

It was also assumed that the obtained dependence could be described by a 1st degree function:

$$Y = ax + b, \tag{9}$$

where $x$ is influence factor; $a$ is an indicator that indicates the change in $Y$ when $X$ changes; $b$ is a free term or the ordinate of the origin.

After that, the adequacy was checked by Fisher's criterion $F_k$. If the condition $F_{table} \geq F_k$ is met, with a given number of degrees of freedom, the hypothesis is confirmed. To characterise the general population by discrete variational features, sample statistical observation is used. The extreme values are denoted as $X_{min}$ and $X_{max}$. The total number of samples n for each of the attributes was taken to be at least 50. At the same time:

$$n = \sum_{i=1}^{n} l(i), \tag{10}$$

where $l$ is a number of elements in the $i$-subgroup.

The statistical series of the feature $X$ was divided into a number of classes $N_k$. $N_k = 10$ with $n \geqslant 50$. The class step $t$ is determined from the expression:

$$t = \frac{X_{max} - X_{min}}{N_k}, \tag{11}$$

where $X_{max}, X_{min}$ – maximum and minimum sample values.

The bounds for any $k$-th class were defined as:

lower bound:

$$X_{k-1} = X_{min}, \tag{12}$$

upper bound:

$$X_k = X_{k-1} + t. \tag{13}$$

Relative frequency of observations for any $k$-th class:

$$P_k = \frac{n_k}{n}, \tag{14}$$

where $n_k$ is the number of variants falling into the $k$-th class; $n$ is the total number of observations. Check formula for verifying the calculations performed:

$$\sum_{k=1}^{N} P_k = 1. \tag{15}$$

Arithmetic mean value of the trait by classes:

$$N_{k.cp} = \frac{(X_{k-1} + X_k)}{2}. \tag{16}$$

The adequacy of the description of the dependence is accepted with a significance level of 0.95, which is recommended for research in agriculture. If $F_k > F_{table}$ the hypothesis about the linear nature of the dependence under study was rejected and the description of the dependence by the expression:

$$Y = a \cdot X^2 + b \cdot X + C; \; Y = a \cdot X^3 + b \cdot X^2 + c \cdot X + d. \tag{17}$$

With repeated checking of the adequacy. The percentage of each component of the crushed mass was determined by the formula:

$$C_{pj} = \left(\frac{m_{pj}}{m}\right) \cdot 100\%; \; C_{ps} = \left(\frac{m_{ps}}{m}\right) \cdot 100\%;$$

$$C_p = 100\% - \left(C_{pj} + C_{ps}\right), \tag{18}$$

where $C_{pj}$, $C_{ps}$, $C_p$ is the percentage of pure juice, peel with seeds and pulp in the crushed mass; $m_{pj}$, $m_{ps}$ is the mass of pure juice, peel with seeds in the crushed mass; $m$ is the total mass of crushed tomatoes.

The percentage of peel with seeds in each group was determined by the following relationship:

$$C_1 = \left(\frac{m_1}{m_k}\right) \cdot 100\%; \tag{19}$$

$$C_5 = \left(\frac{m_5}{m_k}\right) \cdot 100\%; \tag{20}$$

$$C_7 = \left(\frac{m_7}{m_k}\right) \cdot 100\%, \tag{21}$$

where $m_1$, $m_5$, $m_7$ – is the weight of the peel with seeds of each size group contained in the pulp; $m_k$ is the total weight of the crushed peel with seeds.

The principle of operation of the advanced tomato processing equipment is that by placing wiping beats in the inner perforated drum, the tomato pulp is separated, and its final wiping and separation into fractions is carried out in the gap between the inner and additional perforated drum (Fig. 1). The fraction of peel and pulp that has not been crushed is discharged by screw turns.

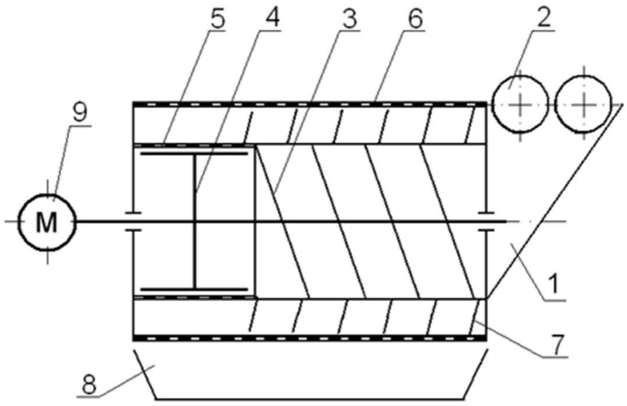


***Figure 1.*** *Diagram of the laboratory installation of the improved design solution*

***Note:*** *1 – intake neck; 2 – rollers; 3 – coils for moving raw materials; 4 – wiping beats; 5 – internal perforated drum; 6 – additional perforated drum; 7 – auger; 8 – juice collection tray; 9 – drive*

***Source:*** *developed by the authors*

As criteria for optimising the technological process of tomato processing, the juice yield $Q$ (%) spent on the technological process was chosen. The factors influencing the course of the technological process included the rotor rotation speed $V$ (m/min); the gap of the scourge-sieve l (mm) and the level of supply of the crushed mass for wiping $M$ (%). The study of the design (gap between the scourge and sieve) and technological (rotation speed of the perforated drum, level of inflow of the crushed mass) factors of the improved tomato processing equipment was carried out. In order to avoid overloading the equipment for wiping tomatoes and to avoid clogging of the sieve, an acceptable level of inflow of the crushed mass for wiping was selected.

## RESULTS AND DISCUSSION

Taking into account the analysis of design solutions for tomato processing machines, the improved design meets the following parameters: increased juice yield, increased productivity, preservation of the physical and chemical properties of the crushed material, reduced energy consumption and increased productivity, increased reliability by preventing screw clogging. The assembly drawing of the improved design is shown in Figure 2.

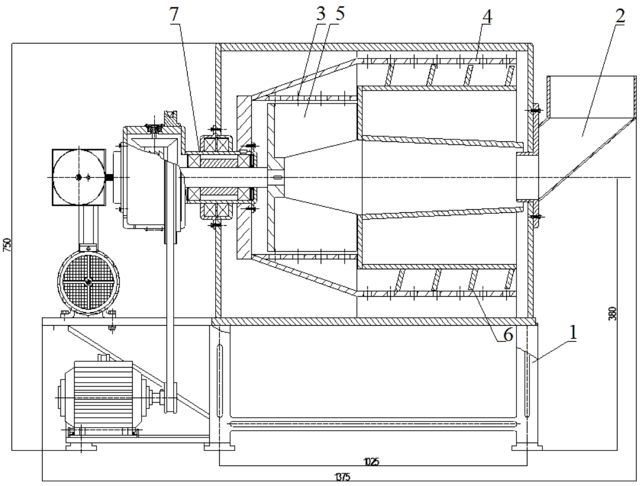


***Figure 2.*** *Improved design solution*

***Note:*** *1 – frame; 2 – receiving chamber; 3 – perforated drum; 4 – outer drum; 5 – grinding device; 6 – auger; 7 – shaft*

***Source:*** *developed by the author on the basis of Patent No. 154661 (2023)*

The proposed design solution allows to significantly reduce the stages of the technological process of tomato processing by combining the processes of grinding and rubbing (Fig. 3). To determine the design parameters of the proposed solution, we determined the angular velocity of movement of raw materials, determined the productivity and power.

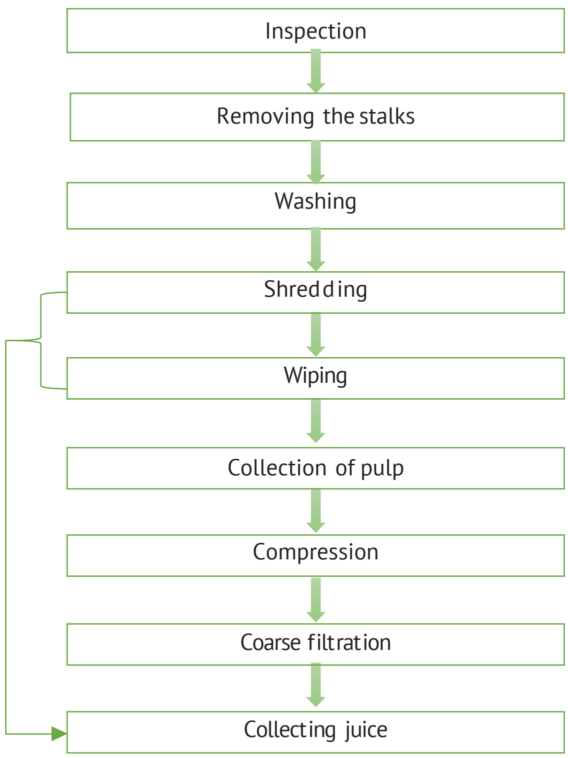


***Figure 3.*** *Stages of the technological process of tomato processing with the participation of an improved design solution*

***Source:*** *developed on the basis of Patent No. 58968 (2011)*

**Determining angular velocity**

The essence of the process of separating juice from pulp using advanced tomato processing equipment is the passage of the crushed mass along a rotating inner surface. This surface can be either an angled cylinder or a conical surface with a horizontal axis. Separation processes on these two surfaces do not differ from each other, since the angle of inclination of a conical surface in practice does not exceed 5-6°. Thus, the theoretical basis for separating material from a cylindrical, inclined surface is fully applicable to a conical surface. When a conical surface is used, a correction factor is introduced to account for the reduction in area compared to an inclined cylinder. In the case of a machine with a horizontal cylindrical drum, if the cylindrical rotor is stationary, the material is retained on its inner surface no higher than point *A* (Fig. 4a), for which the angle *AOD* with the vertical is equal (Lerner & Trigg, 1991):

$$\alpha = \varphi, \tag{22}$$

where $\varphi$ is friction angle of the crushed mass.

Then the friction coefficient can be expressed as:

$$f = tan\varphi. \tag{23}$$

This is based on the equilibrium condition of a body of mass $G$ on an inclined plane with an angle of inclination $\alpha$ (Fig. 4b):

$$G \cdot \sin\alpha - F = 0, \tag{24}$$

where the friction force:

$$F = f \cdot G \cdot \cos\alpha, \tag{25}$$

when the drum is rotating at a circular speed:

$$V = \frac{2 \cdot \pi \cdot R \cdot n}{60} = \frac{\pi \cdot R \cdot n}{30}, \tag{26}$$

where $n$ – is the number of its revolutions per minute.

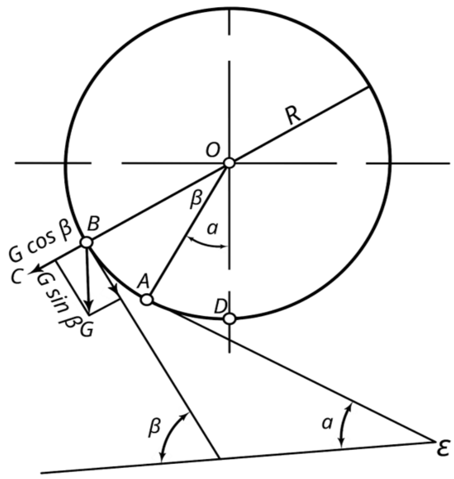


***Figure 4a.*** *Condition of equilibrium and movement of raw materials before determining angular velocity*
***Source:*** *compiled by the author on the basis of A. Maas (2017)*

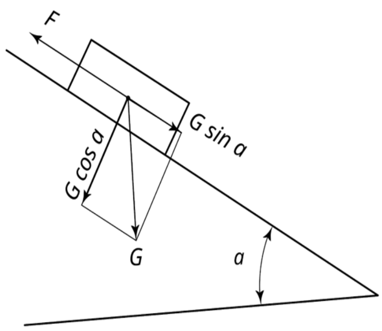


***Figure 4b.*** *Equilibrium condition for raw materials on an inclined plane*
***Source:*** *compiled by the author on the basis of A. Maas (2017)*

A centrifugal force of inertia occurs:

$$C = m \cdot j = \frac{G}{g} \cdot \frac{v^2}{R}, \qquad (27)$$

pressing the material of mass $G$ against the inner surface of the rotor and causing an additional friction force equal to:

$$f \cdot c = f\frac{G}{g} \cdot \frac{v^2}{R}. \qquad (28)$$

Therefore, when a cylindrical drum rotates, the material can rise above point $A$, for example to point $B$, for which the angle of rise $BOD = \beta > \alpha$. The lifting angle increases as the angular speed of rotation n increases. You need to derive the relationship between the angle of elevation $\beta$ and the angular velocity of rotation of the cylinder n. The equilibrium of the material at the desired point $B$ is possible only if the following conditions are met:

$$G \cdot \sin\beta - f(c + \cos\beta) = 0, \qquad (29)$$

or:

$$\sin\beta = f(\frac{v^2}{g \cdot R} + \cos\beta), \qquad (30)$$

therefore:

$$\frac{\sin(\beta - \varphi)}{\cos\varphi} = \frac{\sin\varphi \cdot v^2}{g \cdot R \cdot \cos\varphi}, \qquad (31)$$

and finally:

$$\sin(\beta - \varphi) = \frac{\sin\varphi \cdot v^2}{g \cdot R}. \qquad (32)$$

The angle $AOB = \alpha - \varphi$ at any circumferential velocity $v$ can be determined when the material friction angle $\varphi$ and the drum radius $R$ are known. The lifting angle $\beta$ increases with the increase in the circumferential speed $v$. The higher the material rises above point $A$, the greater the angle $\beta - \alpha$, the faster the material will move down, the less efficient the wiping of the raw material will be, which is generally possible only up to the relative material speed mm/min, which is determined by the formula:

$$v = 73.5\sqrt{d}, \qquad (33)$$

where $d$ is diameter of holes; sieves, mm.

At a sufficiently high-speed $v$, the centrifugal force $C$ keeps the material pressed against the inner surface of the cylinder at all times; in this case, in the absence of relative movement of the material along the sieve, any possibility of grinding and passage of raw materials can be excluded. Optimal operating conditions of a rotary shredder can be achieved at a rotational speed sufficient to lift the material to some point $B$, which is higher than point $A$, so the angle of lift should be slightly greater than the angle $\alpha - \varphi$. Based on the data from the practice of using rotary shredders, the lifting angle $\beta$ is equal to:

$$\beta = \alpha + (5° - 10°) = \varphi + (5° - 10°), \qquad (34)$$

therefore:

$$\beta - \varphi = 5° - 10°. \qquad (35)$$

Solving the equation with respect to $v$, the expression is transformed as follows:

$$v = \sqrt{\frac{g \cdot R \cdot \sin(\beta - \varphi)}{\sin\varphi}}, \qquad (36)$$

then the number of rotation *n*:

$$n = \frac{30 \cdot v}{n \cdot R} = \frac{30}{n \cdot R}\sqrt{\frac{q \cdot R \cdot sin(\beta - \varphi)}{sin\,\varphi}} = 30\sqrt{\frac{sin(\beta - \varphi)}{R \cdot sin\,\varphi}}, \qquad (37)$$

where $R$ measured in meters, and the acceleration of gravity $q = 9.81$ measured in m/min$^2$.

Since the material has to start moving not only on the shredder's screen surface, the upper pieces of material can slide on the layers of material below, the angle of friction of material on material at rest can be assumed to be on average: $\varphi = 35°$, this gives for the lifting angle $\beta = 40° - 45°$.

Now it is obtained under $\beta - \varphi = 5°$.

$$n = 30\sqrt{\frac{\sin(\beta-\varphi)}{R\cdot\sin\varphi}} = 30\sqrt{\frac{\sin 45°}{R\cdot\sin 35°}} \cong \frac{12}{\sqrt{R}}, \quad (38)$$

where $R$ measured in meter.

The angular velocity of the rotary shredder ranges from:

$$n = \frac{8}{\sqrt{R}} \div \frac{14}{\sqrt{R}}. \quad (39)$$

The angular velocity of a rotary shredder is inversely proportional to the square root of its diameter, which is fully confirmed by the practice of their operation. In general, the linear (circumferential) speed $v$ of a rotary shredder is in the range of:

$$v = 0.6 - 1.25\left(\frac{m}{min}\right). \quad (40)$$

At the lower limit of the circumferential velocity, the material layer on the sieve increases and the efficiency of the grinding passage deteriorates; at speeds above the upper limit, the drum sieve openings stick under the centrifugal force and the passage also deteriorates.

**Defining productivity**

The shape of the individual pieces of material, the value of the friction coefficient and the rotational speed have a direct impact on the angle of rise. That is, the material can either actually rise with the points on the inner surface of the rotor and then slide rapidly down the line of greatest slope. The projection of the average material velocity onto the slow, continuous sliding of the material downwards and out of the plane of rotation itself must be equal to the circumferential velocity v of the rotor and correspond to the continuity and uniformity of the process. In the case where the movement of the material up and down occurs with pauses, as evidenced by how much material rises up in a unit of time, the same amount must fall down in the same time, since the material cannot leave the constant zone at a constant rotational speed. This pattern of material movement is only valid for machines with conical or cylindrical perforated surfaces that have a low angular speed. Consequently, the material moves internally in a regular helical line with a lifting angle $W = 2\alpha$.

Thus, the relative trajectory of the material on the cylindrical surface of the rotor deployed in the plane will be depicted as a straight-line *AF* (Fig. 5), going at an angle, and to the deployed circle by the formula:

$$AB = 2k\cdot\pi\cdot R, \quad (41)$$

where $k$ is the number of revolutions that a rotor with a diameter of $2R$ must make so that a particle of material, moving along the line $AF$, passes the entire length $L$; $M$ is the direction of material supply.

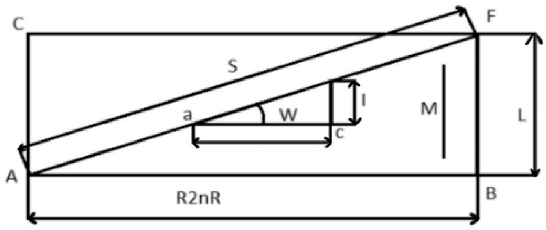


***Figure 5.*** *Relative trajectory of material movement on a surface deployed in a plane*

***Source:*** *developed by the authors on the basis of A. Maas (2017)*

Based on the above, it can be noted that the material moves along the helical spiral, represented in the unfolded form by the line $AF$, with such an average speed that its projection onto the plane of rotation is equal to the $v$-circular speed of the latter. It follows that the length of the path $V$ metres per second along the circumference of the rotor corresponds to the path $L$ along the rotor axis, equal to:

$$L = v\cdot \text{tg}\omega = v\cdot\text{tg}2\alpha, \quad (42)$$

but since this path is travelled by the material in one second, as is the path $v$, $L$ and is the average feed rate along the axis:

$$v_0 = L = v\cdot\text{tg}2\alpha, \quad (43)$$

hence the feed rate is equal:

$$v_0 = v\cdot\text{tg}2\alpha = \text{tg}2\alpha = 0.105R\cdot n\cdot\text{tg}2\alpha. \quad (44)$$

The feed rate is therefore directly proportional to the rotor diameter, its angular velocity and the tangent of the double angle of inclination; this shows that the feed rate increases very rapidly with increasing rotor angle. The feed rate at a steady state is completely independent of its length. The performance is expressed by the formula:

$$Q = \psi\cdot y\cdot v0\cdot F, \quad (45)$$

where $\psi$ is the loosening coefficient of the moving material; $y$ is the specific gravity, kg/m$^3$; $v_0$ is the average feed speed, m/s; $F$ is the cross-sectional area of the moving material layer, m$^2$.

The productivity is equal to:

$$Qi = Q\frac{60\cdot 60}{1{,}000} = 3.6\cdot\psi\cdot y\cdot v0\cdot F\,(\text{m/h}). \quad (46)$$

It is necessary to express the cross-sectional area *F* of the moving layer of material depending on the rotor radius *R* and the layer thickness *h*:

$$\frac{d}{2}\sqrt{R^2-(R-h)^2}=\sqrt{2R}\cdot h-h^2. \qquad (47)$$

Since the height of the material layer must be negligible for successful juice separation, its value $h^2$ can be neglected in practice compared to the value $2R \cdot h$. Then, for the chordal value $AB = d$:

$$d=2\sqrt{R}\cdot h=2.83\sqrt{2R}\cdot h. \qquad (48)$$

Taking the formula for the area of a small segment $F$ as the area of a parabolic segment, the expression is:

$$F=\frac{2}{3}d\cdot h=\frac{2}{3}h\cdot 2.83\sqrt{2R}\cdot h\cong 1.9\sqrt{R\cdot h^3}. \qquad (49)$$

Now the performance can be expressed as follows:

$$Q_t=3.6\psi\cdot y\cdot 0.105R\cdot n\cdot \tan 2\alpha\cdot 1.9\sqrt{R\cdot h^3}, \qquad (50)$$

or after simplification:

$$Q_t=0.72\psi\cdot y\cdot n\cdot \tan 2\alpha\sqrt{R^3\cdot h^3}. \qquad (51)$$

If we assume that the coefficient of loosening of a material moving in a quiet thin layer is equal to:

$$\psi\cong 0.8, \qquad (51)$$

then the sedimentary expression for performance:

$$Q_t=0.6\cdot y\cdot n\cdot \tan 2\alpha\sqrt{R^3\cdot h^3}, \qquad (52)$$

where linear dimensions $R$ and $h$ are measured in meters.

The productivity is directly proportional to the rotational speed, the tangent of the double angle of inclination, the drum radius and the material layer thickness – both of which are in the power of 3/2, so it increases dynamically with increasing angle of inclination, drum radius and material layer thickness; changes in the rotor speed have a smaller effect on the machine's productivity. The thickness of the material layer $h$ to some extent depends on the rotor radius $R$. The larger $R$, the smaller $h$ for the same amount of material entering the rotor at the same time. Typically, the thickness of the material layer is in the range of 1.5 ÷ 5 cm. That is, $h$ cannot be less than the transverse pieces entering the separation. The length of the path $S$ of the material passing through the sieve, represented by the line $AF$, is equal to:

$$S=\frac{L}{\sin W}=\frac{L}{\sin 2\alpha}. \qquad (53)$$

The value of $S$ characterises the degree of separation perfection: the higher the $S$, the more efficient the separation. Therefore, it is better at small angles $\alpha$; however, at small angles of inclination $\alpha$, the performance drops rapidly. If $\alpha$ is changed from 2° to 14°, the path length will be determined by

$$S=\frac{L}{\sin 4°}-\frac{L}{\sin 28°}=14.3L-2.13L. \qquad (54)$$

Therefore, it is necessary to determine how many revolutions the rotor must make so that the material has time to pass the entire length of its $L$:

$$L=k\cdot 2\pi\cdot R\cdot \tan W, \qquad (55)$$

from where the desired number of rotor turnovers is determined as:

$$k=\frac{L}{2\pi\cdot R\cdot \tan 2\alpha}, \qquad (56)$$

so, the longer the rotor, the more is $k$.

**Determining power consumption**

According to practical observations, the most appropriate design is the one with a central drive shaft, as opposed to the option with support rollers. This is due to the fact that the total length does not exceed 3,500 mm. The design with a central drive shaft is much less bulky and more compact than the one with support rollers (Lee *et al.*, 2010).

In this case, the following static moments around the shaft are applied during operation:

1) Torque from the friction of the shaft trunnions in the bearings:

$$M_1=f_1\cdot r(G+G_0), \qquad (57)$$

where $f_1$ is a rolling friction coefficient, $f$ = 0.03; $r$ is shaft journal radius, *m*.

2) Friction torque of the crushed mass on the inner surface of the rotor sieve:

$$M_2=f_2\cdot G_0\cdot R, \qquad (58)$$

where $f_2$ is mass a friction coefficient on the perforated surface, naturally $f_2$ = 0.15-0.25; $G_0$ is a weight of the material in the rotor, kg; $R$ is rotor radius, m. When calculating a conical machine, the largest cone radius is used.

3) The moment from lifting the material to a certain height *H*, determined by the angle of lifting $\beta$ = 45° $\varphi$ is 35°, (Fig. 6). The height of the material is determined by the segment *bb'*, where *b* is the centre of gravity of the material layer *ABC* in the lowest position. The distance *x* of the centre of gravity *b* in segments *ABC* from the centre of the circle *O* is determined by the formula

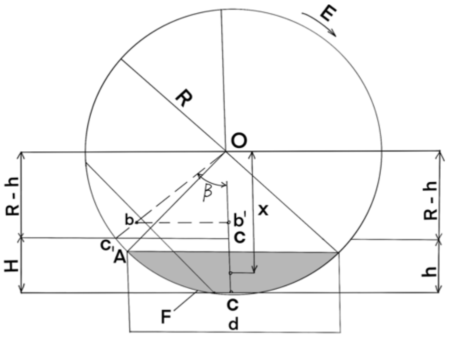


***Figure 6.*** *Location of the material on the inner sieving surface*
***Source:*** *compiled by the authors on the basis of L.N. Hand & J.D. Finch (2008)*

$$x=\frac{d^3}{12F}. \quad (59)$$

For the chord *b*, we have: $d=2.83\sqrt{R}\cdot h$, and for the square *F* segment: $F=1.9\sqrt{R}\cdot h^3$. Hence, it is used for small *h*:

$$x=\frac{d^3}{12F}=\frac{(2.83\sqrt{R}\cdot h)^3}{12\cdot 19\sqrt{R}\cdot h^3}. \quad (60)$$

Therefore, instead of the exact value of *bb*, the following interval is taken as the magnitude of the rise *cc* = *H* (Fig. 6).

$$R-H=R\cdot\cos45°, \quad (61)$$

hence:

$$H\cong 0.3R. \quad (62)$$

Thus, the material in the rotor with mass $G_0$ rises to a height *H* during the time the rotor rotates by an angle $\beta=45°$ , i.e. 1/8 of a complete revolution. If we denote the time of one complete revolution of the rotor by *T* (in seconds), then at n revolutions per minute, it is obvious:

$$T=\frac{60}{n}, \quad (63)$$

then the rotor turnover time per angle , the material is lifted to a height of *H*, is equal to:

$$t=\frac{45°}{360}T=\frac{1}{8}T=\frac{1}{8}\frac{60}{n}=\frac{7.5}{n}, \quad (64)$$

hence the power consumed to lift the material to a height *H* is equal to:

$$W=\frac{G_0\cdot H}{T}=\frac{0.3R\cdot n\cdot G_0}{7.5}=\frac{R\cdot n\cdot G_0}{25}\left(\frac{kgm}{m}\right). \quad (65)$$

Power consumption for lifting the material is equal to:

$$N_3=\frac{W}{102}=\frac{R\cdot n\cdot G_0}{102\cdot 25}=\frac{R\cdot n\cdot G_0}{2.550}(kWh). \quad (66)$$

As for the power consumption in the first two stages, it can be determined, knowing the static moments, by the formula:

$$M=716.2\frac{N}{n}, \quad (67)$$

whence:

$$N=\frac{M\cdot n}{716.2}=\frac{f\cdot r(G+G_0)\cdot n}{716.2}. \quad (68)$$

Then the expression takes the form:

$$N_1=\frac{M_1\cdot n}{716.2}=\frac{f\cdot r(G+G_0)\cdot n}{716.2}, \quad (69)$$

where *r* is radius of the shaft journal, *m*.

$$N_2=\frac{M_2\cdot n}{716.2}=\frac{R\cdot n\cdot G_0\cdot f}{716.2}(kWh). \quad (70)$$

Thus, the total static moment is equal:

$$M=M_1+M_2+M_3=2f\cdot G_0\cdot R+f_1\cdot r(G+G_0). \quad (71)$$

The friction coefficient of the crushed mass on the wet sieve should be assumed to be *f* = 0.25, and the rolling friction coefficient of the rotor shaft bearing supports (*f* = 0.03). The ratio of the rotor radius *R* to the shaft radius varies within the limits:

$$\frac{R}{r}=12-17. \quad (72)$$

This ratio decreases as the rotor diameter decreases. Assume an average of *R/r* = 15 and, increasing the total torque by 10% due to the centrifugal force of the material, the expression will be:

$$M=1.1[2\cdot 0.25G_0\cdot 15r+0.03r(G+G_0)]=\frac{r(G+25lG_0)}{30}, \quad (73)$$

and for greater clarity and practicality, the expression will look like:

$$R=15r,$$

then the total static moment:

$$M=\frac{R(G+251G_0)}{450}. \quad (74)$$

The power required for the drive will be:

$$N=\frac{M\cdot n}{716.2\cdot 1.36}=\frac{R\cdot n(G+251G_0)}{716.2\cdot 1.36\cdot 450}=\frac{R\cdot n(G+251G_0)}{44\cdot 10^4}. \quad (75)$$

**Determination of optimal design and technological factors of advanced tomato processing equipment**

Rotary juicer machines are manufactured with a diameter of 700 to 1,300 mm, with a length of up to 4,000 mm. As a rule, the central shaft is tubular, 75 mm in diameter, with additional stiffeners. Only stamped sieves made of galvanised steel sheet with a thickness of 1 mm are used. When installing stamped sieves, the most serious attention must be paid to the correct location of the punch holes on the drum surface. The rough side of the sheet (from the side of the stamp exit) should be a non-working surface. The working side is smooth. The correct installation of the sieves ensures that the material slides easily on the inner working surface – 0.540 and 0.438, and on the steel surface – 0.532, 0.428 and 0.495. The laboratory setup had the following main parameters: the length of the wiping drum was 650 mm, 4 wiping beats and the diameter of the drum holes was 5 mm (Dotsenko, 2019).

During the selection of the optimal technological parameters of the tomato processing equipment, the drum rotation speed varied from 5 to 30 m/s. When analysing the results of the laboratory study, it can be concluded that the maximum juice passage through the holes of the grinding drum occurs at a rotor speed of 20 m/min. This is due to the fact that at the lower value of the rotor rotation speed, the value of centrifugal force is insufficient, and, consequently, the juice yield does not meet the technological requirements, and in the case of the maximum value of the drum rotation speed, the drum holes stick and the juice yield decreases. The level of supply of shredded mass to the wiping, which varied from 65 to 85%. The research determined that in order to achieve a juice yield of 90-95%, the level of supply to the grinding mass should be in the range of 75-80%. Also, during the research, the gap between the scourge and the sieve was adjusted within the range of 1 to 3 mm. When the gap was set at 3 mm, the juice yield was minimal, while when the gap was set at 1 mm, the peel and seeds were damaged, which partially fell into the juice fraction instead of the waste fraction. Therefore, the optimal gap for the scourge sieve was 2 mm. Analysing the data in Table 1, it can be concluded that the optimal design and technological parameters of tomato processing equipment are a drum rotation speed of 25 m/min, a level of supply of crushed mass for wiping up to 80% and a sieve gap of 2 mm. These parameters will help to avoid overloading the equipment, clogging the sieves and maximise the juice yield at 90-95%.

***Table 1.*** *Study of design and technological factors of improved equipment for tomato processing*

| *Q*, % | *V*, m/min | *M* , % | *l* (mm) |
|---|---|---|---|
| 75 | 5 | 65 | 3 |
| 80 | 10 | 75 | 3 |
| 85 | 15 | 75 | 3 |
| 90 | 20 | 75 | 2 |
| 95 | 25 | 80 | 2 |
| 100 | 30 | 85 | 1 |

**Note*:*** *Q – juice output, V – drum rotation speed, M – level of chopped mass entering the wiping, l – gap of the scourge-sieve*
***Source:*** *developed by the authors*

While theoretical models can provide a general understanding of the process, experimental studies are needed to fine-tune equipment and parameters. These studies will help to determine the optimal conditions for different tomato varieties and types of equipment, as well as identify possible problems and solutions. The technological process of tomato processing includes preparatory stages: inspection, sorting, washing and stem removal, and the actual processing stages: chopping, wiping, juicing and filtration. Tomatoes have high demands on the market as they are used for everyday food needs and the colour of a tomato determines its level of maturity. Using computer analysis, it is possible to sort tomatoes by colour. For the study by S. Widiyanto *et al.* (2021), a computer was trained using Faster R-CNN models to recognise the maturity of tomatoes, as Faster R-CNN supports image classification and object detection. Technologies based on automated machine learning are becoming increasingly important in agriculture and the food industry. J.R. Pangilinan *et al.* (2022) evaluated the performance of neural network algorithms in terms of the accuracy of tomato ripeness determination. C.N. Vanitha *et al.* (2023) noted that the ripeness of tomatoes is one of the main conditions for high-quality processing, so automated colour identification facilitates the processes of sorting and preparing for processing tomatoes in the context of agricultural production. Using the proposed design solution, the tomato processing equipment is integrated into modern processing lines of processing enterprises, which include not only equipment for mechanical processing of raw materials, but also electronic machines for sorting.

O. Vitriak *et al.* (2025) noted that the processing of tomato products and the introduction of canned food production technologies based on the use of fruit and vegetable raw materials in small farms contribute to the development of processing enterprises and strengthening of the Ukrainian canned fruit and vegetable market. The researcher M.A. Cherier (2020) assessed the efficiency of the operation of equipment for processing tomato raw materials and concluded that it is necessary to develop technologies and improve the equipment of processing enterprises based on the assessment and selection of the best enterprises for the supply of raw materials. The developed methodology is used to rank alternatives in order to select the best tomato farms. The use of the constructive solution proposed by the authors will provide both additional processing of tomato raw materials in private farms growing tomatoes and for improving the production lines of canneries. J.T. Teleken *et al*. (2022) noted that theoretical research on the processes of processing enterprises is an important condition for the design and modernisation of equipment. H. Ghaffari *et al*. (2024) investigated the degree of crushing of tomato fruits after single and multiple dynamic loads and their ability to withstand successive impacts, which play a crucial role in the processing process, which is an important aspect in the development of food processing equipment. This correlates with the authors' study that when designing tomato processing equipment, it is important to take into account the conditions of balance and movement of raw materials, the relative trajectory of the material on the surface that is deployed in a plane and the location of the material on the internal screening surface.

S. Haniva & S.F.A. Iskandarini (2023) outlined alternative strategies for increasing the income of tomato farmers, namely optimising existing potential by increasing equipment productivity and reducing production costs. D. Mengistu & T. Sharew (2024) analysed the level of product losses that occur during harvesting, packaging, transport, storage, and processing. The reasons for these losses include outdated processing equipment and lack of technological advances in production processes. Solving these problems is important for increasing the efficiency and sustainability of tomato production and minimising production losses. The use of the proposed constructive solution contributes to solving these problems, namely, it will reduce energy consumption for the production of tomato products by combining the technological processes of crushing and rubbing and increase the productivity of tomato processing lines. Despite the potential, the tomato processing industry faces challenges such as inadequate processing capacity. M. Kaundal *et al*. (2024) noted that the demand for tomato processing products has been growing in recent years, with an increasing range of products being offered. The introduction of advanced processing methods can reduce losses and increase product value. M. Dalvi-Isfahan & M. Mahmoodi-Eshkaftaki (2024) emphasised the need to optimise tomato processing methods, thereby improving the quality of canned tomato products and saving resources for canneries. A team of authors (Kedir *et al.*, 2025) carried out a comparative study of the physicochemical properties of the product obtained using different types of tomato crushers. The study correlates with the authors' point of view that the choice of the optimal design solution for processing tomato raw materials contributes to increasing the productivity of equipment and the overall efficiency of processing enterprises.

S.G. Ye & A.K.H. Lingani (2022) outline the practical aspects of the use and maintenance of technological equipment at a tomato puree processing enterprise. The authors outline the technical and operational characteristics of the equipment of a tomato processing plant, the processed products and the design and kinematic parameters of the equipment, as well as the methods of care or maintenance of the equipment before and after use. The authors noted that the process of crushing and mashing tomatoes to produce juice is a complex and multi-stage technological process that requires careful analysis and optimisation of various parameters. At the grinding stage, it is necessary to take into account the size of the particles obtained as a result of grinding, the uniformity of grinding and minimisation of juice losses. The main parameters for mashing tomatoes after crushing to separate the juice from the skin, seeds and other particles include the size of the mesh, the mashing speed and the pressure applied to the tomato mass. Optimising these parameters maximises juice yield and quality while minimising solids content. The authors confirm the thesis stated in the paper that the main technological parameters affecting the process of crushing and mashing tomatoes are: the speed of rotation of the chopper blades: high speed produces smaller particles, but can lead to overheating and oxidation of the juice; the size of the sieve opening: smaller openings provide cleaner juice, but can reduce productivity and straining pressure: high pressure can increase juice yield, but requires more powerful equipment. Therefore, the use of the proposed design solution and compliance with the design and technological parameters outlined in this paper will allow obtaining optimal process parameters, reducing energy consumption and increasing productivity.

## CONCLUSION

Tomato processing is a complex and multi-stage process that requires careful optimisation at each stage. Based on the analysis of the known designs of tomato processing lines, the article selects the complete equipment for the technological line for tomato processing, which is proposed for implementation in production conditions. The stages of the technological process of tomato processing with the participation of an improved design solution are considered. A constructive solution for tomato processing equipment that combines two technological operations – grinding and rubbing – is presented, as well as a laboratory setup. The design of the equipment for processing tomato raw materials was based on the study of the conditions of equilibrium and movement of raw materials, the relative trajectory of the material on the surface deployed in a plane and the location of the material on the internal sieving surface. The design parameters of the improved equipment for tomato processing, namely, performance indicators, power, and determination of the angular speed of rotation of the drum, were calculated. The technical characteristics of the proposed design solution are presented.

A study of the process of pulp grinding and wiping has been carried out, which shows that the gap between the beaters and the sieve of the wiping drum should be 2 mm, the drum rotation speed should be 25 m/s, the level of supply of crushed mass for wiping should be up to 80%, which ensures pulp wiping at the level of 90%. The selection of optimal design and technological parameters of tomato processing equipment will increase the overall productivity and have a positive impact on the technological process. The use of the proposed constructive solution of equipment for wiping tomatoes is promising in the conditions of farms of various forms of ownership and canning shops. Prospects for further research are the calculation of the energy intensity of the process and ways to optimise it to reduce costs and increase efficiency. Further research and innovation in this area can significantly improve product quality, reduce costs, and increase production sustainability.

## ACKNOWLEDGEMENTS

None.

## FUNDING

None.

## CONFLICT OF INTEREST

None.

## REFERENCES

[1] Bezusov, A.T., & Totsenko, O.V. (2017). Analysis of modern tomato processing methods. *Food Science and Technology*, 11(2), 45-55. doi: 10.15673/fst.v11i2.513.

[2] Bortz, J., & Schuster, C. (2010). *Statistics for human and social scientists*. Berlin, Heidelberg: Springer. doi: 10.1007/978-3-642-12770-0.

[3] Cherier, M.A., Bennekrouf, M., & Meliani, S.M. (2020). The application of AHP-TOPSIS methodology for selection of agriculture farms in tomato processing industry: Algerian case study. In *2020 IEEE 13th international colloquium of logistics and supply chain management (LOGISTIQUA)* (pp. 1-5). Fez: Morocco. doi: 10.1109/LOGISTIQUA49782.2020.9353915.

[4] Convention on Biological Diversity. (1992). Retrieved from https://www.cbd.int/convention/text/.

[5] Dalvi-Isfahan, M., & Mahmoodi-Eshkaftaki, M. (2024). Headspace and viscosity: Key factors in the thermal processing of tomato paste (A CFD study). *Journal of Food Process Engineering*, 47, article number e14779. doi: 10.1111/jfpe.14779.

[6] Despotovic, Z.V., Pavlovic, A.M., & Ivanic, D. (2019). Exciting force frequency control of unbalanced vibratory actuators. In *20th international symposium on power electronics (Ee)* (pp. 1-6). Novi Sad: Serbia. doi: 10.1109/PEE.2019.8923574.

[7] Dotsenko, N.A. (2019). The results of the study of the capacity of the chopper-wiper of tomatoes. *Proceedings of the Tavria State Agrotechnological University*, 21(1), 116-124. doi: 10.31388/2078-0877-2021-21-1-116-124.

[8] DSTU 7160:2020. (2020). *Seeds of vegetable, melon, fodder and spice and aromatic crops. Varietal and sowing qualities. Technical specifications*. Retrieved from http://online.budstandart.com/ua/catalog/doc-page.html?id_doc=90394.

[9] DSTU 8439:2015. (2015). *Seeds of vegetable and melon plants and fodder roots. Documentation*. Retrieved from http://online.budstandart.com/ua/catalog/doc-page?id_doc=80194.

[10] Eslami, E., Carpentieri, S., Pataro, G., & Ferrari, G. (2025). Comparative life cycle assessment (LCA) of packaging materials for tomato-based products to pave the way for increasing tomato processing industry sustainability. *Sustainability*, 17, article number 3648. doi: 10.3390/su17083648.

[11] Eslami, E., Elfatih M.A.E, Pataro, G., & Ferrari, G. (2024). Increasing sustainability in the tomato processing industry: Environmental impact analysis and future development scenarios. *Frontiers in Sustainable Food Systems*, 8, article number 0274. doi: 10.3389/fsufs.2024.1400274.

[12] Ghaffari, H., Ghassemzadeh, H., Mohammadi-Ghermezgoli, K., Rafat, S., & Halimi-Milani, O. (2024). Response of tomato fruit to consecutive impact loading. *Journal of Aridland Agriculture*, 10, 108-119. doi: 10.25081/jaa.2024.v10.8944.
[13] Hand, L.N., & Finch, J.D. (2008). *Analytical mechanics*. Cambridge: Cambridge University Press.
[14] Haniva, S., & Iskandarini, S.F.A. (2023). Analysis of tomato farmer income increasing strategies in Karo District, Indonesia. *European Journal of Social Sciences Studies*, 8, 207-218. doi: 10.46827/ejsss.v8i6.1508.
[15] Kaletnik, G., Tsurkan, O., Rimar, T., & Stanislavchuk, O. (2020). Determination of the kinetics of the process of pumpkin seeds vibrational convective drying. *Eastern-European Journal of Enterprise Technologies*, 1(8(103)), 50-57. doi: 10.15587/1729-4061.2020.195203.
[16] Kaliniewicz, Z., Anders, A., Markowski, P., Tylek, P., & Owoc, D. (2021). Analysis of the physical properties of spindle seeds for seed sorting operations. *Scientific Reports*, 11, article number 13625. doi: 10.1038/s41598-021-93166-z.
[17] Kaundal, M., Sharma, K., & Anand, H. (2024). Processing, value addition and post-harvest technology of tomato: A scoping review on global and Indian perspective. *Journal of Advances in Biology & Biotechnology*, 27 (11), 339-347. doi: 10.9734/jabb/2024/v27i111619.
[18] Kedir, H.J., Tilinti, B.Z., & Mekonnen, K.T. (2025). Physicochemical characterization of fresh and powdered tomato in Arba Minch, Ethiopia. *Recent Progress in Nutrition*, 5(2), article number 013. doi: 10.21926/rpn.2502013.
[19] Kotov, B., Spirin, A., Kalinichenko, R., Bandura, V., Polievoda, Y., & Tverdokhlib, I. (2019). Determination the parameters and modes of new heliocollectors constructions work for drying grain and vegetable raw material by active ventilation. *Research in Agricultural Engineering*, 65(1), 20-24. doi: 10.17221/73/2017-RAE.
[20] Lee, J.M., Kubota, C., Tsao, S.J., Bie, Z., Echevarria, P.H., Morra, L., & Oda, M. (2010). Current status of vegetable grafting: Diffusion grafting techniques automation. *Scientia Horticulturae*, 127(2), 93-105. doi: 10.1016/j.scienta.2010.08.003.
[21] Lerner, R.G., & Trigg, G.L. (1991). *Encyclopedia of physics*. (2nd ed). Weinheim: VHC Publishers.
[22] Maas, A. (2017). *Theoretical mechanics. Lecture in WS 2016/17 at the KFU Graz*. Retrieved from https://www.academia.edu/35573618/Theoretical_Mechanics_Lecture_in_WS_2016_17_at_the_KFU_Graz.
[23] Mengistu, D., & Sharew, T. (2024). A comprehensive review of tomato post-harvest losses: Understanding impacts and contributing factors in Ethiopia. *Advances in Sustainable Agriculture*, 2, 525-535. doi: 10.3923/asb.2024.525.535.
[24] Mukhopadhyay, K., *et al.* (2021). *Organic vegetable seed production*. Nadia: ICAR. doi: 10.13140/RG.2.2.24563.45601.
[25] Pangilinan, J.R., Legaspi, J. & Linsangan, N. (2022). InceptionV3, ResNet50, and VGG19 performance comparison on tomato ripeness classification. In *5th international seminar on research of information technology and intelligent systems (ISRITI)* (pp. 619-624). Yogyakarta: Indonesia. doi: 10.1109/ISRITI56927.2022.10052920.
[26] Patent No. 154661. (2023). *Method of producing tomato pulp*. Retrieved from https://dspace.mnau.edu.ua/jspui/handle/123456789/17120.
[27] Patent No. 58968. (2011). *Complex production line of complete cycle of processing tomatoes with separating seeds*. Retrieved from https://sis.nipo.gov.ua/uk/search/detail/249492/.
[28] Sena, C., Júnior, J., Souza, J., Pêgo E., Adão, B., Rafael, C.D., & Junior, E. (2025). Remote sensing in the estimation of evapotranspiration of tomato cultivation for industrial processing. *Bioscience Journal*, 41, article number e41002. doi: 10.14393/BJ-v41n0a2025-70757.
[29] Shebanin, V., Atamanyuk, I., Gorbenko, O., Kondratenko, Y., & Dotsenko, N. (2019). Mathematical modelling of the technology of processing the seed mass of vegetables and melons. *Food Science and Technology*, 13(3), 118-126. doi: 10.15673/fst.v13i3.1480.
[30] Teleken, J.T., Dutra, A.C., Laurindo, J.B., & Carciofi, B.A.M. (2023). Numerical modeling of heating tomato pulp in continuous flow microwave-assisted thermal processing: Estimation of quality parameters. *Journal of Food Process Engineering*, 46(2), article number e14216. doi: 10.1111/jfpe.14216.
[31] Vanitha, C.N., Malathy, S., Krishna, S.A., Manikantan, M., Kumar, P.D., & Cibi, M.G. (2023). Detection of ripe and raw tomatoes using internet of things. In *7th international conference on computing methodologies and communication (ICCMC)* (pp. 1255-1260). Erode: India. doi: 10.1109/ICCMC56507.2023.10084228.
[32] Vitriak, O., Khrebtan, O., & Volkova, R. (2025). Research on the Ukrainian canned fruit and vegetable market (2020-2024). *International Scientific-Practical Journal Commodities and Markets*, 53, 40-53. doi: 10.31617/2.2025(53)03.
[33] Widiyanto, S., Wardani, D.T., & Wisnu Pranata, S. (2021). Image-based tomato maturity classification and

detection using faster R-CNN method. In $5^{th}$ *international symposium on multidisciplinary studies and innovative technologies (ISMSIT)* (pp.130-134). Ankara: Turkey. doi: 10.1109/ISMSIT52890.2021.9604534.

[34] Ye, S.G., & Lingani, A.K.H. (2022). Training in good practices for the use and maintenance of equipment at a tomato processing unit in Ouahigouya in the northern region of Burkina Faso. *World Journal of Advanced Research and Reviews*, 16(2), 673-678. doi: 10.30574/wjarr.2022.16.2.1189.

## Обґрунтування конструктивних параметрів вдосконаленого обладнання для переробки томатів

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**Анотація.** Здійснення повного циклу переробки томатів це складне технологічне завдання, що вимагає ретельного контролю різноманітних параметрів для забезпечення високої якості кінцевого продукту. Основними стадіями процесу є підготовка сировини, механічне подрібнення томатів, відділення соку від м'якоті і шкірки, а також додаткова обробка для поліпшення органолептичних і поживних показників соку. Робота ставила на меті дослідження залежності продуктивності від оптимальних параметрів вдосконаленого обладнання для переробки томатів, а саме: зазор бич-решето, швидкість обертання перфорованого барабану та рівень надходження подрібненої маси. В статті представлене вдосконалене конструктивне рішення обладнання для переробки томатів, особливістю якого є поєднання технологічних операцій подрібнення і протирання, за рахунок чого знижується металоємність конструкції та енергоємність процесу. В дослідженні здійснювалося визначення процентного вмісту компонентів подрібненої маси плодів шляхом важення кожної фракції. На основі отриманих даних проведене апріорне ранжування чинників, яке виконується методом експертної оцінки. Визначені чинники, які найбільше впливають на технологічний процес. За допомогою методу математичного моделювання та експериментальних досліджень визначено оптимальні режими роботи обладнання, що забезпечують максимальний вихід томатного соку при мінімальних енергетичних витратах. Основна увага приділялась врахуванню конструктивних і експлуатаційних параметрів, таких як визначення кутової швидкості обертання барабана, продуктивності та потужності обладнання. На основі аналізу конструктивних та технологічних чинників, які впливають на технологічний процес визначено, що зазор бич-решето повинен бути 2 мм, рівень надходження на протирання подрібненої маси до 80 %, швидкість обертання барабану до 25 м/с, що забезпечить протирання пульпи на рівні 90 %. Отримані результати можна використати для модернізації існуючих ліній переробки томатів і створення нових виробничих потужностей з урахуванням сучасних вимог ринку

**Ключові слова:** подрібнювач томатів; протирання сировини; пульпа; агропромисловість; механічна обробка