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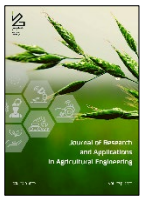

Analysis of the Waste Generated during the Cutting Process in Onion Topping and Tailing

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Onions are one of the most popular cultivated vegetables. In Europe, Poland is a leading producer of this vegetable and a hub where it is peeled and then sent in peeled or chopped form to western EU countries. After the top and root removal process, husks remain that require further management. It is also crucial to minimise their amount by applying appropriate topping and tailing processes in industrial machines. This is done in order to help prevent food waste and reduce the amount of waste generated. The article presents methods of cleaning onions in terms of cutting off the roots and green parts of the vegetable, focusing on the amount of waste generated in this process. The authors present examples of possible solutions for the cutting process and compare them in terms of the theoretical waste they generate, to identify the method with the greatest raw material savings. Additionally, the article presents the results of theoretical studies on the waste generated by the selected method, considering its various geometric variables.
An analysis of the results is made and conclusions are drawn.

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1. Introduction

Poland is one of the leading onion producers in Europe. According to data from the Central Statistical Office, onion harvests in Poland in 2023 were estimated at 636,000 tonnes [1]. In Poland, many varieties of onions are cultivated, including early-medium, medium-late, and overwintering types. Among these varieties are Action, Banco, Bonus, Wolska, Armstrong, Durango, Cymes, Agra, Polanowska, Grabowska, Labrador, and others [2]. A significant portion of the harvest is designated for industrial processing. A crucial stage of this is the process of removing the dry husk (for example, using compressed air) and

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cutting off the undesirable parts: the top (green) part and the bottom (root) part. This task is performed by specially designed industrial machines that carry out the cutting operation using knives having various shapes and principles of operation [3]. There are also machines that carry out the onion preparation process solely by removing the husk while retaining the root and green parts of the vegetable. These partially cleaned onions, intended for direct retail sale in stores, have an extended shelf life compared with topped and tailed onions, which are used for immediate processing.

2. Factors Influencing the Amount of Waste

The main factor influencing the amount of waste generated in the process of cutting off the green and root parts of the onion, related to its geometry, is its shape [3], [4], [5], [6], [7]. This directly affects the length of the knife's cutting line and its penetration into the material being cut. The shape of an onion is often a varietal characteristic. Even within a single species, differences in onion shape can be observed, relating for example to the onion's diameter (for instance, the larger the onion, the flatter or more elongated it is). Growth conditions, such as the amount of water during the growth cycle, also significantly influence the shape. Onions can be classified as elongated, ovoid, spherical, spherical-flattened, or flattened, based on the onion shape coefficient [8, 9]. This is determined based on measurements of the three basic dimensions of the onion (Fig. 1):

- height Dp – the distance measured from the root base to the end of the green part,
- width De – the largest dimension of the onion measured on a plane perpendicular to the height of the onion,
- thickness T – the dimension perpendicular to both the diameter and the height of the onion.

The shape coefficient Wk [8, 9] is determined using the following formula:

$$W_k = \frac{D_p}{\sqrt{D_e * T}} \quad (1)$$

where:
Dp – height [mm]
De – width [mm]
T – thickness [mm]

For onions with a flattened or spherical-flattened shape, the shape coefficient is less than 1, whereas for onions with an ovoid or elongated shape, it is greater than 1. In the case of spherical (round) onions, the shape coefficient is approximately equal to 1 [8, 9].

The method used to cut off the root and green parts of the onion has a significant impact on the amount of waste. Among the possible cutting methods, three selected ones are presented in Fig. 2:

- straight blade cutting (Fig. 2a) (very commonly used in industrial equipment) which results in the removal of discs from the ends of the onions,
- cylindrical milling cutting (Fig. 2b) – producing a cylindrical cut,
- angled cutting (Fig. 2c) – resulting in a conical cut.

Literature reviews [10] have shown that conical cutting methods result in the smallest amount of waste. Depending on the size of the onion, the percentage of waste ranged from 10% to 15%. For other methods, the waste ranged from 15% to 22% (Fig. 3).

The literature review identified a research gap related to determining the relationship between the amount of waste and the cutting angle of the onion in conical cutting methods. Therefore, studies were conducted to determine the theoretical percentage of waste generated during the onion cleaning process using the cutting operation. The cutting geometry was analysed to ensure it generated minimal waste while simultaneously ensuring the proper execution of the process, i.e., the complete removal of undesirable parts of the vegetable.

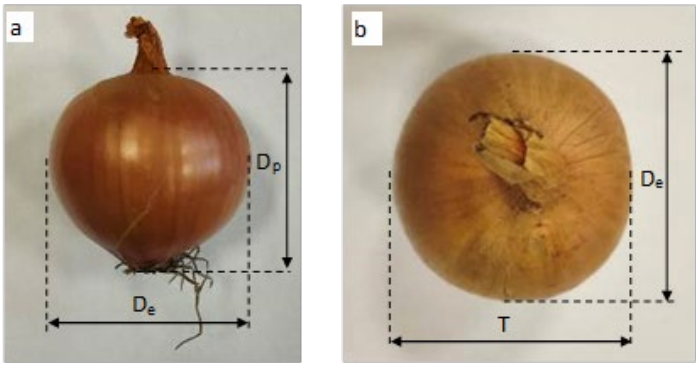

Fig. 1. Onion dimensions: a) view of the onion from its side, b) view of the onion from its top [source: own work]

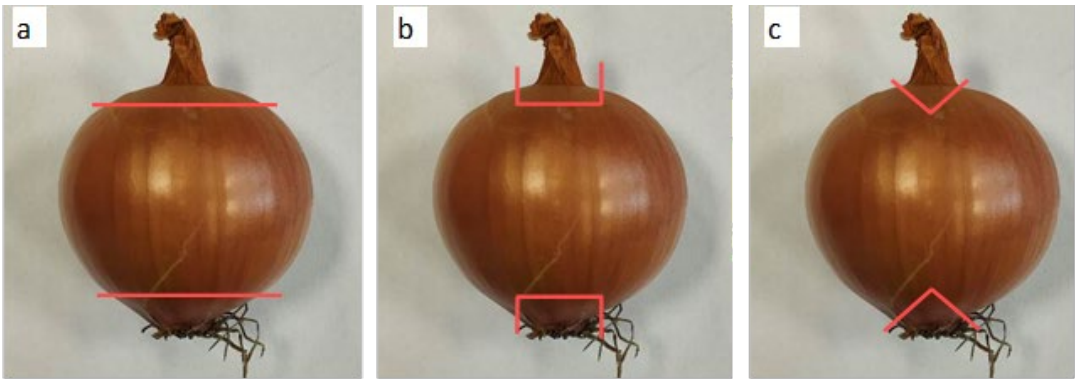

Fig. 2. Shapes of onion cutting lines: a) flat, b) cylindrical, c) conical [source: own work]

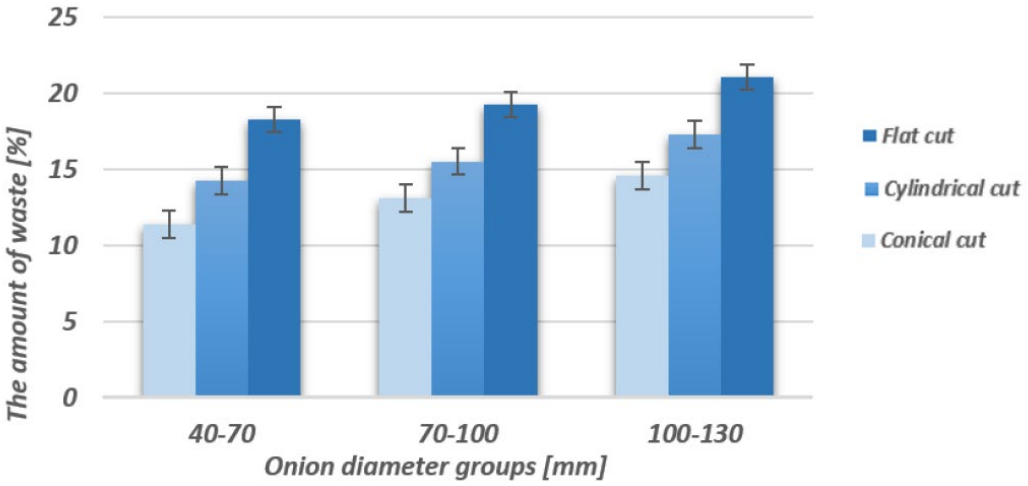

Fig. 3. Experimental results on waste generated during the onion cutting process depending on the method and onion diameter [10]

3. Objective of the study and methodology

The objective of the study was to determine theoretically the percentage of waste generated during the process of cutting off the green and root parts of onions using the conical cutting method. The studies assumed a spherical (round) shape for the onion. The cross-section of the upper half of the theoretical onion, along with the cutting lines and the variables described above, is shown in Fig. 4.

A constant cutting height h of 15 mm was assumed for all trials. The variables used in the calculations were the onion diameter D and the cone angle α. The studies were conducted using SolidWorks software. Investigations were carried out for three different diameters: 50 mm, 75 mm, and 100 mm, and five different cutting angles α: 60°, 75°, 90°, 105°, and 120°. The volume of each onion was recorded based on the model properties before and after cutting, which allowed determination of the percentage loss (waste). A view of example modeled cut-out onions is shown in Fig. 5.

4. Results and discussion

Table 1 below shows theoretical results obtained for the percentage of waste depending on the onion diameter and the cone cutting angle. For onions with the smallest diameter (50 mm), the theoretical percentage of waste ranges from 3.13% to 14.92%. For a diameter of 75 mm, the waste ranges from 0.97% to 5.36%. For the largest diameter (100 mm), the waste values range from 0.42% to 2.53%.

The results show a clear trend of decreasing waste as the onion diameter increases and the cone angle decreases (Fig. 6). Additionally, a trend can be observed whereby the variation in waste values increases with the cone angle applied to onions of the same diameter. Moreover, there is a noticeable decrease in the variation in waste difference for a given angle as the onion diameter changes.

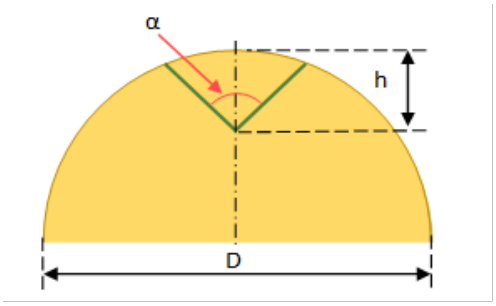

Fig. 4. Cross-section of the upper half of the theoretical onion, along with the cutting lines: green line – conical cutting, h – cutting depth, α – cone angle, D – onion diameter [source: own work]

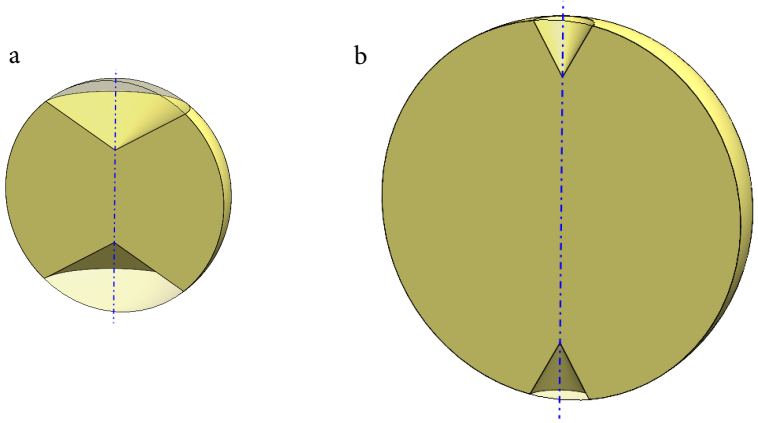

Fig. 5. Example of modeled cut-out onions with the same cutting depths: a) onion with the parameters D=50mm, α=120°; b) onion with the parameters D=100, α=60° [source: own work]

Table 1. Theoretical percentage of waste obtained from cutting the green and root parts of the onion [source: own work]

α [°]	**Theoretical percentage of waste obtained with particular onion diameters [%]**		
	50 mm	75 mm	100 mm
60	3.13	0.97	0.42
75	5.07	1.61	0.70
90	7.60	2.49	1.11
105	10.84	3.71	1.69
120	14.92	5.36	2.53

6. Conclusion

The research on the theoretical percentage of waste generated during the cleaning process indicates that the knife cutting angle affects the amount of waste produced. Although the assumed onion model does not fully represent the actual shape, it enables estimation of the waste resulting from the chosen cutting method.

The conical cutting method for removing the root and green parts of the onion has significant potential for minimising waste in industrial onion topping and tailing processes. Proper selection of the cutting angle relative to the onion diameter can reduce the amount of waste. However, the theoretical considerations do not account for efficiency, i.e., the condition of proper execution of the process – the complete removal of the green and root parts.

The theoretical analyses showed that the cutting angle is a crucial factor determining the amount of waste. Therefore, further research will involve studies on actual objects to determine the real waste and assess the efficiency of the peeling process.

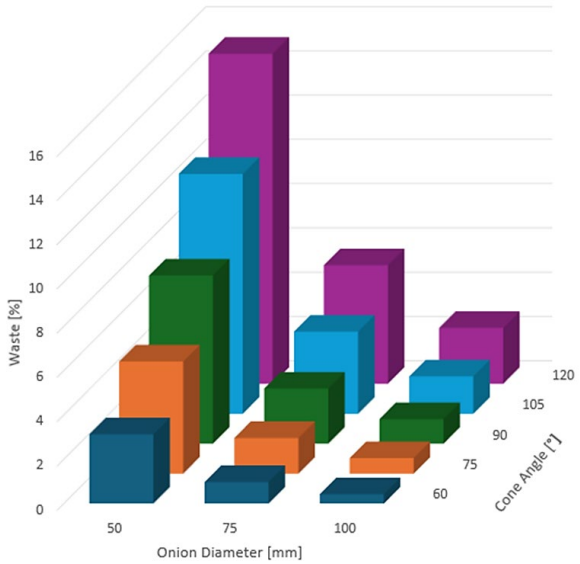

Fig. 6. Graph of theoretical percentage of waste as a function of onion diameter and cone angle [source: own work]

Bibliography

[1] "https://stat.gov.pl/download/gfx/portalinformacyjny/pl/defaultaktualnosci/5509/5/22/1/wynikowy_szacunek_glownych_ziemioplodow_rolnych_i_ogrodniczych_w_2023_r..pdf."
[2] "https://coboru.gov.pl/Publikacje_COBORU/Listy_opisowe/LOORW%20-%20cebula%202019.pdf."
[3] P. Woźniak, A. Bieńczak, T. Kiczek, and K. Gaszek. 2022. "Analiza technologii mechanicznego oczyszczania cebuli w maszynach przemysłowych," *Technika Rolnicza, Ogrodnicza, Leśna*, 2: 53–60.
[4] K. G, T. V, K. G, and K. V. 2015. "Studies on Properties of Multiplier CO 4 Onion Bulb (Allium cepa L.var. aggregatum. Don.)," *Madras Agricultural Journal*, 102 (1): 84–88. doi: 10.29321/MAJ.10.001073.
[5] H. Shoba, N. Rajeshwari, and G. Nagaraja. 2017. "A Study on Physico-Mechanical Properties of Onion Varieties Under Koppal District, (Karnataka).," *Current Agriculture Research Journal*, 5(3): 381–386. doi: 10.12944/CARJ.5.3.18.
[6] M. Dabhi and N. Patel. 2017. "Mukesh Dabhi, Nagin Patel. Physical and Mechanical Properties of Talaja Red Onion Cultivar," *Bioprocess Engineering*, 1(4): 110–114, doi: 10.11648/j.be.20170104.13.
[7] L. Mieszkalski. 2015. "Mathematical modeling of the shape of the onion head saccharic (Allium cepa L.) by the parametric equations," *Postępy Techniki Przetwórstwa Spożywczego*, 2: 68–71.
[8] A. H. Bahnasawy, Z. A. El-Haddad, M. Y. El-Ansary, and H. M. Sorour. 2004. "Physical and mechanical properties of some Egyptian onion cultivars," *J Food Eng*, 62(3,): 255–261, doi: 10.1016/S0260-8774(03)00238-3.
[9] B. Devojee. 2021. "Studies on engineering properties of multiplier onion," *Agricultural Engineering Today*, 45(1): 11–18. doi: 10.52151/aet2021451.1529.
[10] P. Woźniak, S. Nosal, and A. Bieńczak. 2021. "Analysis of technology and machining devices for cleaning onion in the food industry," *MATEC Web of Conferences*, 343: 01006. doi: 10.1051/matecconf/202134301006.
[11] J. Bohdziewicz, G. Czachor. 2010. "The impact of load on deformation progress for ball-shaped vegetables," *Inżynieria Rolnicza*, 14(1): 85–91.