Analysis of technology and machining devices for cleaning onion in the food industry

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Abstract. Over the last few years, the fruit and vegetable processing sector has recorded a systematic growth and thus strengthens its position within the food industry in Poland. The article presents the varieties of onions grown in Poland for processing purposes with the growing and storage periods, as well as technological treatments of mechanical cleaning onion. The division of individual stages of the processing process will be characterized with various methods of removing the root, tops and skin in vertical and horizontal technology. Machining tools for removing the root and tops as well as systems for cutting and removing skin will be presented. The authors will present the results of the onion processing stand tests, including exemplary processing tools, taking into account the advantages and disadvantages of the applied technology.

1 Introduction

According to data from the Central Statistical Office of Poland, in the 2019/2020 season, the onion harvest amounted to 580 thousand tons [1]. Among the bulbs grown in Poland, popular for peeling onion are the following varieties [2]: Action, Baltido, Banko, Bonus, Bratko, Carlos, Exhibition, Lagergold, Majka, Meranto, Valentino and Vicking. These are Polish and Spanish varieties which are characterized by high yield, strong root system and a long growing season. Currently, the most popular method of cleaning onions in Poland is manual processing. Low performance and the inconvenience of manual onion cleaning as well as harmful working conditions (odor) and the related difficulties with recruiting employees force the automation of this process in industrial conditions [3, 4].

Currently, a number of machines for the mechanical cleaning of onions are offered on the world market, which can be divided into 2 groups depending on the purpose of the peeled raw material. Figure 1 shows an example of a machine for mechanical onion cleaning.

The first type are machines that remove only the outer (yellow) skin - the onion is intended for sale as a finished product. Machines of the second type have the ability to clean the onion from the skin, but also remove the root and tops - the onion after cleaning in this type of machines is used in processing. For processing plants, it is important that the machine for mechanical onion cleaning carries out the process without prior segregation. Such a solution allows to reduce the operating costs of the process and helps to reduce the waste of raw material [6].

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Fig. 1. An example of an onion peeling machine [5].

The size of the waste depends on the raw material itself, but also on the method of its treatment. Information on the morphological features of onions is available in the literature [7]. Its diversity as well as the treatment systems used in the mechanical cleaning process have a significant impact on the amount of waste generated. Its size is mainly influenced by the type and shape of the knives used to cut the tops and root parts, as the method of their removal determines the quality of the peeled onion.

The article analyses the applied technologies of industrial onion peeling in order to determine the premises for the development of the most favorable technological process and the results of preliminary tests of the tops and root removal operation to determine the amount of waste are presented.

2 Methods of peeling onion technology

There are several solutions of onion cleaning machines on the European market [5, 8, 9], which differ in the method of cleaning and the tools used. In principle, all machines can be divided into five basic steps, shown in Figure 2 in the form of modules.

Fig. 2. Onion cleaning stages (own work).

In the first stage of cleaning, the onion from the charging hopper is delivered to the transport table (Fig. 2, module I). In the next stage, the onion is transported (Fig. 2, module II) to the system for cutting the dry skin and removing the root and tops (Fig. 2, module III). Then the onion is blown off the dry skin (fig. 2, module IV) and directed to the inspection table (fig. 2, module V) for possible manual cleaning.

Figure 3 shows a block diagram of the onion mechanical cleaning technology.

Fig. 3. Block diagram of the mechanical onion cleaning technology (own work).

The process of mechanical cleaning of onions begins with a charging hopper, to which the onions are delivered from heaps or directly from the field, where they are divided into individual pieces, which are transported by a chain or belt conveyor in rows in an amount depending on the efficiency (duplication of processing lines) [8]. In the second stage, on the transport table, the onions placed in the processing nests are manually positioned in the vertical or horizontal direction with respect to the onion axis. The empty nests are supplemented with additional onions, and the excess is removed [5, 8, 9]. In the third stage, the dry skin is cut with circular knives or fixed blades fixed in the handles. The incision of 2 to 4 lines is usually made parallel to the axis of the onion. The next step in the cleaning process is the removal of the tops and roots with cutting knives, cutters or rotating discs. The onions are then transported to the blowing system with compressed air. Two types of blowing are most commonly used - on rotating rollers or on a worm roller. In the lower part of the machine, post-production waste is collected on a belt or screw conveyor, which can be compacted and destined for biomass [10].

The market is dominated by machines that use two different cleaning technologies, divided into the processing of the raw material in the horizontal and vertical directions. Each type of processing takes into account different methods of positioning and transporting the onions.

Table 1 shows the advantages and disadvantages of both processing technologies.

Table 1. Comparison of advantages and disadvantages of horizontal and vertical technology.

Horizontal technology	Vertical technology
Advantages: - capacity 4800 ÷ 6000 pcs /h depending on the size of the onion; - positioning onion by 1 person; - blowing nozzles close to the onion, low air requirement; - collision-free, no possibility of jamming the bulbs.	Advantages: - capacity from 3000 ÷ 12000 pcs / h, regardless of the size of the onion; - tactic movement (start / stop) more precise control of onion positioning; - adjustable and replaceable knives for cutting skin, removing tops and roots, reducing the size of waste.

<p>Disadvantages:</p> <ul style="list-style-type: none">- no possibility of extending the line in one device, constant performance;- straight cutting causes a lot of waste, especially for large, flat, narrow and long bulbs;- manual onion positioning without stopping belt causes its low precision;- complicated and unreliable system of cutting dry scales.	<p>Disadvantages:</p> <ul style="list-style-type: none">- service for a minimum of 4 people;- step motion, extended machining time;- high air consumption in auger blowing;- collision in the roller system, the possibility of onion jamming.
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To summarize the advantages and disadvantages of the horizontal and vertical technology, the machines for mechanical onion cleaning available on the market, it can be concluded that the most desirable parameter of the innovative technology is the efficiency of the process.

In connection with the above, it is important, inter alia, reduction of production waste, which was a premise for the development of a new technology of mechanical cleaning.

3 Identification of the physical quantities of the selected onion variety

The analysis of the onion cleaning technology showed that it is necessary to provide information on the amount of waste generated in the process of removing the tops and root parts, taking into account the size (diameter) of the onion. The geometric features and the shape of the onion are also important, as they are among the basic input parameters taken into account when designing processing devices, which is justified in the publication by L. Mieszkalski [7]. The identification of these parameters allows to assess the possibility of the processing tool sinking into the onion in order to clean it thoroughly and to determine the amount of waste in the process of removing the roots and tops. There were three groups of onion sizes, with diameters of 40-70 mm, 70-100 mm, and 100-130 mm, respectively, for which tests were carried out to obtain information about the size of waste depending on the onion diameter. The onions were placed on graph paper to mark the height of the tops and root parts to be removed. Figure 4 shows an example of bulbs from three diameter groups.

Fig. 4. Identification of the removal depth of the tops and root parts depending on the diameter: a) 40-70 mm, b) 70-100 mm, c) 100-130 mm (own work).

It was found that regardless of the diameter of the onion, the length of the tops was in the range of 15-17 mm, and the length of the roots in the range of 7-10 mm.

In order to determine the amount of waste, tests were then carried out for three methods of removing the onion root and root parts. Fig. 5 shows the following methods of removing the mentioned parts: a) cylindrical cut, b) conical cut, c) flat cut.

Fig. 5. Shape of the root and tops notch: a) cylindrical, b) conical, c) flat (own work).

For the onions from each "diameter" group, 20 repetitions of the tops and root removal were performed using the three treatments. Each onion was weighed before and after the tops and root removal process. Based on the research results obtained, the percentage weight loss of the onion was determined.

4 Results and discussion

The results of the tests of selected methods of cutting the top and onion root are shown in Fig. 6. To assess the size of the waste, the skin covering the entire onion was also removed.

Fig. 6. Shape of the root and tops notch: a) cylindrical, b) conical, c) flat (own work).

Fig. 7. Sample measurements of onions after cutting: a) cylindrical, b) conical, c) flat (own work).

The illustrations shows the shape of the onion peeling notches and analyzes were performed to measure the weight of the onion before and after notching to determine the amount of waste shows on Figure 7.

Figure 8 shows the average amount of waste in the root removal process and tops depending on the diameter of the onion.

Fig. 8. The size of the waste from the root and tops parts depending on the onion diameter and cutting method (own work).

For onions with a diameter of 40-70 mm, the weight loss is in the range of 11.38-18.32%. The flat cutting method in this group generates 38% more waste compared to the taper cutting method and 23% more than the cylindrical cutting method. For the diameter group of 70-100 mm, the percentage weight loss is in the range of 13.12-19.24%. The flat cutting method in this group generates 41% more waste compared to the tapered cutting method and 19% more than the cylindrical cutting method. For onions with a diameter of 100-130 mm, the percentage weight loss is in the range of 14.60-21.11. The flat cutting method generates 31% more scrap compared to the taper cutting method and 19% more than the cylindrical cutting method. Summing up, the largest waste for all onion sizes is generated by the flat cutting method, which is characteristic of the horizontal technology.

5 Conclusions

Based on the research, the following conclusions can be drawn:
1. The analyses of the horizontal and vertical technology have shown the basic differences in the mechanisms of operation of individual stages of the process. The vertical technology

is more advantageous due to the possibility of adjusting the performance to the customer's needs, greater positioning precision and the variability of machining tools.

2. Designated heights of removal of the tops part from the onion, amounting to 17 mm and 10 mm of the root part, will allow to achieve high-quality cleaning of the onion, while maintaining the minimum amount of waste.

3. The most preferred method is the conical cut, which generates the smallest waste in each onion diameter range.

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