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Design Parameters Of The Spacer Organs For The Pigeon Pea Sheller (Cajanus Cajan L.) Green.

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Abstract:
The objective of this research is to calculate the design parameters of the separating organ of a green pigeon peeling sheller for the production of canned peas. A software and data on the physical-mechanical properties of the pods and grains of green pigeon pea were used for the calculation. As a result, it was obtained that the separator rollers with a diameter of 40 mm will have 2.26 mm of play between them, with an angular speed of the drive roller of 2.01 rad/s and thus achieve a total flow of 14.54 sheaths/s for a productivity of 67.81 kg/h of processed green pigeon peas.

Key words*: Smooth rollers, grain peelers, green pigeon pea, design.*

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I. Introduction

Legumes are considered strategic crops, due to their high nutritional content and diversity of uses, both for human and animal food. The pigeon pea (Cajanus cajan (L.) Mill sp), is one of those highly promising tropical crops and legumes in the current context of climate change, soil degradation and poverty (1)

The pigeon pea is an edible grain legume that can be grown all year round and is a good quality and inexpensive source of vegetable protein, (2). The use of whole, debarked or flour seeds in forage can be used as animal feed, while the seeds are used in human food with a protein content between 10 and 17%, (3; 4).

Long time ago, obtaining green beans from any of the types of beans has been generally artisanal, due to the ease offered by the pod to remove the beans from it, but when production tends to be greater, this task is done very monotonous and unsustainable. Hence, several authors have attempted to automate the threshing process of green pigeon peas and other grains, using various technologies, with the aim of increasing productivity and achieving greater efficiency in the process of obtaining the grain, (5;6).

One of the technologies used for the shelling of green beans is the use of smooth rollers, these have a wide application in the mining, metallurgical, food, chemical, pharmaceutical and agricultural industries (7; 8; 9. 10; 11; 12; 13).

Some authors such as (14 & 15), refer to the grip conditions of the rollers. While 16; 17 & 18, theoretically analyse the process of compression of vegetable masses by means of cylindrical rollers, present the distribution of pressure in the feeding and discharge zone based on the compression of the material and obtain expressions for the determination of the reactions in the rollers and the power required in the process.

In Cuba, current bean threshing technologies are based on threshing pods in the dry state, which do not allow the threshing of legumes in the green state, such as the pigeon pea. Taking into account the above, the present research aims to: Determine the design parameters of the threshing organ of a pigeon peal sheller machine for the production of canned green peas.

II. Material And Methods

The research was carried out by applying the CALROD software "Software for the Calculation of Adequate Regulation and Design Parameters of Smooth Rotary Rollers for the Feeding or Separation of Materials" (19) on Mathcad 2000 Professional support.

The data used to determine each of the design parameters comes from the physical-mechanical properties determined by (20).

Theoretical basis for calculating the geometric design parameters of the organ is separated by smooth rotating rollers.

From the fulfillment of the grip condition of the component that is desired to pass through the rollers, as well as the "no grip" condition of the component that is desired not to pass, the clearance (a) between the rollers is calculated.

Gripping condition: $a \geq dp - D(1 - \cos(\Phi p))$ (1)

Non-grip condition: $a \leq dn - D(1 - \cos(\Phi n))$ (2)

where:

dp - diameter of the stems or height of the layer of material to be passed through the rollers;

dn - diameter of the component that it is desired not to pass through the clearance between the rollers;

D - diameter of the rollers;

Φp - angle of friction between the material of the rollers and the material of the component that is desired to pass between the rollers;

Φn - angle of friction between the material of the rollers and the material of the component that is desired not to pass between the rollers.

Once the physical-mechanical properties of the product to be processed are known, the different values necessary to obtain the design parameters of the sheller organs are determined.

Calculation of the maximum magnitude of 93% of the component that must pass (pods) *(dpmáx):*

$$dp_{máx} = dp + 2\sigma dp, \text{ mm} \quad (3)$$

Calculation of the minimum magnitude of 93% of the component that must pass *(dpmín):*

$$dpmín = dp - 2\sigma dp, \text{ mm} \quad (4)$$

Calculation of the maximum magnitude of 93% of the component that must not pass (grains) *(dnmax):*

$$dnmáx = dn + 2\sigma dn, \text{ mm} \quad (5)$$

Calculation of the minimum magnitude of 93% of the component that must not pass *(dnmin):*

$$dnmín = dn - 2\sigma dn, \text{ mm} \quad (6)$$

Calculation of extreme minimum games required for the grip of the component that must pass *(amín1; amín2):*

$$a_{mín1} = dp_{máx} - Dd\left(1 - \cos(\Phi_p)\right), \text{ mm} \quad (7)$$

$$a_{mín2} = dp_{mín} - Dd\left(1 - \cos(\Phi_p)\right), \text{ mm} \quad (8)$$

Calculation of extreme maximum games required for the non-grip of the component that must not pass *(amax1; amax2):*

$$a_{máx1} = dn_{mín} - Dd(1 - \cos(\Phi_n)), \text{ mm} \quad (9)$$

$$a_{máx2} = dn_{máx} - Dd(1 - \cos(\Phi_n)), \text{ mm} \quad (10)$$

Calculation of the play *(a)* between the rollers (diameter *Dd*):

$$a = \frac{a_{máx1} + a_{mín1}}{2}, \text{ mm} \quad (11)$$

Roller limit diameter calculation *(Dlim):*

$$Dlím = \frac{dp_{máx}}{1 - \cos(\Phi_p)}, \text{ mm} \quad (12)$$

Theoretical basis for calculating the kinematic parameters of the organ design is separated by rotating smooth rollers.

To guarantee the continuity of the flow, the speed of advance of the particle in the horizontal direction *Vp* must coincide with the tangential speed of the driving roller *Vrod*, considering a slip coefficient .

Knowing that the speed of advance of the particle transported in the horizontal direction is given by the expression *(Vp):*

$$Vp = S * f, \text{ m/s} \quad (13)$$

where:

S - advance in the horizontal direction of the particle in the feeding device, m/cycles;

f - number of cycles per second, cycles/s;

So:

$$Vrod * \xi = Vp, \text{ m/s} \qquad (14)$$

however:

$$Vrod = \omega_{rod} * \frac{D}{2}, \text{ m/s} \qquad (15)$$

where:

ω_{rod} - angular velocity of the driving roller, rad / s;
D - diameter of the rollers, mm;
So, it can be said that the angular velocity of the driving roller *(ω_{rod})* is calculated as:

$$\omega rod = \frac{Vp}{\frac{D}{2} * \xi}, \text{ rad/s} \qquad (16)$$

Then the revolutions per minute of the rollers (nrod) are determined:

$$n_{rod} = \omega_{rod} * \frac{60}{2 * \pi}, \text{ rpm} \qquad (17)$$

The frequency of rotation of the rollers (frod) is calculated by the following expression:

$$f_{rod} = \frac{n_{rod}}{60}, \text{ cycles/s} \qquad (18)$$

Then, the number of pods fed simultaneously in the effective width of the cylinders and the surface (Nb) is expressed as:

$$Nb = \frac{B}{p} * \psi, \text{ pods/s} \qquad (19)$$

where:

B - effective width of the cylinders and the surface, m;
p - surface groove pitch, m;
ψ - filling coefficient.
The number of pods being processed by the rollers per unit time (pod flow) *(Qv)* is assumed to be:

$$Qv = \frac{Vp}{Lv} * Nb, \text{ vainas/s} \qquad (20)$$

where:

Lv - average pod length, m/pod.

III. RESULTS AND DISCUSSION

Table 1 shows the results achieved during the determination of the maximum and minimum diameters of pods and grains. As can be seen, for 93% of the total grains the dimensions will be greater than 5.54 mm, while for 93% of the total pods the dimensions will be less than 5.47 mm.

Table 1. Results achieved for maximum and minimum diameters for 93% of the total pods and grains.

Grains		Pods	
$dn_{máx}$ (mm)	$dn_{mín}$ (mm)	$dp_{máx}$ (mm)	$dp_{mín}$ (mm)
7,26	5,54	5,47	2,47

Therefore, it can be argued that the results indicate differences in the dimensions of grains and pods, therefore inferring compliance with the principle of separation of two components, with (grains) as the first component and pods as the second component.

Similar results were obtained by (20), during the determination of the variational curves of frequency distribution of the thickness of pods and pigeon peas, observing the existence of significant differences for a confidence level of 95% during the comparison mutual of both dimensions.

According to expression (11), the play between the rollers (a) will depend on the maximum and minimum extreme clearances required for the grip and non-grip of the component that must pass and the component that must not pass; In turn, these values will depend on the physical-mechanical properties of the pigeon pea beans and pods (19) and the diameter of the rollers.

The values obtained during the determination of the play and of the limit diameter of the rollers that allow the pods to pass and not the grains, are presented in Table 2.

Table 2. Results achieved during the determination of the games and the limit diameter of the rollers.

Grains		Pods		*a* (mm)	*Dlím* (mm)
$a_{máx1}$ (mm)	$a_{máx2}$ (mm)	$a_{mín1}$ (mm)	$a_{mín2}$ (mm)		
3,097	4,817	1,437	-1,563	2,267	54,25

As observed in Table 2, the play between the rollers should not be greater than approximately 2.2 mm in order to achieve the possibility of separating grains and pods of green pigeon peas, in the same way it is recommended by calculations that the diameter of the rollers must not be greater than 54.2 mm.

Results of the proper kinematic parameters of regulation and design of smooth rotary rollers.
The results achieved during the determination of the kinematic parameters of the rollers are shown in Table 3.

Table 3. Results of kinematic parameters of rotating smooth rollers.

ω_{rod} (rad/s)	n_{rod} (rpm)	f_{rod} (cycles/s)	*Nb* ()	*Qv* (pods/s)	*Qg* (grains/s)	*Qh* (kg/h) of grains
2,01	19,22	0,32	21,25	14,54	53,82	67,81

As shown in the previous table, the results of the calculation of the kinematic parameters of rotary smooth rollers, for the separation of pods and green pigeon peas, the drive roller must have an angular velocity of 2.01 rad/s, thus form a roll speed of 19.22 rpm is achieved.

With this speed (19.22 rpm) a rotation frequency of 0.32 cycles/s is achieved, which will allow the smooth rotating rollers to be fed with 22 pods of green pigeon simultaneously, in order to achieve approximately a total flow of 14 pods/s, and achieve a shelling capacity of 53 grains / s equivalent to 67.81 kg/h.

Similar results were obtained by (21) who, during the design calculation of the rollers for a hydrated soybean peeling machine with a capacity of 50 kg/h of soy beans, obtained an angular speed of the rollers equal to 23 rpm.

IV. CONCLUSIONS

The proposed green pigeon peeler sheller machine will have tangential rollers with a play or separation between them of 2.26 mm and a diameter of the rollers not greater than 54.25 mm,

The angular speed of the driving roller will be 2.01 rad/s, with which a total flow of 14.54 pods/s is achieved, for a productivity of 67.8 kg/h of shelled green pigeon peas.

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