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Application of mixed methodologies to increase the productivity of an agro-industrial company

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***Abstract*– The agroindustry is one of the sectors with the highest consolidated growth detected in recent years. In Peru, this sector is an essential part of the economy, contributing considerably to the PIB and generating many jobs per year. Therefore, companies in this sector seek to improve continuously for these reasons. However, many of these have problems such as low productivity in their processes caused by a lack of organization and order in the work areas, high downtime, unnecessary movements between activities and machine failures. Due to this, the main objective of this research is to increase the productivity of the avocado production process of the selected company through an improvement proposal using 5s, SLP, TPM and work standardization. Likewise, to validate the success of the improvement proposal, the Arena software was used, the scope of the proposal covers the arrival of the raw material from the warehouses to the packing of the finished product. The results obtained were an increase in productivity of 36.62%, an increase in the general efficiency of the equipment by 18%, an increase in yield by 13% and a reduction in unproductive times by 86%.**

***Keywords*—Lean Manufacturing, TPM, SLP, 5S, Standardized Work, productivity, process improvement, agroindustry.**

I. INTRODUCTION

Agroindustry includes activities in the manufacturing sector related to the conservation, processing, and transformation of raw materials, as well as intermediate agricultural, livestock, fishing and forestry products [1]. According to Passport Euromonitor, between 2019 and 2021, the consumption of food related to agribusiness grew by 3.64%. Therefore, the growth of the market and the high competitiveness in the agribusiness force organizations to increase their productivity and reduce their waste using new tools and methods [3]. Productivity is one of the most appropriate measures to monitor long-term manufacturing excellence [4]. For example, a literature review shows that after applying the corresponding Lean tools, a medium-scale organization in India managed to increase its productivity by 9% [5].

On the other hand, in Peru it was demonstrated in a case study that industries managed to reduce their waste by 15%, obtain savings of 30% in machines and increase their total equipment efficiency (OEE) by 25% [6]. According to Torres for the Gestión newspaper, agribusiness is consolidated in Peru as one of the fastest growing sectors, due to the increase in exports in recent years, this sector contributes 5.6% of Peru's GDP, in labor terms, for the year 2018, it concentrated 28% of the economically active employed population [7]. On the other hand, during 2014-2018, agribusiness reported a growth of 13.7% [1], demonstrating this sector's importance in the industry and national economy.

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One of the foremost frequent problems detected in companies in the manufacturing sector is untimely stops during production due to a lack of maintenance in the machinery. These companies want adequate performance levels in the market to require correct prior maintenance [8]. Another of the most frequent problems detected is the loss of time, which one of its causes is due to a poor distribution of the plant, generating unnecessary and excessive movements [6]. According to the review of the literature, the problem can also be a consequence of the difficulty in controlling the process, the generation of waste in production, the inappropriate use of the equipment, and the poor establishment of procedures and work methods [9]. Likewise, in another investigation in Peru, it was identified that low productivity is also explained by the high downtime of machinery and the high production setup time, directly affecting compliance with production planning, and generating losses of both hours man as machine. Consequently, by applying tools such as Total Productive Maintenance (TPM) it was possible to reduce downtime by 36% and increase overall equipment efficiency (OEE) by 5% [10].

In this sense, the need for manufacturing companies to improve their productivity and be more efficient in such a way that allows them to increase their profitability is verified. Therefore, this study seeks to identify the main causes of the problem, which have been discussed or detected through the different case studies mentioned, among which are high unproductive times, incorrect distribution of work areas, and machinery failures [3]. This research seeks to increase the productivity of the avocado production process of a company in the manufacturing sector using lean manufacturing tools such as TPM, work standardization, SLP and 5S. In addition, this research arises with the idea of developing an improvement proposal for a continuous production line. On the other hand, it seeks to contribute to the scientific community with new topics in the sector, given that the reviewed articles contain little information regarding the application of Lean Manufacturing, especially in the Latin American sector, therefore the need to contribute with this investigation.

This academic article has the following structure: Introduction, where cases are presented and the benefits of Lean tools are explained; State of the art, where the problem arises. from different perspectives developed; Validation, where the results obtained are shown through indicators after the execution of the solutions and the simulation; Discussion;

Conclusions and recommendations that allow readers further guidance.

II. Literature Review

A. Increased productivity in the manufacturing sector

Companies in the manufacturing sector that process agricultural products present various problems, some of them are the high percentage of losses, they do not consider the order of the work area, the cleanliness of the production area as essential factors for the development of their operations, and they do not have with a maintenance plan or do not comply with the plan [5]. On the other hand, the low general efficiency of the equipment (OEE) and the lack of process standardization is a common problem in companies in this sector [10]. Due to all the above, MYPES in the manufacturing sector have low productivity and with the high level of competitiveness demanded by the environment, it is imminent to implement tools that allow significant improvements to be achieved and install a work philosophy in employees to achieve the level of productivity that maximizes profits and that allows satisfying the needs of customers and the quality that they demand [12]. First, it will seek to have a clean and orderly area with the help of the 5's tools [13]. Subsequently, a standardization of processes will be achieved and then conclude with the implementation of the TPM tool, specifically its pillars of autonomous and preventive maintenance.

The correct application of Lean Manufacturing tools will increase the equipment's efficiency (OEE), which will directly impact productivity [4]. As a result, it was possible to increase the global efficiency of the equipment from 71.5% to 83.16% [14].

B. TPM in the manufacturing sector

Poor maintenance practices lead to a reduction in production performance, a reduction in the general efficiency of equipment and low reliability, which causes a loss of reliability in the organization [15]. Therefore, it is necessary to have a preventive maintenance plan and comply with it, since this will directly impact the reduction of unproductive times due to stops due to machinery failures. On the other hand, if another pillar is added to preventive maintenance, which is autonomous maintenance, it will be possible to reduce costs since the operator of the equipment will have the technical knowledge of the machinery to make the adjustments to avoid small failures that can lead to others more serious[16]. The top management of the organization must be fully involved in the implementation of the tool, otherwise it is very likely that it will fail and not achieve the expected results[15].

During TPM implementation, it is necessary to identify the impact of other critical factors such as technology, training and employee engagement [18]. The implementation of TPM successfully increased production efficiency, reducing machine downtime by 13%. Furthermore, this tool is suitable for implementation in organizations seeking to increase production productivity and their machinery's overall efficiency [19]. In addition, the main achievements obtained with this tool are the decrease in corrective maintenance, which increases the MTBF, as well as a 26.6% increase in performance. [20].

C. 5 S in the manufacturing sector

This typology explains about the 5s, which is one of the techniques of the Production Management System or Lean Manufacturing, this and other techniques belonging to this group are related seeking continuous improvement in the workplace [21]. Continuous improvement is one of the most important tasks that organizations currently have, what is sought with this is to improve the process, increase production, productivity and others [22]. Continuous improvement is also built, eliminating waste, inefficiencies, systematically improving the organization and focusing on its objectives.

The objective of applying this tool is to increase the productivity of a manufacturing company, achieving this leads to a reduction in manufacturing costs [22]. On the other hand, the application of this tool in work areas makes it possible to regulate the flow of the work area, systematizing said area and thus contributing to continuous improvement [23]. In addition, a direct relationship with the operational performance of the personnel is verified, since the 5s are focused on allowing the work environment to be adequate so that the operators dedicate themselves 100% to performing their indicated functions and feel safe when performing them. The 5s methodology consists of five steps which are: eliminate, order, clean, standardize and control, which follow the sequence of steps in search of maintaining and improving productivity, total quality, competitiveness and the conditions of the organization [24]The implementation of this tool helped to preserve the environments with greater order, which reduced the times in the operations that are carried out [25].

D. Standardization of work in the manufacturing sector

One of the ways to improve general productivity is by applying the standard work, this is based on establishing specific instructions to develop a product with high efficiency, it also allows the identification of waste present in the process [26]. On the other hand, work standardization consists of three elements: takt time, work sequence, standard inventory.

The Lean Work Standardization tool is directly related to the productivity of the company. As can be seen, Lean Manufacturing helps various factors within which it is identified that allows the company to become more flexible. When we talk about flexibility, it refers to the fact that organizations can take charge of the variations in demand to which they are exposed in the market to which they participate[17].

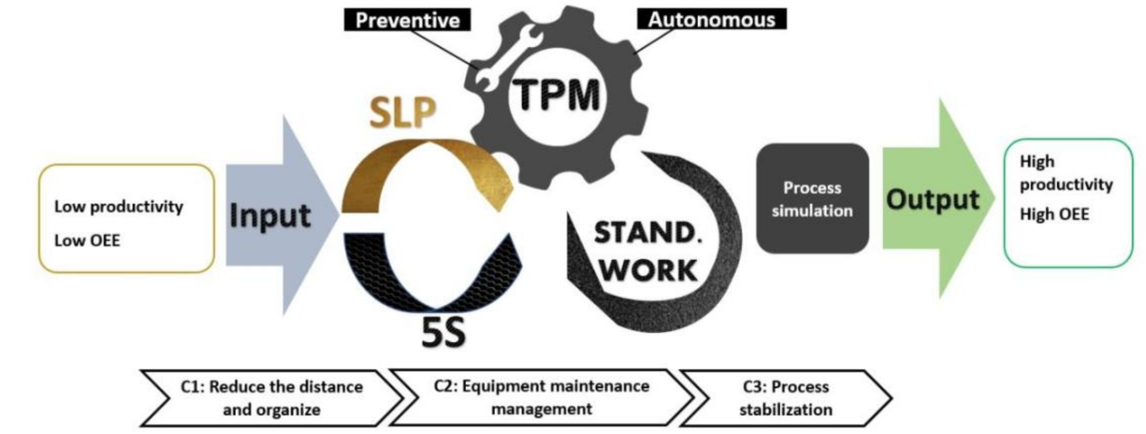

Figure1:Proposed model to increase productivity. Adapted from [9],[11],[20]

E. SLP in the manufacturing sector

This typology is based on the systematic layout planning tool, a correct plant layout has a considerable influence on productivity, plant layout is an optimal plan for the facility, including personnel, equipment, the storage. space, materials and the rest related to the end of the installation [17]. Some of the results found through the application of this tool is the reduction of the effort in the transport of materials or raw material by approximately 62%, reduction of material change times by 57%, also contributes to the reduction in the search for materials and increased OEE [11]. In addition to these results, there is also a reduction in transport times, an increase in value-added time, which leads to an increase in productivity and a decrease in downtime.

III. CONTRIBUTION

A. Model Basis

Today, companies in the manufacturing industry are looking to be more competitive, for which they need to be part of continuous improvement, to reach this goal they begin to implement Lean Manufacturing. Through a literature review, we were able to identify different articles that provide us with a better overview of the tools to be used, for which components were established and to be able to classify them as shown in Table I. [15] present a model like the one we want to apply, using the tools that we are proposing as an improvement proposal, this allows us to have the guide model for solving the initial problem. Unlike the other models under study, our model is based on agribusiness since most of the sources studied use methodologies and present problems in the manufacturing or food industry. This model seeks to contribute by incorporating new components to the sector, such as work organization, machinery maintenance, plant design and process improvement.

COMPARISON MATRIX OF THE CAUSES OF THIS RESEARCH VS. THE STATE OF THE ART

Components / ***Articles***	***Reorganization of workstations***	***Machinery maintenance***	***Layout Redesign***	***Optimizing working methods***
[22]	5S			
[15]		TPM		Standardized Work
[6]	5S			Standardized Work
[4]	5S	TPM		Standardized Work
[11]	5S		SLP	Standardized Work
[9]	5S		SLP	Standardized Work
Proporsal	**5S**	**TPM**	**SLP**	**Standardized Work**

B. Model components

With the systematic review of the literature of various scientific articles, it seeks to have as an information base to propose a model of productivity improvement based on the application of Lean tools such as 5S, work standardization, SLP and TPM in a company in the sector. manufacture. As shown in Figure 1 the proposed model is made up of the following 3 phases: Reducing distances and organization, equipment maintenance management and process stabilization.

Component 1. Reduce distance and organize

It begins with the implementation of the SLP, firstly, the activities of the process are analyzed to identify the most relevant ones. Subsequently, a relational diagram of activities is elaborated that helps to verify the distances that exist between activities and the times that the transport takes from this the proposals for the new layout of the plant are presented, taking into account the relationships that the activities have. areas with each other. Then the new distributions are evaluated and if their impact is significant, the redesign is carried out.

Then the 5S methodology that helps to generate order and organization in the plant is implemented, it begins with the classification of materials in the work area, here the necessary materials are separated from the unnecessary ones. Work areas and tools are then labeled, so operators don't waste time looking for them. Later, cleaning policies are established, so that the area is always kept clean. Finally, work sequences and checklists are implemented where the operator supervises order and cleanliness.

Component 2. Implementation of maintenance management

In this phase, the TPM methodology, Autonomous Maintenance and Preventive Maintenance pillars are implemented. This implementation seeks to eliminate two of the main causes of low productivity, which are: unscheduled stops of the machines due to lack of a maintenance plan and machine stops due to jamming of parts or poor calibration of the equipment. Here, a favorable environment is created where all personnel are involved and accountable, seeking the commitment and participation of the production area in basic functions, but of great importance such as cleaning, inspection, adjustment and lubrication. In addition, a maintenance plan is carried out where critical machinery, maintenance activities and their duration are identified. Therefore, both pillars allow a direct increase in productivity, improving the efficiency and availability of the main machines in the avocado production process (mixer and packer), which are essential for the process, since, if they have a sudden stop, they create a bottleneck.

Component 3. Process stabilization

The final phase is the implementation of the standardized work, with the main objective of establishing a work methodology with little variability and very efficient. Here a work guide is established for the operators, so that in the pulping stage they save as much time as possible, and the raw material is extracted as efficiently as possible. For this, an evaluation of each operator and their way of working was carried out, considering a study of times carried out for each type.

C. *Model indicators*

In order to measure the impact on the results obtained after the implementation of the proposed tools, the main indicators are presented below, which will prove whether the objectives set were achieved and will allow a comparison with the current situation.

Productivity: it is the quotient between the total kg of finished product obtained in a shift and the total man-hours used

$$productivity = \frac{(total\ kg\ of\ finish\ product)}{total\ man - hours\ employed}$$

Yield: amount in kg of finished product over the amount in kg of raw material that enters the process

$$yield = \frac{(total\ kg\ of\ finish\ product)}{total\ kg\ of\ raw\ material}$$

Overall Equipment Effectiveness (OEE): is an indicator that measures the general efficiency of the equipment. To calculate it, the performance, quality and availability rates of the equipment are multiplied.

$$OEE = \%yield\ x\ \%quality\ x\ \%availability$$

IV. VALIDATION

A. *Validation scenario*

As a validation tool, this study will use Arena software to perform simulation and the 5s tool as a pilot plan. To validate the improvement, first the model of the current situation will be proposed, and then the model with the proposed improvement. In addition, the scope of the system, variables, and sample size will be considered using the input analyzer, entities, simulation elements, and system replicas.

The simulation and pilot plan to be presented cover the production area, specifically the avocado production process where we have different process activities to improve

B. *Initial diagnosis*

The company selected for this study is dedicated to the processing of different fruits and vegetables, within which they have the avocado process. An existing problem was evidenced, since, by not maintaining a fixed productivity, there is a considerable economic loss. In this case, the objective of the standard sought in productivity will be 8.4, compared with the average of the productivities obtained during this campaign, which would be 6.99. Assuming a labour cost: 3.5 $/ hh. On the other hand, considering that last season a total weight of finished product of 1,688,101.21 kg was obtained. A total of USD 141,882.61 could be saved if we reduced the variability of productivity and maintaining said productivity at the established standard and even exceeding it would bring better profitability for the organization.

On the other hand, concerning unproductive times which are generated by poor organization within the work area, the times taken in movements within the stages of the process and machine stops, considering that the total number of operators, which is 120 people required for the process, considering that the productivity of the plant influences the total number of people. In addition, an average downtime of 2.14 hours per day would give us a total cost of USD 161,784.00 per campaign generated by downtime alone.

C. *Validation design*

a) *Pilot plan*

In order to demonstrate the validation of the 5S tool used in the production area, as the tools were in disarray and operators wasted time searching for the tool they were going to use, a pilot plan was carried out to demonstrate such validation

To determine the current state of the company with respect to the 5S, an initial audit was conducted during the selected process stages. A checklist was used to record the state and quantity of materials at the time of the audit and thus be able to classify them into general groups to maintain greater order. In addition to this, what is not necessary is separated from what is necessary. For this, red cards were used. Machines that are not being used, which are normally used for other processes and take up space in the production area, were also given red cards and were designated to a place that does not interrupt the current process.

A modification was made to the shelf so that we can organize by each generalized classification that we have found. In addition, we will mark specific areas where we will have the tools so that when entering the work area, the staff knows which material code corresponds to them and they do not waste time taking the materials. On the other hand, the delimitation of areas for operating equipment and equipment for maintenance was implemented. We also mapped leaving spaces free for the correct transit of personnel and to move the product in trays, always seeking to minimize movement. The coding was carried out as shown in the following image.

Figure3: Area after the pilot plan

Finally, for the materials that are used directly in the process, such as spoons, knives, and forks, a secure box was adapted for these utensils so that it is easier to distribute the tools at the beginning of the process and deliver them at the end of the process. Each tool was coded and a relationship between the code and the person responsible for the delivered tool will be established. Thus, if a person is given the large spoon with code CG01, this person will be responsible for caring for and returning the material in good condition at the end of the day. The model will be as follows.

Additionally, a weekly cleaning plan was created in search of encouraging operators to keep their work areas clean and organized. Also, a documented cleaning manual was proposed, which will allow us to create a cleaning standard, where time is controlled, and this will allow us to plan.

In the initial audit results, a 52% was obtained as the initial result, and at the end of the 5S pilot test, an 83% was obtained, a considerable improvement.

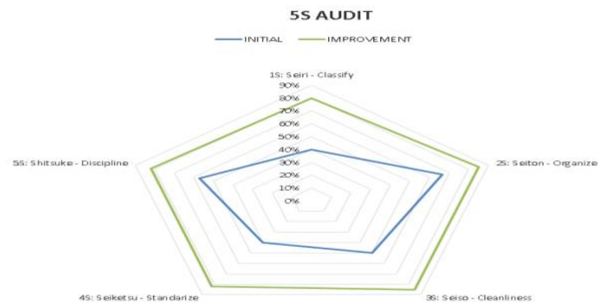

Figure4: 5´S audit results

b) *Inputs variables*

To carry out the simulation of the production process of avocado pulp, the times for all the activities involved in the production of avocado delimited by the scope were recorded. The variables are separated according to their level of control as shown in Table II. The controllable and non-controllable variables are detailed below:

TABLE II
INPUTS VARIABLES

Controllable variables	**Uncontrollable variables**
Number of operators	Time between arrivals and departures
Working hours	Activity time
Number of maintenance operators	Time between failures
Kg of raw material	Time for a repair
	kg of finished product

c) *Distributions used*

By using the Input Analyzer of the Arena software, it was possible to determine the most appropriate distribution for each activity of the process as can be seen in the Table 3.

TABLE III
ENTITY DISTRIBUTION TIME

Random Variable	**Input Analyzer**
Arrival of raw material	UNIF (2,5)
Washing and disinfection	UNIF (1,1.2)
Transfer to court	UNIF (3,5)
Cut	UNIF (10,12)
Pulped	UNIF (14,18)
Mixed	CONSTANT (5)
Packaging	UNIF (0.2,0.4) * Q
Embedded	UNIF (30,45)

d) *Simulation validation*

The purpose of the simulation is to validate the optimization in the process times, specifically in the activities

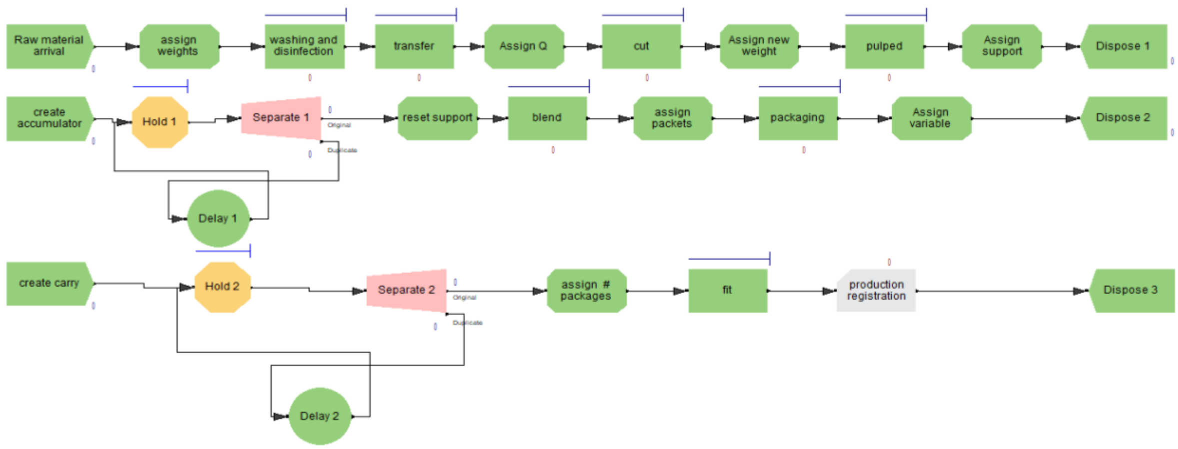

Figure5. Simulation model in Arena software.

where we are implementing the tools, as well as the increase in productivity with the data obtained at the end of the process. Figure 2 shows the model of the process under study in detail, considering the activities that are part of the scope of the simulation.

In the first place, during the period during the first month, an increase in production is obtained from 402,848.22 to 550,604 kg of finished product. This represents a good indication of increased productivity, since we assume that, under the same conditions, the same hours you work and the same number of personnel, the output of the process increases.

Secondly, the proposed model manages to reduce waiting times in queues at a general level, it is worth highlighting the transfer queues, this means that distances are reduced, and times are minimal, therefore the flow becomes more fluid. and demonstrates the success of the SLP implementation, in addition to this they reduce the waiting time in the mixing and packaging queue, which indicates that the mixing and packaging machine has increased its availability, decreasing the frequency of failures that were taken into account. the current diagnosis.

The queue time prior to pulping is reduced, which reflects the improvement implemented through the standardization of work and 5S. Since the improvement of both was specifically focused on the cutting and pulping area. The waiting time generated in the cutting stage is also reduced, since these tools also influence them. Also, it should be noted that in the initial diagnosis, a 20% weight loss was lost within the process, in the pulping area. After the implementation of work standardization, this weight loss was reduced to 17.5%, increasing yield of process.

Finally, it should be noted that the use of the resources involved, in this case, the mixing and packing machines increases, since, by returning a flow with greater fluidity and fewer stops, or loss of time within the process, the use increases considerably of the equipment and personnel involved in said process. Table 4 shows the results based on the indicators designated for this study.

TABLE IV
INDICATORS RESULT

Indicators	**Present**	**Objective**	**Variation (%)**
Productivity	6.99 kg/hh	9.55 kg/hh	36.6%
Yield	52%	65%	13%
OEE	63%	81%	18%
Improductive times	2.14 horas	1.15 horas	-86%

VI. CONCLUSIONS

Mainly, it is concluded that the use of Lean tools, such as those used in this case study, contributes significantly to improving productivity in a company, providing better profitability.

The implementation of the proposed model allows to increase the current production by 36%. On the other hand, by increasing production taking into account the same conditions, it allows us to improve productivity by 36.62% thanks to this, the company under study can have economic savings of approximately 226, 582 dollars per campaign.

In addition, the loss in weight of the product during the process was reduced by 13%, that is, it was possible to increase the yield of the process by 13%, thanks to the standardized work implemented during the stages where we had different methodologies in the operators.

Correctly implementing the 5s and SLP, result in savings in unproductive times that affect productivity and process performance. This is verified in this study with the reduction of waiting times in the stages and the improvement of the fluidity of the current flow. In this study, unproductive times are reduced by 86%, which proves the effectiveness of implementing these tools.

When applying TPM, specific machines to supervise and control must be selected, and the necessary pillars to apply must be determined. In this case, by applying autonomous maintenance and preventive maintenance, a training plan for operators and a proper preventive maintenance plan must be integrated, with the real benefit of increasing machine availability. The benefit obtained thanks to the application of this tool is an increase in OEE by 18%, allowing greater machine availability and avoiding idle times for the operator.

All this demonstrates that the proposed model allows significantly improving the indicators mentioned in the agro-industrial sector company under study.

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