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CONDITION ANALYSIS OF STONE FRUIT CROPS DURING THEIR PROCESSING ON PERFORATED SURFACE UNDER CENTRIFUGAL FORCES

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Annotation. In this article there is analysis of condition of stone fruit crops in fresh during their rotative movement on immobile perforated surface of cylindrical coating under field of centrifugal forces aimed at division onto semi-product (flesh) and waste (stones). Division is being performed via separation of flesh fragments from stones by hole edges. Separation intensiveness (productivity of the process) depends on structural-mechanical properties of fruit fleshes and their rotative speed.

On the example of separate fruit it has been experimentally proved that besides rotative movement on inner surface of the coating there is rotative movement of a fruit around its own axle what promotes even separation of flesh. Such a rotation is typical for fruits with maturity stage even throughout the volume, otherwise breach of skin with following flesh separation occurs locally.

Experimental researches carried out with apricot fruits and cornel have shown that productivity of the process of fruit separation depends of strength features of tissues and rotative speed of blades. Offered way of processing is carried out in non-stop mode and may be realized for all types of stone fruit crops independently on association between flesh and stone.

Keywords: stone fruit crops, perforated surface, processing, semi-product, waste.

АНАЛІЗ СТАНУ ПЛОДІВ КІСТОЧКОВИХ КУЛЬТУР ПРИ ЇХ ПЕРЕРОБЦІ НА ПЕРФОРОВАНІЙ ПОВЕРХНІ В ПОЛІ ВІДЦЕНТРОВИХ СИЛ

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Анотація. У статті виконано аналіз стану плодів кісточкових культур у свіжому вигляді при їхньому обертальному русі по нерухомій перфорованої поверхні циліндричної оболонки в умовах відцентрового поля з метою поділу на напівфабрикат (м'якоть) і відходи (кісточки). Поділ виконується способом відокремлення фрагментів м'якоті від кісточок крайками отворів. Інтенсивність відокремлення (продуктивність процесу) залежить від структурно-механічних властивостей тканин плодів і їхньої колової швидкості.

На прикладі одиничного плоду експериментально доведено, що крім обертального руху по внутрішній поверхні оболонки також відбувається обертальний рух плоду навколо власної осі, що сприяє рівномірному відокремленню м'якоті. Такий обертальний рух характерний для плодів з однаковою ступеню стиглості по всьому об'єму, в іншому випадку руйнування покривної тканини з подальшим відділенням м'якоті відбувається локально.

Експериментальні дослідження, виконані з плодами абрикосу та кизилу, показали, що продуктивність процесу поділу плодів залежить від міцності властивостей тканин і колової швидкості лопатей. Пропонований спосіб переробки виконується в режимі безперервного дії і може бути реалізований для всіх видів кісточкових культур, незалежно від зв'язку між м'якоттю і кісточками.

Ключові слова: кісточкові плоди, перфорована оболонка, переробка, напівфабрикат, відходи

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Introduction

To build up food security of the country, the principal importance gain branches of agricultural production which satisfy needs of population in food-stuff. The important place in agriculture of Ukraine is taken by gardening. Fruits and berries are one of the main sources of provision of substances necessary for human organism.

Fruits of stone fruit crops are the element of horticultural vegetal resources. This group embraces fresh as well as processed fruits and vegetables. The topicality of this group is, that after minimal processing (inspection, washing) some fruits and vegetables may be used fresh, and after processing at food industry factories the one gets preserved food.

As a result of fast transformation of planned distribution system into the market one and flawed mechanism of privatization of perennial plantings, apparently expressed negative tendencies have formed in the industrial gardening of the country: production of fruits and berries decreases, planting areas decrease sharply, their renewal tempos have fallen critically.

Current state of capacities of fruit-processing industry of Ukraine and does not currently foster modern processing of fruits and berries grown in the country. As a result, losses in many farmsteads make 25 –

30 % and more, what in general decreases economic indexes of gardening branch; besides, in modern conditions of market relations, renewal and further development of fruit-processing branch in Ukraine must be directed onto production of only economic profitable competitive products that must satisfy needs of a consumer in quality and composition

One of rational directions is introduction of wasteless technologies. From this point of view, stone fruit crops are one of the most demanded kinds of stock. Thus, there is a production of oil and almond paste started out of stone cores of stones of stone fruit crops, whereas activated carbon, special glue filler, polishing material for metal-cast production and so on are being produced out of stone shells.

Currently, there is a task of maximal preservation of initial (biological) properties of stock in the ready product during processing of vegetal stock. For this reason, there is a tendency in a world practice on stock processing in initial condition, or in fresh. Such approach allows to decrease the number of fulfilled operations without loss of quality of the final product, to simplify the technological line, to receive stones without loss of initial properties.

Topicality of the problem

During processing of vegetal stock depending on requirements to the final product, the important role is alloted to analysis of composition of its separate kinds. Afterward, properties of separate contents and their interconnection are learned. Such an approach allows to set up optimal modes of stock processing, to create effective technological schemes of its processing, to design new equipment.

The formation of a fruit is typical for all kinds and sorts of stone fruit crops and consists of three main components which in their formation and structural-mechanical properties reasonably differ from each other: by exocarp (exodermis or peel), mesocarp (parenchyma tissue or flesh) and endocarp (lignified shells, in the middle of which is the core). At the same time, properties of exodermis differ from those ones of flesh, properties of stones are typical for solid objects [1-3].

So, complexness of processing of fruits of stone fruit crops in fresh is in research of such modes, under which process of division onto components can be realized without breach of integrity of stones during maximal disintegration from flesh.

Literature overview

The processing of vegetal stock aimed at receiving the final product is being conditionally divided into three stages: preparatory, primary and final. The main goal of the preparatory stage – separation of non-edible or inferior components of fruits in the sense of food relations. Depending on the type of stock and its features, this task is being solved according to different technological schemes, but the defining one should be the scheme which maximally preserves natural properties of the initial stock. Selection of the scheme depends on the type of stock, its composition and requirements to the final product.

During processing of pomaceous stock for receiving clarified juice with flesh, mash, fruit butter, jelly and other homogeneous and non-homogeneous products, fruits are being pulped after washing and inspection. During this, mills are being used; they differ by constructive and mode features: roller, knife, hammer, turbo mills and others [4,5]. After pulping, the mixture is being heated up to certain temperatures and is being separated onto semi-product (cell sap, peel fragments, cellular walls) and waste (peduncles, seeds, seed cases, sepals, strengthening tissues). Selection of the equipment depends on pulping grade and requirements to the final product. presses, filters, separators, centrifugals, decanters. During processing stone fruit crops such a scheme cannot be realized because a stone is a solid object possessing fragile properties. In case of destruction their fragments get into semi-product, what makes following operations difficult.

Currently, division of stone fruit crops at processing plants is being carried out by either removal of stones from fruits, or separation of flesh from stones. In the first turn, stones are being removed either via stone-knock-out machinery, or the one pressing stones from fruits out. The disadvantage of the means is the fact that only such fruits may be processed, where stones are being easily separated from flesh, and there is a necessity of resetting machinery after changing a kind or a sort of fruits.

Separation via division of flesh from stones is being carried out via use of perforated surfaces with different grade of perforation. As a rule, these are wiping machines which may be appertained to the group of rotor machinery [4,5]. But use of such machinery is possible only after preliminary heat processing of fruits which is aimed at destruction of connections between cells of tissues of a fruit, and between flesh and stones as well if such a connection exists at all.

Among disadvantages of the method are: decrease in quality of final product as a result of heat processing, additional expense of heat energy, complication of processing lines due to presence of equipment for heat processing of stock.

In the work [6] the method of processing of stone stock is offered, using machinery, devices and working principle of which is equal to wiping machinery, modes of which during processing of pulped and heated up vegetal dispersion are researched in the work [7].

Wiping machinery appertains to the group of rotary machinery which has working organ as a perforated shell and a blade rotor, a number of blades makes four pieces.

A perforated shell is a thin-walled casing; wall thickness makes (0.4 – 1.5) mm. Holes are generally produced via punching. Depending on the state of utilities,

properties of metal, performed functions and other factors, hole edges at the entrance and at the exit of a utility as a rule have different state – from rounded ones at the entrance and sharp ones, often with burrs, at the exit. Diameters of holes alter in range of (0.4 – 5.0) mm depending on requirements to the final product.

It is known [8] that a a result of rotation of blades the shell is being exposed to fluctuating loads, what negatively influences strength of the shell itself as well as the quality of performed functions. For extension of service time they being mantled either into hard perforated frames, or strengthened by special elements: rim-like rings, spiral winding of steel tapes, other variants are applied too, their choice depends on loads upon the shell.

Objects of processing in working areas of wiping machinery are pulped and heated-up vegetal suspensions of pomaceous fruits or sodden fruits of stone fruit crops stock.

Thus, the following may be concluded from the mentioned above: without prior pulping and heat processing of stock, operation of wiping machinery with indicated parameters is impossible, this determines impossibility of processing stock in fresh, in particular, fruits of stone fruit crops.

The Primary part

Behavior of a fruit during moving on immobile perforated surface as a result of rotary movement of blades under conditions of centrifugal field has a rather complicated character. Such a movement is equal to movement of a ball or a cylinder on horizontal surface under influence of external force [9]. Beside progressive advance an object also rotates around its own axle. The same happens during movement of an object on the surface of immobile hollow cylinder with flat surface. In case of presence of holes, wards and other constructive elements, behavior of a body changes in dependence on geometric, kinematic and other parameters.

Fruits of stone fruit crops appertain to real objects of biological origin which possess properties of elasticity, plasticity and viscosity [10]. Indicated properties constantly alter from the moment of insemination up to condition of certain maturity grade: physiological, technical or consumptive one. As a rule, processing of stone vegetal stock is being realized on the stage of technical maturity.

During rotation of blades, the fruit is being influenced by centrifugal force pushing it to the inner surface of the shell and to working surface of a blade. This time a fruit takes stable position depending on its shape. By shape of a fruit close to spheric one (cherries, sweet cherries, peaches) its orientation in front of a blade is casual, by shape other from the spheric one (ellipsoid, egg-shaped, flattened along biological axle, pear-shaped and other), fruits take position, by which biological axle is parallel to the surface of a blade due to full fruit symmetry as well as due non-parallel one, for example in case of pear-shaped shape.

Fig. 1, 2 and 3 shows state of a fruit at typical moments of time. Fig. 2 and 3 shapes of fruit and stone are taken conditionally as spheric.

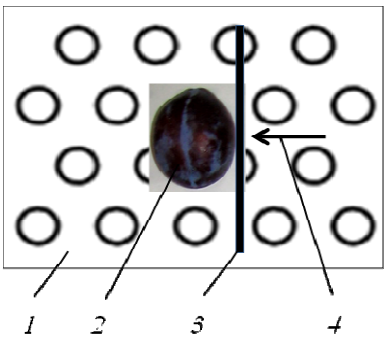


Fig. 1. Position of a fruit of plum, sort "Hungarian italian", during its relative motion along immobile perforated surface under influence of rotary movement of blades: *1* – perforated surface; *2* – fruit; *3* – blade; *4* – blade movement direction

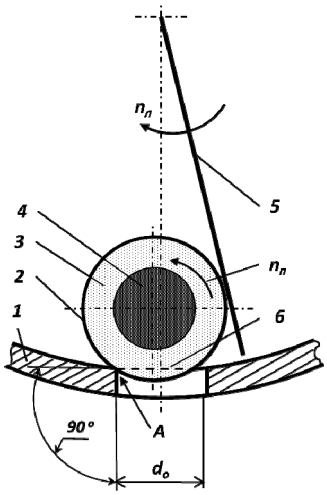


Fig. 2. Position of fruit in regard to perforation holes (transverse section): *1* – perforated surface; *2* – peel; *3* – flesh; *4* – stone; *5* – blade; *6* – conditional line of separating flesh from the stone

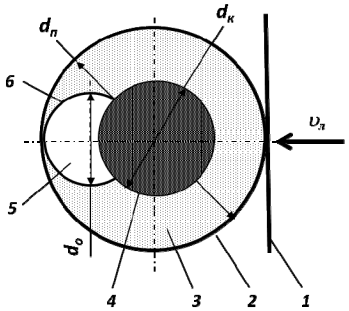


Fig. 3. Position of fruit in regard to its movement under influence of rotating blade regarding an individual hole (top view): *1* – blade; *2* – peel; *3* – flesh; *4* – stone; *5* – holee; *6* – working edge of a hole: d_o, $d_к$, $d_п$ – corresponding diameters of a hole, a stone and a fruit

Availability of perforation holes leads to cyclic impacts of edges of holes onto defined areas of fruit surface. Herewith, similarly to operation of machinery and mechanisms during wiping of boiled fruits and vegetables [11], length of the active (working) pat of an edge cannot exceed the value

$$\ell \leq (\pi d_o)/2 \qquad (1)$$

where ℓ – length of contact line of fruit surface with hole edge; d_o – hole diameter.

As it has been indicated, except rotative movement on inner surface of the shell, the fruit performs rotary movement around its own axle. But, in difference to solid objects, fruit tissues, and firstly tegments (peel), cyclically deform by working edges of holes. Herewith, deformation grade (in our case – up to complete destruction) according to experimental observations depends firstly on grade of maturity in general (physiological, technical or consumptive) as well as on grade of maturity due to volume of a separate fruit in regard to its orientation "south-north" during growth in application to separate kinds and sorts of fruits.

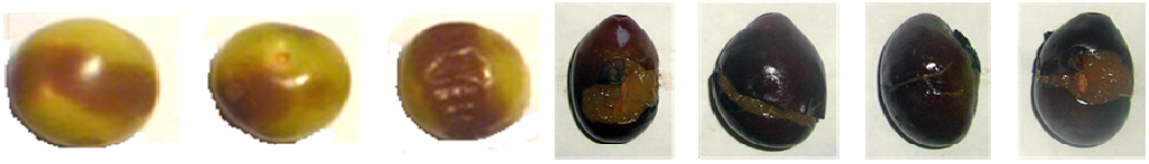
Also grade of destruction (grade of separation of flesh from stones) is influenced by strength of fruits' flesh, geometric parameters of holes (diameters) and rotary speed of blades.

Table 1 gives results of pierce test of strength of peel of certain fruits by cone penetrometer with cylindric tip with area of 1 mm^2 in transversal section

Table 1 – strength of cover tissues of fruits and flesh of technical maturity according to pierce test

Fruit	The strength of coating fabrics and pulp, σ, g/mm ^{2}				
	Minimum and maximum values strength covering tissues of fruits		Averages covering tissue strength, σ_s^{av}	The average values of the pulp strength, σ_m^{av}	Attitude $\frac{\sigma_s^{av}}{\sigma_m^{av}}$
	σ_s^{min}	σ_s^{max}			
Apricot «Home№	14	36	22,5	8	2,8
Alic «Small-fruited»	30	73	48,5	6	8,1
Cherries «Shpanka early»	14	27	19,7	7	2,8
Dogwood «Vladimirovskaya»	20	46	30,9	20	1,5
Plum «Hungarian Italian»	20	70	43,4	12	3,6
Cherries «Melitopol»	23	48	34,8	16	2,2

For confirmation of hypothesis on rotation of fruits in indicated conditions, special tests with verdant fruits of damson, sort «Fortuna», and plums, sort «Green gage» in the stage of technical maturity, have been conducted, see Fig. 4 *a*, *b*.



a *б*

Fig. 4. State of fruits surface according to results of tests:
***a* – damson, sort «Fortuna»; *b* – plum, sort «Hungarian Italian»**

Presence of meridional rings on fruits of damson, formed as a result of traumatizing cells on edges of holes during movement on inner surface of a shell indicates that fruits are in rotary movement around their axle.

Destruction of cover tissues in circumferential direction of fruits of plums on their widest transversal section indicates the fact of rotary movement around their axle.

It can be supposed that local separation of flesh on the first and fourth samples of plum indicates on various strength grade of fruits on their volume, and destruction occurs on areas of surface where strength of tissues is less.

For the purpose of analysis of impact of rotary speed of blades onto time of destruction of fruit tissues and intensity of separation of flesh from stones; results are given on the Fig. 5 and 6 accordingly. During this, fruits of apricot, sort «Domashniy», and cornel, sort «Vladimirovskiy», were used. At each level, tests have been repeated eight times. For better studying of the process of destruction of fruit tissues with following separation of flesh, tests were conducted with separate

fruits. For visual observation and analysis of fruits' behavior, strobe light effect has been used.

Tests have been conducted with use of perforated shell, diameter 125 mm, hole diameter 6mm and free area ratio of 40 %. Rotary speed of blades has been varied on levels of 4, 6, 8, 10 and 12 m/sec.

Complete description of test equipment and testing methods are given in work [6].

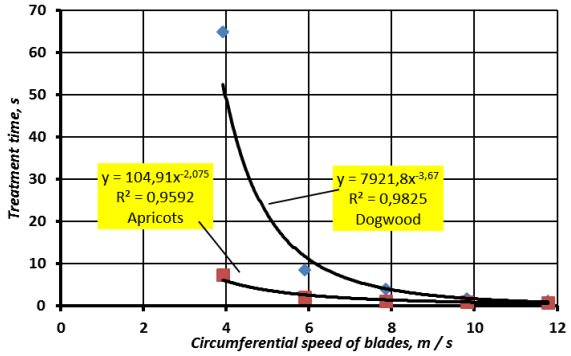


Fig. 5. Influence of rotary speed of blades onto time of fruit tissue destruction: of apricot, sort «Domashniy», and cornel, sort «Vladimirovskiy»

According to Fig. 2, destruction of peel occurs on the line of contact of hole edge with fruit surface in zone A. In this location, a certain part of fruit is situated below estimated line 6, along which flesh fragment separates. Herewith, the quantity of separated flesh is being influenced by following parameters: ratio of diameters of fruit and hole, value of centrifugal force and structural-mechanical properties of peel and flesh. Value of centrifugal force in its turn depends on mass of fruit, rotary speed of blades and radius of perforated shell.

If presumed that maturity grade of fruit on its volume is even, during further movement regarding to holes, the fruit will perform even movement around its axle, what in its turn leads to even and complete separation of flesh from stone.

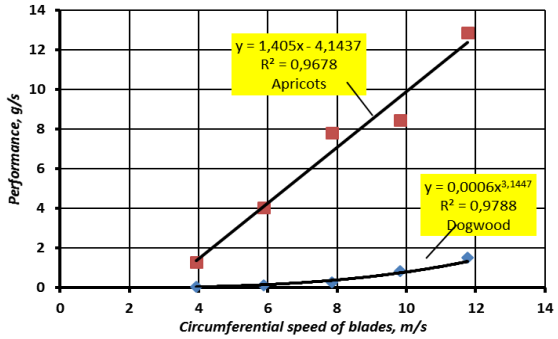


Fig. 6. Influence of rotary speed of blades onto intensity of separation of flesh from stones: of apricot, sort «Domashniy», and cornel, sort «Vladimirovskiy»

According to Fig. 3, destruction of stone is possible when ration of hole diameter and equivalent diameter of a stone are subject to conditions

$$d_o/d_к \to 1 \qquad (2)$$

where d_o is diameter of a hole; $d_к$ is diameter of a stone.

Results of tests presented on Fig. 5 indicate the fact that time of destruction of tissues of fruits with following separation of flesh, depends on strength characteristics of fruit tissues and rotary speed of blades. Such an approach allows to determine modes when destruction of fruit tissues dies not depend on their strength characteristics, see Fig. 5, range of rotary speeds (10 – 12) m/sec

Sharp differences in productivity of processing, Fig. 6, may be explained by elastic-plastic properties of fruit tissues, and, in first turn, cover tissues under similar conditions of experiment: diameter of holes (6 mm) and similar rotary speeds of blades. Thus, during processing of fruits with easy-destructible tissues on the level of minimal speeds, the process of flesh separation has linear character (e. g., apricots.) During processing of fruits with a firmer tissue structure, the process is subject to power parameter. This may be explained by lesser grade of tissue deforming in the hole zone.

Conclusions

1. Processing of fruits of stone fruit crops in fresh on perforated surface under centrifugal field for purpose of division onto semi-product (flesh) and waste (stones) is being realized in two stages. At the first stage, as a result of cyclic influence of hole edges, there is a destruction of cover tissues (peel), at the second one there is a separation of flesh from stones.

2. The main resistance to breach of fruits by hole edges is being done by cover tissues. This is connected to their formation features. Cells of there tissues are interconnected rather firm, without airspaces; cell membranes are being exposed to various chemical conversions which help saturation with suberins, cutins and other substances increasing their mechanical properties.

3. The diagram on Fig. 5 shows that breach time of fruits depends on rotary speed of blades; with its increase the difference decreases taking into account practically similar definitions. In this case, the decisive condition of acceptance of speed value is the condition of non-destruction of stones.

4. Intensity of flesh separation from stones (process productivity) during processing of fruits of different kinds depends on mechanical connections between tissue cells. Such a connection explains capability of tissues to deform around a hole. This explains linear dependence of separation of flesh from stones during processing of apricots, whereas during processing of cornel the process is subject to the power law, Fig. 6.

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АНАЛИЗ СОСТОЯНИЯ ПЛОДОВ КОСТОЧКОВЫХ КУЛЬТУР ПРИ ИХ ПЕРЕРАБОТКЕ НА ПЕРФОРИРОВАННОЙ ПОВЕРХНОСТИ В ПОЛЕ ЦЕНТРОБЕЖНЫХ СИЛ

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Аннотация. В статье выполнен анализ состояния плодов косточковых культур в свежем виде при их вращательном движении по неподвижной перфорированной поверхности цилиндрической оболочки в условиях центробежного поля с целью разделения на полуфабрикат (мякоть) и отходы (косточки). Разделение выполняется способом отделения фрагментов мякоти от косточек кромками отверстий. Интенсивность отделения (производительность процесса) зависит от структурно-механических свойств тканей плодов и их окружной скорости.

На примере единичного плода экспериментально доказано, что кроме вращательного движения по внутренней поверхности оболочки также происходит вращательное движение плода вокруг собственной оси, что способствует равномерному отделению мякоти. Такое вращение характерно для плодов с одинаковой степенью зрелости по всему объему, в противном случае разрушение кожицы с последующим отделением мякоти происходит локально.

Экспериментальные исследования, выполненные с плодами абрикоса и кизила, показали, что производительность процесса разделения плодов зависит от прочностных свойств тканей и окружной скорости лопастей. Предлагаемый способ переработки выполняется в режиме непрерывного действия и может быть реализован для всех видов косточковых культур независимо от связи между мякотью и косточками.

Ключевые слова: косточковые плоды, перфорированная обечайка, переработка, полуфабрикат, отходы.

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