Automation of pitahaya production through the implementation of a new fruit transport and separation system

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Abstract
Globalization requires countries to improve their markets and domestic production for export. In Ecuador, an industry that can emerge and be profitable is the export of Pitahaya, especially the "Palora" ecotype.
In this project, the different production areas of the pitahaya post-harvest process in the province of Morona-Santiago are analyzed. From this, the washing and disinfection, classification and packaging threads are automated to reduce manual work and maintain quality, considering the requirements for export to countries such as the United States, China, and Saudi Arabia. Based on the above, the process control is designed with ladder programming for PLCs and both the current post-harvest process, and the new process are simulated to verify the changes in their idle times, production quantity and production flow. process.

Keywords: Pitahaya, manufacturing process design, automation, Ecuador.

I. INTRODUCTION

I.I Problem description

Ecuador has substantial petroleum resources, representing around 40% of the country's income in recent years, and the fluctuations in world market prices impacts its economy. So, it is necessary to improve emerging markets, such as the production of pitahaya, to become more competitive in relation to the external market. [1]

According to data from [2], Ecuador has more than 2,300 hectares of pitahaya production that have allowed it to export up to 18,300 metric tons in 2020 to countries such as China, the United States, the Netherlands, and Saudi Arabia, as its shown in Figure 1. Likewise, it is expected to increase this figure, supporting the production of up to 10,000 hectares by the year 2025.

Figure 1. Pitahaya export destinations graph.

In addition, the packaging process of products for export, such as fruits, does not have an automated system, it is carried out entirely by people, leading to inconsistencies with performance and productivity, due to errors, shortcomings, and human limitations. According to [3], the most cultivated and harvested product in the country is the yellow Pitahaya due to its more pleasant external appearance for the buyer and it is divided into two ecotypes: "Pichincha" and "Palora".

Currently, the pitahaya packaging system is carried out in an artisanal way, from harvest and post-harvest. According to the Agro quality plant, around 5,000 kg of this fruit are sent to other countries, and it's expected an increase in customers, in this case international countries, such as Germany and the United Arab Emirates. For this reason, it is convenient to automate the production process in certain sections, such as the transfer of this fruit, both in packages and others.

This project requires the design of an automated transport and selection system for pitahayas for export that is more fluid and maintains quality factors. In that sense, a study of the times and motion of the production process of the current system is carried out to identify the routes and areas with the highest traffic. In the same way, the two processes are simulated to compare processing times, number of operators, idle times, and number of final products for a working day.

I.II Theoretical Framewotk

Pitahaya: The pitahaya is a seasonal tropical fruit, widely accepted nationally and internationally due to its good taste, appearance, and quality. In Ecuador, pitahaya cultivation is distributed in the Coast and Amazon regions, provinces of Guayaquil, Los Ríos, Manabí, Santa Elena, Napo, Pastaza, Zamora Chinchipe, Esmeraldas, Santo Domingo de los Tsáchilas and El Oro. [2]

Export: Exports are goods and services that are produced in one country and sold to buyers in another. Exports, along with imports, make up international trade [4]. The top exports of Ecuador are Crude Petroleum ($4.9B), Bananas ($3.83B), Crustaceans ($3.83B), Processed Fish ($1.19B), and Cut Flowers ($835M), exporting mostly to United States, China, Panama, Russia, and Chile [5].

Figure 2. Pitahaya for export.

Manufacturing Process: Process manufacturing is a production method that creates goods by combining supplies, ingredients, or raw materials, using machines to produce large amount of goods, such as food, beverages, refined oil, gasoline, etc. [6]

Production time: This is the time spent transforming raw materials into finished goods. [7]

PLC: A PLC is a programmable logic controller, an industrial computer that processes all the data of a machine to later control the actuators connected. This is used to control any industrial process automatically [8].

Sensors: Sensors are elements used to measure and record all the values that guarantee the ideal conditions for the correct operation process when they are controlled [9].

Actuators: An actuator is a device that converts energy taken form a source (like electricity), into a desired movement [10].

Time and motion study: This is a scientific method for recording time spent on a variety of tasks. It helps by assisting in finding the most efficient method of doing work [11].

I.III Secondary Research

According to the Agro Quality Plant Health Unit, 5,000 kilos of this fruit can be sent to these countries as the European union, USA, Asia, hoping that 1.6 million kilos will be sent annually where it is expected that countries such as Germany and the Arab Emirates will join as clients, having a Product need greater approximately 6 times more than what can be exported weekly according to Agro Quality, this is why it is intended to automate the process of selection, washing and packaging of this fruit to increase the efficiency of product delivery, reduce costs in the long term and reduce the delivery time of the product in hermetic boxes for export [12].

Ecuador is an agricultural country, so the development of this project implies benefits for the internal and external market, remembering the advantage of location and productive design that this activity currently presents. According to the above, the design of an automated system for the post-harvest stages of pitahaya Palora will be highlighted, which includes washing, disinfection, classification, and packaging of the fruit. In addition to a technical selection of the most suitable sensors, actuators, and connections for this industry, considering the working conditions in Morona Santiago.

II. METHODOLOGY

II.I Concurrent Design

The packaging of products for export, such as fruits, does not have an automated system, but is carried out entirely by people, for this reason, performance and productivity are inconsistent, due to errors, shortcomings, and human limitations.

A production model based on the principles of flexible manufacturing systems is proposed, to increase the performance and productivity of the company, from the entry of the harvested fruit to its respective packaging and storage, for this reason the process is separated by stages and those where performance can be increased considerably will be automated, as shown in the illustration

II.I.I The proposals are:

- Solution A: An FMS type IV or "Flexible Transfer Multi-Line" model, with straight line type cells for entry, disinfection, and quality review, and a closed rectangular cycle for classification and packaging processes, with the purpose to provide redundancy to the process, and keep its production constant with a relatively simple control. As for incorporated devices, there will be local warehouses between multi-purpose stations, vaporizers to disinfect fruits, conveyor belts, separating and packing machine, loading car.
- Solution B: An FMS type I or “Flexible Machining Cell” model consists of using only a linear type of cell from entry to packaging, with only one compound machine, or point-to-point machines where most of the work is carried out. process functions and an AS/RS vehicle for storage, largely automating the entire process, and consequently reducing human errors.

- Solution C: An FMS type III or "Flexible Transfer Line" model, making use of linear type cells an ordered route, consisting of tanks for washing/disinfection, local warehouses between stations, conveyor belts, separating machine, a packaging station manual and saved with Miniload.

II.I.II The validation criteria to improve its market value are:

- **Production capacity, volume, and efficiency:** The purpose of updating the packaging process is to be able to have an increase in the production of packages, that is to say, to improve the efficiency of the process to obtain a higher capacity per hour than the previous one, for them is production is the most important factor to consider.
- **Investment cost:** The objective is to have a higher production to obtain more income, even so, a budget must be evaluated according to the level of automation to be printed, and to decide if it is economically viable for the company.
- **Cost of maintenance with energy summation:** Part of the economic and financial study of the proposal is to consider the power supply of the machines, as well as the price of the maintenance that must be performed, and the losses that can be generated by the hours off work that a machine spends.
- **Flexibility and adaptability of the process:** It is important that even if a machine is out of operation the process does not stop, even if the production rate drops, it must continue to run, so it must be considered how prone the proposal is to decrease its capacity in case of unforeseen events.
- **Process control, management, and configuration:** By automating the process it changes the way of control and monitoring, improved the way of probing the desired variables, but also leads to a new type of configuration and management of the same due to the new implementations, so that the ease with which these can be understood and adopted by operators and supervisors is of great importance.

II.I.III Weight criteria:

Table 1. Weight Criteria Table.

Production > Flexibility > Maintenance > Investment > Control							
Criteria	**Production**	**Investment**	**Maintenance**	**Flexibility**	**Control**	**Σ+1**	**Percentage**
Production		1	1	1	1	5	0.33333333
Investment	0		0	0	1	2	0.13333333
Maintenance	0	1		0	1	3	0.2
Flexibility	0	1	1		1	4	0.26666667
Control	0	0	0	0		1	0.06666667
					Total	15	1

II.I.IV Criteria evaluation:

Table 2. Criteria evaluation table.

Solution B > Solution A > Solution C					
Production	Solution A	Solution B	Solution C	**Σ+1**	**Percentage**
Solution A		0	1	2	0.333333333
Solution B	1		1	3	0.5
Solution C	0	0		1	0.166666667
			Total	6	1
Solution C > Solution A > Solution B					
Investment	Solution A	Solution B	Solution C	**Σ+1**	**Percentage**
Solution A		1	0	2	0.333333333
Solution B	0		0	1	0.166666667
Solution C	1	1		3	0.5
			Total	6	1
Solution C > Solution B = Solution A					
Maintenance	Solution A	Solution B	Solution C	**Σ+1**	**Percentage**
Solution A		0.5	0	1.5	0.25
Solution B	0.5		0	1.5	0.25
Solution C	1	1		3	0.5
			Total	6	1
Solution A > Solution B = Solution C					
Flexibility	Solution A	Solution B	Solution C	**Σ+1**	**percentage**
Solution A		1	1	3	0.5
Solution B	0		0.5	1.5	0.25
Solution C	0	0.5		1.5	0.25
			Total	6	1
Solution C > Solution A > Solution B					
Control	Solution A	Solution B	Solution C	**Σ+1**	**Percentage**
Solution A		1	0	2	0.333333333
Solution B	0		0	1	0.166666667
Solution C	1	1		3	0.5
			Total	6	1

II.I.V Conclusion table:

Table 3. Conclusion table.

Conclusion	Production	Investment	Maintenance	Flexibility	Control	**Σ+1**	**priority**
Solution A	0.111111	0.044444	0.05	0.133333	0.022222	0.361111	1
Solution B	0.166667	0.022222	0.05	0.066667	0.011111	0.316667	2
Solution C	0.055556	0.066667	0.1	0.066667	0.033333	0.322222	3

II.I.VI Quality Function Deployment (QFD) Matrix:

Once it was obtained that option A met the criteria in the best way, the QFD matrix was carried out (Figure 24), where what the client needed and wanted was taken into account and a weight was given, while seeks an engineering interpretation to observe the relationship and the level of resolution that the proposed solution grants to the proposed objectives, the selected solution is also compared with other existing solutions.

User demands can be summed up as increased production and quality, greater system flexibility and better monitoring, and lower cost. As technical characteristics to measure the satisfaction of the solution, the production rate, failure and repair times, storage capacities, and the different costs are taken into account, with the weighting it was confirmed that the most important points are quality, production and flexibility, the point of greatest strength of the proposed solution is the production and quality of the products, surpassing the competition, and maintaining an acceptable response in the other objectives.

II.II Time and Motion Study

In order to identify the bottle neck areas that can be improved, we make a motion study of the whole process. In this stage, we analyze every micro-movement based on the different tasks made by the workers, considering each hand motion. The symbols were taken from the Therbligs Motion System.

Table 4. Motion Diagram of Post-harvesting Process.

Manual Process Diagram Operation: Pitahaya Harvesting *Prepared by: Group 10*			
Left Hand Tasks	***Symbols***	***Right Hans Tasks***	***Symbols***
Take the pitahaya	TE, F, H	Take the pitahaya	TE, F, H
Move it to the entrance warehouse	TL, DA	Move it to the entrance warehouse	TL, DA
Place the pitahaya over the table	P	Place the pitahaya over the table	P
Clean the fruit	H	Clean the fruit	H
Separate the export pitahaya	Sh, St, I, TL	Separate the export pitahaya	St, TL
Place the defective pitahaya	DA	Place the defective pitahaya	DA
Pickup deboning equipment	TE	Pickup deboning equipment	TE
Cut pitahaya grade 4	A	Cut pitahaya grade 4	U
Check cuts	H	Check cuts	I
Disinfection of utensils	PP, DA	Disinfection of utensils	PP, DA
Move it to the Good Fruit warehouse	H, TL	Move it to the Good Fruit warehouse	H, TL
Locate it in the sorting area by size	P	Locate it in the sorting area by size	P
Distribute the pitahaya to their respective areas	I, St, TL	Distribute the pitahaya to their respective areas	I, St, TL
Label the pitahaya	G, PP, A	Label the pitahaya	G, A
Entangle pitahaya	H, G, P	Entangle pitahaya	G, P, A
Locate pitahaya in corrugated cardboard boxes	DA	Locate pitahaya in corrugated cardboard boxes	DA
Pack in containers	H, G, P	Pack in containers	G, P, A

Table 5. Application results of the process diagram.

Results			
Area	*Operations*	*Tasks*	*Micro-movements*
Harvest	6	6	72
Washing and Disinfection	12	10	216
Stem Cutting	6	6	36
Clasification	6	4	48
Box assembling	6	8	114

According to Table 5, the higher area of micro-movements is the washing and disinfection area. Also, it's important to consider the box assembling area. Both are key areas that can be improved for the new system. Specially if they are automated, so it wouldn't be necessary to have hand-labor and we can keep the quality of final products.

For time study, we need to define the workers performance to get the standard time of the process. This percentage were taken from the Westinghouse tempo ratings, Figure 3.

Figure 3. Westinghouse tempo ratings.

Table 6. Workers' performance percentage.

Porcentaje de Actuación de Operarios		
Factor	*Clasificación*	*Valor*
Habilidad	A2	0.13
Esfuerzo	A2	0.12
Condiciones	B	0.04
Consistencia	A	0.04
	Total	*0.33*

Supplements are percentages considered for resting times each worker may have for this process. This percentages are given by the International Labor Organization, and we considered the following three in Table 7.

Table 7. Statistical Supplement

SUPLEMENTOS	*%*	*VALOR*
A. Suplementos por necesidades	5%	0.05
B. Suplemento base por fatiga	4%	0.04
C. Suplemento por trabajar de pie	2%	0.02
TOTAL	*11%*	*0.11*

Table 8. Results of the time analysis per area (in seconds).

Results of the time analysis in seconds							
Area	*Observed Time*	*Factor W.H.*	*Normal Time*	*Tolerance Factor*	*Standard Time per area*	*Workers*	*Standard Time per workers*
Harvest	12	1.33	15.96	1.11	17.7156	1	17.7156
Washing and Disinfection	90	1.33	119.7	1.11	132.867	1	132.867
Stem Cutting	24	1.33	31.92	1.11	35.4312	1	35.4312
Clasification	132	1.33	175.56	1.11	194.8716	1	194.8716
Box assembling	150	1.33	199.5	1.11	221.445	1	221.445

Table 9. Results of the time analysis of the process (in seconds).

Resultados del análisis de tiempos del proceso en segundos	
Tiempo Observado	408
Tiempo de Ciclo	542.64
Tiempo Estándar	602.33

Applying the Time Analysis, we found that also washing and disinfection process requires more time per worker. So, it can be improved by implementing an automated system that uses new machines, with fewer hand-labor. Also, there are problems with the Classification and Box assembling sub-processes. So, these three areas are going to be automated in our new system.

II.III Requirements, Specification, and Design

Currently, the pitahaya package in Ecuador is made in a traditional way, where people are in charge of cleaning, disinfecting, and classifying the fruits. Therefore, the use of machinery is proposed to carry out this work, in the disinfection area, a Fruit Vegetable Washing Machine should be used, in the classification area a sorting machine is used, and finally a packaging machine. Likewise, use is made of actuators, sensors, and connections of the machine in the manufacturing system.

So, it is proposed to change certain traditional processes for autonomous ones, obtaining an improvement in the manufacturing system, making it

more flexible and autonomous. Compared to the traditional process you will get:

- longer production time
- higher staff savings
- flexibility in manufacturing processes
- feedback and programmable control loops in machines

II.IV Mechanical layout (pitahaya system)

As can be seen in Figure **25**, the traditional processes which are going to be changed are, those of disinfection, classification, and packaging, each process will be changed by machines which will have their respective sensors, PLCs, connections and more for the respective control of these, thus avoiding failures or any major problem in the machines.

- Disinfecting machine

Figure 4. Disinfection Machine by: [13]

Specification:

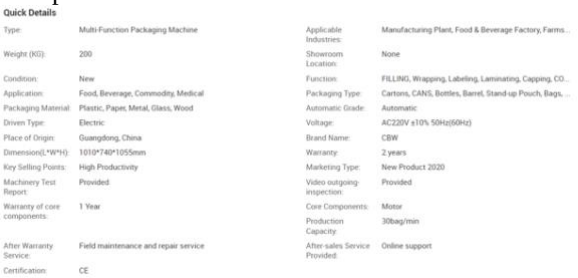
Quick Details			
Condition:	New	Applicable Industries:	Manufacturing Plant, Food & Beverage Factory, Farms...
Showroom Location:	Viet Nam	Video outgoing-inspection:	Provided
Machinery Test Report:	Provided	Marketing Type:	New Product 2021
		Warranty of core components:	1 Year
Core Components:	PLC, Engine, Motor	Model Number:	GG-XQ2500
Brand Name:	GELGOOG	Place of Origin:	Henan, China
Voltage:	220/380V	Weight:	380 KG
Warranty:	1 Year	Application fields:	Snack food factory, Meat processing plants, Fruit pro...
Machinery Function:	Vegetables Washing Equipment	Raw material:	Fruit, Vegetables
		Key Selling Points:	Multifunctional
Name:	Chilli Washing Machine Rotary Fruit Vegetable Washi...	Material:	304 Stainless Steel
Feature:	High Efficiency	Advantage:	Easy Wash
Application:	Fruit Vegetable	Function:	Multifunctional
Item:	Automatic Machine	Usage:	rotary vegetable and fruit washing machines

Figure 5. Specification Data of disinfection machine.

- Packing machine

Figure 6. Packing Machine by: [14].

Specification:



Quick Details			
Type:	Multi-Function Packaging Machine	Applicable Industries:	Manufacturing Plant, Food & Beverage Factory, Farms...
Weight (KG):	200	Showroom Location:	None
Condition:	New	Function:	FILLING, Wrapping, Labeling, Laminating, Capping, CO...
Application:	Food, Beverage, Commodity, Medical	Packaging Type:	Cartons, CANS, Bottles, Barrel, Stand-up Pouch, Bags, ...
Packaging Material:	Plastic, Paper, Metal, Glass, Wood	Automatic Grade:	Automatic
Driven Type:	Electric	Voltage:	AC220V ±10% 50Hz(60Hz)
Place of Origin:	Guangdong, China	Brand Name:	CBW
Dimension(L*W*H):	1010*740*1055mm	Warranty:	2 years
Key Selling Points:	High Productivity	Marketing Type:	New Product 2020
Machinery Test Report:	Provided	Video outgoing-inspection:	Provided
Warranty of core components:	1 Year	Core Components:	Motor
		Production Capacity:	30bag/min
After Warranty Service:	Field maintenance and repair service	After-sales Service Provided:	Online support
Certification:	CE		

Figure 7. Specification data of packing machine.

- Classification machine

Figure 8. Classification machine by: [15].

Specification:

Quick Details			
Applicable Industries:	Restaurant, Food Shop	Showroom Location:	None
Condition:	New	Place of Origin:	Henan, China
Brand Name:	RB	Model Number:	RB-100
Type:	fruit processing line	Voltage:	380V
Power:	8KW	Weight:	3000kg
Dimension(L*W*H):	1.2*1.1*1m	Warranty:	1 Year
After Warranty Service:	Online support	Local Service Location:	None
After-sales Service Provided:	Online support	Application:	Fruit
		Name:	Fruit Sorting Machine
Function:	Multifunctional	Product name:	Fruit Processing Machine
Usage:	Commercial Usage	Material:	Stainless Steel
Item:	Automatic Fruits Juicer Machine	Capacity:	3-5t/h
Feature:	High Efficiency	Keywords:	Tomato Drying

Figure 9. Specification data of classification machine.

III. RESULTS

III.I Flow Diagram of the process

Figure 26 shows the flow diagram of the current process. At the beginning of the working day, the first thing is to carry out any previous preparation of the machines, as well as their ignition, check that the communication in the process is in order so as to give way to the flow of pitahaya that is entering the process. When entering the fruit, it goes through a wash, where an operator, if available, checks the quality of the fruit and stores it depending on its condition. Being of good quality, the fruit directly from its warehouse enters the sorting machine, where, according to its size is transported to a corresponding packer, they all count to 6 fruits, due to the size of the package, once they are all, the package is sealed and an operator, if available, transports it to the respective warehouse.

III.II P&ID Diagram

As shown in Figure 27, the process has a PLC to control and monitor the different actuators and sensors, the actuators consist of different motors to allow and direct the flow of the fruit, and sensors to count the fruit in the warehouses, and multivariable and multifunction systems for the process machines which work with more than one type of information to communicate, The PLC is connected to the dispatcher

to be able to notify when an operator is required for a manual task and to receive information when it is completed.

III.III PLC Programming

It should be noted that in the programming of the different stages of the process, the programming of the washing and disinfection sub-process has been separated from the classification sub-process, to represent two independent automatic processes, since there is always an entry of fruit. In addition to each state of the processes has contactors that open the line to stop the previous process if necessary.

In the washing and disinfection thread (Figure 10), fruit enters through conveyor belt 1, the processing time is approximately 1.5 seconds and once the mentioned area is reached, the disinfection machine is activated. Each fruit takes 2 seconds to be washed and at the end of the action, the Clean Fruit indicator is activated. This indicator turns off again when an operator indicates through a button that it was picked, and he performs the quality control to deposit it in the Damaged Fruit warehouse or the Good Fruit warehouse. A counter has been placed as process security to consider a maximum of 1 fruit per cycle.

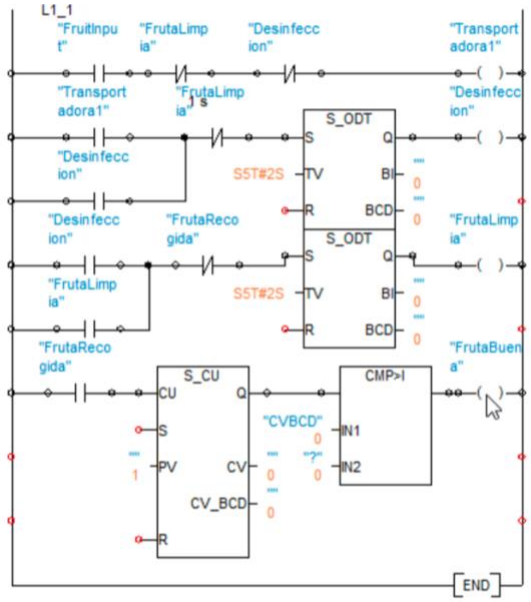


Figure 10. Programming of the pitahaya washing and disinfection process.

For the classification of fruit, it is considered that good fruit enters through a conveyor 2 for 1.5 seconds. Then, the sorting machine starts the sorting process using a multi-function and multi-variable control sensor, this procedure lasts 2 seconds. Subsequently, the fruit is positioned based on the value delivered by the sensor, in this case 1, 2 or 3, which through a comparator identifies its size and the positioning sensors are activated: Pos1 for small fruit, Pos2 for medium fruit and Pos3 for large fruit.

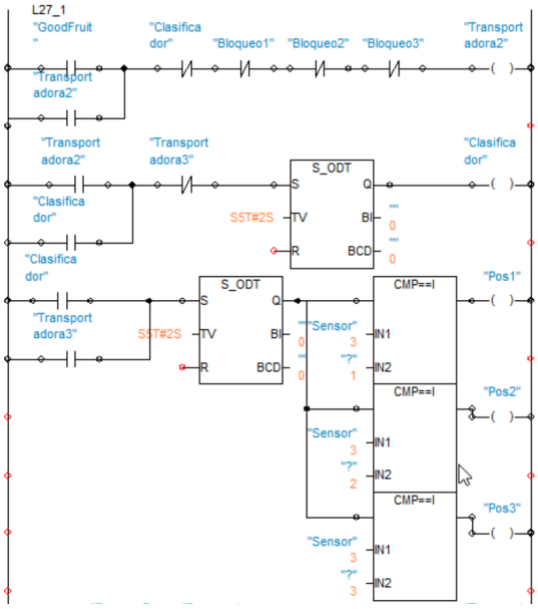


Figure 11. Programming of the sorting process.

The pitayas are transferred to their respective packaging machines through conveyor belt 3. As there is only one conveyor belt connecting both areas, it was programmed as shown in Figure 12. Likewise, normally closed contacts were placed for the buttons that indicate that one of the packaging lines must be picked up, this part of the process is connected with the programming of the Figure 15.

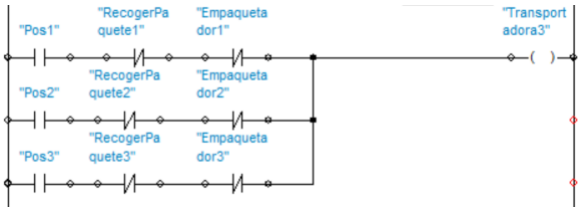


Figure 12. Activation of conveyor belt 3.

After conveyor belt 3 presence sensors have been placed that indicate that the fruit has completed the journey and it is time to start its respective packaging process, the transfer of pitahaya by conveyor belt 3 takes approximately 2 seconds. That is why in Figure 13 there is a timer and the 3 outputs depending on the previously selected position.

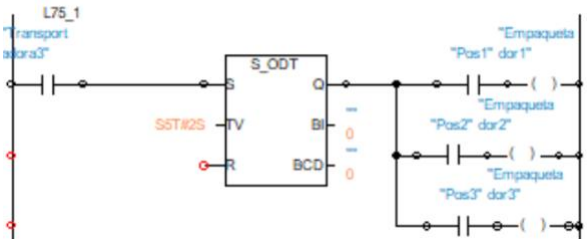


Figure 13. Activation of packaging machines.

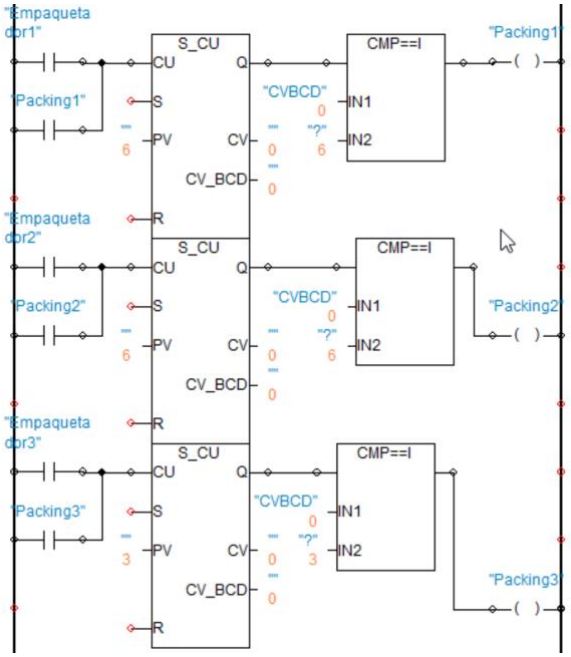


Figure 14. Packaging programming according to the size of the pitahaya.

After starting the machine, counters were programmed that do not allow the output of the cardboard box that stores the fruit until there are 6 of the same size, as shown in Figure 14. Due to the program, comparators have been placed that have as input the value of the counter and the total number of pitahayas expected per package. This process occurs independently for each size.

Once the 6 pitahayas are counted, they all are packed and this procedure occurs for approximately 12 seconds, which is why a timer with this value has been set, and immediately afterwards the RecogerPaquete# coil is activated (Figure 15), which is also an indicator that is shown in the HMI screen (Figure 17) for an operator to pick up the package and move it to a warehouse.

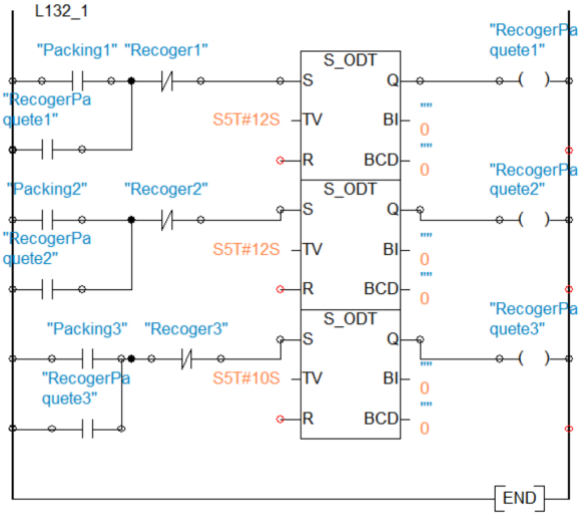


Figure 15. Activation of pick-up indicators for packages of 6 pitahayas.

As security measure, it was programmed in Figure 16, that if pitahaya of the recently packed size enters again and the operator has not yet picked up the package, the system hangs and the process stops until the package is picked up.

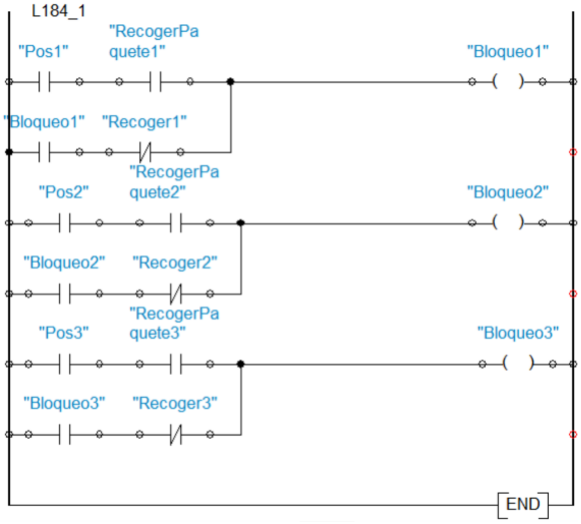


Figure 16. Scheduling lockout of sorting process.

Finally, in Figure 17, the design of an HMI screen is shown with the buttons programmed for an operator to confirm the completion of a certain stage, indicators of all the stages of the process, which were placed on the right side, indicators on the left side of the number of pitayas on real time in the packaging process and the buttons for operators to indicate that the packages have been collected if necessary.

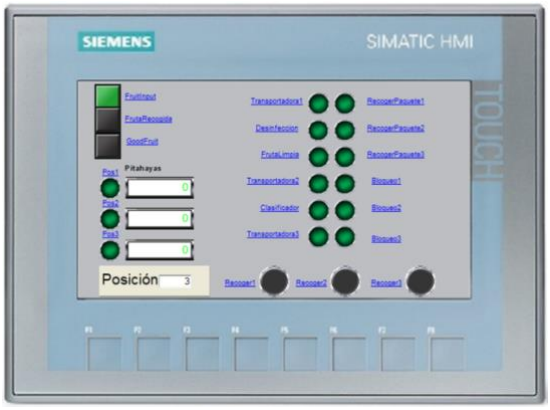


Figure 17. HMI screen with process buttons and indicators.

Based on the needs of digital inputs and outputs, as well as analog ones. It has been decided to select the S7-1200 PLC as the controller, which has the following characteristics:

- 14 Digital Inputs/Outputs
- 2 Analog Inputs (0-10V)
- DC/DC/DC?
- 24 V DC

III.IV Implementation of Prototype

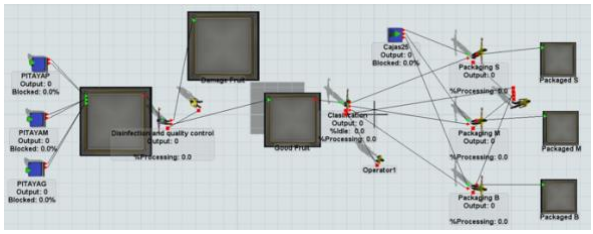


Figure 18. Simulated model of the manual system

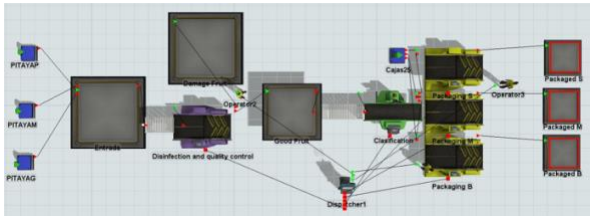


Figure 19. Simulated model of the semi-automatic system

The simulation shown in Figure 18 and Figure 19 shows the implementation of the aforementioned machines and how they replace the traditional methods, thus optimizing the system, obtaining an automation of the flexible manufacturing system. From the 8 workers required for the packaging process, it was reduced to only 3 for essential tasks, such as quality control and transportation, also a dispatcher is available to optimize the performance of the tasks between operators.

III.V Prototype results

III.V.I Results of the manual system simulated model

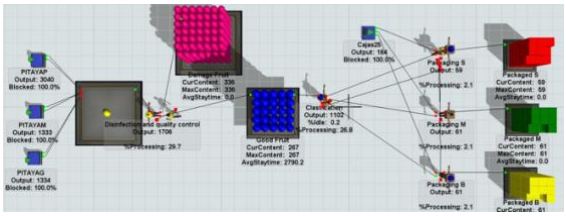


Figure 20. Simulated manual system 8 work hours

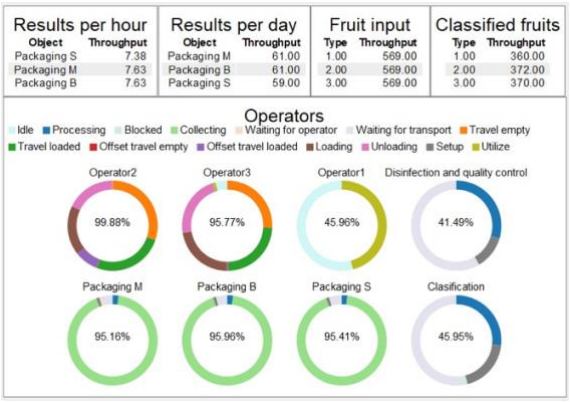


Figure 21. Results of 8 hours of simulation

It is shown in Figure 20 and Figure 21 that in this model a bottleneck is generated at the time of sorting the fruit, which causes that much of the fruit in good condition is stored locally, so that at the end of the day about 1100 fruits are sorted, while 267 remain unsorted, so it is obtained that per hour about 21 packages are produced, and at the end of the working day there are a total of 180 packages. The so-called operators are in charge of the transport and assistance tasks, of these 3, operator 1 spends more than half of his free time since the burden of assisting the others is not so heavy, while the other 2 are busy carrying out the transport process. The other elements are operators specialized in the tasks of their names, disinfection, and quality control, grading and packing. Of these, the packers spend most of their time waiting to complete the packing, while the other two spend most of their time waiting for an operator to transport the fruits once they have gone through their processes.

III.V.II Results of the semi-automatic system simulated model

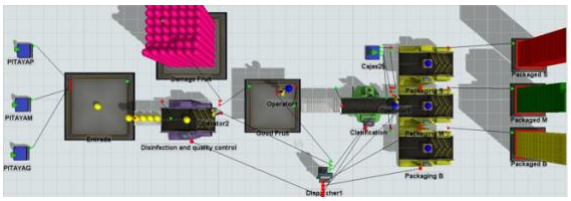


Figure 22. Simulated semi-automatic system 8 work hours

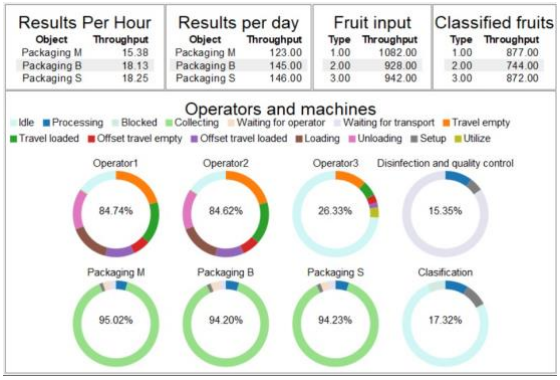


Figure 23. Results of 8 hours of the new simulation

Figure 22 shows the semi-automatic process where a machine oversees disinfecting the fruit, quality control and transport to the corresponding warehouse corresponds to the 3 operators who, once the fruit is sorted and packaged, one of them transports the package to its respective storage area; the operators are managed by a dispatcher who distributes the work to optimize operation and production times. Figure 23 shows the results of the simulation, which indicates that 41 packages are produced per hour, doubling the production compared to the previous model, giving a total of 414 packages at the end of a working day. In this model only the operators are called as such, it can be seen that the load decreases for the 3, even if this

means that one of them has a lot of free time, the other elements are the machines that replaced the operators in these stages of the process, these also have more free time or waiting time, but perform their processes more quickly and safely, resulting in higher production and quality.

IV. DISCUSSION

It can be highlighted that the implementation of the equipment and its different locations can be key to increase production, since the distances between them can lead to better mobility of operators, or in the application of strategies for the development of activities, so we designed and simulated up to 5 different models, those shown in this document are those that showed better production results, but you can also consider the percentages of time that operators and machines work, or spend unoccupied.

On the other hand, the fact that 3 operators are required for the optimal functioning of the process, and taking into account that these should not only be able to perform their basic tasks, but also have knowledge of the equipment, to have the ability to, in case of failure, be able to perform an inspection and / or simple maintenance, in addition to being able to alert and inform technically to the superior, this leads to the fact that 5 workers minimum should be dismissed or relocated, and the remaining 3 should be given their respective training courses.

V. CONCLUSIONS AND RECOMMENDATIONS

V.I Conclusion

- The company will experience an 8% increase in its export market share, compared to when it performed its tasks manually. The workload of the workers was reduced by 15%, although the number of operators was reduced, the distribution of tasks was optimized by using a dispatcher.
- A flexible manufacturing system was designed to semi-automate the system, which in comparison with the previous packaging method doubles the production of packages per hour by working smoothly, and in the case of failure or maintenance of a machine during working hours, operators can manually perform the process of that machine, which although it would decrease the production per hour, it would not stop the system.
- The company will experience an 8% increase in its participation in the export market, compared to when it carried out its tasks manually, it was possible to reduce the workload of the workers in to 60%, since 100% of the tasks are carried out by them.
- A functional stable mechatronic system was developed where we can see that there is an automation of the system compared to the traditional packaging method

V.II Recommendation

- The designed model allows to increase the flow of fruit to be packed, but the remaining operators can generate bottlenecks if they are overwhelmed by the workload, so it is suggested to fully automate the system, and only keep staff to control the different stages, or hire more staff to cope with the increased flow.
- Test more models derived from the one made, changing the location of machines, warehouses, operators, their capacities, distances, etc. to compare the results obtained, and thus achieve a better model that improves the system's capacity.

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APPENDIX

		Voz del Ingeniero										A	B	C	D	E	F	G	H	I
Voz del Usuario	Tipo de Demanda	Tiempo de programado/ejecución	Tasa de producción media por hora de la planta	Tiempo medio de produccion	Tiempo medio entre fallas	Capacidad de almacenamiento	Tiempo medio de reparación	Costos anuales	Costo por paquete	Trabajo en curso	Nivel de flexibilidad	propia solución	competencia 1	competencia 2	Objetivos	Indice de mejora	Factor de Venta	Importancia	Ponderación	Ponderación en %
Facil de controlar	O	9	0	0	0	0	0	0	0	0	9	4	5	3	3	0,8	1,2	3	2,7	4,7
Aumentar los paquetes hechos a diario	O	0	9	9	9	9	9	1	3	3	3	4	3	2	4	1,0	1,5	4	6,0	10,5
Poder ver los generar reportes en medio proceso	E	0	0	0	0	0	0	0	0	9	1	3	5	3	4	1,3	1	2	2,7	4,7
Que sea mas rapido	O	1	9	9	3	0	9	0	0	1	9	3	4	3	4	1,3	1,2	4	6,4	11,2
Menos problemas en el proceso	B	0	3	1	9	0	9	0	0	3	9	4	3	3	5	1,3	1,5	4	7,5	13,1
Manejo de distintas cantidades de fruta a procesar	B	1	9	0	0	9	0	1	0	3	9	5	5	5	5	1,0	1,2	4	4,8	8,4
Mantener el trabajo constante	O	0	9	9	9	3	3	1	0	3	9	4	4	4	4	1,0	1,2	3	3,6	6,3
Poder adaptarse a imprevistos	O	0	9	3	9	0	3	0	0	3	9	3	4	3	5	1,7	1,5	4	10,0	17,5
Entregar productos de mejor calidad	B	0	0	3	3	0	3	0	3	3	3	4	3	4	5	1,3	1,5	4	7,5	13,1
Precio costo de la renovación	E	0	0	0	0	0	0	9	9	1	1	2	3	3	3	1,5	1	4	6,0	10,5
												Evaluación del Usuario							57,2	100,0
propia solución		3	5	4	4	3	4	2	2	3	2									
competencia 1		3	3	3	5	4	3	3	2	2	2									
competencia 2		5	4	4	3	4	3	2	3	2	2									
incidencia		35,5	300	204	286	108	242	68	95	155	364	1857								
incidencia en %		1,91	16,1	11	15	5,82	13,1	3,7	5,1	8,3	20	100								
Valores de referencia		10 min	50 paquetes/horas	1,2 min	80 días	500 paquetes/ciclo	16 horas	10, 000 dólares	3 dólares	300 frutas	poco-flexible									

Figure 24. Quality House of Solution A.

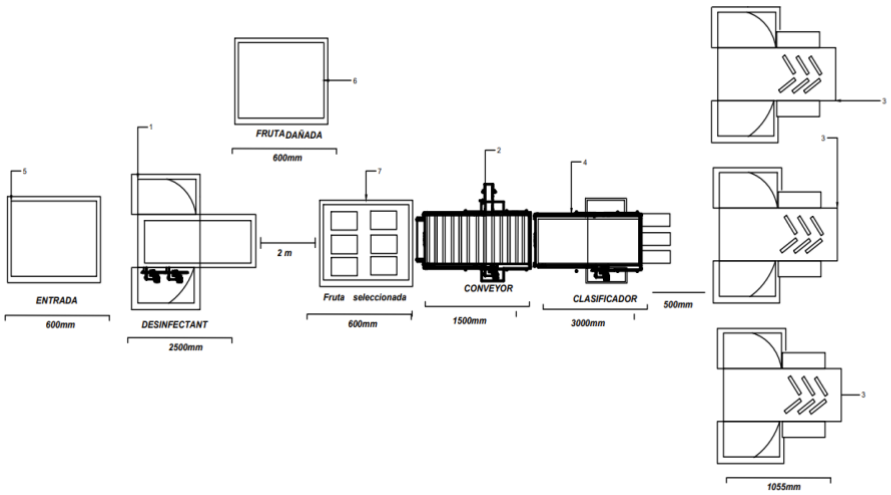

Tabla de Componentes			
1	Desinfectant	Professional Vegetable And Fruit Washer Bubble Hash Chili Washing Machine Rotary Fruit Vegetable Washing Machine	Dimension: 2500mm x 1550mm x 1500mm Power: 0.75Kw / 2.2Kw
2	Conveyor	automatic gravity roller Conveyor line conveyor belt system roller conveyor	unfolded 1500 mm x 600 mm folded 500 mm x 600mm
3	Emabaladora	linear weigher packing machine powder sticky food filling machine quantitative packing scale	dimension: 1010mm x740mmx1055mm
4	Clasificador	Avocado Orange Fruit Washing Waxing Drying And Grading Sorting Machine	3000mm x 900mm x 500mm and power supply 1.1 Kw
5 6 7	WorkSpace Fruit	Fruta ingresada Fruta dañada Fruta seleccionada	600 mm

Figure 25. Mechanical layout of the plant.

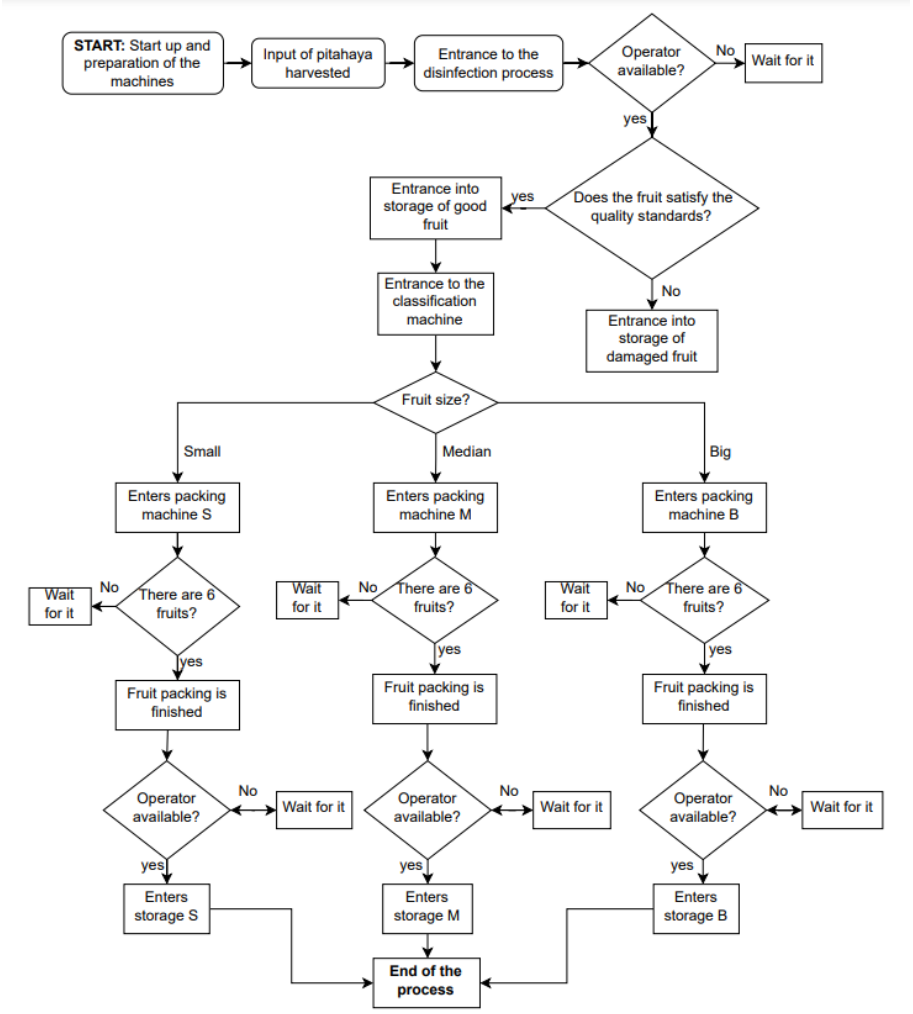

Figure 26. Flow Diagram

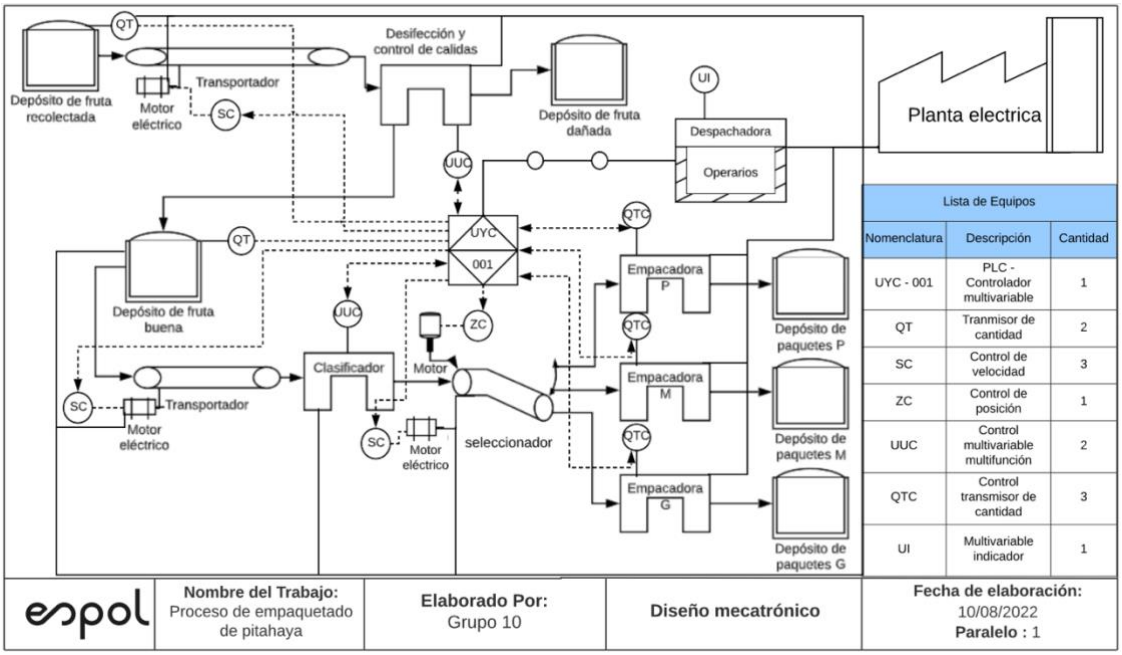

Figure 27. P&ID Diagram.