Design and Control of a Tara Flour Processing Machine in Ayacucho – Peru, 2023

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Abstract. This article proposes the design and control of a Tara flour processing machine with the aim of increasing profitability and reducing the time required for its processing. The research presents a mechatronic system composed of two main systems: one mechanical and the other electrical-electronic. The mechanical system consists of three parts. In the first part, the feeding and dosing is carried out, where the Tara is filled and shelled. In the second part, there is the shaking process, which consists of separating the seeds from the shell. The third part refers to the grinding of the Tara, thus obtaining the final product: flour. The electric-electronic system incorporates an AtMega 328P microcontroller to regulate the speeds of the motors based on the readings of the sensors used for proper processing. The implementation of this project would reduce the production time of Tara flour in the city of Ayacucho by 75% compared to the traditional method. This demonstrates the possibility of improving the production process of Tara flour.

1 Introduction

Tara is a legume whose most valuable part is the "pod" and the seed, which contain "tannins" commonly used in the tanning industry and rubber production through certain processes [1]. Peru covers 80 % of the world export market for tara, and in the last 10 years, the production of tara powder has experienced an average annual growth of 5.5 % [2]. Until October 2022, between 10 and 12 tons of pods were produced, and the main exporting regions are Ayacucho, Áncash, Cajamarca and Ica. Currently, the prices of the pods range between S/. 6.00 and S/. 8.00 per kilogram [3]. With these data, the following question arises: How can a tara flour processing machine be designed to meet the needs of the population of Ayacucho in 2023?

In previous research [4], I design an intelligent machine to peel peanut red layer, with the aim of automating and speeding up the peanut peeling process. In addition, it sought to provide farmers with state-of-the-art technology to help them catch up with technological advances. In another study [5], a semiautomatic green mango peeler was designed, manufactured and tested to achieve 75% peeling of mango skin, thus helping cooperatives reduce waste of surplus mangoes, and keep up to date in this prevention practice. In a similar case [6], he carried out the Development of a Coffee Grinder with Servo Mechanism and Analysis of the Relationship between Processing Conditions and Particle Size, in order to obtain a constant distribution of the size of the dust particles, and to compare the current control, accordingly, vary the speed of the servomechanism. In addition [7], he proposes the Design and experiment of a 4YQZ-3A corn harvester, with the purpose of recovering the straw at the time of harvesting, thus taking advantage of the forage for cattle breeding. On the other hand [8] he proposes the Design and Analysis of a High Efficiency Recycling Process Hammermill Machine with the aim that the machine is capable of grinding all types of waste (soft and hard). Finally [9], he proposes a mechatronic seed meter assisted by artificial vision for precision maize sowing in order to prevent and reduce sowing losses.

Considering the information presented above, the purpose of this article is to improve profitability and reduce processing time compared to artisanal methods. In addition, it seeks to add greater value to products derived from tare. This article proposes the design and control of a tara flour processing machine in Ayacucho, Peru, for the year 2023.

2 Materials and methods

The system design uses the methodology developed by the "Association of German Engineers" VDI 2206 (Verein Deutscher Ingenieure, VDI) [10]. It was considered suitable for carrying out this research work, the research presents mechatronic systems, one mechanical and one electrical as shown in Fig 1.
The first of them is a mechanical system that includes a hopper for the initial filling. Subsequently, the peeling process will be carried out through the use of a rubber roller designed to separate the tara pods without damaging the seeds obtained, thus guaranteeing the desired results. Once the peeling process is complete, the separation stage will proceed, where the shaking technique with a grid will be used to achieve optimal separation between the seeds and the tara shells. Next, the material will move through a controlled drop slope, while an operator supervises the movement process, until it reaches the mill where the crushing of the tare will take place. The second process refers to the electrical and electronic system, which will include a dosing process. For it, photoelectric sensors will be used to control the filling level and the opening of the gates during the peeling phase. In addition, sensors will be used at the entrance and exit of the screening process for better control in the grinding stage. Surveillance (inductive) sensors will also be used to monitor the motors and rollers of the machine. The third process corresponds to the process control system, where an Arduino mega 2550 will be used as the central element. This system will work with a 220V power supply and will be supervised by an operator in charge of the machine. See Fig. 2.

Determination of corrected power (Pc).

\[ P_c = P \times F_c \]  

Where: \( F_c \) : service factor(1,2) and \( P \): power in HP.

For the transmission calculation the following formula will be used:

\[ D_p = i \times d_p \]  

Where: \( D_p \): Major diameter, \( i \): transmission ratio and \( d_p \): Minor diameter.

To calculate the length of the strap:

\[ L = (2x) + \left(1.57 \times (D_p + D_p)\right) + \frac{(D_p - D_p)^2}{4x} \]  

Where: \( L \): length of the belt, and \( c \): Distance between centers.

To calculate the diameter (\( \phi_b \)):

\[ \phi_b = \sqrt[3]{\frac{32 \times m}{5 \times \pi \times \pi} \times \frac{M_A}{T^2}} \]  

Where: \( \phi_b \): Roller diameter, \( n \): Safety factor, \( M_A \): Moment, \( T \): Torque.

Torque key length (\( L' \)):

\[ L' = \frac{F}{\alpha \times \tau_a} \]  

Where: \( L' \): Length of the key, \( F \): Safety factor, \( \tau_a \): Effort due to crushing.

Fig. 3 shows the general control diagram, made up of subsystems in charge of more specific tasks.

For the mechanical design it is required to carry out mechanical calculations, for which certain formulas and tables are required [11], [12], [13].

Fig. 1. VDI 2206 methodology

Fig. 2. General plan of the equipment isometric view

Fig. 3. Flowchart of the control system

Fig. 4 shows the operating diagram of the tara seed and shell processor, where the subsystems that interact together for optimal system functionality can be observed.
3 Results

3.1 Mechanical Calculations

Taking into account equation (1), it is taken as data; motor power 0.25 HP, driven rpm 300 rpm, work regime (normal 5) and service factor (Fc=1.2). The corrected power is obtained $P_c = 0.3 \text{ HP}$.

To determine the belt section, we obtain the corrected power from the SKF design catalog. Which would correspond to the type A band, the minimum primitive diameter is 63 mm, substituting in equation (2) we obtain $D_p = 365.4 \text{ mm}$. In the case of the belt, the belts and pulleys to be used for $L > 3$, $c = 350 \text{ mm}$ are identified. Once the previous values are obtained, they are replaced in equation (3) resulting in $L = 1437.9 \text{ mm}$.

For the scheme of the project we have the following values: $R_A \alpha y = 0.72 \text{ N}$; $R_B \alpha y = 0.72 \text{ N}$ and Maximum moment in the xy-plane: $MA = 196 \text{ Nmm}$. For the static design, a material that meets the required parameters is considered, which is the engineering nylon packing for the construction of our shaft: Nylon 6/6, which has the following properties: $S_y = 800 \text{ MPa}$; $Sut = 1000 \text{ MPa}$ and Safety factor $\eta = 3$ which we consider in equation (4) to obtain the diameter.

For the design of the coupling elements, accounts are taken into account, $F = 20577.43 \text{ Nm}$, $\tau_a = 116 \text{ MPa}$, $\alpha = 0.005$ and by tables we have for a shaft diameter of $\varphi = 19.05 \text{ mm}$ we have $b = 8 \text{ mm}$, $h = 7 \text{ mm}$; where the dimensions of the key correspond to: $L' = 36 \text{ mm}$, $b = 6 \text{ mm}$, $h = 6 \text{ mm}$.

3.2 Mechanical design in inventor

Fig. 5 shows the first feeding and dosing part of the machine. The reference image (isometric view) shows the important components and parts of the first stage, consisting of a hopper of proportional dimensions and a manual dosing system to be handled by the operator.

Fig. 5. Operation diagram

3.3 Electronic Electrical System

The prototype requires a microcontroller to regulate the speed of the motors accompanied by a series of contactors and thermal protection. The controller will receive the signal from the barrier sensors at the beginning of the process, from the start, stop and emergency button buttons and the connection of a peripheral (LCD screen) that will show the tare level in the hopper. See Fig.7.

Fig. 6. Feeding and dosing

Fig. 5, shows the screening system, it will have holes with a diameter of 7 mm ($\pm 5\%$), the average size that tara seeds have, so that they can pass through without any problem. Measurements and specifications are detailed.

Fig. 6. Shaking structure

Fig. 7. Control board location

The power system will consist of a solid state relay SSR - 40 DA whose technical characteristics are considered sufficient to control the $\frac{1}{2}$ HP single-phase
motor that will be used for the operation of the rollers and screen. The previous connection scheme for relay protection is shown in Fig. 8.

![Fig. 8. Main schematic electronic system](image)

**3.4 The electronic system**

Fig. 9 shows the main connection diagram of the electronic system, it shows the connection of the input signals to the controller (AtMega 328P) [14], such as the on, stop and emergency button; In addition, the signals coming from the infrared sensors, the Arduino power supply module, the output signals that are made up of a previous circuit towards the power circuit relays. In addition to this, the connection of the LCD peripheral is shown through an I2C connection.

![Fig. 9. Main schematic electronic system](image)

The advantages reflected by the Tara processing equipment in relation to a normal cost of processing tare from its collection are evidenced. Table 1 shows the difference in costs of processing Tara in a traditional way and using the new automatic Tara processing equipment.

<table>
<thead>
<tr>
<th>Table 1. Comparison of traditional and automatic tare processing</th>
</tr>
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<tbody>
<tr>
<td><strong>No Machine</strong></td>
</tr>
<tr>
<td>1 kg shell</td>
</tr>
<tr>
<td>1 kg Grind</td>
</tr>
<tr>
<td>1 kg bag</td>
</tr>
<tr>
<td>coarse powder</td>
</tr>
</tbody>
</table>

Table 2. Traditional and automatic harvest of tara

<table>
<thead>
<tr>
<th>No Machine</th>
<th>With Machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 working hours</td>
<td>5,700kg</td>
</tr>
<tr>
<td>Monthly 24 working days</td>
<td>136.8kg</td>
</tr>
<tr>
<td>Annual working months</td>
<td>547.2kg</td>
</tr>
</tbody>
</table>

**4 Discussion**

The work of P. Rengphathananagit and P. Lakawathana [15] proposes the design of a machine to separate damaged from normal beans through deep learning. However, it would be a better design if the roasting and grinding process were included. In the same way, S. Zhang and J. Ruan [16] propose the grinding of flour using 2 rollers driven by dual motors, making one rotate faster than the other, thus achieving excellent grinding, even so, the proposal does not does not have prior processes or an automated system.

Unlike the aforementioned works, the results obtained in our design proposal differ, since a mechatronic system is proposed, which consists of automating the process of making tare flour, the mechanical part is divided into 3 stages, which are: peeling stage which consists of crushing the product, the screening stage where the seed is separated from the shell, finally the grinding stage where the tara seed is crushed, obtaining flour for various purposes.

**References**

4. Q. Jia and B. Zhao, "Design of Intelligent Peanut Red Coat Peeling Machine," 2022 3rd


