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Modeling fetus melon as an object of technical processing

B Shaymardanov[1*], A Borotov[1] and Y Jumatov[1]

[1]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan

bakhtiyor1961@ mail.ru

Abstract. The Republic of Uzbekistan is one of the leading regions for the production of gourds - especially the most valuable varieties of melons. The nutritional value is primarily due to the high sugar content, and the taste value is due to the sucrose content. Summer grades with a sugar content of 12 ... 19% are considered the most sugary. The sucrose content is 60 ... 80%, but these varieties for long-distance transportation are practically unsuitable, so they are used in growing areas. It has been established that in non-waste processing from 1 ton of melon fruit it is possible to obtain: melon jam - 155...165 kg or concentrated melon juice (“honey”) – 65 ... 70 kg or dried (dried) melon – 70...75 kg; vegetable oil from seeds – 2.5...3 kg; protein flour from the peel – 20...23 kg. The article presents the results of a study of the physicomechanical properties of melon fruits as an object of technical processing of peel, pulp, and seeds. To conduct studies of the physicomechanical properties of melon fruits, a methodology for experimental research has been developed.

1. Introduction

The developed technology for processing melon fruits includes the following list of main and auxiliary technological operations [1, 2, 18].

Harvesting. Melons are harvested as they ripen when the fruits reach a standard size. A sign of maturity of early summer varieties is a sharp yellowing of the fruit and the appearance of a strong “melon” flavor. Many Central Asian summer melons, when ripe, also change the color of the fruit to yellow, but they do not have a “melon” flavor. Those of them that do not turn yellow slightly lighten. Winter melons rarely change color; their maturity in storage is established by softening the bark. The quality of fruits has certain requirements.

Manual harvesting of melon fruits, their removal to the edges of the field, transportation in vans, cars or trolleys to places of shipment to the consumer is adapted for direct consumption of fruits or their quick sale.

Repeated weighing of fruits, shifting them in layers (the fruits under pressure from each other), all this leads to surface damage and decay of the damaged areas. Such fruits are not preserved even within the implementation period. When loading onto a car or bogies, you cannot throw fruits out of your hands, as they can damage the seed nest, which will cause internal decay of the fetus. It is advisable to remove the fruits on the field in boxes. This makes it possible to take into account the amount of production and not outweigh it several times. The loading and unloading of boxes are easy to mechanize. To do this, boxes should be made standard. The bottom and walls should be soft-lined, boxes can be placed in containers.

Gourds should be sown with a tape method to improve the care and transport of vehicles across the field and the export of crops.

Winter melons are adapted for transportation over long distances, they are harvested exclusively in Central Asia, and they are transported to cities, as a rule, in the fall, right from the field. Therefore, Central Asian melons go on sale immature and sick along the way, with very poor quality [3 – 7].

Winter melons should be sold only after they have matured in storage at the place of cultivation. Summer varieties of melon during transportation lose a lot of sugar and are unsuitable for storage.

2. Methods

In Central Asia, early-growing varieties of melon begin to ripen in late June and mid-season - in early August. Late ripe melons of winter varieties are removed in late September – early October, they can be stored until spring. Early and mid-season melons are harvested every 3 ... 5 days as they mature. In total, produce 5...6 fees.

For on-site consumption, normally ripened fruits are removed (consumer maturity). For transportation and storage, the fruits are harvested slightly unripe (technical maturity), the fruits must have stalks. Fruits are harvested in the early morning, in the absence of containers they are carried out of the field on their hands or in a soft stretcher under a canopy or immediately closed with tops of water on the field.

3. Results and Discussion

Fruit storage. Based on studies of the physicomechanical properties of melon fruits and determination of bearing capacity during transportation or storage at the processing site for a period of not more than 10 days, we recommend laying melons in 2...3 layers with layering them with soft litter (tops, reeds) [8].

Determination of technological parameters of processing industries. As a result of the analysis and development of technological processes schemes for the primary processing of melon fruits, the directions and methods of processing are determined, which should be combined based on the specific conditions of state, collective, or farms [9].

The main criterion for determining the capacity (processing volumes of agricultural products) of processing enterprises is to ensure conditions for equal productivity of the processing line and productivity of the small-scale sector supplying raw materials for processing. The amount of processed raw materials (annual production Q_g) at the enterprise depends on the area occupied by a particular crop and the utilization rate of this crop for processing:

$$Q_g = \sum_{i=1}^{i=n} Q_i = \sum_{i=1}^{i=n} \left(\gamma_i u_i S_i \right) \qquad (1)$$

where Q_i is quantity, i – h raw materials processed at the enterprise, t ;

n is the number of types (varieties) of agricultural products, scheduled for processing;

γ_i is utilization rate i – go raw materials for processing;

u_i is productivity i- th raw material, t/ha;

S_i is the cultivated area i – th raw material, ha.

Replaceable plant productivity in processing i – th type of raw material is defined as:

$$Q_{sm}^{i} = \left(1+\mu_i\right)\frac{Q_i}{\tau_i} \text{ t/sm} \qquad (2)$$

where μ_i is non-uniformity ratio i - h raw materials for processing, it is μ_i = 0,22…0,35; τ_i is average cleaning time i – th type of raw materials, days.

Delivered raw materials can be stored for a certain time on raw material sites and equipped storage facilities (refrigerators) pending processing. The shelf life of raw materials, depending on the storage method and type of product, can vary within wide enough limits.

To store certain raw materials, storage areas are determined by the formula:

$$F_{xp} = \gamma_{xp} \sum_{i=1}^{i=n} \frac{Q_{sm}^{i} \left|\tau_i\right|}{\left|P_i\right|}, \quad m^2 \tag{3}$$

where γ_{xp} is coefficient taking into account the uneven loading of raw material sites, a also the area used for the passage of vehicles and the placement of transporting equipment. According to literary recommendations, you can accept γ_{xp} = 1.35…1.38;

$\left|\tau_i\right|$ is permissible storage duration i – of raw materials at the site, depending on the adopted method of temporary storage, h.;

$\left|P_i\right|$ is permissible storage load i – of raw materials at the site, depending on the type of storage container used, t/m^2.

The determination of the number of washing machines, grinders (crushers), homogenizers (presses for juice in the production of juice), evaporation plants and other machines included in the production line is carried out according to the formula:

$$n_j = \frac{Q_{sm}}{\tau_{sm} q_{\text{sm}}} \text{ kg / h,} \tag{4}$$

where β_{nap} is standard coefficient of steam consumption for technological needs (for sterilization of products and processing of containers).

The consumption of water and energy for the implementation of the main technological process is determined by the formula:

$$q_{\text{water}} = \sum_{j=1}^{j=m} \beta_{\text{water}\,j} q_{sm} \quad \text{m}^3/\text{h} \tag{5}$$

$$q_{\text{energy.}} = \sum_{j=1}^{j=m} \beta_{water.j} \quad \text{kW} \tag{6}$$

where $\beta_{water.j}$ is specific water consumption j – th consumer, m^3 /t;

$\beta_{energy.j}$ is installed capacity on j – th energy consumer, kW;

m is the number of machines installed in the production line.

Consumption of water and energy for domestic needs and support operations are determined by the norms of consumption.

The purpose of the study is to model the melon fruit of the Republic of Uzbekistan for non-waste technical processing, both primary and deep.

Consider the fruit of melon as a raw material for technical processing. Figure. 1 shows the basic geometric characteristics that should be considered when developing technology and technical means affecting the fetus [10, 11].

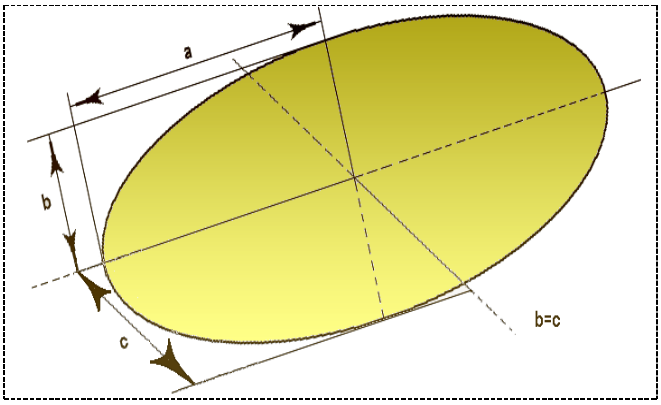

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Figure 1. Geometric characteristics of melon fruit

In the literature, the ratio of the length to the diameter of the melon fruit is usually defined as the index of the shape $k = a/b$.

But the external geometric parameters of the fruits do not give an idea of the actions that should be performed on the fruit to perform the initial and complete technological processing.

Figure 2 shows a cross-section of melon fruit. Here it is necessary to highlight several basic elements: - peel having a thickness h_k;

- pulp having external and internal diameters d_{pulp} and $d_{\text{floor.}}$, formed by the skin and internal cavity; placenta with seeds enclosed in the internal cavity.

Therefore, when prescribing processing methods for cutting constituent fruits, one should take into account the volume that constituents of the fetus have.

In the longitudinal section of the fetus (Figure 3), we select the length of the internal cavity, which determines the volumes of pulp and placenta with seeds.

As noted in the shape of the melon fruit can be ellipsoid, oblong, pear-shaped, etc. But to generalize all sets of forms, we assume that the melon has the shape of an elongated ellipsoid. We also introduce a simplification that, with a slight error, can be accepted for subsequent research, that the surface of the peel, pulp, and inner cavity are equidistant to the outer surface of the fetus [12, 13].

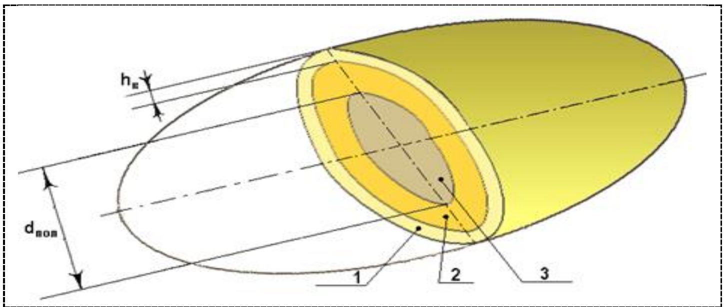

Figure 2. Cross-section of a melon fruit
1-peel; 2 pulp; 3-internal cavity (placenta with seeds).

Then, the volume of the fetus as a whole is determined by the formula:

$$V_{пл} = \frac{4}{3}\pi a b, \ \text{m}^3 \tag{7}$$

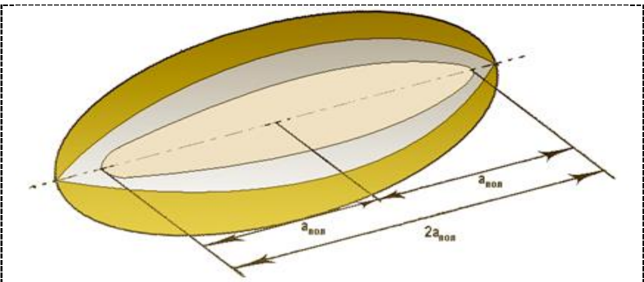

Figure 3. Fourth longitudinal section of a melon fruit: $2a_{\text{floor}}$ - cavity length

Given the accepted designations, according to Figure 2 and Figure 3, we determine the volume of the peel V_{leather}, pulp V_{pulp}, and placenta (internal cavity) $V_{\text{floo r}}$ according to the formulas:

$$V_{\text{leather}} = \frac{4}{3}\pi\left[ab^2 - (a-h_\kappa)(b-h_\kappa)^2\right]m^3$$
$$V_{\text{pulp}} = \frac{4}{3}\pi\left[(a-h_\kappa)(b-h_\kappa)^2 - a_{\text{floor}}\left(\frac{d_{\text{floor}}}{2}\right)^2\right]m^3 \quad (8)$$
$$V_{\text{floor}} = \pi\frac{a_{\text{floor}}}{3}d_{\text{floor}}^2 \quad m^3$$

The problems of cutting the peel from the surface of the fruit are associated with the need to justify the parameters of the working bodies of the machine [14]. When choosing cutting methods, the viscoelastic properties of the material are taken into account [15]. To account for properties, a mathematical model of the material is required. The mathematical description of the mechanical properties of materials in rheology is described by a combination of elements with sufficient accuracy, reflecting the properties of materials: elasticity, viscosity, ductility. With this combination, priority is given to those properties that are essential for solving the task. We assume that the characteristics of the behavior properties of fibrous materials under load are more suitable for a physical model containing three series-connected elements (Figure 1):

element E_1 instantaneous elasticity;

a storage elasticity element E_2 connected in parallel with a viscosity element;

a flow element connected to the first two in series.

To believe that the deformation of each of the elements E in this model obeys the Hooke law, and the elements obey Newton's law, which means simplifying the task significantly. Nevertheless, with this assumption, this model allows us to explain the essence of the process of deformation of viscoelastic materials under load. So, with the rapid loading of the model, its complete deformation will occur mainly due to compression of the spring (element) E_1. When fixing the model in a compressed state, the E_1 spring will begin to move the piston of the element. As the latter advances, the E_1 spring will expand and the voltage will decrease. We get a picture of stress relaxation under constant deformation.

The creep phenomenon characteristic of elastic-viscous materials can be obtained on this model provided that a constant load is applied to it. Under its action, first, a quick deformation of the model occurs due to the compression of the spring of the element E_1, and then a gradual deformation due to the compression of the spring of the element E_2 along with the movement of the piston of the element η_2. When the load is removed, the spring of the E_1 element will unclench instantly and E_2 can only be unclenched, acting on the element piston η_2. Item position η_1 fixes permanent deformation.

An analytical description of the plant material model is reduced to a differential equation of the form:

$$T\sigma + H\sigma + K\sigma = \eta_2\varepsilon + E_2\varepsilon \quad (9)$$

where *T*, *H*, and *K* are some constants whose values are defined as:

$$T = \frac{\eta_2}{E}; \qquad H = 1 + \frac{E_2}{E_1} + \frac{\eta_2}{\eta_1}; \qquad K = \frac{E_2}{\eta_2}. \quad (10)$$

An analysis of the solutions of particular cases of equation (3) makes it possible to establish to what extent the adopted model has the properties of an elastic-viscous material and, in particular, the phenomena of creep and stress relaxation. So if at a point in time $t = 0$ voltage begins to act $\sigma = const$, then equation (3) takes the form:

$$\sigma = \eta_1\left(\frac{\eta_2}{E_2}\frac{d^2\varepsilon}{dt^2} + \frac{d\varepsilon}{dt}\right) \quad (11)$$

The solution of this equation will give the dependence of the change in strain in time - the creep equation:

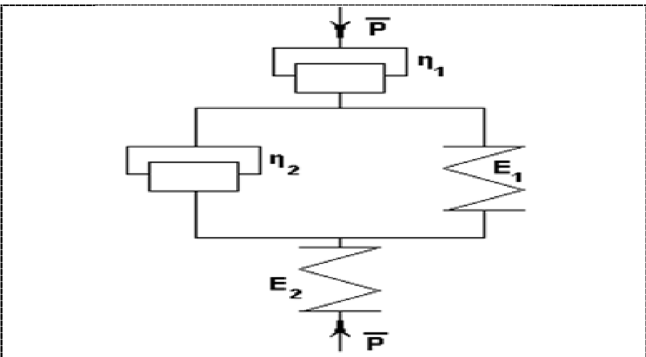

Figure 4. Rheological model of plant material

$$\varepsilon = \sigma\left[\frac{1}{E_1} + \frac{1}{E_2}\left(1 - e^{-kt}\right) + \frac{t}{\eta_2}\right] \tag{12}$$

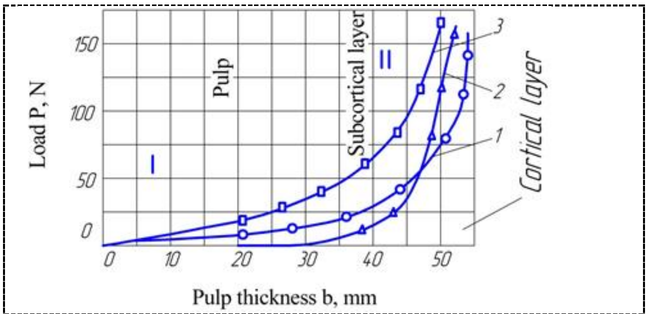

Figure 5. Residual deformation under the influence of a static load on the melon fruit of the working surface in the form of a cylinder with a diameter of 50 mm and a length of 60 mm

According to this equation for $t = const$ material gets instant deformation ε, while increasing t the deformation grows, which is characterized by creep. On condition $\varepsilon = const$ the right side of equation (5) vanishes, i.e.

$$\sigma + H\sigma + K\sigma = 0 \tag{13}$$

The general solution to this equation is:

$$\sigma = Ae^{-\alpha_1 t} + Be^{-\alpha_2 t} \tag{14}$$

the characteristic equation will be written as

$$\alpha^2 + \frac{H}{T}\alpha + \frac{K}{T} = 0 \tag{15}$$

based on the solution of which the coefficients are determined α_1 and α_2.

Arbitrary constants A and B of equation (8) are determined from the initial conditions $t = 0$.

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$$B = \varepsilon E_1 - A; \qquad A = \varepsilon \frac{E_1^2 \left(\frac{1}{\eta_1} + \frac{1}{\eta_2} \right) - \alpha_2 E_1}{\alpha_1 - \alpha_2} \tag{16}$$

From which it follows that the constants *A* and *B* depend on the final strain value ε. The solution of equation (7) gives the dependence of stress relaxation (8). From the analysis of the latter it follows that with $t = const$ voltage matters $\sigma = A + B$, with increasing voltage decreases exponentially.

The residual deformation on the fruits, depending on the current load when a cylinder with a diameter of 50 mm and a length of 60 mm is introduced into the body of melon, is shown in Fig. 2. As can be seen from the graph, it obeys a linear dependence, which is described by an equation of the form:

$$\varepsilon = -3{,}44 + 0{,}037P \ \ mm \tag{17}$$

The specific tensile strength at a plunger pressure of 1 sm^2 on the side of the pulp along the horizons is shown in Figure 3. Three characteristic zones are distinguished in the diagram: *I*-zone (approximately 80% of the pulp thickness) - a zone of low strength; *II* – zone - zone of increase in the strength of the pulp layer; *III* – zone – zone of sufficiently high strength - cortical layer. In this case, the concept of “inedible part of the pulp of the fetus” on the graphs is expressed by the *III* – zone. Obviously, this zone is the boundary thickness of the cut layer of the peel. To assess the influence of the forces included in the obtained equation, we consider the results of experiments obtained by dynamically cutting the peel from the surface of the fetus, as well as those obtained by cutting a knife into the body of a melon.

Figure 4 shows the dependence characterizing the process of cutting the subcortical layer of melon pulp. During the study, the relief was measured in the cutting zone and the measurement was recorded simultaneously with the *PS-4* self-cleaning device.

Relative deformation ε pulp characterized by periods of instant compression *AB*, then a period of gradual compression is observed *BC*, subsequently, there is a process of instant expansion CD, completion of the process is characterized by a gradual release DE.

The specified process corresponds to the mathematical model described above. Process AB corresponds to instant element compression E_1 Figure 1, the process *BC* is gradual compression of an element E_2 together with the movement of the pistons η_1 and η_2, the process CD is the instant release of the element E_1, the process DE is gradual decompression of the element E_2 and EF is residual deformation. Therefore, our assumption that the mathematical model of elastic-viscous material is consistent is confirmed by an experimental study.

The above dependencies allow us to calculate the volume and taking into account the density of individual elements and their mass. This allows you to plan the production of different types of products with waste-free processing of melon fruit [10, 16, 19, 20].

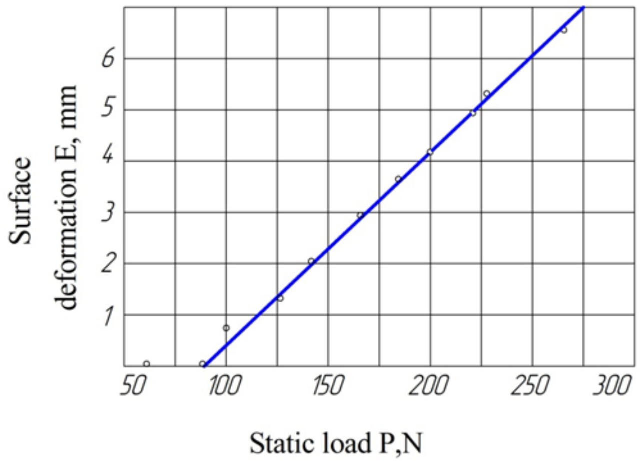

Figure 6. The diagram "load-deformation" to determine the hardness of the pulp with the peel from the side of the seminal cavity: 1-Ak-uruk; 2 – Ich-dogwood; 3 – Assate.

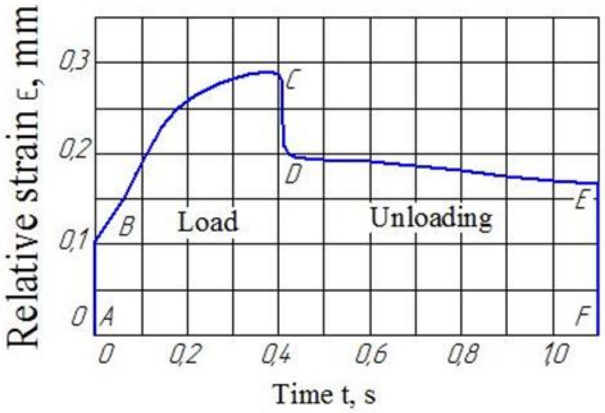

Figure 7. Experimental dependence of the relative deformation of the subcortical layer when cutting the peel 8 mm thick at the fruit of the Ak-Uruk melon with a cutting speed of 0.3 m/s with a knife 1.2 mm thick

4. Conclusions

1. The above dependencies allow us to calculate the volume and taking into account the density of individual elements and their mass. This allows you to plan the production of different types of products with waste-free processing of melon fruit.

2. The replaceable productivity of technological equipment for processing raw materials should correspond to the possible daily harvest of the crop to be processed. Taking into account real melon crops of summer and autumn varieties, which are available in farms of several regions of Uzbekistan (on average, allocated for melon planting $S_{\partial.}$ *=40…60 ha* of the cultivated area) and real productivity (average melon productivity is $U_{\partial.}$ *= 25…35 t/ha*), it is possible to determine the amount of work equal to $Q_g = 1000...2000\frac{\pi}{4}$ t. From this volume for processing send $k_{per.}$ = 60…70 % harvest that will $G_{per.}$ *= 600…1400 t*. Assuming that the melon fruit processing process corresponds to the harvesting time, which is $\tau_{ub} = 40...50$ days, and also considering that storage of fruits before processing may amount to $\tau_{xp.}$*=10* days.

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3. Taking into account the above for the adopted average conditions, the shift capacity of the melon fruit processing workshop will be Q_{sm} = 12…20 t/sm.

4. Technological equipment for the non-waste processing of melon fruits should be oriented to the processing of pulp (65 ... 70%), peel (20 ... 25%) and seeds (10 ... 15%).

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