ENGINEERING OF OBTAINING VEGETABLE PEPPER SEED

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Summary. The article contains the theoretical pre-conditions for the creation of a new machine for obtaining the seeds of sweet and hot pepper. A principal scheme of the new machine, the technological line for obtaining the seeds of sweet and hot pepper and the results of the field and laboratory tests are presented in the article.

Key words: impurity of seed, losses of seed, whip mechanism, supplying the seed

INTRODUCTION

The production of the seed material of vegetable crops is one of the important problems that exists in the industry of processing agricultural products. The question of obtaining the seeds of sweet and hot pepper has not been studied yet. It is proved by the fact that the bulk of seeds of the solanaceae (60...80%) is imported from the nearby foreign countries (Russia, Hungary, Romania and others). The rest of the seeds needed is provided by small farms, and it usually takes 16-20 hours of manpower to get 1 kg of seeds. It is impossible to meet the demand in seeds of their own production in four basic regions (Odessa, Mikolayiv, Kherson and Autonomous Republic of Crimea) which are engaged in growing pepper, spending such amount of human labour, taking into account that the average statistical indexes prove that the amount of necessary seeds reaches from 2.8 to 3.2 tons of seeds per year.

The problems of mechanization of processes of obtaining seeds of vegetables, melons and gourds, pepper in particular, were studied by: I.F. Anisimov, V.P. Medvedev, A.V. Durakov and some other scientists. A majority of equipment which remained on the specialized farms in the South of Ukraine nowadays is morally and physically out-ofdate. In addition, a number of machines created earlier were not intended for obtaining the seeds of pepper. Adopted lines which are used for production of seed of other vegetable crops (tomatoes, egg-plants, water-melons) do not allow to obtain high-quality seeds. The use of the IBK-5 and USB-8 machines is an example, as a rule; they contain garden-stuff machines, grinder, a separator, a machine for washing the seeds and a drying aggregate. Both of them foresee the complete grinding of fruit and, as a result, most of the obtained seeds of pepper do not meet the agrotechnical requirements, as there are plenty of particles equal to the size of the left seeds. The purity of seed makes only 78...86%, and the losses are 15...20% [Miedviediev and Durakom 1985, Anisimov 1987].

Consequently, there is a necessity in creation of a new equipment for the production of the seeds of pepper, which is an urging question for the national economy, as having high-quality seed material is one of the terms that will allow to increase the productivity and cut the costs of the grown products.

The latest research devoted to the obtaining of vegetable seeds, melons and gourds can be found in the articles dating back to the end of the 80s and beginning in the 90s of the last century. Those are the publications devoted to rather out-of-date technologies which are not used now, as they do not meet modern agrotechnical requirements concerning the quality of the obtained seeds.

Besides, the research of mechanic and technological properties of the carpels and seeds of sweet and hot pepper have been stopped recently. It created a difficult situation in the industry, as the production was added by the new productive varieties of the crop, the properties of which have not been studied, which, in turn, makes it impossible to use them for obtaining the seeds by the mechanized means. There are no such important indexes as the dependence of the deformation of seeds on the applied static effort, firmness of seeds after the shock loadings, coefficients of the seeds renewal after a blow, for the garden-stuff of the oblong shape the dependence of their length on a transversal size, etc. [Pastushenko *et al.* 2005a]. All this is conditioned by the fact that the seed growing makes only 2-3% of the production of market vegetables.

MATERIALS AND METHODS

On the basis of the conducted analysis of the problem of mechanization of the process of obtaining seeds of sweet and hot pepper it is possible to make a conclusion about the necessity of conducting a deep theoretical and experimental research in order to create a new machine.

In a theoretical research it is necessary to solve such tasks:

- determination of physical and mechanical parameters of the carpel;
- estimation of influence of the force of air resistance at free falling of the carpel;
- determination of the contact pressure of blow of a whip plate on the carpel;
- research of the tensely-deformed state of the carpel;

determination of law and motion curve of the carpel on a cylinder surface of the drum;

- development of the mathematical model of «shaking» off the seeds Experimental research must contain such stages:

- making a laboratory model of the machine;
- conducting laboratory tests;
- testing the machine in the conditions of production.

RESULTS AND DISCUSSION

Taking into account the biological features of the fruit of pepper and the possibility to deliver not the fruit but the carpels into the area of processing grinders, it is possible to assert that the process of the direct grinding is not necessary. Processing the carpel whose seeds are on the surface of the core it is possible to apply the methods of knocking out or «shaking» off the seeds, which require considerably less input of energy as compared to the methods of grinding, do not need the use of water and diminish injuring of seeds.

In the process of theoretical grounding the construction of a new machine for obtaining the seeds of sweet and hot pepper the following aspects were analyzed:

The parameters of three-phase environment of the body of carpel (Fig. 1) were modeled and the speed of distribution of the compression waves was determined:

$$c_{i} = c_{i} \sqrt{\frac{\rho_{i} / \rho_{i}}{\gamma_{i} \gamma_{i} \left(1 + \frac{\gamma_{i}}{\gamma_{i}} \rho_{i} / \rho_{i}\right)}}$$
(1)

where:

 c_1 – is speed of compression waves in mid air;

 ρ – is density of carpels components;

 γ – is volume concentration of carpels components.



Fig. 1. «Fastenings» of seed: 1 - body of the carpel; 2 - seed; 3 - stalk

It was found out analytically, that the speed of distribution of the compression waves in the body of the carpel is $c_1 \approx 30 \div 45$ m/s. This value is close enough to the rubber materials $36 \div 60$ m/s [Rabotnov 1988], that is indirect proof of the rightness of the approach to the design of parameters of the three-phase environment of the carpels body.

Such descriptions of the durability of carpel and seed as a module of resiliency and a border of fluidity were determined (Fig. 2) [Rabotnov 1988].

Namely: module of resiliency

$$E = q \frac{a^2}{b^2 - a^2} \left[(1 - \mu) - (1 + \mu) \frac{b^2}{a^2} \right]$$
(2)

where:

a – radius of needle;

b – middle radius of pepper pip;

- μ is the Poisson coefficient;
- q is radial constituent of needle loading.

Border of fluidity of material

$$\sigma_{T} = N \frac{a}{1,2\delta} \tag{3}$$

where:

 δ – is average thickness of pepper pip;

N – is axial effort of needle.

As a result of calculations:



Fig. 2. Chart of puncture determination of durability of seed: 1 - seed; 2 - needle

Influence of the air resistance on the body of carpels was determined analytically, and the speed of falling of carpels was built in a dimensionless form $\overline{V}(\xi)$ to parameter ξ by means of mathematical apparatus Matcad (Fig 3.):

$$\overline{V}(\xi) = \sqrt{\frac{1 - e^{-\xi}}{\xi}}$$
(4)

where:

 $\xi = 2kh$.

Interation of the whip and carpel (Fig. 4) at a blow is explored with the determination of the motion speed of the whip plate, contact tension and deformations [Dinnik 1952].



Fig. 3. Dependence of speed of falling of carpels $\,\overline{V}\,$ on parameter $\,\xi\,$



Fig. 4. Kinematics of motion of whip plate and carpel body

Thus, the motion speed of the whip is determined by the expression:

$$V_{k} = (r_{0} + 2r_{1})\omega_{0} + \omega_{0}r_{0} = 2\omega_{0}(r_{0} + r_{1})$$
(5)

Contact tension:

- by the unwaving model of deformations:

$$\sigma_{k} = 0.8 \frac{1}{(1-\mu^{2})^{\frac{4}{5}}} \cdot \rho_{0} c_{0} V_{0} \left(\frac{V_{0}}{c_{0}}\right)^{\frac{2}{5}}$$
(6)

- by the waving model of deformations:

$$\sigma_{k} = \rho_{0}c_{0}V_{0} = \rho_{0}c_{0}^{2}\left(\frac{V_{0}}{c_{0}}\right)$$

$$\tag{7}$$

Dependences that describe the tensely-deformed state look like:

$$u(x,t) = \frac{c_0}{E} P_0 \sum_{k=0}^{\infty} \left\{ H\left(t - (2k+1)\frac{l}{c_0} + \frac{x-l}{c_0}\right) + H\left(t - (2k+1)\frac{l}{c_0} - \frac{x-l}{c_0}\right) \right\}$$

$$\sigma(x,t) = P_0 \sum_{k=0}^{\infty} \left\{ H\left(t - (2k+1)\frac{l}{c_0} + \frac{x-l}{c_0}\right) - H\left(t - (2k+1)\frac{l}{c_0} - \frac{x-l}{c_0}\right) \right\}$$
(8)

where:

H(t) – is a single function of Heaviside with properties:

$$H(t) = \begin{cases} 0 & t < 0\\ 1 & t \ge 0 \end{cases}$$

The described differential equation of carpels body motion in the middle of the cylinder drum of the machine [Vasilenko 1996] looks like:

on a circle
$$V^{2}(\varphi) = \left[V_{1}^{2} - 2gr_{0}\frac{(1-2\mu^{2})}{(1+4\mu^{2})}\right] \cdot e^{-2\mu\varphi} + \frac{2gr_{0}}{(1+4\mu^{2})}\left[(1-2\mu^{2})\cos\varphi - 3\mu\sin\varphi\right]$$
 (9)
$$x(t) = V_{2}t - \mu g \left\{\frac{a_{0}}{2}\frac{(1-e^{-2\mu\pi})}{2\mu\pi} + \frac{d_{0}}{\pi}\right\}t^{2}$$

along an axis

$$x(t) = V_2 t - \mu g \left\{ \frac{a_0}{2} \frac{\left(1 - e^{-2\mu\pi}\right)}{2\mu\pi} + \frac{d_0}{\pi} \right\} t^2$$
(10)

where:

$$a_{0} = \frac{V_{2}^{2}}{r_{0}g} - 2\frac{(1 - 2\mu^{2})}{(1 + 4\mu^{2})} = 1 + \frac{V_{2}^{2}}{r_{0}g} - \frac{3}{1 + 4\mu^{2}},$$

$$d_{0} = -\frac{6}{1 + 4\mu^{2}}.$$

Using the data of the above mentioned theoretical research three basic mathematical models [Cse *et al.* 1966] of the process of dynamic «shaking» off the seeds (Fig. 5) with the determination of contact tension of destruction of the carpels-seeds connection were developed. Exactly such amount of models is rational for the reflection of physical reality of the process.



Fig. 5. Dynamic models of «shaking» off the seeds: a) – a blow on seed; b) – a blow on the body of carpels; c) – a blow on the body of carpels and seed; 1 – a body of carpels; 2 – seed;
3 – neck (a stalk of a pip); m₁ – mass of carpels body; m₂ – mass of pip (or all seeds)

Tension of destruction of carpels-seeds connection for every model looks accordingly like:

a)
$$_{max}\sigma = \frac{E \cdot V_0}{l \cdot \omega_0}$$
; b) $_{max}\sigma = \frac{E \cdot y_0}{l}$; c) $_{max}\sigma(t) = \frac{F_0}{S_{N2} \cdot \omega \cdot m_1}$;

where:

E – module of neck resiliency of neck;

- V_0 speed of pip motion;
- ω_0 circular frequency of harmonic motion x(t);
- l length of neck;
- y_0 relocation bias;
- F_0 force of blow on the system;
- ω circular frequency of motion of the system;
- S_{N2} area of the neck of pip or pips.

On the basis of the results of the theoretical research by the Problem Research Laboratory for Constructing Energy Efficient Agricultural Machinery and Technologies at Mykolayiv State Agrarian University a new machine (Fig. 6) for providing the mechanized technology for obtaining the seeds of sweet and hot pepper was created. The machine has a planetary type of the working organs 8, 12 and a perforated cylinder drum 2 with a closed frame 1, which separate the seeds from a pedicle by a shock interaction. It results in «shaking» off the seeds from the carpels that, in turn, guarantees a substantial decrease of small particles in the treated mass which has to be separated. This construction has got two invention patents in Ukraine [Goldshmidt *et al.* Pat. 52942 A, Dumenko *et al.* Pat. 17351 A].



Fig. 6. Chart of machine for obtaining the seeds of sweet and hot pepper

One of the positive features of the new machine is that the technological process (Fig. 7) of obtaining the seeds with it does not need the use of water. Due to that, in addition to the machine for cutting out the seed balls 1 and screw 8 that provides the feeding of seeds into the boiling layer, it is possible to include (into the 2 technological chain, a dielectric seed separator 12) for further processing, the application of which allows to easily separate admixtures and increase the energy of the field growth.



Fig. 7. Technological chart of obtaining pepper seed

The use of such machine allows to provide a separation of seeds from the ground mass, reduce injuring of seeds and process the fruits with the seeds of different descriptions of hardness.

During 2002–2004 laboratory tests of the machine were conducted, with the purpose of obtaining experimental information about its work capability. The tests were carried out using the theory of experiment planning. After casting aside the insignificant factors and ranging the factors which have greater significance, the four factored and three leveled plan of Box of the second order was chosen for conducting the experiment [Pastushenko and Dumenko 2005].

In accordance with the experiment plan, the estimation of the dependence of indexes of quality of the implementation of technological process influencing the quality of the machine performance was conducted, among them being an angle of slope of the whip plate (X_1) , a gap between whip-sieve (X_2) , the speed of whip motion (X_3) , and the level of feeding the seeds for processing (X_4) .



Fig. 8. Two-measured crossings of surfaces of reaction

Research on equations of regression was conducted using the method of twomeasured crossings. It was thus stated that the optimization of the explored parameters related to the compromise tasks. A gradual increase of the purity of seeds in a certain area and the change of independent factors results in an increase of losses. In Fig. 8., the two-measured crossings of the reaction surfaces, the dependence of seeds purity and losses caused by the change of four factors are shown. The most optimum combination of factors on the surfaces of reaction is marked by a double stroke.

The comparison of the results of the theoretical research with the experimental data was conducted according to the factors of the angle of the whip plate slope (X_I) and the speed of the whip motion (X_3) which were the determining ones for the development of differential equation of the pepper carpels motion inside the machine and became the basis of mathematical models of the process. As a result of theoretical calculations, the speed of the whip shoulder blade did not have limitations and could fluctuate in a wide enough range. But the experimental research of the effect of speed motion of the shoulder blade on the carpels showed that at speed less than 3,25 m/s «shaking» off the seed from the carpels does not occur, and at speed more than 6,7 m/s injuring of seed is taking place.

According to the theoretical considerations, the optimum angle of the whip plate slope to the axis is in the range of 14-19°, which is marked on the two-measured crossings of the surfaces of reaction by a dark bar. The superposition of the horizontal bars which represent the theoretical considerations on the optimum areas of the experimental data (Fig. 8) specifies the adequacy of the conducted theoretical research to the data obtained as a result of the experiments.

The results of production verification of the new machine for obtaining the seeds of sweet and hot pepper in the field conditions (Phot. 1) are represented in Fig. 9–10 as graphic dependences [Pastushenko *et al.* 2005b].



Phot. 1. Line for providing the mechanized technology of obtaining the seeds of sweet and hot pepper







Fig. 10. Dependence of seed losses on the seed of whip motion

CONCLUSIONS

The analysis of the graphic dependences of the two-measured crossings of surfaces of reaction obtained as a result of the laboratory tests of the new machine for the selection of seeds of sweet and hot pepper enables to assert that the optimum technological parameters of the new machine are as follows: an angle of slope of the whip plate to the axis of the whip placed in the middle part of the variation area of the experiment is $X_1 =$ 13 ... 18°; a whip-drum gap is within the limits of $X_2 = 11...17$ mm; the speed of motion of the whips is $X_3 = 3,7 ... 4,5$ m/s; the level of feeding of the garden-stuff seeds is $X_4 =$ 0,9...1,3 kg/s. At such values of the factors, the criteria of the optimization are in the following range: purity of seeds (PS) = 99,45 ... 99,50%; the losses of seeds (LS) = 8...10%.

An analysis of the graphic dependences, which represent the results of the field tests, enables to assert that the laboratory tests of the new machine are conducted at the sufficient level with disagreement which does not exceed 5%.

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