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MODELING THE FLOW OF FRESH AND DEEP FROZEN CALIBRATED FRUIT BY ROTATING SIZING MACHINES
MODELIRANJE PROTOKA KALIBRISANOG SVEŽEG I DUBOKO ZAMRZNUTOG VOĆA NA ROTACIONIM DISKOSNIM KALIBRATORIMA

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ABSTRACT

The principle of rotating sizing machines based on a division of the fruits of various geometrical characteristics of the gaps of the same dimensions are typical for any given class separately. The classes are deployed from the smallest to the largest in the direction of rotation of the disk, and arc sizing board can be mixed performance, as slope metering gape and step metering gape. This paper discusses the movement of fruit in relation of their speed, and analyzes the model for determining the capacity of rotating sizing machines for different kinds of fresh fruit and deep-frozen raspberries. Mass flow calibrator or capacity for fruits tested in this paper are similar to those obtained in some other known methods. Calibrated mass flow is proportional to the weight of fruit and fruit in inverse proportion to the diameter of treated fruit.

Key words: *sizing fruit, rotating disk, sizing board, metering gap, flow.*

REZIME

Princip rada rotirajućih diskosnih kalibratora zasniva se na odvajanju plodova različitih geometrijskih karakteristika kroz zazore odgovarajućih dimenzija karakterističnih za svaku zadatu klasu posebno. Klase su raspoređene od najmanje do najveće u smeru rotacije diska, a lučna kalibraciona pregrada može biti dvojake izvedbe, sa konstantno opadajućom širinom zazora i sa kaskadnom širinom. U ovom radu se razmatra kretanje plodova sa aspekta njihove brzine, i analizira model za određivanje kapaciteta rotacionih diskosnih kalibratora za različite vrste svežeg voća kao i za duboko zamrznutu malinu. Maseni protoci odnosno kapaciteti kalibratora za ispitane vrste voća u radu su približni onim koji su dobijeni nekim drugim poznatim metodama. Maseni protok kalibriranog voća srazmeran je masi i obrnuto srazmeran prečniku plodova za tretirano voće.

Ključne reči: *kalibrisanje voća, rotacioni disk, kalibraciona pregrada, merni zazor, protok.*

INTRODUCTION

Fruit after harvest differ in many characteristics. This primarily refers to the variety, maturity, damage, dimensions, etc. Selection of fruits after harvest is a set of unit operations that enable the selection of fruits for bringing to market, store or use immediately, and for industrial processing. For distribution of products on the market it is necessary to ensure equality of products in quality and dimensions. For big fruit producers all of this operations is necessary because of the competitiveness in the market. Due to the export potential of raspberries, it is necessary to invest in this type of production in all its phases, from planting to operations that are performed after harvesting. This includes numerous operations, from the transportation of fruit, removal of impurities, sorting, calibration, to the final operations, which refer to further processing, if aplicable (cutting, pureeing) or packaging of selected fruits according to size and quality *(Veljić et al., 2010)*.

The number of influential factors that define the possibility of equalizing the quality of fruit, according to defined criteria, indicates the complexity and importance of operations postharvest processing of fruits *(Gladon, 2006)*. The term processing of fruits is primarily related to the separation and grouping of fruits in large degree similar in quality and dimensional characteristics. Without marginal other operations which precede or are in connection with the operation of sorting and sizing should be as much as possible use of mechanized methods, partly in the selection of products by their quality, and greater extent in selecting products by their dimension or weight. Aggravating factors when choosing products by geometric or weight requirements of the diverse form of fruit: round, elongated or flattened shape. In any case, as the view of complexity, volume and cost levels specified post-processing operations and packaging fruit can be taken by the fact that processing 1.0 tons apple spent the 20-40 worker-hours, equivalent to 50-60% of the cost of collection and nearly one-third total production *(Veljić and Maric, 2002)*. In order to rationally postharvest processing of fruit should be taken about the choice of working groups to sort and sizing as well as the possibility of using such elements in the formation of more complex systems to ensure higher productivity *(Đević and Dimitrijević, 2005)*.

Nomenclature

D (mm)	- diametar of metering gap,
d(mm)	- average diametar of calibrated crops,
g (m/s^2)	- constant of gravitation,
k_e	- extent ratio,
k_f	- feed ratio,
k_d	- distribution ratio,
m (kg)	- average mass per one crop,
n (min^{-1})	- round per minute,
Q (kg/h)	- flow rate of calibrated crops,
t (s)	- time,
V (mm/min)	- velocity,
ω (rad/min)	- angle velocity,
Greek symbols:	
α(°)	- cone angle of rotating disk,
Indexes:	
p	- portable motion,
r	- relative motion,
N	- numbers,
m	- mass masa

MATERIAL AND METHOD

According to the principle of work sizing machines can be translational or rotational in case of separation of fruits in size. Most of today's commercial and industrial sizing machines based on translational, translational-vibratory system of sorting the fruit by size. Capacity of those machines were 3-10 t/h depending on the type and quality products. Rotating sizing machines on the other hand is characterized by a significantly lower capacity and flow sorted by size fruit. Their flow is certainly less than 3 t/h, which in certain cases it may be an advantage if such calibration is not required greater capacity on the other side makes more complex the machine and reduces its productivity and profitability even more. Reduction in capacity can be compensated by coupling multiple parallel rotating sizing machines and linking their equivalence classes conveyor system. Unfavorable aspects of such a system would be to increase the length of the path of fruit after the calibration, increasing the possibility of such damage. The advantages of rotary sizing machines are many times smaller dimensions than the translational. The main part of rotating sizing machines consists of a rotating disk and sizing board. This board is always arch shape, is located above the disk at its outer or one of the internal volume, and can be diverging metering gap (Figure 1a) or constant metering gap (Figure 1b). In the first case of slope metering gap of which depends on which class will be reported each crop change along metering gap and rotating disk by which performs sizing, while the step metering gape size changes gradually so that the gap is constant for each particular class. Fruit is delivered to the disk over the feeding tray. Fruit distributed in volume of the disc moves from the inside wall of the sizing board. Metering gaps are arranged from smaller to larger in the direction of rotation of the disk, so that stands at the beginning of the smallest classes, and at the end of the large crop. Number of class is limited, but may be applied three (small, medium and large) and possibly the fourth largest calibration that includes fruits that are not classified in any of the previous, by model. After passing through the metering gap between the rotating disk and a sizing board crops due to one of the receiving tray for acceptance of certain crops class.

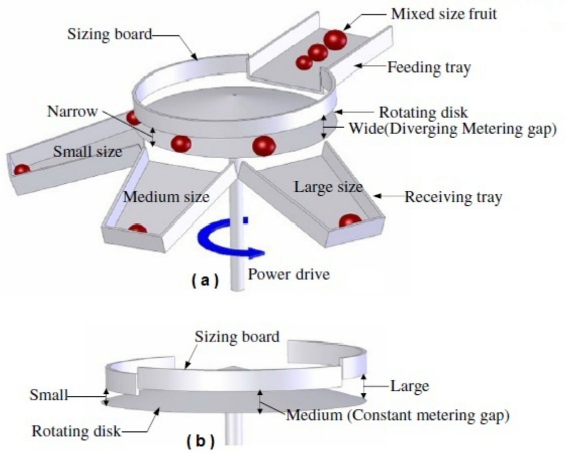

Fig. 1. Model of rotating disc fruit sizing machine. (a) Slope metering gape and (b) step metering gape (Jarimopas et al., 2007)

RESULTS AND DISCUSSION

Crop that is on the rotating disk has a transmission and the relative speed. The transmission speed of the crop is a consequence of rotation disk, and it is, in the case of ona series of fruit near sizing board, calculated approximately as:

$$V_p = \omega \frac{D}{2} = n\pi D, \tag{1}$$

while the relative speed of the fruit due to their movement on a steep plane which corresponds to the angle of cone rotating disk, and is calculated as:

$$V_r = gt \sin\alpha \cdot \tag{2}$$

Cone angle of disk conduce discharge of disk through metering gap between rotating disk and sizing board so that grown relative velocity of crops and decrease chance for obstruction. When the crops start with sizing board when calibrating in a single series crops, $k_f = 1$, which is mostly the case, then the relative velocity of the fruit does not exist, so the absolute speed is equal to the transmission speed of the crops. Functional dependence for this velocity of round per minute and diameter rotating disk is shown with graphic in Figure 2.

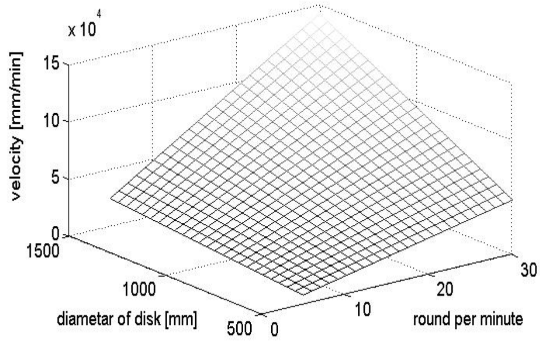

Fig. 2. Velocity as function of diametar of disk and round per minute

Just when the crop is found against the metering gap on the sizing board whose dimensions exceed the dimensions of the crop, then it board no longer stops the relative motion, and the result obtained and the relative velocity component moving rotating disc down and pull-down in receiving tray for a class.

Total mass flow of the calibrated section of fruit at the exit of sizing machine:

$$Q_N = 60 k_e k_f k_d \frac{(D-d)\pi}{d} \cdot n, \tag{3}$$

Total numbers flow of the calibrated section of fruit at the exit of sizing machine:

$$Q_m = 60 k_e k_f k_d \frac{(D-d)\pi}{d} \cdot m \cdot n \cdot \tag{4}$$

Extend ratio, $k_e < 1$, is construction parametar in relation of wide feeding tray and space it occupy above rotating disk. Feed ratio, $k_f \geq 1$, grown if feed tray have more parts. Crops during moving are not dispose whole sizing board along, as well its decrease velocity due to stopping, sliding, rebound and rubbing, so that it is necessary to attend correction of flow by distribution ratio, $k_d < 1$. The average diameter of selected fruits are usually equal to the width of the middle gap of step metering gap or width of gaps in the slope metering gap.

Determination of volumetric flow expressed by the expression (1) was applied for different kinds of fruits and the results shown in Table 1 and shown with diagram in Figure 3 and 4. Adopted as the disk diameter D = 600 mm and speed disk n = 21min-1 in which the lowest calibrated crops are damaged *(Jarimopas et al., 2007)*. Coefficients which exists in these terms were adopted $k_e = 0.7$, $k_f = 1$, $k_d = 0.5$.

Table 1. Properties of eight kind fruit and calibrated crops mass and numbers flow

No	Kind of fruit and variety	Average crop diametar (mm)	Average crop mass (kg/1000)	Date by reference	Calibrated crops flow (numbers/h)	Cali-brated crops flow (kg/h)
1	mangosteen	55	80	*Jarimopas et al., 2007*	13722	1097.7
2	tangerine Clementine	60	82	*Sahraroo et al., 2008*	12463	1021.9
3	orange Tompson	77	218	*Sharifi et al., 2007*	9405	2050.4
4	apple Redspar	80.4	229.6	*Kheiralipour et al., 2008*	8949	2054.7
5	peach Filina	68.1	181	*Zhivondov, 2010*	10816	1957.6
6	apricot Rajabali	43	53	*Mirzaee et al., 2009*	17937	950.7
7	cherry Cha-bestar	21	6	*Naderi-boldaji et al., 2008*	38179	229.1
8	deep frozen raspberry	20	6	measured in factory ITN „EKO POVLEN“ Kosjerić	40157	240.9

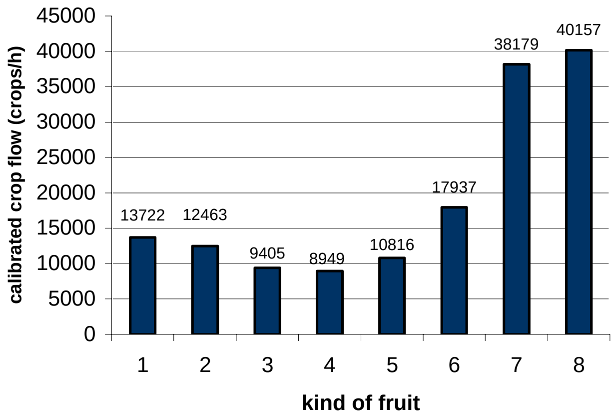

Fig.3. Diagram of calibrated crops numbers flow

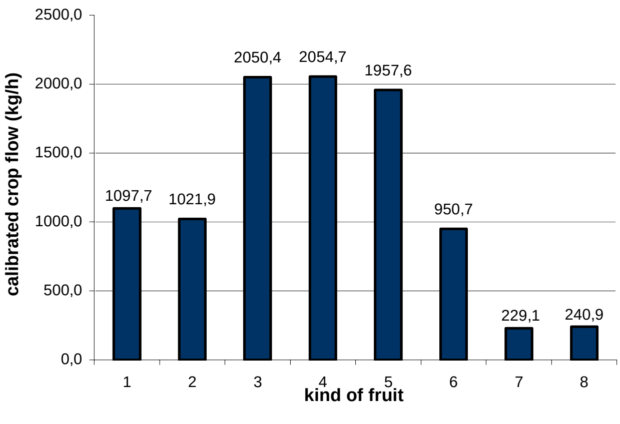

Fig.4. Diagram of calibrated crops mass flow

Most of the fruits varies considerably by varieties in relation to physical characteristics, and are treated in Table 1 to reference varieties for which it can be argued that the typical representatives of their species. Functional dependence of mass flow rate of the average diameter of fruits and their average weight is shown with graphic in Figure 5 On the diagram is evident that the capacity and efficiency of rotary sizing machines increases with increasing weight and decreasing diameter of the crop.

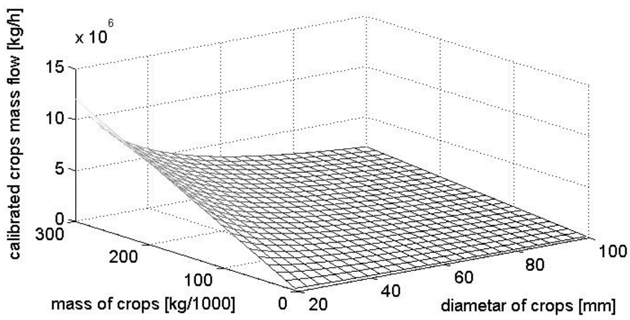

Fig. 5. Calibrated crops mass flow as function of diametar of disk and round per minute

CONCLUSSION

In sizing fruit is possible birth defects due to stroke, swelling, and frozen fruit in calibrating the possibility of fractures. In both cases it is necessary to optimize the speed of the disk and the capacity of these calibrators to calibrate more efficient with less damage to crops. Due to the complex movement of fruits on a rotary calibrators are suitable almost exclusively for fruit whose fruit spherical, while the calibration of other types of fruit was necessary to increase the angle of the cone disk. In the case of aggregating multiple individual rotating sizing machines their advantage which refers to the small dimensions disappears in comparaton to translational sizing machines of the same rank by capacity.

Further studies of rotating sizing machines should be adapted to each type of fruit individually for their specific form and dimensions in the direction of optimizing the following parameters of rotating sizing machines: diameter metering gap, the rotating disk rotation speed, angle of the cone rotating disc ratios contained in the calculation of theoretical capacity, listed and described in this paper as well feed rate and mathematical model of the motion of fruit per rotating disk .

In terms of production, processing and trade of fruit in Serbia rotary calibrators have the ability to use by wholesalers of fruits and plants for processing and packaging of smaller capacity.

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