Continuously adjustable berry sorter

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Abstract. The article has indicated the principle scheme for post-harvest processing of cultural berries according to the possibilities of the developed new berry sorter. The article tackles the constructive features of the post-harvest treatment of berries as well as of the belt sorter that functions on the principle of successive sorting method. The aim of study was to evaluate the technological features of the berry sorter, based on test results, and to determine problematic assemblies in the construction of the device. Continously adjustable gaps between pulleys as new technological solution for belt sorter was tested and initial results are presented in this article with future improvements. Initial results in this article show that novel continuously adjustable berry sorter functioned satisfactorily. The properties of berry fractions produced with novel berry sorter were possible to change with short time. It was also determined that settings to ensure highest berry fraction purity need to be clarify.

Keywords: *agricultural engineering, post-harvest treatment, berry sorter, blueberry*.

INTRODUCTION

The berry mixture, collected with a berry harvesting machine, contains besides berries also leaves, branches, other plant remains, insects and pieces of peat or soil (Fig. 1). Berries indicate here are blueberries, cranberries and dewberries. For cleaning the berry mixture, differences related to the physical-mechanical traits of its components have to be taken into account, such as density, geometric measures, shape, hardness, elasticity, colour and aerodynamic characteristics. In order to remove all extra materials from the berries, one trait is not sufficient, but a set of traits has to be used, in several parallel or successive treatments.

Depending on variety, ripeness, humidity and other factors, the physical-mechanical characteristics of the components of the berry mixture differ in a large extent, whereas the change has a random character (Bosoi et al., 1977). During sorting, the main physical-mechanical features of the berries are their geometric dimensions (Bosoi et al., 1977). There are many berries and varieties of berries. For example, lowbush berries and fruit of the species *Vaccinium corymbosum* are with the diameter of 4 to 12 mm, while the berries of the blueberry '*Northblue*' are with the diameter of up to 20 mm (Starast et al., 2005; Noormets, 2006). The table berries of different varieties have to be preferably at the same diameter, while the minimum for table blueberries is 8 mm (Starast et al., 2005). This presupposes sorting of berries according to their size.

Two sorting methods of bulk are well-known – successive and parallel. In the case of successive sorting method, size groups for sorting of berry set in the order of size are first small, then average and finally big. In case of parallel sorting, the grouping occurs in decreasing order. The book by Grote & Feldhusen (2007) indicates that according to the construction of the working unit, roll, net, line, drum and belt sorters are differentiated.

Figure 1. Berry box filled by the blueberry harvester.

The main disadvantage of belt sorters is the fact that shifting the pulleys of the drum is time-consuming and troublesome, requires great precision and attention. If different varieties of berries have to be sorted, the multiple readjusting of the berry sorter decreases considerably its capacity during the post-harvest primary processing of different berries. The aim of this study was to evaluate the technological features of the berry sorter, based on test results, and to determine problematic assemblies in the construction of the device.

MATERIALS AND METHODS

When developing the post-harvest processing technology of the berries, the technological scheme developed by Lakewood Process Machinery (2014) was adopted as the basis. The technology indicated on Fig. 2 follows the machine harvesting of the berries (Käis & Olt, 2006; Olt & Arak, 2012).

The post-harvest processing of blueberries contains different work procedures. The intake unit for the berries has to ensure a continuous and balanced feed of berries to the processing line. The work operations begin with removal of larger branches from berry mix. Thereafter, light debris (blueberry leaves, pieces of leaves and peat, etc.) is removed from berry mix; this could be best done in an air flow, using the different aerodynamical properties of the berry mixture components. Removing of additives ends with removing of stems from berry mix. This is followed by fractioning of berries into three groups with the help of a novel sorter device. For the separation of berries in fractions by size, belt sorter functioning on the principle of successive sorting method is used in this case (Fig. 2). First fraction is formed by small berries which are moved to litter box. Berries with average diameter form second fraction. Berries of the second fraction are packaged into boxes, deep frozen and then sent to food industry. Third fraction contains only berries of largest diameter and these are used as table berries. After fractioning, bruised and crushed berries are separated from sound berries with the help of an inclined conveyor. Then, the third fraction berries move to the picking table, which is a belt conveyor. Semi-ripe berries, for example, are removed on the picking table. The packaging of table berries, going to the distributive network, is made by an automatic packaging machine. The poor quality berries removed on the inclined conveyor and picking table can be used as industrial berries if necessary. In what follows, one part of the post-harvest processing of berries is described – the construction and working principle of the novel belt sorter.

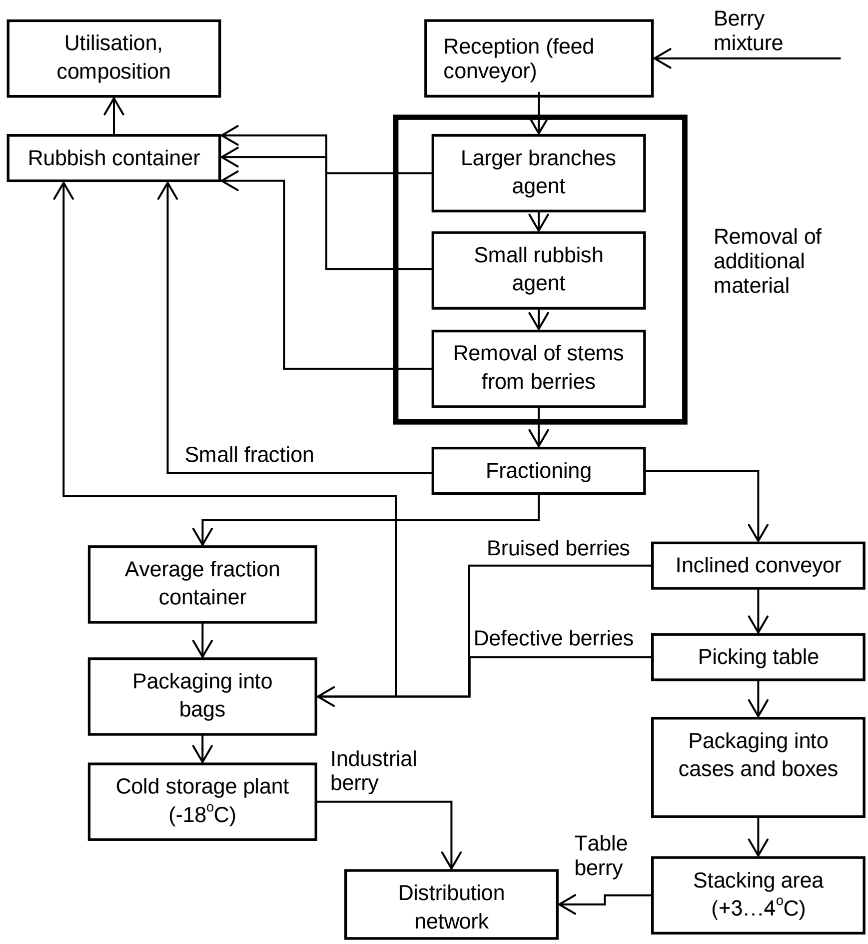

Figure 2. Principle scheme of the post-harvest processing of berries.

The development of the new berry sorter is in its essence solving of a typical product development task (Ulrich & Epinger, 2011). To solve the product development task, TIPS methodology (*Theory of Inventive Problem Solving*) was used (Pahl et al., 2007).

Recesses with a continuous interval for keeping belts are designed for the nonadjustable drum (Fig. 3, position 1), located in the beginning of the sorting area (Fig. 3, position 3) of the berry sorter. The regulated drum (Fig. 3, position 2), located in the end of the sorting area has been compiled from pulleys, the intervals of which can be simultaneously and continuously changed. The adjustable drum (Fig. 4) contains pulleys, a steering shaft, equipped with variable step guiding grooves, steering levers, whereas the tip of each steering lever is connected to a pulley and the other tip is located in the steering shaft groove. The drum contains also a pipe-shaped case for the steering shaft that is equipped with the case's longitudinal opening, which is meant for directing the movement of the steering levers by the axis, a regulating lever with a handle and a fixed disk with a fixator. The steering shaft is equipped with guiding grooves of right and left-hand thread, while at the one side of the circular groove, located at the centre of the steering shaft, there are guiding grooves with right-hand thread, and on the other side, grooves with left-hand thread. Thread handedness is consistent to Fischer et al, 2010. The steering shaft is rigidly connected with a regulating lever, through which the steering shaft can be rotated in relation to the case of the steering wheel. The steering zone of the steering shaft is designed so that the steering rods, attached rigidly to pulleys and positioned through the case opening, the free side of which is in the steering groove, ensures whatever angle of rotation of the pulleys or the same distance in case of position. A disc with split holes is rigidly connected with the case. A fixed disk with a fixator is rigidly attached to the regulating lever. A significant advantage of the innovative sorter is the user friendliness and work efficiency of the constructive solutions of the regulating lever, a good sorting quality, simple handling and readjusting speed. This is the step-free adjustable berry sorter with a fractioning slot (Patent EE05642 B1, 2013).

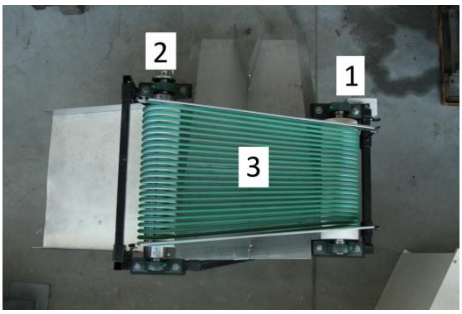

Figure 3. The new berry sorter: 1 – first drum; 2 – smoothly adjustable drum; 3 –sorting area.

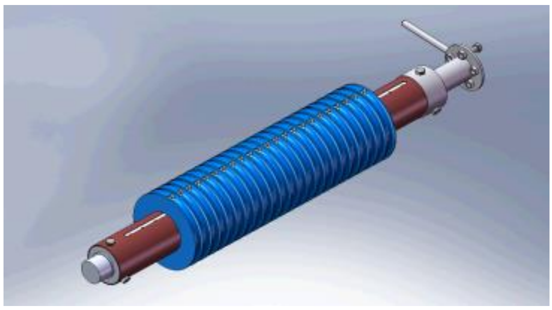

Figure 4. The berry sorter's drum that can be smoothly regulated (Patent EE05642 B1).

Blueberry sorter contains at least three drums with the belts installed on them, which form the sorting area of the blueberries, whereas the regulating drum consists of pulleys, the distance of which can be simultaneously and step-free changed. The regulating drum contains pulleys, a steering shaft equipped with guiding grooves of a changing thread step, steering rods, while the one end of the rod is connected with a pulley and the other end is located in the steering groove of the steering shaft, a pipe-shaped case of the steering shaft that is equipped with the case's longitudinal opening, which in turn is meant for directing the movement of the steering rods by the drum axis, a regulating lever with a handle and a fixed disc with a fixator.

As an explanation, it should be mentioned that screw-shaped guiding grooves have been cut onto the steering shaft, the steps of which correspond to the following conditions:

$$t_{v,n} > \ldots > t_{v,3} > t_{v,2} > t_{v,1} > t_0 < t_{p,1} < t_{p,2} < t_{p,3} < \ldots < t_{p,n}$$

that is, $t_{v,i} > t_0 < t_{p,i}$

where: t_0 – the middle guiding groove of the steering shaft, which is threadless, that is, it is with circular thread, $t_0 = 0$;
t_v – left-sided guiding groove step; $t_v = \Delta \cdot i$;
t_p – right-sided guiding groove step; $t_p = \Delta \cdot i$;
Δ – change of the guiding groove step, mm rotation^{-1}
i – guiding groove serial number, counted from the circular groove located at the centre of the steering shaft;
$i = 1, 2, \ldots, n$.

Each steering groove has a start and end point, while the location of the groove's beginning is determined with the product bi; the location of the groove end is determined with the product $i(b + \Delta)$.

In order to study the functioning of the patented technical solution of the new berry sorter, a prototype of the new berry sorter was manufactured (Fig. 3). The study of the berry sorter sets out determining how and what effect does regulating of the belt distance have on the distribution of the sample mixture between three output fractions received with fractioning. For the research results, the following measurements were implemented:

1. The mass of the berry mixture at the beginning of each experiment.
2. Distribution of output fractions.
3. The average diameters of the berries forming the output fraction.

It was also decided to evaluate the new berry sorter during experiments in a working situation, in order to determine problematic assemblies in the construction of the device.

The tested berry sorter is one part of the post-harvest processing line of berries and this has to be taken into account in planning the laboratory experiments of the prototype. When using post-harvest processing line (Fig. 2), the berry sorter is located relatively at the end part of the line. Before the berries reach the berry sorter the additives are removed from berry mixture.

The novel berry sorter enables to separate berries according to their diameter into 3 fractions. Also, the division of the berry mixture between 1^{st} and 2^{nd} fraction can be adjusted by changing the position of the interim plate. On Fig. 5, the plan of the new berry sorter has been indicated.

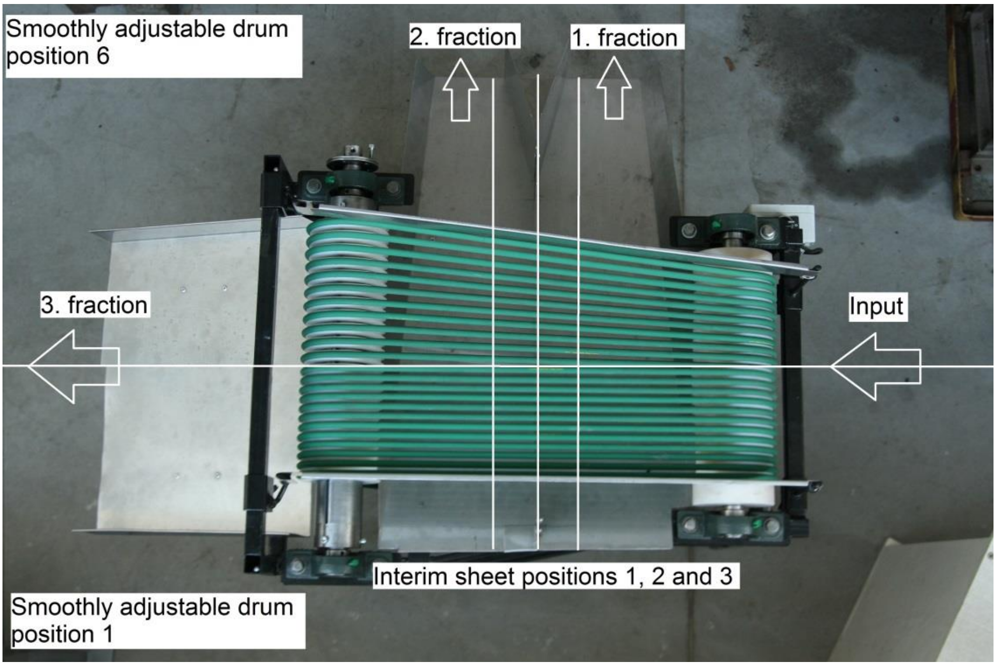

Figure 5. Photo of the berry sorter.

The laboratory experiments of the new berry sorter prototype were conducted in spring 2013 in the agricultural equipment laboratory of the farming and production technology department of the Estonian University of Life Sciences. As adjustable drum did not have fixed regulation steps, then a fixed disc with 6 fixable positions was manufactured for repeating the experiments and limiting the amount of the experiments. The berry mixture included berries with the diameter of d = 1.8–14.5 mm. The total mass of the berry mixture during experiments was m = 4,870 g. To measure mass of fractions, a digital weigh with 10 g precision was used. To determine the diameter of the berries, a gauge block with the precision of 0.05 mm was used. The linear speed of the sorting area, i.e. belts, is $v = 0.12$ m s^{-1} and it was not changed during experiments.

RESULTS AND DISCUSSION

In conducting the first experiments with the new berry sorter, all 18 regulation levels were used. 18 planned experiments were conducted, which formed of six fixed regulating drum positions and three berry deflector nr 2 interim plate positions.

The test results of the new berry sorter have been indicated on Figs 6 to 8 in the case of the interim plate position nr 2, where the division of the sorting area length for fraction 1 and 2 was equal (see Fig. 5). As an explanation, it can be added that the first member of the experiment number indicates the position of the drum that can be regulated and the other member shows the position of the interim plate. The indicated line charts reflect 1/3 of all test results; in this article, test results for the interim plate positions in case of positions 1 and 3 have not been indicated.

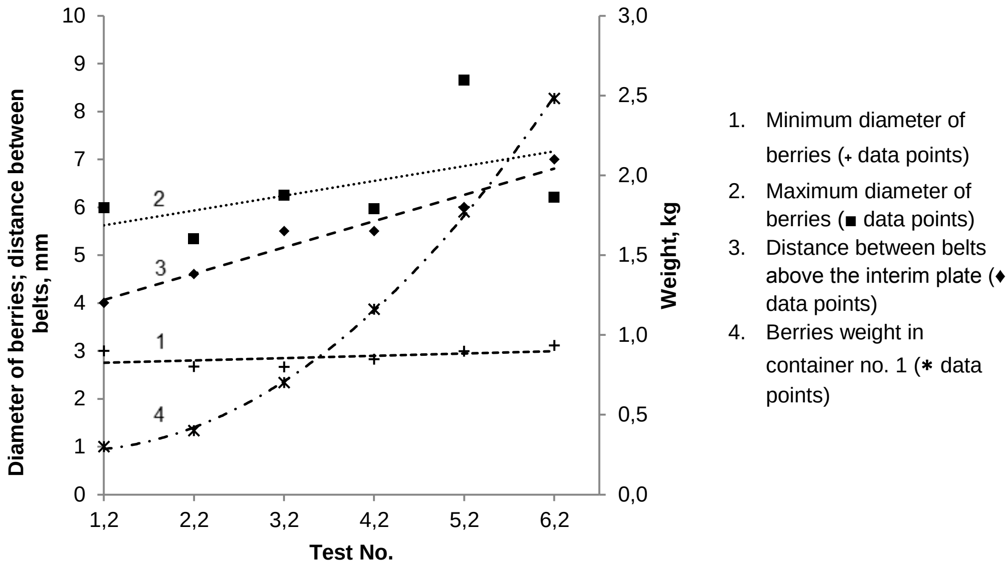

Figure 6. Test results of the first output fraction in case of the interim plate position nr 2. Data points are indicating test results.

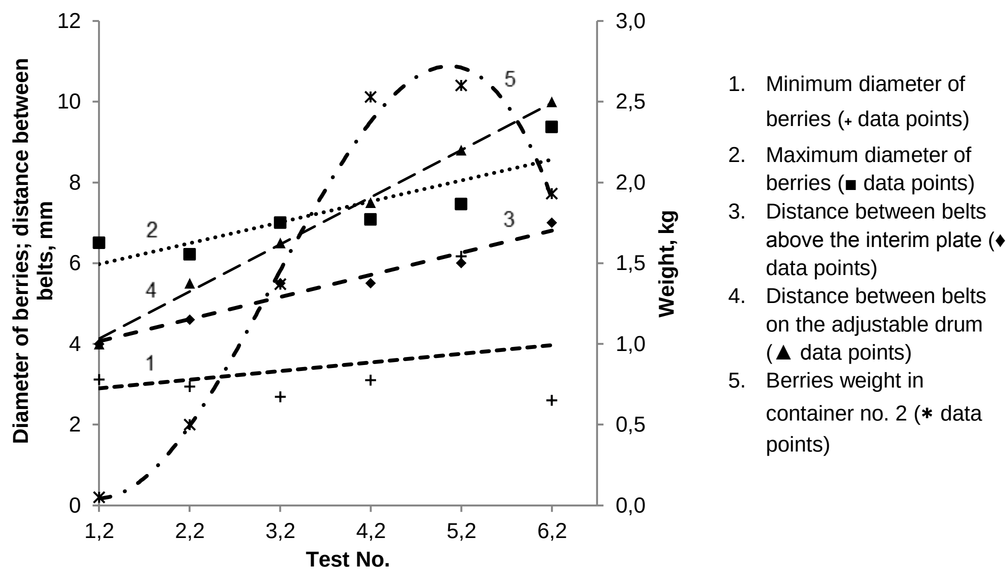

Figure 7. Test results of the second output fraction in case of the interim position nr 2. Data points are indicating test results.

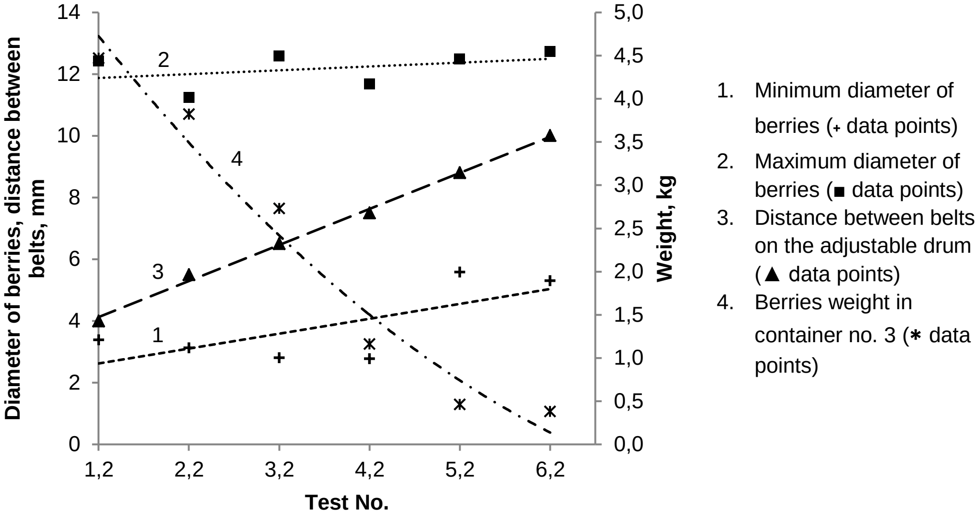

Figure 8. Test results of the third output fraction in case of the interim position nr 2. Data points are indicating test results.

Studying the change of the maximum diameter of berries on Fig. 6 on the basis of the berry mixture that has reached vessel 1, a steep ascent can be seen in experiment 5.2. The line charts indicated on Fig. 7 and 8 indicate that in experiment 5.2 a steep ascent has occurred in the minimum diameter of the berries in vessels 2 and 3. This was probably caused by the back-and-forth movement of the pulleys of the smoothly regulated roller by the drum axis, which is one of the foremost problems at this point.

During tests, there was no indication of the determinate growth or decline of the first fraction berries' diameter, although a certain tendency in the growth of the berries' diameter was sensible. During tests, the first fraction mass increased by increasing the regulatory level of the roller, which was also expected. The bigger sorted area the interim plate of the berry deflector left for the berries going to the first fraction, the bigger was the mass of the berry mixture going into the first fraction. The information indicated on Fig. 6 shows that the maximum diameter of the berries that formed the first fraction is bigger than the distance between belts, except for during experiment 6.2. This was caused by the back-and-forth movement of the belt washers by the drum axis as well as the elasticity of the belts used.

By increasing the distance between pulleys located on the smoothly regulated drum of the berry sorter and thereby also the distance between the belts themselves, the mass and diameter of the berries forming the second fracture increased considerably. Moving the interim plate of the berry deflector nr 2 had an influence also on the second fraction. The bigger sorting area the interim plate of the deflector left for the berries going to the second fraction, the bigger was the mass of the berries forming the second fraction. Fig. 6 indicates that in half experiments, the maximum diameter of berries is bigger than the distance between the belts, and this was caused by the circumstances described in the previous paragraph. Fig. 7 additionally suggests that in case of all experiments (except for experiment 5.2) the minimum diameter of the berries of second fraction is smaller than the distance between the belts above the interim plate. It became evident that this may have been caused by an insufficient length of the sorting surface and the movement technology of not thoroughly developed berries on the sorting surface.

By increasing distances between pulleys, located on the smoothly regulated drum of the berry sorter, the mass of berries of third fraction considerably decreased, while the average diameter of the berries of the third fraction increased. Moving the interim plate did not have an effect on the third fraction. The information indicated on Fig. 8 shows that the minimum diameter of the berries of the third fraction is in case of all tests smaller than the distance between belts on the smoothly regulated roller. Why these berries did not go to the second fraction needs further research.

Based on the test data, it can be said that regulating the distance between the new berry sorter's belts had a significant impact on the division of the berries mixture, and moving the interim plate of the berry deflector nr 2 had an influence on the division between the first and second fraction of the berry mixture. Tests indicate that shifting the pulleys that form the drum was not time-consuming or troublesome, because all pulleys can be moved simultaneously and step-freely. Based on the test results, it can be claimed that when different varieties of berries have to be sorted, then the readjusting of the new berry sorter during the post-harvest initial processing of different berries probably decreases the readjustment time of the berry sorter.

CONCLUSION

The article has presented the methodology for the development of the post-harvest processing devices of the blueberry machine cultivation technology, as well as a description of the test results. During product development work a new berry sorter was developed that is sufficiently flexible for sorting berries of different size. The novel berry sorter with the fractioning slot that can be smoothly regulated functioned satisfactorily. It becomes evident that in berry fractioning, the technology for moving or mixing the berry layer on the belts has to be further improved. Attention has to be also turned to the back-and-forth movement of the pulleys of the smoothly regulated drum by the drum axis in a work situation. The existence of smaller berries in the third fraction that should have been in the second fraction needs further research.

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