



EFFECT OF WORKING ELEMENT DESIGN ON SEED QUALITY DURING MAIZE (*ZEAMAYS L.*) COBS CLEANING

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SUMMARY

Maize (*Zea mays* L.) cobs' cleaning from husks is one of the most important stages in seed production for obtaining high-quality seed material. In this process, the diameter, surface shape, friction properties of cleaning rollers, and forces generated during contact with the cob play a key role. The study revealed the optimal diameter of the rollers and the contact angle with the cob to ensure the effective grasping and removal of husks in maize cobs. The theoretical and experimental analyses of cob deformation and friction forces have enabled the justification of structural variables of working organs. In this research, the mathematical models of husk removal in maize cobs have succeeded in their development, having accelerated the process efficiency by calculating the compression and tension forces developed between the rollers. According to results, the parameters, such as the cob deformation angle and the impact radius of the compression mechanism, have reached optimization, which considerably minimized the risk of mechanical damage to seeds and enhanced productivity by 20%–30%. The proposed technological solutions will develop a scientific basis for designing the new generation cleaning machines in the seed industry and contribute to resource conservation.

Keywords: Corn (*Z. mays* L.) cobs, coating cleaning, cobweb, friction properties, deformation, force analysis, seed technology, seed material

Key findings: The rollers' diameter and surface shape were the most important constructive parameters in removing the husks from maize (*Z. mays* L.) cobs. Keeping the contact angle between the cob and roller closer to a right angle enhanced the efficiency of husk gripping. Determining the optimal parameters of working units can result from calculating cob deformation and friction forces.

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INTRODUCTION

In maize (*Zea mays* L.) cobs, the husk removal process directly affects the seed material quality, since improper removal can cause mechanical damage to the kernels, reduce germination capacity, and negatively influence seed storage stability. The efficiency and precision of this process exert a significant influence on the germination capacity of seeds, the degree of mechanical damage, their physical properties, subsequent productivity, and ultimately on the commercial value of the variety. In modern seed production technologies, the right selection of constructive parameters of working units is strategically important in minimizing losses due to mechanical damage and improving seed quality (Zheng *et al.*, 2023; Chen *et al.*, 2025; Huseynov *et al.*, 2026c).

At present, the demand for high-quality corn seed has substantially increased due to the expansion of hybrid cultivars and the intensification of the cropping systems and agricultural practices. These perspectives have placed greater emphasis on the optimization of husk-removal technologies, where even minor improvements in mechanical design can lead to substantial gains in seed quality and viability and, eventually, crop yield (Mammadov *et al.*, 2026a; Mammadov *et al.*, 2026b). However, these challenges lie in balancing efficiency with gentleness, ensuring that separating seeds from husks will not compromise their biological integrity (Chen *et al.*, 2025).

Furthermore, the integration of modern materials and adaptive control systems into husk-removal machinery has opened numerous possibilities for precision in seed processing. Smart sensors and automated adjustments enable machines to adapt to variations in cob size, as well as husk thickness, thereby reducing losses due to seed mechanical damage while improving uniformity and quality. This technological evolution aligns with the broader trend of digital agriculture, where data-driven optimization is becoming a vital key to production systems (Li and Wang, 2021; Gumbatov *et al.*, 2024).

Ultimately, the scientific investigation of husk-removal mechanics transcends mere engineering design considerations and constitutes an essential dimension of agricultural sustainability. By minimizing the seed's mechanical damage and maximizing seed germination potential, optimized husk-removal technologies contribute to higher yields, reduced resource wastage, and improved food security. The theoretical foundation for such advancements bridges the gap between mechanical engineering and crop science (Zhao *et al.*, 2020; Huseynov *et al.*, 2025).

Experimental trials conducted by us have shown that the interaction between roller geometry and husk thickness plays a decisive role in determining the efficiency of seed separation. When designing rollers with adaptive curvature, the husk-removal process becomes more uniform, reducing localized stress points and ensuring better preservation of seed quality. Such previous findings highlighted the importance of integrating theoretical models with practical evaluations to refine more the machine design (Sun *et al.*, 2021; Huseynov *et al.*, 2026a).

Moreover, sustainability considerations are increasingly shaping the development of husk-removal technologies. Energy-efficient motors and recyclable construction materials are now priorities in modern machinery design, along with the optimization of mechanical components to reduce seed damage and improve processing efficiency. These innovations not only improve the ecological footprint of seed production but also align with global agricultural policies aimed at promoting environmentally responsible and safe practices (Huang *et al.*, 2022; Huseynov *et al.*, 2026b).

In this study, the theoretical foundations of the corn cobs' husk-removal process underwent investigation, with parameters such as the diameter of rollers, surface shape, and the contact angle between the cobs and the roller analyzed (Fan *et al.*, 2022). Therefore, the presented research aimed to establish a scientific basis for optimizing the cobs' cleaning process.

MATERIALS AND METHODS

The primary methodological basis of the study was the triad system approach, in which the corn (*Z. mays* L.) cobs, machine (cleaning device), and process (applied forces) sustained simultaneous studies at the same level with mutual interactions. This approach proves it possible to evaluate the dynamics of the process and the interactions among these three components more accurately (Chen *et al.*, 2025; Shukurova *et al.*, 2026).

The investigation of biometric parameters proceeded on 100 cobs, with the following characteristics determined, including bulk density (test weight expressed as grams per liter), average mass, cob diameter and length, the number of kernels per cob, and the 1000-kernel weight. The bulk density measurement used a special Purka device with a capacity of one liter. This instrument allows the rapid determination of an important agronomic indicator associated with grain processing. Bulk density also characterized the commercial quality of grains, evaluated as a synthetic quality indicator of seeds (Zheng *et al.*, 2023; Salimov and Huseynov, 2025; Salimov *et al.*, 2025).

An experimental device, earlier developed, accounts for the diameter, surface configuration, and frictional properties of the cleaning rollers. The device comprised a set of rotating rollers, a pressing mechanism, and a threshing chamber. For forces' analysis, the deformation of the corn cob had a cylindrical body model, with the contact angle and friction forces calculated using mathematical methods. During the experiments, the moisture content of cobs varied within the range of 14%–32%. The results reached evaluation using a diaphanoscope and mechanical measuring instruments (Tefal 79898 balance and XS-104 microscope). The microscope provides 4-100× magnification, which was equipped with a coordinate movement system, enabling precise examination of maize kernel damage (Chen *et al.*, 2025; Mammadov *et al.*, 2025; Musayeva *et al.*, 2026).

For the experiments, corn cobs with different moisture contents were the selected

experimental groups. The study determined the kernels' damage levels using an organoleptic method and special support devices. Kernel mechanical damage classification had two groups—macro-damage and micro-damage. Macro-damage refers to defects visible to the naked eye, whereas micro-damage includes cracks detectable only with auxiliary equipment. Detecting kernel damage used a binocular magnifier and the luminiscence (luminiset) method (Zheng *et al.*, 2023; Asadullayev *et al.*, 2024).

The rotational speed of the disk varied, ranging from 1 to 11 m/s, allowing the study of the dynamics of the process. The forces generated at the contact points between the cob and the disk entailed calculation using empirical formulas. The sample mass was not less than 200 g, and the obtained results underwent statistical analysis for data compilation.

RESULTS AND DISCUSSION

According to results, the study determined the diameter of the rollers and the contact angle between the cob (*Z. mays* L.) and the roller directly influenced the gripping power and detachment process of the cob husks. The calculation of cob deformation and friction forces made it possible to considerably determine the optimal parameters of the different working elements of the machine. According to the obtained graphs, an enhancement in the roller diameter facilitates the movement of the corn cobs and ensures more effective removal of husks (Figures 1 and 2).

The findings proposed new technical solutions for eliminating the constructive shortcomings in the existing corn cob threshing machines (Fan *et al.*, 2022; Zheng *et al.*, 2023; Najafov *et al.*, 2026). These results were consistent with the concrete conclusions made by Zheng *et al.* (2023) and Fan *et al.* (2022). They emphasized that the geometric parameters of working elements, particularly roller diameter and contact conditions, considerably affected the husk removal efficiency in maize processing machines. Their

studies also enunciated that proper optimization of roller dimensions and contact angles improves the cobs' gripping power and eventually reduces resistance during husk separation. Consequently, increasing roller diameter can enhance the movement stability of cobs and contribute to more efficient husk detachment.

Several previous studies have contributed to solving technical problems related to the working units of maize husk-removal machines and in determining their geometric parameters. However, at the present stage of technological development, a significantly growing demand exists for a more targeted and obviously justified determination of the constructive parameters of such machines (Li et al., 2023; Huseynov and Aghayev, 2024). These studies emphasized that the efficiency and reliability of maize husking and threshing machines largely depend on the correct selection of structural and kinematic parameters of the working elements. They also reported further optimization of design parameters is necessary to improve husk removal efficiency while reducing maize grains' mechanical damage and energy consumption.

During the designing of working units of corn cob husking machines, several priority factors have emerged as essential. Their clear mathematical justification can ensure full compliance with technological requirements. In

the main working element of the husking device, the roller diameter plays a crucial role in determining whether the cob husk will be easy to grip or not, as well as in defining the surface configuration of the roller. Moreover, the cob rotation around its axis largely depends on the roller diameter. This, in turn, facilitates the movement of the cob along the roller surfaces, contributes to the uniform loading of the device, and simplifies the processing of the surface using various pressing mechanisms (Li et al., 2023; Kuliyeve et al., 2026). Their investigations further revealed the geometric parameters of rollers and their contact conditions with the corn cobs significantly influenced the gripping power, movement, and husk removal process. Previous findings also emphasized the right selection of roller diameter and surface configuration improves the stability of cob rotation and enhances the efficiency of husking mechanisms.

The study considered the gripping condition of corn cob husks by the cleaning rollers. Unhusked cobs move along the cylindrical drum surface under the influence of their own mass, the pressing mechanism, and rotation around the axis. Meanwhile, the rollers rotate in opposite directions, slightly inclined relative to the horizontal axis of the rollers. During this movement, a tangential force T succeeded in its generation on the contact surface (Figure 1). As a result, the husks incurred separation from the cobs, being pulled

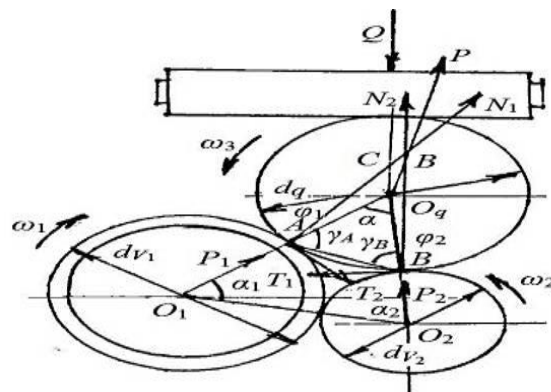


Figure 1. Scheme for determining the gripping angle of the husk by the cleaning rollers and their diameter:

d_q - minimum diameter of the corn cob; D_1 and D_2 - diameters of the rollers; Q - the resultant force created by the weight of the cob and the pressing mechanism; N_1 , N_2 - normal reactions; T_1 , T_2 - tangential forces; and P - the force vector corresponding to the equilibrium state.

between the rollers. With the influence of the force Q exerted by the rollers, normal pressures N_1 and N_2 act upon the cobs, which, in turn, generate the tangential forces T_1 and T_2 :

$$T = fN, \quad (1)$$

Where f is the coefficient of friction between the husk and the rollers.

The following condition must be satisfied for the rollers to grip the husks:

$$f \geq \frac{f_1 + f_2}{2}, \quad (2)$$

Where, f_1 = the friction coefficient of the leg cover along the grain, $f_1 = 0.29$, f_2 = the friction coefficient between the cover leaves, and $f_2 = 0.35$.

Thus, for the husks to be gripped and detached from the cob, the surface of the cleaning rollers must have a coefficient of friction of $f \geq 0,32$.

Satisfying the following conditions will prevent the cob from slipping between the rollers:

$$Nf \cos \alpha < N \sin \alpha. \quad (3)$$

During the technological processing, the position of cobs was between a set of rotating rollers, which were subjected to the influence of the pressing mechanism. The gripping condition

and angle of the cob, as well as the magnitude and nature of the reactions on the surfaces of the working elements, attained determination using a mathematical method.

For a set of rollers with equal diameters, the triangle (AO_qB) was equilateral (Figure 2). Therefore,

$$\gamma_A = \frac{\alpha_1 + \alpha_2}{2}. \quad (4)$$

For triangle ABC, we write:

$$\cos \beta = \cos[180 - (\phi_1 + \phi_2 + \alpha_1 + \alpha_2)]. \quad (5)$$

According to the law of cosines,

$$P^2 = N_1^2 + N_2^2 - 2N_1N_2 \cos(\psi), \quad (6)$$

$$\cos(\psi) = \cos(180 - \beta). \quad (7)$$

Then

$$\alpha_1 + \alpha_2 = \arccos\left(\frac{N_1^2 + N_2^2 - P^2}{2N_1N_2}\right) - \phi_1 - \phi_2. \quad (8)$$

Here

$$N_1 = \frac{P_1}{\cos \phi_1}; N_2 = \frac{P_2}{\cos \phi_2}. \quad (9)$$

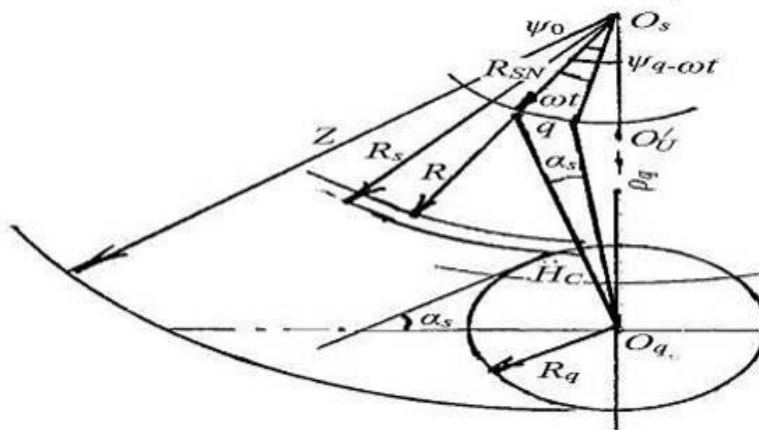


Figure 2. Scheme for determining the deformation of the hip.

From the obtained analytical formulas, an outcome revealed that the values of P_1 and P_2 significantly depend on the constructive parameters of the working elements. The refined values of these forces can be obtainable by considering the anisotropic properties of the plant material, particularly the husk and kernel portions of the corn. The dynamics of the husk gripping and peeling process should be considered concerning the deformation of the working surfaces (rollers and pressing mechanism) and the cob components (husk, kernels, and cob) (Hasanov and Aliyev, 2022; Kim and Zhao, 2025). Their studies enunciated the interaction between plant material and mechanical working elements had significant influences from the physical-mechanical and anisotropic properties of the crop. Their findings also emphasized that accurate modeling of deformation, contact forces, and impact dynamics was crucial to optimize the design of threshing and husking mechanisms.

Further investigating the deformation of the cobs when compressed by the roller, a cylindrical shape modeled it (Figure 2). Here, the working part of the compression mechanism's profile curve is the arc of a circle with radius R_S . R_{SN} is the adjustment radius of the compressor; Z is the distance from the compressor center to the roller; ρ is the distance from the compressor center to the cob center; ψ_0 is the coordinate angle of the contact point with the compressor profile; ψ_q is the cob deformation angle (indicating how much the compressor displaces relative to the cob during its maximum deformation); α_0 is the compressor contact angle; and α_S is the compressor surfaces angle.

Therefore, it was possible to express the mutual relationship of each mentioned angle with the device's parameters as follows:

$$\alpha_0 = \arccos \frac{(R_{SN} + R_S + Z - R_q)^2 - R_{SN}^2 - (R_S + R_q)^2}{2R_{SN}(R_S + R_q)}; \quad (10)$$

$$\alpha_S = \arccos \frac{(R_{SN} + R_S + Z - R_q)^2 + R_q^2 - (R_{SN}^2 + R_S^2 + 2R_{SN}R_S \cos \alpha_0)}{2R_{SN}(R_S + R_q)}; \quad (11)$$

$$\psi_0 = \arcsin \frac{R_S \sin \alpha_0}{\sqrt{R_{SN}^2 + R_S^2 + 2R_{SN}R_S \cos \alpha_0}}; \quad (12)$$

$$\psi_q = \arcsin \frac{(R_S + R_q) \sin \alpha_0}{(R_{SN} + R_S + Z - R_q)}. \quad (13)$$

The deformation size determination can be as the depth of penetration of the compressor into the cob. If the cob slippage by the compressor is neglected, then determining the current value of the deformation (H_C) can be as follows:

$$H_C = (R_S + R_q) - \sqrt{R_{SN}^2 + \rho_q^2 - 2R_{SN}\rho_q \cos(\psi_q - \omega t)}, \quad (14)$$

By differentiating this, the rate of deformation can be detectable:

$$v_{def} = \frac{dH_C}{dt} = \frac{\omega R_{SN} \rho \sin(\psi_q - \omega t)}{\sqrt{R_{SN}^2 + \rho_q^2 - 2R_{SN}\rho_q \cos(\psi_q - \omega t)}}, \quad (15)$$

Here, t is the current time of deformation, varying from $t=0$ to $t=T$. Thus, the identification of deformation conditions of the cob and its relationship with the parameters of the working organs for the grasping and peeling of the cob husk was successful.

CONCLUSIONS

The theoretical and experimental analyses of maize (*Z. mays* L.) husk removal have confirmed that the optimal diameter and surface shape of rollers proved critical for process efficiency. The results provided a scientific basis for designing new-generation cleaning machines to improve seed quality and reduce seed mechanical losses. Mathematical models and empirical formulas justified the influence of roller diameter and contact angle with the cob on compression and tension forces. The results showed enhanced roller surface friction can further increase the husk grasping and removal speed by 15%–25%, significantly minimizing seed losses due to mechanical damage. The results supported the optimization of mechanical processes in maize seed production

and may guide the development of new standards in agricultural machinery, while future research could extend these models to other crops.

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