EXPERIMENTAL CHECK OF THE PROCESS OF CRUSHING SEED FRUIT OF MELON CULTURES

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Seed-farming of vegetables and melons today is one of the most toilsome branches of an agricultural production. So labour input at the growing of 1 ton of seed cucumber amounts to 50-58 man-hours. For melons (a melon, a vegetable marrow, a water-melon, a pumpkin) this parameter changes in the range of 25-40 man-hours/ton while the expenditure of labour on the growing of one ton of grain are, respectively, for wheat – 1.4; corn – 2.0; sugar beet – 2.4 man-hours.

High labour input, reduction in demand for production of vegetables has resulted in the fact that many specialized seed-growing facilities have changed their specialization and started the production of grain and commercial crops which at present are in great demand on the market of agricultural produce.

For the last five years Ukraine has been compelled to make up for the shortage of seed material from vegetables and melons by purchasing it abroad in Hungary, Bulgaria, USA, Holland etc. It results in additional, unjustified expenses in currency or the export of our products which are in great demand at home markets.

The reasons for such difficult situation in the branch are as follows:

− technological and physical ageing of the processing equipment for the allocation, clearing and drying of seeds of melons: the last samples of the seed lines were given to the farms at the beginning of the 90s;

− absence of completed research and development work for the development and modernization of machines and technological lines of allocation of vegetable seeds and melons due to the reduction of volumes of financing;

− blanks in the mechanization of separate stages of the developed industrial technologies for which the necessary grades are created and the system of machines provided for the creation of new technological equipment.

Now allocation of melons seeds is carried out under the technological circuit of grinding seed fruit – separation of seeds – clearing of seeds. For the performance of each of the technological operations separate machines are used.

For crushing seed fruit one-drum-type or two drum-type grinders of shock action are needed. One of the drawbacks of crushing the seed fruit by shock are significant quantities of peel in the crushed mass; the sizes of peel are close to the seeds and significant amounts of peel are further consumed in the technological process. At the same time many foreign countries use the method of grinding by crushing or grinding by attrition [1-3]. The classification circuit of grinders for vegetables and melons is given in Fig. 1.

At the Nikolaev State Agricultural University the research work on the creation of low inertion crushing devices of drum-type, rotary and conveyor types has been carried out since 1996.

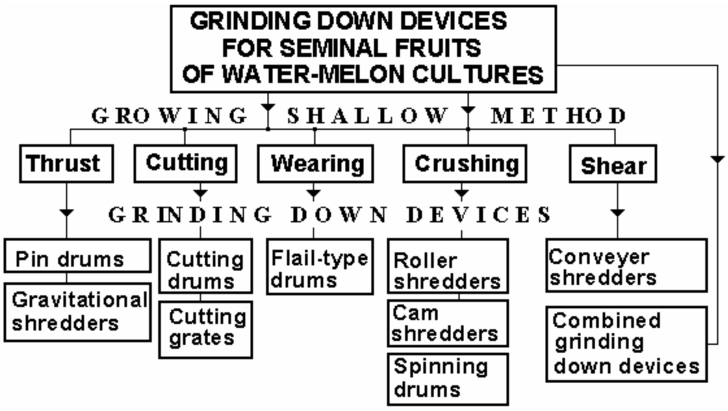

Fig. 1. Classification of crushing devices of seed fruit

Experimental check was carried out with the use of the theory of planning of experiment. Thus was rotatability plan of the second order chosen for three factors [4, 5]. The following values were chosen as independent variables: X_1 – frequency of rotation of a drum; X_2 – a backlash of a drum – deck; X_3 – a level of submission of fruit for crushing. The following served as the criteria of optimization: Y – losses of seeds and Z – a degree of crushing the peel, which were defined as:

$$Y = \frac{m_1}{m_1 + m_2} \cdot 100\% \quad (1)$$

where:

m_1 – weight of the seeds connected with the rind on an exit from a crushing device,
m_2 – weight of seeds which have passed through the apertures concave (decks).

$$Z = \frac{m_3}{m_4} \cdot 100\% \quad (2)$$

where:

m_3 – weight of the particles of the peel which sizes are equal or less than the sizes of seeds,
m_4 – a lump of the crushed part of a fruit without taking into account the pulp and rind.

Melon macerator is represented in Fig. 2.

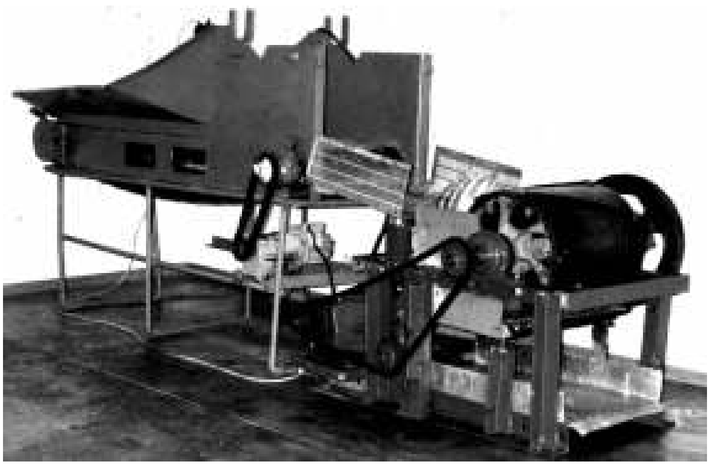

Fig. 2. Melon macerator

The equations of regression which were received after the processing of experimental data look like this:

$$\begin{cases} Y = 7.33 + 0.70 \cdot X_1^2 + 0.62 \cdot X_2^2 - 0{,}26 \cdot X_3^2 + 3.74 \cdot X_1 + 3.60 \cdot X_2 + 1.09 \cdot X_3 + \\ \quad + 1.01 \cdot X_1 \cdot X_2 + 0.58 \cdot X_1 \cdot X_3 + 0.68 \cdot X_2 \cdot X_3 \\ Z = 7.09 + 0.19 \cdot X_1^2 + 0.39 \cdot X_2^2 + 0.06 \cdot X_3^2 - 1.51 \cdot X_1 - 1.39 \cdot X_2 - 0.76 \cdot X_3 + \\ \quad + 0.20 \cdot X_1 \cdot X_2 + 0.03 \cdot X_1 \cdot X_3 + 1.29 \cdot X_2 \cdot X_3 \end{cases} \quad (3)$$

After the statistical processing and rejection of insignificant factors the mathematical models describing the quality of performance of the technological process look like this:

$$\begin{cases} Y = 7.33 + 0.70 \cdot X_1^2 + 0.62 \cdot X_2^2 - 0.26 \cdot X_3^2 + 3.74 \cdot X_1 + 3.60 \cdot X_2 + 1.09 \cdot X_3 + \\ \quad + 1.01 \cdot X_1 \cdot X_2 + 0.58 \cdot X_1 \cdot X_3 + 0.68 \cdot X_2 \cdot X_3 \\ Z = 7.09 - 1.51 \cdot X_1 - 1.39 \cdot X_2 - 0.76 \cdot X_3 + 1.29 \cdot X_2 \cdot X_3 \end{cases} \quad (4)$$

The further analysis will be done by the method of two-dimensional sections [6]. We shall equate to –1 level of submission ($X_3 = -1$). The choice of the given factor is due to the fact that in the equations (4) the factors have a smaller value in comparison with other factors. Hence, the influence of this factor on the criteria of optimization is minimal. At $X_3 = -1$ the system (4) will become:

$$\begin{cases} Y = 5.98 + 0.70 X_1^2 - 0.62 X_2^2 + 3.16 X_1 + 2.92 X_2 + 1.01 X_1 X_2 \\ Z = 7.85 - 1.58 X_1 - 2.68 X_2 \end{cases} \quad (5)$$

Let's take individual derivatives on each of the factors X_1 and X_2

$$\begin{cases} \dfrac{\partial Y}{\partial X_1} = 1.40X_1 + 1.01X_2 + 3.16 = 0 \\ \dfrac{\partial Y}{\partial X_2} = 1.24X_2 + 1.01X_1 + 2.92 = 0 \end{cases} \quad (6)$$

After the solution of the system of equations (6) we shall determine the coordinates of the centre of the surface of the response $\left(X_1^S = -1.32;\, X_2^S = -1.28\right)$. After the substitution of coordinates of the centre in the first equation of system (5) we shall find the size of losses of seeds in the centre of the surface of the response (their minimal value): $Y_S = 2.01\%$

For an initial transformation it is necessary to solve the characteristic equation:

$$f(B)_{BH} = \begin{vmatrix} b_{11} - B & 0.5 \cdot b_{12} \\ 0.5 \cdot b_{12} & b_{22} - B \end{vmatrix} = \begin{vmatrix} 0.7 - B & 0.5 \cdot 1.01 \\ 0.5 \cdot 1{,}01 & 0.62 - B \end{vmatrix} = 0 \quad (7)$$

The roots of which will be: $B_1 = 1.162$, $B_2 = 0.158$

The mathematical model for the losses of seeds in an initial form will be written down as:

$$Y - 2.01 = 1.162 \cdot x_1^2 + 0.158 \cdot x_2^2 \quad (8)$$

Analyzing the expression (8) it is possible to draw a conclusion that a surface of the response for losses of seeds will be ellipsoid, two-dimensional sections being the ellipses. The corner of the turn of the main axes of the surface of a cut equal to the centre of new coordinates is:

$$\alpha = 0{,}5 \cdot ar\,\text{ctg}\left(\frac{b_{12}}{b_{11} - b_{22}}\right) = 0{,}5 \cdot ar\,\text{ctg}\left(\frac{1.01}{0.7 - 0.62}\right) = 42°65' \quad (9)$$

Two-dimensional sections of the surfaces of the response at $X_3 = -1$ are given in Fig. 3.

Consistently equating $X_1 = -1$ and $X_2 = -1$ we shall receive the systems of the equations of regression of the following kind:

At $X_1 = -1$

$$\begin{cases} Y = 4.26 + 0.62X_2^2 - 0.26X_3^2 + 2.59X_2 + 0.51X_3 + 0.68X_2X_3 \\ Z = 8.6 - 1.39X_2 - 0.76X_3 + 1.29X_2X_3 \end{cases} \quad (10)$$

By taking individual derivatives on X_2 and X_3 we shall determine the centre of surfaces of the response for losses of seeds Y and degrees of crushing Z. The centre of coordinates of a surface of the response for losses of seeds corresponds to a point with coordinates $X_2^S = -1.53$; $X_3^S = -1.02$, and values of the function of the response – Y = 2.02%; the corner of turn of axes of coordinates in the centre of experiment $\alpha = 37°46'$. The centre of coordinates of a surface of the response for a degree of crushing Z corresponds to a point $X_2^S = 0.59$; $X_3^S = 1.08$, and the value of function is equal to Z=12.37%.

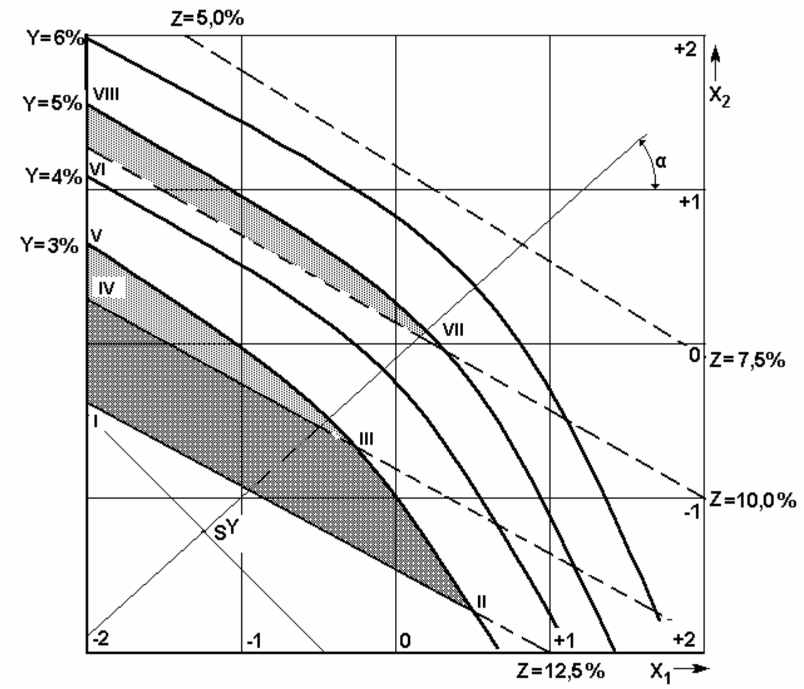

Fig. 3. Two-dimensional surfaces of a cut for losses of seeds (Y) and degrees of crushing (Z) at $X_3 = -1$

The mathematical model of losses of seeds in a canonical form will be written down as:

$$Y - 2.02 = 0.75x_2^2 - 0.39x_3^2 \tag{11}$$

The mathematical model for the degree of crushing:

$$Z - 12.37 = 0.65x_2^2 - 0.65x_3^2 \tag{12}$$

A graphic interpretation of results of the experiment at $X_1 = -1$ is given in Fig. 4.

Let's carry out similar transformations at the level of fixing of a backlash “drum-concave” $X_2 = -1$:

$$\begin{cases} Y = 4.32 + 0.7X_1^2 - 0.26X_3^2 + 2.73X_1 + 0.41X_3 + 0.58X_1X_3 \\ Z = 7.09 - 1.51X_1 - 2.09X_3 \end{cases} \tag{13}$$

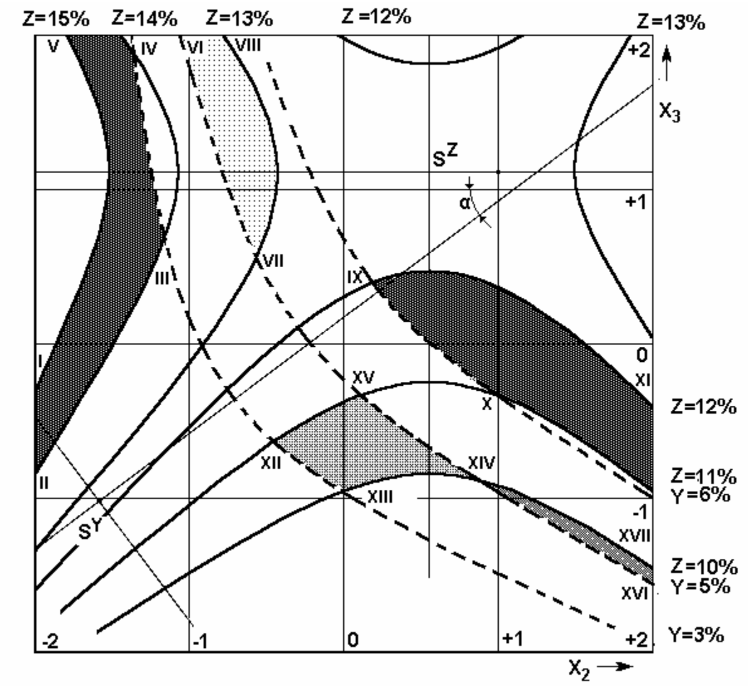

Fig. 4. Two-dimensional surfaces of a cut at $X_1 = -1$

And the equation in an initial form for losses of seeds:

$$Y - 2.00 = 0.78x_1^2 - 0.34x_3^2 \tag{14}$$

Two-dimensional sections of surfaces of the response for this case are given in Fig. 5.

Analyzing diagrams of two-dimensional sections of surfaces of the response, we can see that the zone of an optimum combination of factors at the frequency of rotation at the bottom level (X_1= 82 rev/min) is limited to the curves which are crossed in points I-II-II-IV-V. Thus losses of seeds do not exceed 3%, and the degree of crushing lays in the range of 14-15%. However the given value of a degree of crushing will not allow to receive the cleanliness of seeds of 10-12%. Technological requirements as to the development of agricultural machines for seed vegetable, melon and gourd cultures provide losses of seeds at a level of 4-5%. Thus the optimum combination of a backlash in a working zone and a level of submission will be between the curves which are crossed in points XIV-XVI-XVII. The degree of crushing will not exceed 10%, and losses of seeds will be at a level stipulated by the technological requirements.

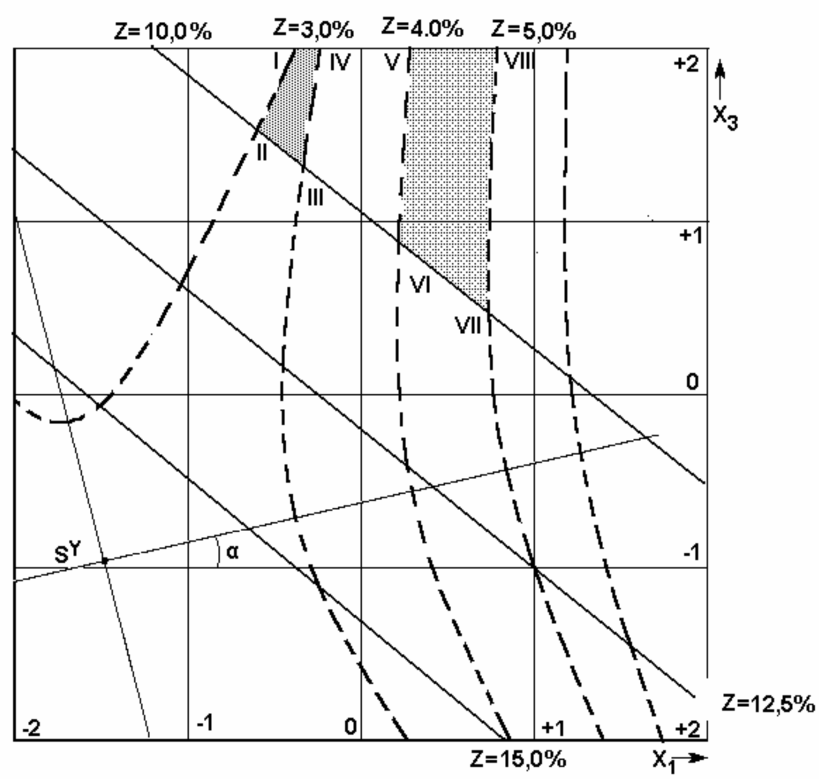

Fig. 5. Two-dimensional surfaces of a cut at $X_2 = -1$

Let's analyse the quality of work of a grinder at the size of a backlash between concaves equal to 17 mm ($X_2 = -1$). The optimum parameters on losses of seeds are reached by a drum in the zone I-II-III-IV (Fig. 4). Thus the losses do not exceed 3% and the degree of crushing is less than 10%. Allowing that the losses of seeds remain in the borders of 4-5%, the zone of an optimum combination of factors is limited to the curves which are crossed in the points V-VI-VII-VIII. One of the advantages of the given mode is that in this case the level of submission achieves the maximal value (1.5 kg/c). It allows to receive the productivity in the range 3.6-5.4 t/h.

CONCLUSIONS

At the experimental check of a grinder it has been established, that the chosen criteria of an estimation of quality of technological process are in mutual discrepancy. Reduction of losses of seeds results simultaneously in an increase of a degree of crushing. Therefore, creating the crushing devices with the drums of a pressing type (low inertial grinders), the regulation of a backlash in a working zone in the range of 10-50 mm and the change of the frequency of rotation of a drum from 100 up to 250 rev/min are necessary.

For further improvement of the design it is expedient to carry out additional research on such cultures as marrow, melon and cucumber.

REFERENCES

1. **Wehner T.**: A plot scale extractor for cucumber seeds. Hortscience, 1983. № 19. V. 2, p. 15-16.
2. **Reed G. L.**: Pressure Sprayer Eliminates Fermentation Process for Cleaning Muskmelon Seed. Hortscience. Vol. 16(2). April, 1981. p. 191.
3. Industries Incorporated (Orlean, Canada, USA) FEO engineering sales, HHH5500
4. **Goldshmidt O. W.**: Teoretycznyj analiz procesu podribnennija nasinnewych płodiw owoczewych kultur. Mechanizacja silskohospodarskoho wyrobnyctwa. NAU Kyiw 2002. p. 193-197.
5. **Opria A. T.**: Matematyczna statystyka. Urożai, 1994. p. 188.
6. **Lwowskij E. N.**: Statisticzeskije metody postrojenija empiriczeskich formuł. Wyższaja szkoła, 1988. p. 238.

SUMMARY

The article deals with the experimental researches of the process of crushing of the seed fruit melon cultures. On the basis of studying the materials the classification of the crushing devices was made to choose the optimum one from the point of view of the quality of work and power consumption. During the realization of the experimental research the compromise was reached as to the problem, that an improvement of one of the criteria of optimization resulted in a deterioration of another one. Experimental research which was carried out with the use of the theory of planning has allowed to optimize the design and technological parameters of the device.