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Application of Lean Tools to Reduce Waste in an Organic Mango Exporting Company: An Investigation in Peru

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Abstract. Today, the agro-industrial sector has experienced a boom in its growth, especially in fruits and vegetables, and with it the customer's demand. One of the most requested conditions by users are the product quality and services offered. Therefore, it is essential to identify all the processes and activities that follow each of the materials along the supply chain. To have better inventories control, it is necessary to have an efficient traceability system that ensures accurate products tracking. The proposed model was based on four lean manufacturing techniques: Jidoka, Kanban, Visual Control, and Standardized Work to improve the inputs search time and, consequently, reduce product losses that currently represent 2.06% of net profit. With the tools used we were able to reduce labeling errors by 2%, excess pallets decreased by 0.72% and the search time for a product was reduced to 4.5 hours/day, saving 1.21 hours a day.

Keywords: traceability, lean manufacturing, Jidoka, Kanban, visual control and work standardization.

1. Introduction

Inventories are one of the most important elements in the supply chain because their correct management allows decreasing the negative impacts caused by the demand variability, increasing the possibilities of satisfying the user's needs. Currently, companies have presented problems when managing inventories, due to the lack of a traceability system or its inefficient implementation. [1]explains that not having a correct inputs identification in the database affects decision-making and customer service levels. In addition, Guevara mentions that the inefficient traceability systems operation in Latin American countries causes problems in the traceability of products, resulting in delays and inputs loss [2]

Traceability favour's the improvement of processes, thanks to the localization and identification of the main problems root causes presented. According to León the implementation of a traceability system in a manufacturing company helped to detect errors main causes presence in the production line, improving by 15% the workers efficiency and reducing the failures concurrence in the line [3]. Good use of the system guarantees that the products comply with the quality standards, generating more confidence in the clients [4]. Likewise, Guevara mentions that the implementation of a traceability system must go together with constant workers training, since, if they do not comply rigorously with the inventory control methods, they can bring inconveniences in the handling of the merchandise, errors in the process and product losses [2].

Faced with this problem, this article aims to reduce the waste generated by the lack of a correct traceability system. For this, we have chosen a case of study that represents the sector in the products location delay due to failures in traceability. The errors that were identified were: incorrect labelling, poor inventory control, and disorderly interim storage, which generate monetary losses of 2.5% of net profit. Most of the articles reviewed applied technological tools to achieve their objectives. The research contribution is manifested through a proposal to improve traceability with the implementation of Lean Manufacturing techniques: Jidoka, Kanban, Visual Control, and Standardized Work. The combination of these tools is represented in a model which seeks to mitigate the errors previously exposed. The motivation of this article is due to the lack of literature with a focus on internal traceability in addition to the fact that most articles on traceability tend to focus only on the safety and product quality, but only one sector focuses on inventory management. For this reason, in this research, we offer a new input and finished products management model through traceability, which decreases the time to search for a product by more than an hour a day.

The scientific article is divided into five parts, which are: Introduction, State of the Art, Contribution, Validation, and Bibliography.

2. State of the Art

2.1.Jidoka

It is a Lean Manufacturing technique that not only takes care of identifying defects in the process, but also helps to generate continuous learning to workers and consequently improve the process [5]. Automation facilitates the operators work, helping them to perform their tasks faster in the possible simplest way, reducing the errors number generated. By having better control over production failures, a large percentage of quality costs are reduced [6]. Several studies prove that the Jidoka implementation has eliminated a large amount of waste, such as unnecessary waiting times and generating a higher percentage of reliability in the system [7]. Likewise, it reduces the defective products rate, increasing the company's productivity and improving the fulfilment of scheduled deliveries [8].

2.2.Kanban

Kanban is a visual tool that facilitates the production control through an analysis of the input materials and the demand, achieving a production without stock [9]. It uses visual signals such as cards, boards, or electronic devices that aim to activate the replenishment process and indicate to workers how much material is needed to produce only what is necessary [10]. The lack of supplies generates several inconveniences, among the most seen are the processes delays, which generate unnecessary waiting times [11]. Kanban aims to manage production, reduce inventories and mitigate the tasks that do not add value to the production system [10].

2.3.Visual Control

Visual Control is a management system, which communicates relevant and easy-to-understand information using visual stimulation. This management system allows to illustrate the industrial processes of the organization by providing relevant information to all company levels. Some of the most used visual control tools in the industry are the panels management indicators, priorities classification, projects schemes, among others [12].

2.4.Standardized Work

The work standardization tool facilitates the achievement of positive results in companies, thanks to the fact that the detailed definition of procedures decreases the probabilities of error by its workers. In addition, it allows the elimination of operations that do not generate added value to the product or service; consequently, productivity and efficiency increase significantly in the process [13]. The correct implementation of this tool has been able to present several advantages in the organizations, such as the reduction of bottlenecks and waiting times, allowing to increase the production [14]. Also, the standardization of work allows reducing the cycle times of a product and the errors number, increasing the production rate [15].

3. Contribution

3.1.Model Fundament

The state of the art was used to identify the tools belonging to the Lean Manufacturing philosophy most used and with the greatest positive impact on organizations. The selected techniques will help to efficiently manage the company's production and reduce the identified drawbacks

Table 1 compares the lean tools found in the reference articles with the tools that will be use in this work.

3.2.Proposed Model

The proposed model showed in Fig. 1 focuses on improving traceability, based on the lean methodology tools, specifically: Jidoka, Kanban, Visual Control, and Standardization of work.

In this process, the inputs were defined as the deficiencies found in the company. We had, the high average time to find an order, the errors percentage in labelling, and the number of boxes produced in excess.

The outputs refer to the economic benefits, the reduction of waste, and the decrease in reprocessing times and products location.

The development of this proposal was encompassed by the Kanban tool which allows generating the necessary production quantities at the required time. In addition, it has four phases. It starts with the Visual Control tool, which allows capturing simply the situation of the production system, highlighting anomalies and waste, also enriches internal communication through visual tools. Next, the Jidoka application aims to reduce reprocessing times, because this tool helps to detect problems and seeks quick solutions for them. Complementing the previous tool, the standardized work is proposed, to reduce the probability of errors. Finally, the proposal concludes with the visual control tool, to communicate to the workers the main indicators progress and advances. The Kanban tool was linked with Jidoka and Standardized work and was applied in parallel to achieve the objectives set.

Table 1: Comparative Matrix of the Components of the model VS. the State of the Art

Authors	**Components**			
	Reduction of errors in production	**Control and programming of the production system**	**Management of information on current situation and improvement**	**Improved worker efficiency**
Castellano, L. (2019).		Kanban and Push System		
Muñoz, I. Peñalva, PJ. (2011)	Jidoka, 5S, Poka Yoke	Kanban		
Suárez, M. (2020).	Jidoka			
Allauca, M., & Inca Y. (2021)	5S			Standardization of work
Ballesteros, D. & Ballesteros, P. (2008).	Poka Yoke	Kanban	Visual Control	
This research	Jidoka	Kanban	Visual Control	Standardization of work

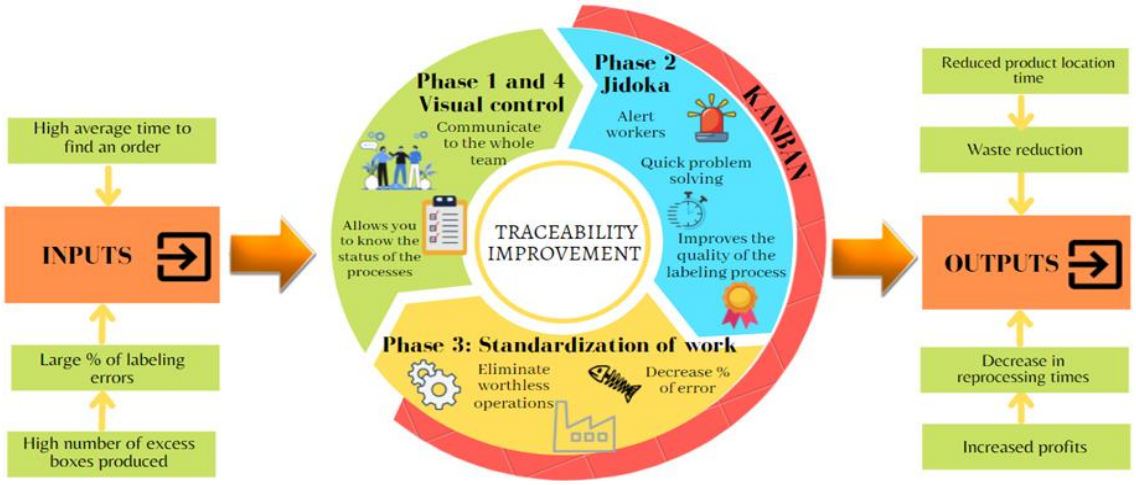

Fig. 1 Proposed model for waste reduction

3.3.Model Components

In this section, we will describe the different model phases.

3.3.1. Visual control

Using the visual control tool, the Lean Manufacturing philosophy will be explained simply together with the optimal results that it has produced in different companies in the field. Also, it will be represented through graphs and indicators of the current company problems and the steps that the improvement proposal will follow. The objective is to inform the workers about the proposed tasks and to make them feel part of the improvement team so they consider that their activities will have repercussions on the company progress.

3.3.2. PHASE 2: Jidoka

We start identifying the anomalies and proceed to analyse the possible root causes. Finally, an alarm is installed, which is triggered by an operator every time a change in the content of the label is required. It is important to mention that this solution seeks to solve the communication problem that exists between the operators when they change the content of the label, this problem is considered the root cause. Also, it was complemented with the Kanban tool, which is indicated later.

3.3.3. PHASE 3: Standardized work

To reduce the probability of errors in labelling and other process operations, the work standardization tool will be used to prepare the technical data sheets of the four types of Kent mangoes marketed by the company. Likewise, an instruction manual will be prepared for the alarm correct operation, to facilitate its application. Both documents will help to reduce the errors probability in labelling and improve the workers performance. Like Jidoka, Standardized Work was implemented together with Kanban to obtain better results.

3.3.4. PHASE 4: Visual Control

It starts by analysing the indicators that were subject to improvement and comparing the results with those obtained initially. It continues with the development of a board placed in the factory where all operators can see it. The board contains the target KPIs and historical data of the same. Finally, the workers are trained on the board interpretation and the objectives to be achieved.

3.3.5. Kanban

To implement this technique, we started with an analysis of the production line with a Value Stream Map to know in detail the processes. Also, we considered the inputs and outputs in each operation, to calculate the number of parts needed in each Kanban. Then, it is essential to study the demand in the campaign months to identify the quantities of final products required and thus define the production plan, which must maintain small batches. Next, the design of the cards is important since they will include fundamental information on the required components. Finally, the recall process was inspected, and at the same time, we calculate the quantities of the product that will be removed from the line. This tool was implemented in all production line operations; therefore, it was put into operation with Jidoka and Standardization of Work.

3.4.Indicators

Indicators will be used to contribute to the analysis and evaluation of the improvements achieved with the proposed tools.

- Defective labelling index: It allows to know the boxes percentage that were labelled incorrectly. It counts the number of boxes that have been labelled with incorrect parameters. It should be kept in a range of 2 - 5%

$$\%\, Boxesincorrectlylabeled = \frac{Boxesincorrectlylabeled}{Totallabeledboxes} \quad (1)$$

- Overproduction rate: It gives us information on the pallets percentage that have not been able to enter the cold storage due to lack of capacity. It should be kept in a range of 13 - 15%.

$$\%\, ofexcesspallets = \frac{Palletsoutsidethecoldroom}{Tot.Palletsproduced} \quad (2)$$

- Percentage of lost product: Of the pallets that have not been able to enter the cold room for lack of space, there is a quantity that decomposes for not being stored at the right temperature. This

indicator shows us how many pallets are lost per month for not entering the cold storage at the right time. The percentage should be between 3 - 5 %.

$$\%\ of lost pallets = \frac{Palletsdescomposed}{Palletsoutsidethecoldroom} \quad (3)$$

- The amount of time per day that an operator spends looking for mango pallets. In this indicator, we will reflect the total amount of hours spent looking for a box of mangoes in a working day. The time should not be more than five hours per day.

$$Productsearch\ time\ = Hoursittakestofindaproduct \quad (4)$$

4. Validation

4.1.Initial diagnosis

Currently, the company loses about 26%, while the average in other organizations is 20% [16]. One of the main causes is that the lack of an efficient traceability system in the company, as most of the fruits, are not located correctly or it is difficult to their search. Using tools such as Value Stream Map, Ishikawa diagram, and the five Whys analysis it was possible to determine the reasons for the delay in finding a product, which is: The errors presence in the raw material labelling and the occasions when the fruit is deposited outside the cold storage. Then, the root causes were found, among them, have ineffective communication between areas of the factory and poor scheduling for the production plan. The selected tools seek to reduce the errors caused by these two root causes.

4.2.Simulation

To validate the model, a simulation was carried out in Arena software 16.1 Fig.2. As mentioned above, the simulation sought to reduce the time it takes for workers to find a mangoes box; that is, to improve the company traceability. The simulation begins with the first entity input: the crates of mangoes. The model ends with the pallets ready to be exported. To facilitate the analysis of the indicators, the model will be run for one month, respecting the working hours of the plant: twenty-six days per month and twelve hours per day. To simulate the improvement model, two simulations were carried out, one representing the current situation of the company and the other, the improved situation with the implemented proposal. For the second simulation, three changes were made to the system:

- The Hold tool was used in the activities that present queue, to hold the production when there are enough pieces in the Kanban. As mentioned above, the purpose of the Kanban tool is to reduce the mangoes boxes overproduction.
- Reduced the percentage of mislabelled boxes according to the success stories studied from the Jidoka and Standardization of Work tools.
- The time of the dispatch operation, which represents the search for a box of mangoes, was reduced as calculated.

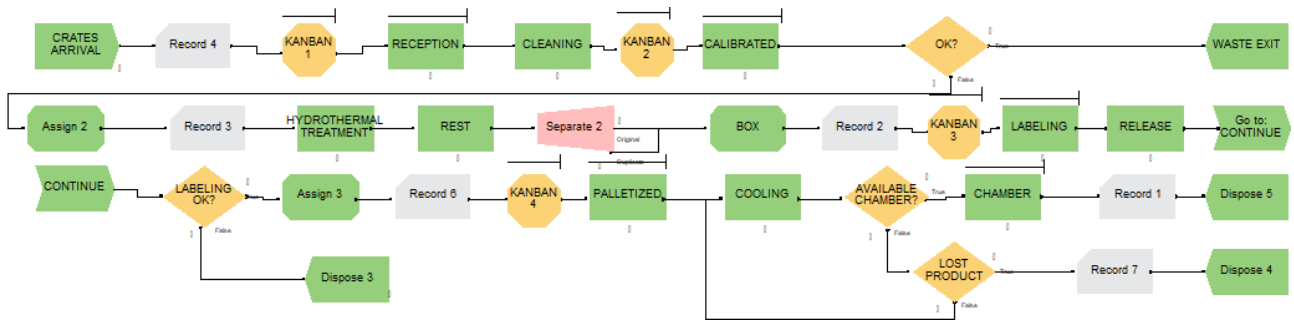

Fig. 2 Simulation of the system

4.3.Evaluation of the results

After performing the simulations for the current model and the improved model we were able to obtain the following results, exposed in table 2:

Table 2Indicatorresultsmatrix

Indicator	Initial	Target	Enhanced
% of boxes incorrectly labeled	7.62%	3.5%	2%
% of excess pallets	17.39%	14.5%	16.67%
% of pallets lost	9.09%	3.5%	13.64%
Product search time	5.71 hours / day	54.46 hours / day	4.5 hours / day

4.4.Discussion of results

Kanban, Jidoka, and Visual Control tools were chosen to reduce the search time of a mangoes box in the factory, which resulted in improving traceability in the company. According to the literature reviewed, it was expected to significantly improve the four indicators detailed in the previous chapter. Boxes percentage labelled incorrectly: The Jidoka and Standardized work tool allowed a decrease in the number of boxes labelled with the following parameters incorrect, avoiding reprocessing and facilitating their subsequent search by workers. The result obtained was 1.5% less than the proposed objective; in other words, expectations were exceeded.

Percentage of excess pallets: The Kanban tool was intended to reduce the number of excess pallets. In the simulation it was reflected that the indicator could improve by 0.72%; however, it did not reach the proposed target, the latter being 2.7% less compared to what was achieved.

Percentage of pallets lost: The Kanban tool was also used to reduce the number of pallets lost due to improper storage. While it was possible to reduce the number of pallets that did not enter the cold storage, the percentage of lost pallets increased by 4.55%; consequently, the calculated goal could not be achieved.

Product search time: As it has been mentioned, the objective of this work is to improve the products traceability; that is to say, to reduce the time that workers take to find a product. All the Lean Manufacturing tools allowed to reduce the search time by 1.21 hours compared to the current situation. Although, indeed, it was not possible to obtain what was planned in some indicators, in general terms the objective of the research was achieved: to improve the company traceability.

This research can be implemented not only in the agro-industrial sector, it also could be develop in different sectors because the Lean Manufacturing tools used are adaptable to any industrial process. Also, other tools, such as Poka Yoke, could be used to improve traceability, since one of the causes of inefficient product traceability is the labelling errors. The Poka-Yoke tool is a system that avoids the errors.

Also, a refrigerated waiting area could be considered in another investigation for the care of the mangoes that have not been able to enter the regular cold chamber, thus avoiding the raw material loss and the product could return later to the process.

5. Conclusions

- The Jidoka and Standardized Work tools reduced errors in the labelling area by 5.62%.
- The Kanban tool was able to decrease the number of excess pallets that could not enter the cold storage by 0.72%.
- Improved time to find the finished product by spending 1.21 hours less to identify the location of a mangoes box.

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