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Tesis

Automation in Carrot Seed Purification: Integration of Mechanical and Electronic Technologies

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Automation in Carrot Seed Purification: Integration of Mechanical and Electronic Technologies

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***Abstract*— In this research, an innovative mechanical-electronic device has been developed for the efficient purification of carrots seeds, a critical process in agricultural production due to its impact on the quality and yield of future crops. The device uses mechanical and electronic principles to effectively separate impurities and unwanted seeds from carrots. Through detection and classification technologies together with mechanical elements of transport and separation, the quality of the resulting seeds is sought to improve, ensuring their purity. This development represents a significant advance in the automation of agricultural production, enabling farmers to benefit from higher quality seeds and higher productivity. This project shows how the integration of mechanical and electronic technologies can address the challenges in food production. In addition, the carrot seed cleaning machine offers notable advantages in reducing the workload to obtain seed-fit seeds, improving the efficiency and quality of production. The inclusion of sensors in seed selection is crucial, enabling accurate and efficient detection that supports informed seed classification decisions, improving their quality. The Atmega328 microcontroller is a good choice due to its robust and versatile capabilities for controlling trench engines. The machine stands out for its innovation and its ability to produce high-quality seeds. However, emphasis is placed on the importance of regular maintenance and proper calibration for optimal performance, including constant review of mechanical components and monitoring of electrical and electronic components. In addition, an innovative prototype of mechanical-electronic device for the efficient purification of carrots seeds was designed and constructed. The prototype, built with materials such as MDF and double-sided acrylic, uses modified servomotors as engines, incorporating control systems and released internal brakes. Key components, such as the engine ignition system, the injection system and the mixing system, perform critical functions for achieving efficient and high-quality seed cleaning. The comparative evaluation phase demonstrates that the manual cleaning of 1 kg of seeds takes 1 hour and 30 minutes, while with the machine it is carried out in only 10 minutes, which translates into a significant improvement in efficiency and cost. Annual production costs show a noticeable economic improvement when using the machine compared to manual work. This prototype not only stands out for its efficiency and quality in seed production, but also for its potential impact on the agricultural economy.**

Keywords—Seed purification, carrot, automation, agricultural production.

I. Introduction

In agricultural production, the quality of seeds plays a crucial role in the success of crops. Seed purification, an essential process to remove impurities and unwanted material, directly affects the viability and yield of subsequent crops. With the aim of improving this critical process, an innovative mechanical-electronic device has been developed that seeks to optimize the purification of carrots seeds. This device, by combining mechanical engineering principles with electronic advances, has the potential to revolutionize agricultural seed production by ensuring greater quality and uniformity in results. The importance of high-quality seeds in modern agriculture cannot be underestimated. Research has shown that the quality of seeds is directly related to the health, growth and yield of crops [1]. In addition, the presence of unwanted impurities and seeds can lead to increased susceptibility to disease and decrease the quality of the final product [2]. There is therefore an urgent need to develop technologies that improve seed purification, thereby contributing to the advancement of food security and agricultural sustainability.

In response to this need, the mechanical-electronic device presented in this study integrates state-of-the-art detection and classification systems with precisely designed mechanical components. The detection technology, which uses advanced computer vision and image analysis methods, allows the precise identification and separation of high-quality carrots seeds from those with defects or impurities [3]. At the same time, mechanical components, such as transport and separation systems, ensure careful handling of seeds during the process [4].

This article discusses the results obtained from this project, detailing the operation and benefits of the carrot seed cleaning machine. It is highlighted how the inclusion of sensors in the seed selection stage and the strategic choice of the microcontroller Atmega328 have contributed to the success of the device. The implications of this research for the agricultural industry are also discussed, stressing the importance of maintaining the optimal operation of the device through proper maintenance and calibration. Ultimately, this research demonstrates the potential of integrating mechanical and electronic technologies to address key challenges in food production and improve the quality of agricultural crops.

II. Materials and Methods

This study is based on the VDI 2222 methodology to guide the design and development of a mechanical and electrical device for the efficient purification of carrots seeds. Through a structured approach that covers planning, design, design and development, the process of purification of agricultural seeds is sought to be optimized, thereby contributing to the advancement of the production of high-quality crops [5-6].

A) Planning: The study of the market of carrots seeds reveals the presence of various varieties, such as Chantenay, Colmar, Criolla and Nantesa, which are marketed at a price higher than $21 per 100 grams. These varieties are known for their vigor and height, as well as characteristics such as conic roots of various sizes and slightly sweet flavors. At this stage, the objectives, scope and requirements of the project are defined in a precise and detailed manner. It is a matter of establishing a solid foundation for further development, considering factors such as market needs, available resources and technological and economic constraints [7].

B) Design: The problem situation in agricultural areas is focused on the production and marketing of seeds for immediate sowing, the primary function of the machine is to carry out a comprehensive seed cleaning process, separating the seeds from common impurities in the harvest. At this stage, the requirements identified in the planning phase are examined in detail and innovative approaches are sought to address them [8]. Through the convergence of ideas and the evaluation of different concepts, the most promising solutions are selected.

C) Project: At this stage, the specific components are defined, dimensioned and the relationships and functions between them are established [9]. In addition, aspects such as technical and economic feasibility, material selection and production planning are considered.

D) Development: At this stage, components are manufactured, assembled and thorough tests are carried out to verify that the final product meets the requirements and specifications set in previous stages [10]. Additionally, final adjustments and improvements can be made based on test results.

A. Black box

The cutting-edge perspective in "black box" simulation modeling, backed by the use of probability distributions and precise automation, marks a significant qualitative leap in the evolutionary process of carrots seed purification machines. Through the integration of state-of-the-art statistical concepts and technological resources, we seek to provide support to agricultural professionals to simplify their work and perfect the end result, with the ultimate aspiration to contribute to soil enrichment and progress towards more sustainable agricultural practices [11-12]. Fig. 1 shows the visual representation of the "black box" applied to the carrot seed purifier.

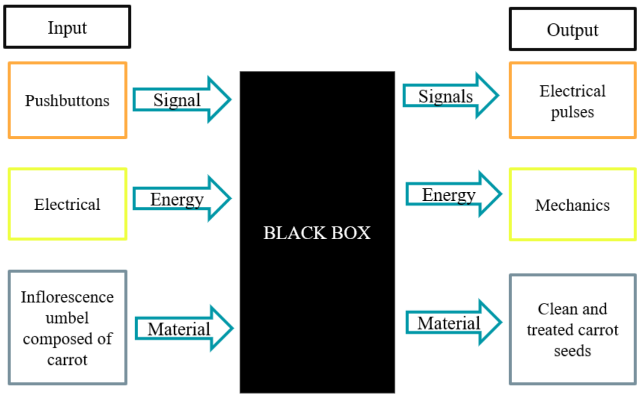

Fig. 1. Black box

B. Morphological matrix

The morphological matrix is a widely used resource in the process of conception of ideas. Although design procedures based on morphological matrices demonstrate their effectiveness in the creation of conceptual structures, there is a difficulty in determining the optimal conceptual design when amalgaming these precepts of resolution functions [13-14]. To carry out the next block, the matrix is quantified, which involves assigning choice variables to each aspect of the solution and subsequently formulating the optimization problem [15]. This process is detailed in Fig. 2, where you can see graphically how it is carried out. Furthermore, it should be noted that this strategy is essential to obtaining better results.

Fig. 2. Morphological matrix

From the results obtained through the combination of data, four solution concepts were identified that have been organized and presented in TABLE I. This categorization process is essential for an effective understanding of the solutions generated from the combination of data..

TABLE I. SOLUTION OF LEGEND BY COLOR

Color	Solution
Orange	C.S.1
Blue	C.S.2
Green	C.S.3
Red	C.S.4

After obtaining the four solution approaches, an analysis will proceed towards the identification of the optimal solution, which will simplify the design selection and validation process. A technical and economic evaluation is a critical tool that will help evaluate the viability and value of any project or investment. It helps you make informed decisions, manage resources efficiently, and maximize benefits while minimizing risks. The following TABLA II shows the most viable option.

TABLE II. ANALYSIS OF THE IDEAL SOLUTION

	Valor Tecnico	Valor economico
LEYENDA	Xi	Yi
Orange	17	8.6
Blue	15.8	7.7
Green	19.4	9.4
Red	20.8	11.1

Finally, the technical (Xi) and economic (Yi) evaluations were obtained. It can be stated that Solution 4 (Color Red) is the most optimal because it has the highest score both economically and technically.

C. Control system

The control system diagram plays an essential role in providing a clear and detailed visual representation of how all components and processes involved in the system will be coordinated and operated. The following Fig. 3 shows the control system with the total operation of the machine.

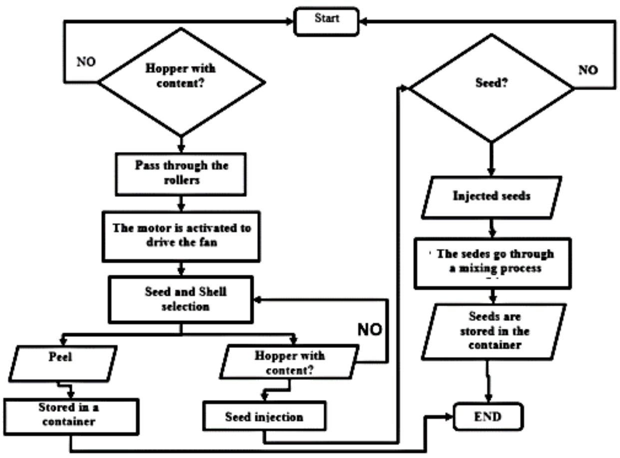

Fig. 3. Diagram of the control system

D. Electronic system

A detailed design of the fundamental steps in the implementation of the machine is presented. At the power stage, a 12VDC 2A power supply will be used to power engines, modules and sensors, with the use of a switched regulator LM2596 to ensure efficiency and reduced power dissipation. In the microcontroller stage, the use of an external 16 MHz crystal is highlighted to provide a precise timing signal that synchronizes internal operations of the microcontrollers. The control of the LCD 16X2 I2C Display is simplified using a PCF8574, PCF2C module, enabling you to display data efficiently with only 4 pins. Infrared sensors are crucial in the process, as they detect objects in the machine and guide the control of the engines. For fan control, a Mosfet N channel is used to handle the required current, avoiding damage to the microcontroller pins that only support 40mA according to the Datasheet. The following Fig. 4 presents the electronic diagram.

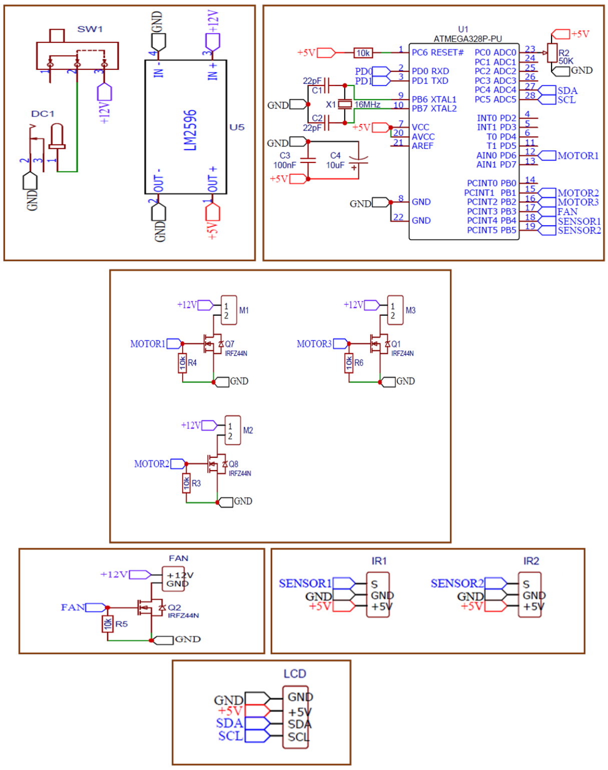

Fig. 4. Electronic diagram

The design of the electronic board for the circuit was carried out using the EasyEda program. EasyEDA is a cloud-based Electronic Computer Assisted Design (EDA) system, free of charge and without installation. This system is designed to provide engineers, educators, engineering students and radio enthusiasts with a practical tool. This is an easy-to-use schema editor, a circuit simulator and a printed circuit board (PCB) design system that can be executed directly in a browser [16].

This choice allowed to optimize the layout of the components on the board, reducing the need for extensive wiring and generating a structured order for each phase of the electronic circuit. In addition, this methodology greatly simplified the connections between the various modules and sensors, contributing to a more efficient and organized system implementation. Fig. 5 shows the design of the printed circuit.

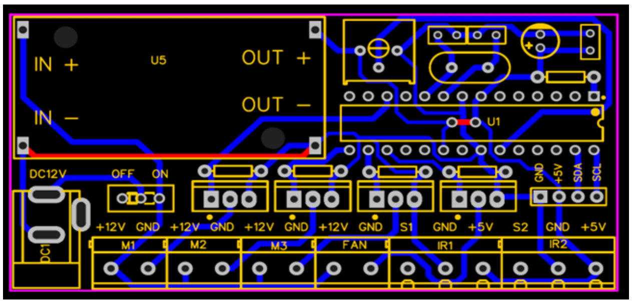

Fig. 5. Printed circuit board design (PCB)

TABLE III provides the main electrical and electronic components for the operation of the machine.

TABLE III. ELECTRONIC COMPONENTS

Amount	Item
6	Infrared sensor
1	Atmega328
1	DIAC-DB3W diode

E. *Mechanical design*

The automation of the machine will be carried out using a microcontroller ATMEGA328P and a frequency controller for the engine. The manual feeding of carrot seeds is carried out in the straw, with an estimated maximum amount of 5 kg. The process continues with the rubbing of the raw material using a roll, which separates the seeds from the waste. A ventilation box system then uses the weight to separate waste and seeds. The next step involves the injection system, in which each seed is treated with specific fertilizers. Finally, the treated seeds pass through a system of horizontal pallets powered by a motor to mix with liquids in the tube, then directed to a container. The key aspects of this process can be seen in Fig. 6.

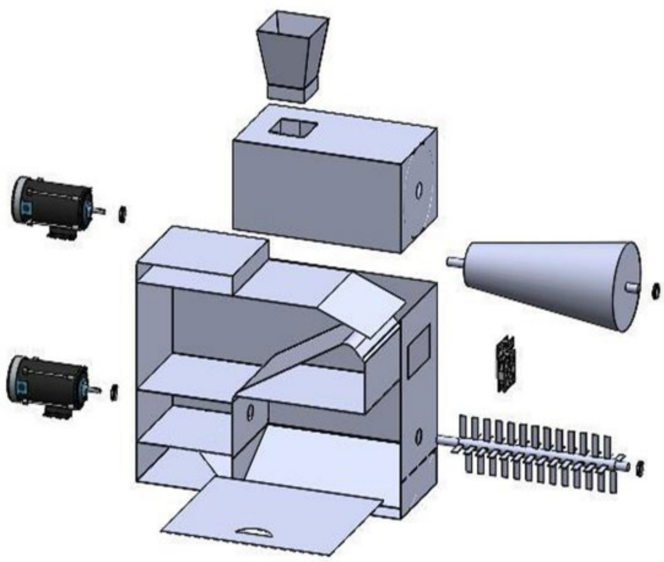
Fig. 6. Mechanical design

TABLE IV shows the mechanical components for the construction of the machine for its operation and durability.

TABLE IV. MECHANICAL COMPONENTS

Amount	Item	Part
1	Stainless steel plate 1x1 m	Dosing System
4	Bearing 4cm diameter	
1	8mm Acme Threaded Rod, 30cm long	
6	M8 Flat Hexagonal Nut Inner Diameter	
1	⅜ #14 Screen Mesh (10 m x 1 m)	Shaking and cleaning system
1	8v Fan	
2	Motor 0.25 HP	Trite system
2	Servomotors	
1	Acronis 200ml	Injection system
1	Crucial 250ml	
1	1/8" Stainless Steel Plate	Structure
2	Iron Angle 1 ¼ x 1/8 (6.00 m)	
2	Acrylic sheet 250 x 150 mm	

III. RESULTS

The prototype was built using a combination of materials and substitutes for different components. The structure was made of MDF and two-sided acrylic to allow monitoring. Modified servomotors were used as engines, after releasing their internal brakes and control systems, which turned them into reducer engines. Components such as the thresher and the axle pallets were made of plastic for convenience. The structure of the prototype was assembled using L joints and angles in the rear to increase its stability. The axles were made with AISI 1040 steel substitutes, able to withstand the loads required for this particular model. Fig. 7 shows the prototyping tests of the machine.


Fig. 7. Prototype design and implementation

The three key stages in the carrot seed purification machine, which comprise the Engine Enlightenment System, the Injection System and the Mixing System, play key roles in achieving an efficient and high-quality cleaning process.

A. *Engine ignition system*

Precise control of servomotors in a range of 0 to 180°, achieved by generating a 50Hz signal with high state intervals between 1 and 2ms, is required. Arduino provides a specialized library that uses the microcontroller timers to generate this signal, allowing the connection of servomotors to different digital pins. For the control of the engines, voltage regulated MOSFET transistors are used: a higher voltage Vgs decreases the Rds resistance, reducing power dissipation and heating. Since the microcontroller offers 5V in its pins, a logical converter with bipolar transistors is created to raise the signal to 12V. The process involves the sequential activation of the engines and the cleaning and mixing steps, detailed in Fig. 8 and Fig. 9 below.

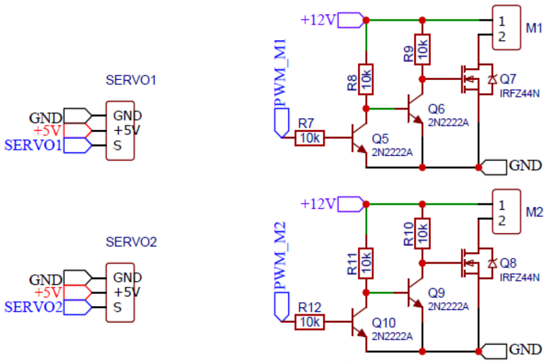

Fig. 8. Electronic scheme of the engine control stage

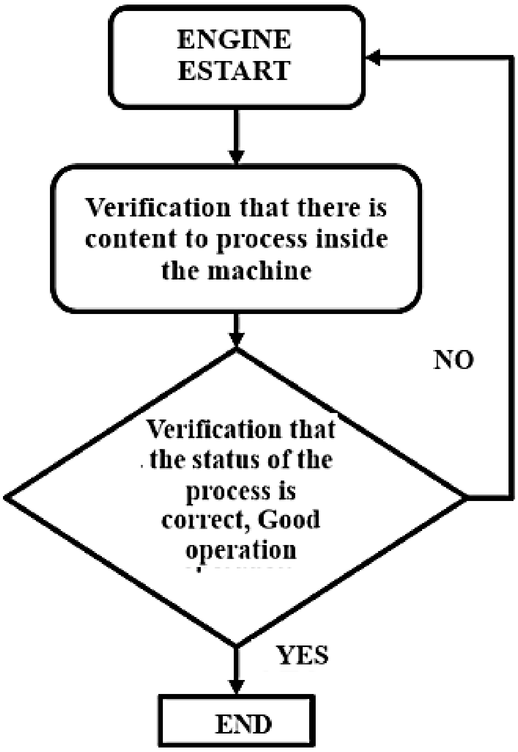

Fig. 9. Engine ignition flow diagram

B. Injection system

This stage plays a crucial role in inserting fertilizers accurately into carrots seeds. The Injection System ensures that each seed receives the right amount of nutrients, which is essential for improving the quality and viability of the seeds. Precision in injection is vital to optimizing the growth and yield of future plants and ultimately guaranteeing the quality of the final product. Details in Fig. 10.

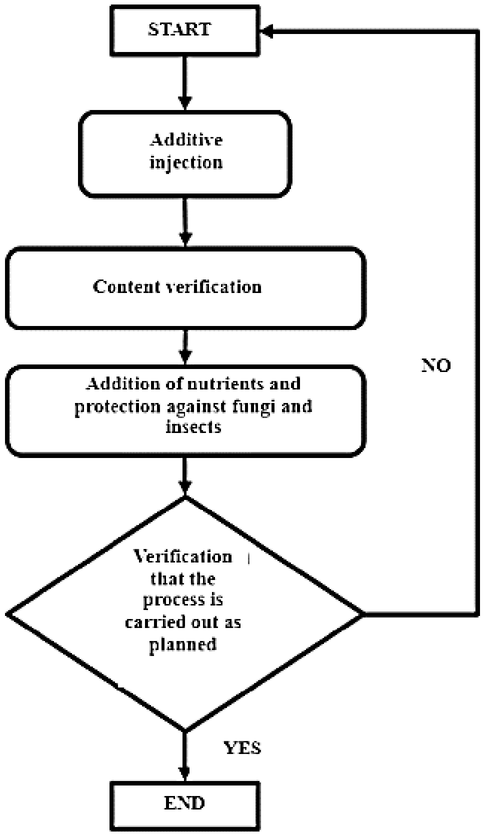

Fig. 10. Injection flow diagram

C. Mixing system

Once the seeds have been treated with fertilizers through the Injection System, the Mixing stage enters into play. This phase is responsible for properly combining the treated seeds with fertilizers, ensuring a uniform and homogeneous distribution of nutrients in the seed batch. Effective mixing is crucial to ensuring that each seed has equal access to nutrients, which promotes healthy and even growth of future plants. Details in Fig. 11.

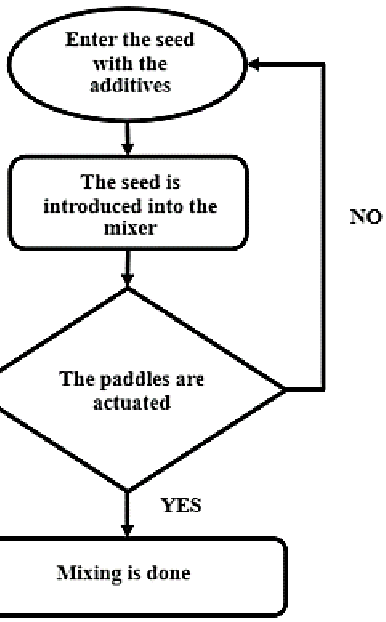

Fig. 11. Diagram of the mixing system

The three stages of the purification process of carrots seeds will directly contribute to improving the quality, uniformity and viability of the seeds, which in turn will manifest in the results as a more efficient, healthy and valuable production. With the implementation of these processes, it was possible to create the prototype in which the machine worked perfectly, without errors. The operation can be seen in Fig. 12.

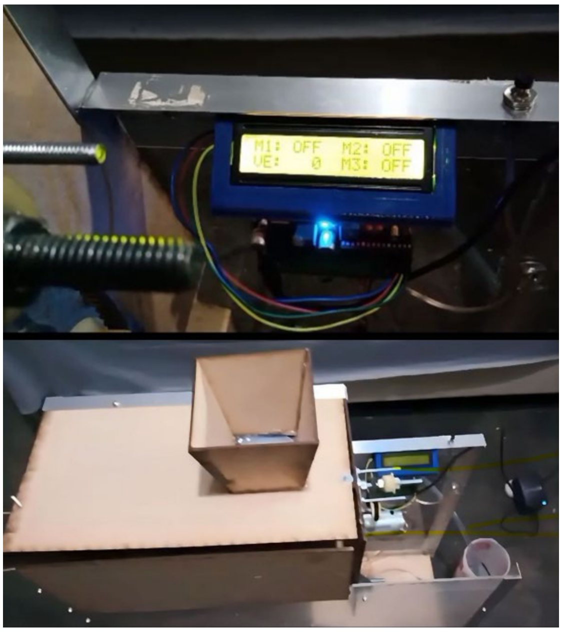

Fig. 12. Operation of the seed purification machine

An evaluation was carried out in which two different scenarios were analyzed. In one of them, manual work was carried out, resulting in significantly longer duration and higher costs compared to machine-assisted work. The results of cleaning carrot seeds are presented in TABLE V, showing the number of kilograms and cost obtained in each case.

TABLE V. COMPARISON PER KILO OF CLEAN SEEDS

Without Machine		With Machine	
1kg in Clean	$200	1kg in Clean	$120
1kg Clean seed	$200	1kg Clean seed	$120
10kg clean seeds	$2000	10kg clean seeds	$1200
To manually clean 1 kg of seeds, it takes 1 hour and 30 minutes.		To industrially clean 1 kg of seeds, it takes 10 minutes.	

Finally, data relating to annual production costs has been finalized. It was found that the expenses incurred without the use of the machine are higher compared to the costs associated with the use of the seed purification machine. This fact has led to a notable improvement in investment and economic performance. The details of production expenditure are detailed in TABLE VI for your reference.

TABLE VI. PRODUCTION EXPENSES – AUTOMATION OF CLEAN SEEDS

Without Machine		With Machine	
8 working hours	$24.05	8 Working hours ($0.16 Kw/h) 1hp = 746 Watts	$1.28
25 business days - monthly	$601.2	25 business days - monthly (24v Motor)	$32.06
4 business months - Annual	$2404.81	4 business months - Annual (24v Motor)	$128.26
		Monthly Operator	$32.06
		Annual Operator	$384.77
		Annual maintenance	$40.08
Annual expenditure	$7214.13	Monthly expenditure	$32.06
		Annual expenditure	$518.37

IV. DISCUSSION

The performance of a carrot seed cleaning machine was evaluated. Automated control was implemented using a microcontroller and a frequency controller for the engine, which allowed precise handling of machine systems and optimized process efficiency. The initial stage of manual seed feeding was designed to process up to 5 kg of seeds, ensuring effective processing of large volumes. The seed mowing stage with a roll on the machine wall was vital for separating impurities and ensuring clean seeds. The fertilizer injection system has been shown to improve the quality and growth potential of seeds, facilitating healthy germination and development. Finally, the motorized pallet system combined the seeds treated with liquids uniformly, ensuring proper absorption of fertilizers. The possibility of adding monitoring sensors is recommended to detect possible problems or blockages during the process and ensure better continuous operation.

V. CONCLUSION

Carrot seed cleaning machine has significant benefits for the carrot production process. The implementation of this machine drastically reduces the workload previously required to produce seed-fit seeds, resulting in a substantial improvement in the efficiency and quality of production in terms of time and results. The inclusion of sensors in the seed selection process proves to be an essential component, enabling accurate and effective seed detection. These sensors provide accurate data that facilitate informed decisions in the classification and selection of seeds, improving the quality and viability of the final product.

The Atmega328 microcontroller emerges as a good choice for the project due to its versatility and extensive processing and programming capabilities. Its application in the control of the engines responsible for the seed thresher demonstrates the adaptability and functionality it brings to the system. Carrot seed cleaning machine stands out in the market for its innovation and high-quality seed production capacity that meets the required standards. However, it is crucial to emphasize that regular maintenance and proper calibration are essential to ensuring optimal machine performance. The periodic review of mechanical components, as well as the monitoring and adjustment of electrical and electronic elements, are fundamental steps to maintain the efficient operation of the machine over time.

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