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УДК 631.356.24
DOI: 10.37128/2306-8744-2025-3-8

TECHNOLOGICAL FEATURES OF GROWING AND HARVESTING CHICORY ROOTS

In the technology of chicory production, the most time-consuming and imperfect process is the process of digging root crops from the soil and cleaning them from soil and plant impurities. The root crop harvesting technology is considered optimal when the least losses, damage and contamination of the harvested root crops with impurities are allowed.

For the collection of root crops of row crops, it is impossible to completely avoid crop losses, which are caused, first of all, by the design features of the harvesting equipment and its use in complex soil and climatic conditions that continuously change during the work (mechanical composition, moisture and hardness of the soil, a wide range of variation in the parameters of the placement of plants in rows, the state of their development, etc.), as well as the difficulty of fulfilling agrotechnical requirements for the processes of separation of leaf-stem mass and extraction root crops from the soil without damage during forward movement of harvesting units. Root chicory has its own specific features, such as the low level of mechanized cultivation technology and the lack of special machines for harvesting chicory root crops in Ukraine and abroad.

During the development of working bodies for digging chicory root crops, it is also necessary to take into account the requirements of the processing industry of chicory root crops to the quality of raw materials. According to the specified requirements, the productive part of chicory roots is determined from the cut line of the leaves from the top of the root heads to the cut line of the tail part with a diameter of 15 mm. Under such conditions, the weight loss of the root crop, depending on the broken off tail part, will be up to 6...7% on average. A comprehensive assessment of the agrobiological and physico-mechanical characteristics of roots of root chicory are theoretical prerequisites for the development and design of working bodies for its digging. The existing modern single-phase technology and technical means used during the collection of chicory roots do not provide the established indicators of the quality of work. At the same time, the contamination of root crops with the remains of ghee and vegetable impurities, waste in the ghee of the mass of cut heads to the mass of root crops, damage to root crops due to chips significantly reduces the quality of raw materials and the yield of their processing products. In this regard, the task of increasing the technical level of root harvesting machines, or indicators of the quality of digging root crops, remains an urgent issue.

Keywords*: technology, root crops, roots, chicory, growing, harvesting, digging up working bodies, classification, combined diggers, spherical disk.*

Introduction. Chicory root crops are an important industrial crop. In terms of cultivation technology and appearance, they are similar to sugar beets, while their physiological and morphological properties resemble those of carrots. The root of wild chicory is thin, woody, and widespread in the temperate zone, growing along roadsides, boundaries, and in dry meadows. Cultivated chicory roots contain 14–20% inulin, which, during hydrolysis, is converted into fructose, alcohol, and sugar—qualities that are significant for medicinal purposes [1].

The processing industry extensively utilizes fruit sugar (fructose) from the roots, as well as valuable raw material for coffee production. Additionally, the root crops contain 2–3% sugars, 1.5–4% protein, and 0.6% fat. Chicory tops (greens) have high nutritional value as fodder. On a dry matter basis, they contain up to 22% crude protein, up to 5% fat, and 35–40% nitrogen-free extracts.

Chicory green mass and silage are suitable for feeding cattle, sheep, horses, pigs, and poultry. Chicory increases animal productivity and has a positive effect on their health. Chicory can be used for green fodder for 2–3 years [2-5].

Analysis of recent research and publications. The technological process of harvesting chicory roots is primarily governed by the agrotechnical properties of the crop, the design of the working parts, and the layout configurations of the root-harvesting machines and devices. In Ukraine, within the chicory cultivation zones, there are processing plants located in Slavuta and Chudniv. Currently, root chicory is a fairly popular crop in European countries, the USA, China, New Zealand, and others [1, 6].

Despite the growing demand for chicory and its processed products, the sown areas are not increasing due to the low level of mechanization in the cultivation process, particularly in harvesting.

The breeding of root chicory is conducted by the Institute of Bioenergy Crops and Sugar Beet (Kyiv) and the Uman Experimental Breeding Station. The chicory root has a conical shape, similar to that of a carrot (Fig. 1) [1, 2].

The most common varieties are Umanskyi 95 and Umanskyi 99, which have a conical shape and medium to elongated size, making them suitable for mechanized harvesting; Cezar, Magdeburzkyi short-rooted, and other population varieties that include many different biotypes. Young plants can withstand light frosts down to –6°C, and up to –30°C under snow cover. Chicory is quite demanding regarding soil quality. It yields the best harvests on deep, fertile soils rich in humus and lime. The average yield of chicory roots, depending on the variety and cultivation techniques, ranges from 130 to 250 centers per hectare (c/ha) [1, 7].

Fig.1. General view of chicory root crops

Among the primary technological operations, a special role belongs to the removal of the main mass of tops (greens) and the topping of residual foliage on the root heads, lifting the roots, cleaning the harvested heap from impurities, loading the cleaned roots into a transport vehicle or the harvester's hopper, and forming field clamps for subsequent loading into transport [1, 3, 8].

The foundation for the further development of the scientific vision for designing chicory-lifting working parts should be the hypothesis of the possibility of simultaneously combining the operations of topping residual foliage and lifting the roots using combined diggers (Fig. 2b). This aim is to improve the quality performance of the diggers and the technological indicators of the root-harvesting machine compared to disk diggers (Fig. 2a) of simple design [1, 8–10].

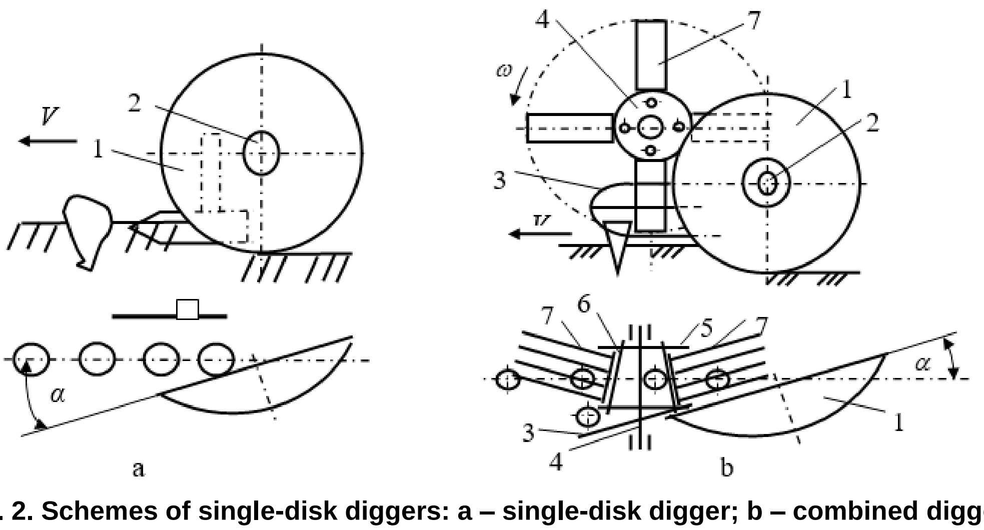

Fig. 2. Schemes of single-disk diggers: a – single-disk digger; b – combined digger

1 – spherical disk; 2 – axle; 3 – root guide; 4 – horizontal cleaning shaft; 5 – flange; 6 – cleaning shaft axle; 7 – flat elastic blades; α – angle between the axes of the cleaning shaft.

The quality of root-harvesting machines during operation is also significantly influenced by the distribution of chicory roots within the rows. Irregular spacing of plants in the rows leads to an increase in substandard (non-conforming) root crops [10, 11]. The growth of root mass continues until late autumn. Therefore, chicory harvesting is carried out as late as possible (throughout October).

Materials and methods.

Based on research into the agro-biological characteristics and physico-mechanical properties of chicory roots, renowned scientists [4, 9–14] have proven that the justification of the parameters for the digging working part must be conducted by directly taking into account the mechanical properties of the soil medium, the probable size-and-mass characteristics of the root crops, and their distribution within the row.

Results. Research has established dependencies that allow for the forecasting of future chicory root yields based on their actual agro-biological parameters and the spacing between plants in a row during the harvesting period [4]:

$P_k = 281{,}65+4{,}93\, S_p;\quad D_k = 48{,}41+0{,}78\, S_p;$ (1)

$L_k = 216{,}95+1{,}09\, S_p;\quad S_n = 45{,}0\, S_p;$ (2)

$k = 0{,}02\, S_p^{-0{,}0015};\quad C = 2222{,}84\, S_p^{-1};$

$У_k = 451{,}67\, S_p^{-0{,}7739},$ (3)

where Sp is the spacing between root crops in a row, mm.

With an increase in the interval between plants, the height of the root heads above the soil surface increases. In this case, the maximum protrusion height of the heads above the soil surface reached x_{max} = 50 mm, and the distribution height h_b of the root crops above the soil surface is approximated by the equation [4]:

$$h_b = 5{,}59 + 0{,}766\, S_p. \quad (4)$$

The lateral deviation S_b of the root crop placement relative to the row centerline is described by a logarithmic curve, and the distribution pattern follows the normal law [4]:

$$S_b = 65{,}483 - lg(S_p). \quad (5)$$

The main technological indicators of the process of lifting a root crop heap with a single-disk digger - based on the study of the total mass flow rate (per second) of the lifted heap and its individual components, namely roots and impurities as a whole - are determined by the total soil mass flow rate M (kg/s) from one row, which varies within the range of 25–35 kg/s according to the formula [13]:

$$M = SV_p\rho - W_k;$$
$$S = 1{,}5h\, sin\, \gamma\sqrt{2Rh - h^2}, \quad (6)$$

where S – the cross-sectional area of the furrow cut into the soil by the disk, m²; V_p – the operating speed of the digger, m/s; ρ – he specific mass of the soil, kg/m³; W_k – the root crop mass flow rate (per second), kg/s; h – the disk working depth, m; γ – the disk angle of attack, deg.; R –- the disk radius, m.

Optimization mathematical models have been established that characterize the changes in the total mass flow rate of the root crop heap M, the mass flow rate of root crops M_k, the total mass flow rate of soil impurities $M_{\rho\partial}$, and the plant impurities M_p, depending on the disk parameters, dimensional characteristics of the root crops, and the operating conditions of the root-harvesting machine; in this case, the total mass flow rate of the heap from one row varies within the range of 10–13 kg/s [14]:

$$M = V_м \left\{ \begin{aligned} & \frac{0{,}125\rho_{гр}K_{в.\rho_2}\, sin\alpha}{h}\left[S - 8h\left(j_1V'_{k_\rho 1} - j_2V'_{k_\rho 2} - \ldots - j_nV'_{k_\rho n}\right)\right] + \\ & + \rho_k K_в\left(j_1V_{k1} + j_2V_{k2} + \ldots + j_nV_{kn}\right) + \\ & + 2K_{в.p2}\, sin\alpha\sqrt{a(D_\partial - a)}\left[U_г\left(\overset{i}{\mu} + \overset{i}{\eta}\right) + \overset{i}{\lambda}\right] \end{aligned} \right\}; \quad (7)$$

$$M_{\rho\partial} = \rho_{гр}V_м K_{в.\rho_1}\, sin\alpha\left[S_\rho - \left(j_1V'_{k_a 1} + j_2V'_{k_a 2} + \ldots + j_nV'_{k_a n}\right)\right]; \quad (8)$$

$$M_p = 2V_м K_{в.p_2}\, sin\alpha\sqrt{a(D_\partial - a)}\left[U_г\left(\overset{i}{\mu} + \overset{i}{\eta}\right) + \overset{i}{\lambda}\right] \quad \textbf{(9)}$$

where $V_м$ - the forward speed of the root-harvesting combine, m/s; α – the setting angle of the spherical disk relative to the root crop row axis, deg.; $K_{в.\rho_2}$, $K_{в.p_2}$ – a coefficient accounting for the degree of soil and plant impurity removal per second, respectively; $\rho_{гр}$ – the specific mass of the soil, kg/m³; $V_{k_\rho 1}, V_{k_\rho 2}, \ldots, V_{k_\rho n}$ – the volume of the underground part of a single i-th root crop with the corresponding dimensional and mass characteristics, m³; $j_1, j_2, \ldots, j_n$ – the number of i-th root crops with the corresponding dimensional and mass characteristics per linear meter of the row, units; h – the depth of the spherical disk, m; R_c – the sphere radius, m; R_∂ – the spherical disk radius, m; a – the spherical disk working depth, m; $U_г$ – the chicory tops yield, kg/m².

The operating efficiency of the cleaner k is determined by [14]:

$$k = m_г / m_o ,\qquad (10)$$

where $m_г$ – the mass of the chicory tops removed from the root crops, kg; m_o – the initial mass of all the tops on the root crop prior to its removal, kg

Conclusions. To enhance the technological efficiency of the chicory root harvesting process, it is necessary to employ technical means that account for real-world operating conditions and soil-climatic harvesting environments. Furthermore, the substantiation of technological, design-kinematic parameters, and operating modes of the combined digger's working elements will allow for an increase in root harvesting completeness and a reduction in root damage by intensifying the destruction process of the surrounding soil environment.

References

1. Humentyk, M.I. (2013). Osoblyvosti tsykoriiu korenevoho i ahrotekhnika yoho vyroshchuvannia. *Zbirnyk naukovykh prats ITsB UAAN*, 18(02), 339–341. [In Ukraine].
2. Voitiuk D. H., Baranovskyi V. M., Bulhakov V. M. ta in. (2005). Silskohospodarski mashyny. Osnovy teorii ta rozrakhunku: pidruchnyk. K.: Vyshcha osvita. 464. [In Ukraine].
3. Bulhakov V. M., & Adamchuk V. B. (2022). Eksperymentalni doslidzhennia dvovalovoho ochysnyka holovok koreneplodiv. *Visnyk ahrarnoi nauky.* No 7. 53-61. DOI: https://doi.org/10.31073/agrovisnyk202207-08. [In Ukraine].
4. Baranovskyj V.M. (2017). The main stages and general principles of current trends of root crop machinery. *Visnyk TNTU*. b.11, №2. P.67-75. [in English].
5. Bulgakov V., Holovach I., & Berezovyy M. (2005). Longitudinal oscillations of the sugar beet root crop body at vibrational digging up from soil. *Research in Agricultural Engineering-UZPI.* No 51(3), 99-104. DOI: 10.17221/4910-RAE [in English].
6. Baranovsky V., Pankiv M., Kukhar O. et al. (2022). Results of the experimental investigations of fodder beets harvesting technologies. *Scientific Journal of the Ternopil National Technical University*. No 2 (106). P. 16-26. URL: https://elartu.tntu.edu.ua/bitstream/lib/40058/2/TNTUSJ_2022v106n2_Baranovsky_V-Results_of_the_experimental_16-26.pdf [in English].
7. Boyko V., Baranovsky V., Pankiv V., Onyshchenko V., & Marinenko S. (2023). The results of the study of the cutter of the remains of root crops haulm. *Scientific Journal of the Ternopil National Technical University*. No 1(109), 99-109. URL: https://scispace.com/journals/visnik-ternopilskogo-natsionalnogo-tekhnichnogo-universitetu-2r6t6584/2023 [in English].
8. Trukhanska O. O., & Shvets L. V. (2017). Matematychne modeliuvannia protsesu tekhnolohichnoi vzaiemodii koreneplodiv z shnekovoiu poverkhneiu. *Tekhnika, enerhetyka, transport APK*. No 4 (99), 128-132. [in Ukrainian].
9. Trukhanska O., & Hadaichuk M. (2024). Analysis of design and technological aspects of functioning of chicory root diggers. *Technology, energy, agriculture transport AIC*. No 4 (127), 30-37. DOI: 10.37128/2520-6168-2024-4-3 [in English].
10. Trukhanska O. (2018). Technological interaction of the roots with the screw surface of the cleaning system. *Vibration in engineering and technology.* No 4 (91), 63-68. URL: http://vibrojournal.vsau.org/storage/articles/February2020/Ffgnmai E5dbAU20EVl0P.pdf. [in English].
11. Trukhanska O. (2022). Research of the working process of the cleaning system of machines for harvesting root crops. *Vibration in engineering and technology.* No 1 (104), 106-116. DOI: 10.37128/2306-8744-2022-1-13. [in English].
12. Hadaichuk M. (2024). The process of digging chicory roots with a combined digger. *Scientific Journal of the Ternopil National Technical University*. No 3 (115), 62-72. https://doi.org/10.33108/visnyk_tntu2024.03.062 [in English].
13. Baranovsky V., Truhanska O. Pankiv M., & Bandura V. (2020). Research of a contact impact of a root crop with a screw auger. *Research in Agricultural Engineering*, 66. No 1. 33-42. https://doi.org/10.17221/75/2017-RAE [in English].
14. Baranovskyi V. M. (2008). Rezultaty teoretychno-eksperymentalnykh doslidzhen sekundnoi podachi vorokhu koreneplodiv. *Mekhanizatsiia silskohospodarskoho vyrobnytstva*. 1. 111-120. [In Ukraine].

ТЕХНОЛОГІЧНІ ОСОБЛИВОСТІ ВИРОЩУВАННЯ І ЗБИРАННЯ КОРЕНЕПЛОДІВ ЦИКОРІЮ

У технології виробництва цикорію найбільш трудомістким і недосконалим є процес викопування коренеплодів з ґрунту та їх очищення від ґрунтових і рослинних домішок. Технологія збирання коренеплодів вважається оптимальною, коли допускаються найменші втрати, пошкодження та забрудненість зібраних коренеплодів домішками.

Для збирання коренеплодів просапних культур неможливо зовсім уникнути втрат урожаю, які зумовлені, насамперед, конструктивними особливостями збиральної техніки і використанням її у складних

ґрунтово-кліматичних умовах, які безперервно змінюються у процесі роботи (механічний склад, вологість і твердість ґрунту, широкий діапазон варіювання параметрів розміщення рослин в рядках, стан їх розвитку тощо), а також складністю виконання агротехнічних вимог до процесів відокремлення листостеблової маси і витягання коренеплодів із ґрунту без пошкоджень при поступальному русі збиральних агрегатів. Для цикорію кореневого додаються свої специфічні особливості такі, як низький рівень механізованої технології вирощування і відсутність спеціальних машин для збирання коренеплодів цикорію в Україні та за кордоном.

Під час розробки робочих органів для викопування коренеплодів цикорію необхідно також враховувати вимоги переробної промисловості коренеплодів цикорію до якості сировини. Відповідно, до вказаних вимог продуктивна частина коренеплодів цикорію визначається від лінії зрізу листків із верхівки головок коренеплодів до лінії зрізу хвостової частини діаметром 15 мм. За таких умов втрати маси коренеплоду залежно від відламаної хвостової частини становитимуть в середньому до 6…7 %.

Комплексна оцінка агробіологічних і фізико-механічних характеристик коренеплодів цикорію кореневого є теоретичними передумовами розробки та проектування робочих органів для його викопування. Існуюча сучасна однофазна технологія та технічні засоби, які застосовують під час збирання коренеплодів цикорію не забезпечують встановлених показників якості роботи. При цьому забрудненість коренеплодів залишками гички та рослинними домішками, відходи в гичку маси обрізаних головок до маси коренеплодів, пошкодження коренеплодів за рахунок сколів значно знижує якість сировини та вихід продуктів їх переробки. У зв'язку з цим завдання підвищення технічного рівня коренезбиральних машин, або показників якості викопування коренеплодів, залишається актуальним питанням.

Ключові слова: *технологія, коренеплоди, цикорій, вирощування, збирання, викопувальні робочі органи, класифікація, комбіновані копачі, сферичний диск.*

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Стаття надійшла 27.10.2025
Стаття прийнята 05.11.2025
Опубліковано 25.12.2025