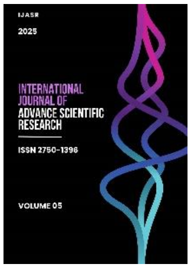
International Journal of Advance Scientific Research
(ISSN – 2750-1396)
VOLUME 05 ISSUE 07 Pages: 21-28
OCLC – 1368736135



Journal Website: http://sciencebring.com/index.php/ijasr

Research Article

Development of A Device for Separating and Fractionating Chickpea Seeds from Pods and Theoretical Study of The Coverage Process

Submission Date: May 27, 2025, **Accepted Date:** June 23, 2025,
Published Date: July 25, 2025
Crossref doi: https://doi.org/10.37547/ijasr-05-07-03

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Abstract

This article presents the development of a device for separating and fractionating chickpea seeds from pods, as well as the results of a theoretical study of the seed coverage process within the device. The results of the theoretical research show that the proposed device ensures high completeness of chickpea seed separation from pods and minimal damage to the seeds when the maximum coverage angle for feeding seeds into the separation mechanism reaches 90°.

Keywords

Chickpea, pod, seed, beater, device, shaft, sieve, hopper, cylinder.

Introduction

It is well known that the development of technologies and technical tools that ensure high-quality execution of the processes of separating and initially cleaning agricultural crop seeds from ears and pods, as well as increasing their efficiency, is considered one of the important tasks of scientific research. In this regard, improving the organization of agricultural crop production in farms and reducing costs requires the development of structurally simple devices that can separate seeds from pods in accordance with agrotechnical requirements, while increasing

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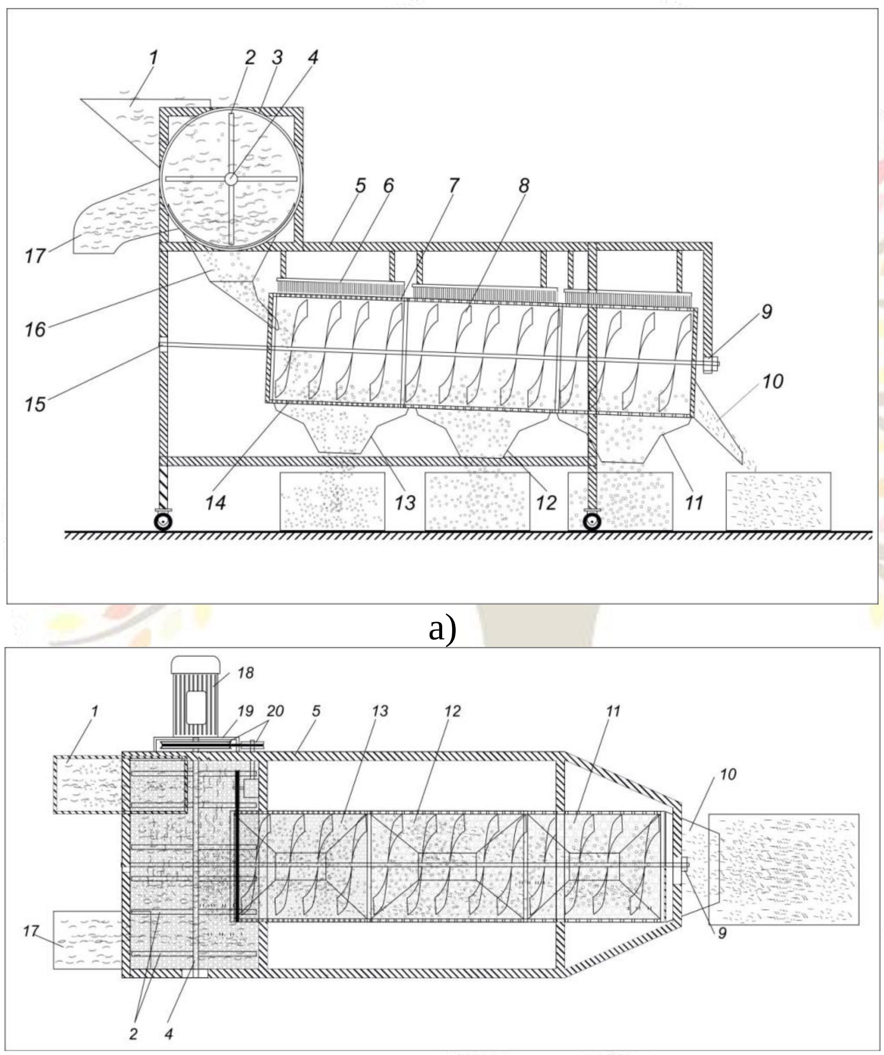
energy and resource efficiency — one of the key objectives of agricultural machinery engineering.

The creation of improved, energy- and resource-efficient devices to perform the above-mentioned tasks on farms is one of today's urgent challenges.

To address this issue, based on previous scientific research, a schematic of a newly designed small-scale device for fractionating chickpea seeds from pods was developed (Figure 1) [1–15].



a) side view; b) top view

1 – loading hopper; 2 – beaters; 3 – cylinder; 4 – shaft; 5 – frame; 6 – brush for cleaning sieve mesh; 7 and 14 – cylindrical sieve; 8 – helical guide; 9 and 15 – bearings; 10 – chute for large *impurities; 11 – chute for large seeds; 12 – chute for small seeds; 13 – chute for small impurities; 16 – chute for feeding seed mixture to the sieve; 17 – discharge outlet; 18 – electric motor; 19 – base; 20 – pulleys*

Figure 1. Structural and technological diagram of the device for separating and fractionating chickpea seeds from pods.

Figure 1 shows the structural and technological diagram of the device, and its working principle is as follows: When the device is connected to the power supply, the electric motor (18), through pulleys (20) and belt transmissions, drives the shaft (4) with attached beaters (2) into rotational motion. At the same time, chickpea stalks with pods are loaded. When the chickpea stalks fall from the hopper (1) into the cylinder (3), the rotating beaters (2) strike them, and due to the impact force, the seeds are separated from the pods. Since the beaters (2) are helically fixed to the shaft (4), they also push the stalks forward in the direction of rotation. Any seeds that remain unseparated are hit again by other beaters (2) further along the path, ensuring complete separation.

The seeds separated from the pods pass through the sieve-like bottom and, via the seed mixture transfer chute (16), fall into the cylindrical sieve (7). The seed mixture that enters the sieve moves toward the end of the sieve due to the rotation, inclination of the sieve, and especially the influence of the helical guide (8). Along the way, the mixture is cleaned from large and small impurities through the perforations on the inner surface of the sieve and is also sorted by seed size.

When chickpea stalks fall into the cylinder through the hopper, they interact with the beaters fixed to the shaft. As a result, the beaters not only draw the podded chickpea stalks into the cylinder but also serve to separate the seeds from the pods. In order to ensure high completeness of seed separation from pods and minimal damage to the seeds, it is crucial to theoretically study the coverage process of the chickpea stalks by the beaters.

To further clarify this process, a theoretical study of the interaction of forces acting on the mass of podded chickpea stalks being fed into the cylinder via the hopper is conducted (see Figure 2).

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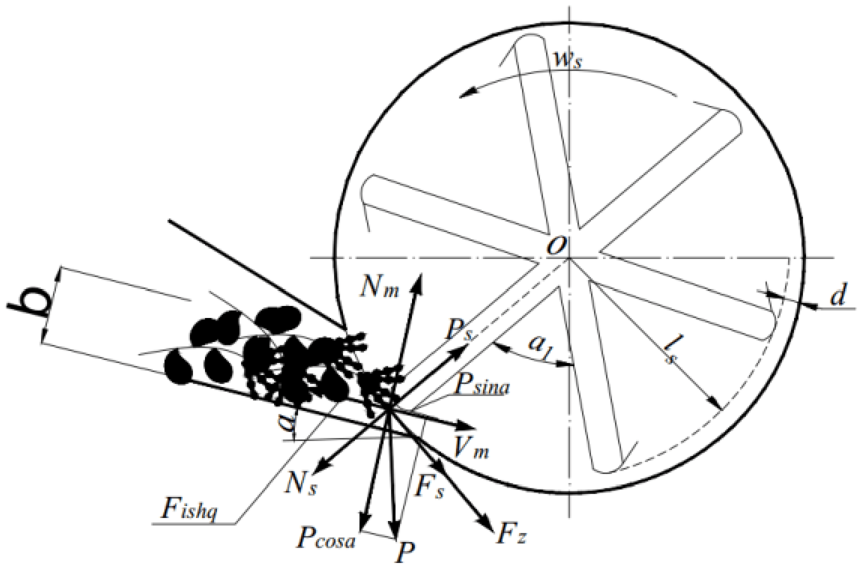

Figure 2. Diagram of the forces acting during the coverage of podded chickpea stalks by the beater

When the podded chickpea stalks, of a certain thickness, are fed at an angle through the hopper into the cylinder, the beaters apply a force to them at the moment they enter the gap between the cylinder's inner surface and the beater. This force pushes them toward the hopper. Then, the weight of the podded chickpea stalks generates a gravitational force, along with a reactive force from the surface of the hopper and a frictional force between the stalks and the hopper surface.

In addition, when the podded chickpea stalks are grasped and compressed by the beaters, a reactive force acts against the surface of the beater, and frictional force arises between the stalks and the inner surface of the cylinder.

Based on the force diagram shown in Figure 2, which illustrates the interaction during the coverage process by the beater, the following condition must be fulfilled for the mass of the podded chickpea stalks to enter the cylinder:

$$F_S \cos(\alpha_1 - \alpha) + P \sin\alpha \ \geq F_{ishq}, \qquad (1)$$

there α_1 – Beater coverage angle of the podded chickpea stalks, degrees

According to the diagram shown in Figure 2, the frictional force is expressed as follow

$$F_{ishq} = f\, N_m = f\, \lfloor P \cos\alpha + F_S \sin(\alpha_1 - \alpha\ ) \rfloor. \qquad (2)$$

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If $F_S = f_1 N_S$, $N_S = P_S$, $P = mg$ is valid, and taking expression (2) into account, then condition (1) will take the following form:

$$f_1 P_S \cos(\alpha_1 - \alpha) + mg\sin\alpha \ \geq f\left[mg\cos\alpha + f_1 P_S \sin(\alpha_1 - \alpha)\right]. \qquad (3)$$

By grouping the terms in expression (3) accordingly, we obtain the following expression:

$$f_1 P_S \left[\cos(\alpha_1 - \alpha) - f\sin(\alpha_1 - \alpha)\right] \geq mg(f\cos\alpha - \sin\alpha). \qquad (4)$$

or

$$f_1 P_S \left[\cos(\alpha_1 - \alpha) - f\sin(\alpha_1 - \alpha)\right] + mg(\sin\alpha - f\cos\alpha) \geq 0 \ . \qquad (5)$$

(5) Analysis of the expression shows that, for this condition to be satisfied in a particular case, the following conditions must be met:

$$\begin{cases} \cos(\alpha_1 - \alpha) - f\sin(\alpha_1 - \alpha) \geq 0; \\ \sin\alpha - f\cos\alpha \geq 0. \end{cases} \qquad (6)$$

(6) By applying certain mathematical transformations to expression (6), we obtain the following form:

$$\begin{cases} \dfrac{1}{\sqrt{1+f^2}}\cos(\alpha_1 - \alpha) - \dfrac{f}{\sqrt{1+f^2}}\sin(\alpha_1 - \alpha) \geq 0; \\ \dfrac{1}{\sqrt{1+f^2}}\sin\alpha - \dfrac{f}{\sqrt{1+f^2}}\cos\alpha \geq 0. \end{cases} \qquad (7)$$

or

$$\begin{cases} \cos((\alpha_1 - \alpha) + \arccos\dfrac{1}{\sqrt{1+f^2}}) \geq 0; \\ \cos(\alpha + \arccos\dfrac{f}{\sqrt{1+f^2}}) \leq 0. \end{cases} \qquad (8)$$

By introducing modifications to expression (8), we arrive at the following solution:

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$$\begin{cases} -\frac{\pi}{2} \le \alpha_1 - \alpha \ + \arccos\frac{1}{\sqrt{1+f^2}} \le \frac{\pi}{2}; \\ \frac{\pi}{2} \le \alpha \ + \arccos\frac{f}{\sqrt{1+f^2}}) \le \frac{3\pi}{2}. \end{cases} \quad (9)$$

or

$$\begin{cases} -\frac{\pi}{2} + \alpha - \arccos\frac{1}{\sqrt{1+f^2}} \le \alpha_1 \le \frac{\pi}{2} + \alpha - \arccos\frac{1}{\sqrt{1+f^2}}; \\ \frac{\pi}{2} - \arccos\frac{f}{\sqrt{1+f^2}} \le \alpha \ \le \frac{3\pi}{2} - \arccos\frac{f}{\sqrt{1+f^2}}. \end{cases} \quad (10)$$

If f=0,655 then

$$\begin{cases} \arccos\frac{1}{\sqrt{1+f^2}} \approx \frac{\pi}{4}; \\ \arccos\frac{f}{\sqrt{1+f^2}}) \approx \frac{\pi}{3}. \end{cases}$$

By substituting this value into the second inequality of expression (10), we find the value of α is $\frac{\pi}{6} \le \alpha \le \frac{7\pi}{6}$. Based on the physical and mechanical properties of the podded chickpea stalks, the coefficient of friction α=34⁰ corresponds to $\alpha = \frac{17\pi}{90}$ $\frac{\pi}{6} \le \alpha \le \frac{7\pi}{6}$, which lies within the acceptable range.

Now, by substituting this value into the first inequality of expression (10), we obtain the following: $\alpha = \frac{17\pi}{90}$ By substituting the value into the first inequality of expression (10), we obtain the following:

$$-\frac{\pi}{2} + \frac{17\pi}{90} - \frac{\pi}{4} \le \alpha_1 \le \frac{\pi}{2} + \frac{17\pi}{90} - \frac{\pi}{4},$$

$$-\frac{101\pi}{180} \le \alpha_1 \le \frac{79\pi}{180}$$

Or

$$-101^0 \le \alpha_1 \le 79^0. \qquad (11)$$

Based on this value, it is concluded that in order for the beater to effectively grip the podded chickpea stalk and lead the seed into the separation zone, the maximum coverage angle must be 90°.

Conclusion

To achieve high completeness of chickpea seed separation from pods and ensure minimal seed damage, it is necessary to properly select the coverage angle of the beater that grips the podded chickpea stalks.

In the proposed device, high seed separation efficiency and low seed damage can be ensured when the maximum coverage angle for leading the seed into the separation process is set to 90 degrees.

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