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Lean Six Sigma in agribusiness: A Case Study in a Cookie Production Plant

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Abstract — *the latest years have witnessed an increased demand for adopting continuous improvement methods and concepts. Lean Six Sigma is a real example that has proven its effectiveness in industrial and service sectors. This article will be the subject of a Lean Six Sigma application within a Moroccan SME specialized in cookie production. This application has followed the DMAIC approach to improve its performance and the quality of its products. Through Lean Six Sigma, the company improved the scrap rate by 6% and operational efficiency by 5.6%. Several results are presented in the article by introducing the set of Lean Six Sigma tools deployed. The article also discusses the application limits especially related to SMEs, and the effectiveness of the results, which has been influenced by the appearance of Coronavirus either for the investment or the project progress.*

Keywords — *Lean Six Sigma, DMAIC, Agribusiness, waste, SME, Case study.*

I. INTRODUCTION

The last few decades have witnessed intense competition from companies, increased pressure from the customer to deliver a product with high quality, lower cost and delivery time [1], and high growth in management and quality improvement in the international context [2]. Since quality is an essential element in the product, leading to the adoption of quality excellence and improvement programs such as Lean, Six Sigma, ISO [3].

Six Sigma LSS is one of the recent continuous improvement methodologies [4], an approach that enables efficient and effective processes, improving overall business performance and customer satisfaction[5]. The power of LSS is justified by its philosophy, which brings together the advantages and benefits of two big approaches, Lean Manufacturing LM and Six Sigma SS. Applying these two methodologies simultaneously always gives better results than implementing them separately [6]. The LM focuses primarily on non-value added activities and six Sigma, which aims at zero defects. They complement each other for a better use of resources and for a product that meets the customer's needs and requirements end-of-process. The LSS methodology is a methodology based on the customer and the project, aiming at the satisfaction of external and internal customers and an adaptation of the managers to a process with unexpected and constantly evolving situations[7].

The literature has uncovered the implementation of LSS in various organizations worldwide [8] in manufacturing and non-manufacturing sectors [9]. Applications have been extended to public services such as police [10], health [11], and education [12]. However, applications related to small and medium enterprises (SMEs) are too limited [11] [12], the same goes for publications related to the agri-food sector [15] where we find other requirements related to this type of organization and which influence the course of the application such as the perishability and heterogeneity of the product range of raw materials [15].

This article illustrates a case study of LSS application in a medium Moroccan company operating in the agribusiness sector in which we will expose the different phases of its application through the DMAIC approach, the various gains, and difficulties encountered during the implementation. The LSS methodology's choice is justified by the need to improve its overall performance and the quality of its products, enabling the company to satisfy its customers and face increased competition in cookie production.

The following section provides an overview of the LSS methodology and its application in SMEs for the article outline. Then, the different steps carried out in the DMAIC cycle are presented in the third section. In the fourth section, an insight into the results and the difficulties encountered is provided. An overall conclusion of the case study and a perspective will be revealed in the last section.

II. LITERATURE REVIEW

A. Lean Six Sigma Concept

No one can deny that the essence of the LM concept is waste elimination and SS is variation minimization. On the other hand, it appears that a precise definition for these concepts does not exist, adding that there is no consensus among researchers, academics, and practitioners on the components of LM, SS, and LSS [16].

a) Lean: The LM can be described in many visions as a set of principles, a process, a practice, a philosophy, a way of thinking, a set of tools and techniques, a manufacturing paradigm, a program, an approach, a concept, a system or a model[17]. The word Lean first appeared in the famous book 'the machine that changed the world' [18], a concept with its roots in the Toyota Production System TPS. For the Toyota company, LM is considered a philosophy that allows an effective and efficient organization. To overcome its problems related to the capacity and the low rate of its production, Toyota based its work on Henry Ford's research on the assembly line development and Frederick Taylor's work [18].

Lean's directive principle uses less time, labor, materials, and other resources needed to achieve the high value-added product that is also economically viable from the customer's point of view[19]. LM improves the speed of the process flow towards the customer, by fixing the connections and interfaces between activities or process steps, with improved process flow and with less effort, which is achieved through systematic and continuous improvement by all employees, within an organizational framework [20]. Furthermore, its contribution to the organization's efforts by bringing value to its customers and creating a respectful culture of others gives it a characteristic of a sociotechnical tool [21].

The applicability of LM has been proven in the literature by hundreds of successful case studies using several non-standardized models. Womack and Jones presented the principles of LM most commonly used in its implementation, which are: value, value stream mapping, flow, pull, and perfection[22] (see Fig. 1). At each of these steps, a Lean toolkit helps to eliminate all non-value-added activities. Those activities that do not add function, form, and value do not support the product or service generating process [23].

b) Six Sigma: LM was invented at Toyota by Taichi Ohno and Shigeo Shingo, while Six Sigma was first introduced at Motorola by its CEO Bob Galvin in 1986 to achieve 3.4 defects per million opportunities or Six Sigma[24] through process improvement by eliminating defects, minimizing process variability [25] and based on SPC [9]. Whereas the Lean toolbox mainly includes visual tools, SS and its toolbox integrate many advanced statistical tools for data analysis [26]. These tools allow identifying and eliminating errors, defects, or process failures that are directly related to customer requirements [27], [28].

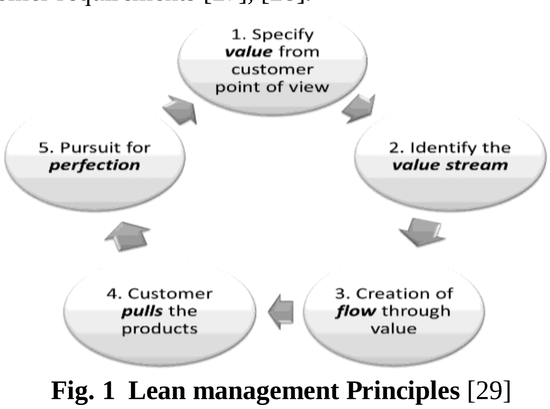

Fig. 1 Lean management Principles [29]

The fundamental difference between SS and other process improvement programs (such as Lean, TQM, etc.) is that SS can provide an organizational context that facilitates problem exploration and resolution in all organizational processes [30]. This approach allows both exploitation and exploration in companies. Six Sigma DMAIC aims to improve existing processes and proactively design Six Sigma DFSS or DMADV to introduce new products and services with high accuracy and precision [31].

c) Lean Six Sigma: The integration and the fusion of LM and SS as two powerful strategies for improving organizations are achieved to eliminate waste and reduce process variation [32] and other complementarity reasons to cover their weaknesses (see fig. 2). Lean attacks variation between processes by standardizing processes but does not address variation within a business process, exploiting statistical controls and the ability to improve operational processes; also for six Sigma, it can improve the speed and acceleration of its processes by taking advantage of Lean thinking in the elimination of waste [33]. Exploring the hybrid LSS methodology overcomes the Lean gaps in reducing variation and quality in processes, which results in net business benefits and increased customer satisfaction [34].

The integration of LM and SS as two approaches has created a new hybrid LSS concept, and it has also integrated their toolboxes and techniques. The new toolbox created includes statistical, non-statistical, and managerial tools such as 5Why analysis, failure mode and effects analysis, Pareto chart, 5S, kaizen, SIPOC, design of experiments, brainstorming, analysis of variance, regression analysis, cause-and-effect diagram, visual management, value chain mapping, standardized work, etc. [35].

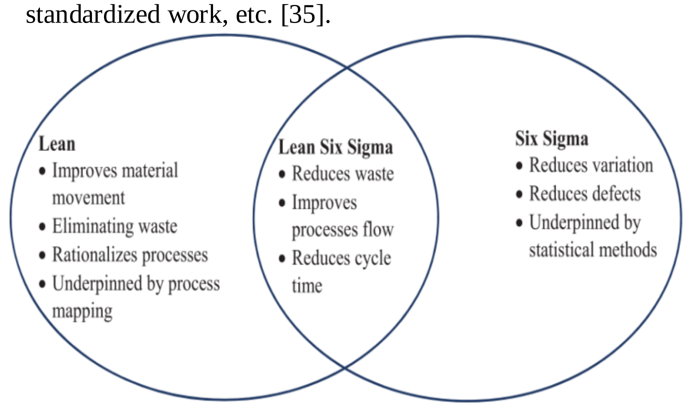

Fig. 2 The integration of LM and SS [36]

To implement the LSS, most projects are carried out through Champions, Master Black Belts, Black Belts, and Green Belts, similarly to Six Sigma [37], [38]. These LSS leaders have the techniques, skills, and tools to reduce waste, optimize resources and improve process efficiency through sustainable solutions [39]. The required skills and knowledge can be exploited through several methods that combine LM and SS [40], but generally, LSS is implemented by adopting the DMAIC approach for systematic and hierarchical implementation.

B. Lean Six Sigma - DMAIC

It is important to note that Six Sigma provided a " global problem-solving process" or "roadmap" within Motorola, known as MAIC (Measure, Analyze, Improve, Control) that could be sufficiently generic and applied to a wide variety of problems, thus eliminating the need to reinvent the Wheel/ cycle with each new project [13]. This MAIC process effectively integrated and linked the different tools to be used at each phase. General Electric GE also played a very important role in the development of the Six Sigma methodology where it added a "Define" step at the beginning of the MAIC process to have the present famous DMAIC approach [41]; this added phase gave stability to the other steps and can be considered as a directive phase of MAIC since the team defined all the essential resources in the project, the objectives and especially having a good definition of the problem and the critical quality.

There are several methods inspired by Six Sigma DMAIC either to improve a process or to create it. About [42], which is an example of the application of SS within Samsung via the DMAEV (define, measure, analyze, enable, and verify) approach invented after an in-depth study and carried out by the Samsung research and development team on the various successful applications of Six Sigma in the supply chain of large companies such as General Electric GE, which applied SS via DMADV (define, measure, analyze, design, and verify), and other companies such as DuPont and Honeywell. So choosing the right process is very relevant, but applying the five steps of Six Sigma requires a thorough understanding of each step, and therefore rigorous training in these methods must be conducted for employees and all staff [40].

The DMAIC model and its extensions were created to apply the Six Sigma approach. However, DMAIC as an approach is the most characteristic method of implementing LSS in organizational processes [43] in which the tools of the two boxes LM and SS are distributed over these five steps in a homogeneous, appropriate and adequate manner. Its application can be repeated if it is not successful at the first time because LSS implementation must also take into consideration the key success and failure factors of DMAIC [44]. It is true that most of the LSS implementations in the literature are carried out through DMAIC and have contributed positively to the effectiveness of adoptive organizations, but at the same time, others have found failures in the application of DMAIC with ineffective results [38]. DMAIC as a systematic roadmap is indeed designed for continuous problem solving and improvement with different steps; however, extensive use of resources can create environmental conflict as the disturbing impact on Sustainability [38] [45]–[48].

C. Lean Six Sigma in SME

The literature reveals a huge number of applications of the LSS methodology, either to validate models on several organization sectors or to test its applicability in specific services such as banks [34], police [48] or to evaluate the impact of this methodology on specific parameters or dimensions such as the environmental factor [50]. Among these case studies, the applications of LSS in large companies are numerous, which is not the case for SME's [51] [24] [14], which is similar to the LSS initiatives known by large companies and relatively unknown by the majority of SME organizations [52].

Some publications have discussed the links between SS, LM or LSS and SMEs to address the gaps in LSS implementation in SMEs within the literature. The reference [53] presents the different barriers cited in the literature concerning the implementation of LM and SS in SMEs; reference [13] also summarizes some of the documents presented in the literature on LSS in SMEs in which it indicated that most of the applications have not achieved the wished results and identifying the different barriers presented in the different LSS applications in SMEs. Additionally, there are studies that are based on or have discussed the factors of failure or success of LSS implementation in SMEs in order to create or propose application models more appropriate to this type of industry[54] [55].

The barriers related to the implementation of LSS in SMEs cited in the literature reviews are too numerous and may also depend on the nature of the organization, the country, or the culture. In the SME sector, barriers can be related to the lack of training, limited investment, low formalization and creation of standards, etc. A study carried out in SMEs in the UK on the initiative to implement the SS requires, in its early stages, training for all staff to launch the project, which is very expensive, and the same applies to the outsourcing of the service, where consultants and experts offer services at a very high cost and generally do not succeed in applying them, which is due to lack of experience and familiarity with the SME environment [56].

In this article, we will present the different phases of LSS implementation in a Moroccan SME, starting from the implementation initiative, the choice of the LSS methodology, the sources of investments, and the barriers encountered in this company.

III. CASE STUDY

A. Project Concept

A governmental initiative provides up to 90% financing to support the emergence of integrated logisticians and the modernization of logistics practices within Moroccan SMEs under a program to enhance the SMEs' logistics, entitled "PME Logis." The " PME Logis " program will rely on the expertise of consulting and accompaniment cabinets to meet the needs for support and technical assistance to SMEs benefiting from the program's products [57].

This case study is a part of this national initiative and accompanies a medium-sized company operating in agribusiness. We participated in this support through a consulting firm with two major missions:

- Elaboration of an operational progress plan
- Diagnosis of the company's Supply Chain performance

To achieve these goals, a number of projects have been decided where the LSS application is one of them. This article illustrates the LSS application and the support of this company to improve the quality of its products and reduce the waste related to the production process.

B. Company Background

The study company is one of Morocco's SMEs with 75 employees, including 10 sales staff. This company specializes in the manufacture and distribution of cookies and confectionery. It produces about 20 items between dry cookies and covered sandwiches cookies.

The cookie market is facing increasingly aggressive foreign competition. The three main competitors of Moroccan cookie factories are the Turks, Egyptians, and Spaniards. Taking advantage of the absence of customs duties on imports due to free trade agreements between producers from these countries and Morocco, we witness a growing import of foreign cookies that would grow 20% each year [58].

In this competitive market, the company is under an obligation to improve its operational performance in terms of raw material supply, production, and distribution to offer its customers competitive prices with product availability in all Moroccan cities.

Also, the company's turnover has decreased for the year 2019, the low profitability has made the company's management worried, and they have contacted two support and consulting firms to explore new opportunities for continuous improvement and to benefit from the financing advantage given by the government

C. Framework for Lean Sigma implementation: a case study

The framework deployed for applying Lean Sigma and its implementation is the DMAIC problem-solving methodology in which Lean Manufacturing and Six Sigma tools are imputing to each of its phases.

a) Define: To define the project's perimeter, the realization of a project charter has been essential. This charter has been made to reduce the non-quality costs from 0.92% of the turnover to 0.5% and the operational efficiency from 50% to a target of 65%.

Cookies Quality Problem: It is essential in an LSS project to design the critical to quality CTQ for the customer, so a series of meetings and brainstorming sessions have been carried out by the members of the company's team and the two external consulting firms who are leading the implementation of the LSS. Figure 3 presents the ISHIKAWA diagram, carried out to detect all the possible causes of cookies' non quality. To designate the most influential factors, a brainstorming was carried out with a higher weighting favoring the production managers who have extensive experience in cookies production.

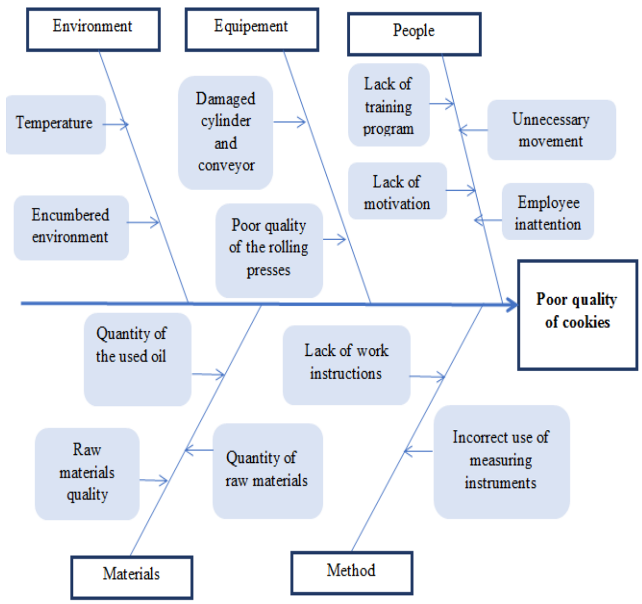

Fig. 3 Ishikawa's Diagram of the Poor Cookies Quality Problem

The team selected the oil quantity and the inappropriate use of measuring instruments as the main causes affecting the production quality, especially the cookie cracking, especially the cracking of the cookies, which is an important factor to judge the good quality of a cookie. In addition, oil consumption represents a very important factor compared to other raw materials and packaging, which is around 25% (see figure 4).

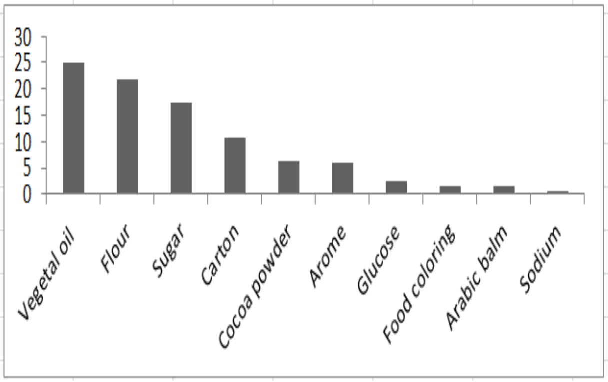

Fig. 4 Raw material consumption

Selection of the study product: Since the company produces a wide variety of cookies, it is necessary to choose products for study and for the different measurements. The team has chosen two criteria for selecting the products, which are :

- The cost of non-quality
- Turnover for each product

The selected products are then grouped according to the manufacturing process (dry cookies, covered cookies, and sandwiches). However, this article will discuss only the part of the dry cookies family.

b) Measure:

Measurement System Validation :

To analyze the oil problem, it is important to validate the measurement system first; actually, the production team uses 11 measuring tools, but the balance is the most frequently used and the most sensitive tool used by the operators and the foremen, this balance is used to weigh the correct oil quantity for each new mixture, a repeatability and reproducibility study has given a measurement capability of 0.83, which is unacceptable (see figure 5).

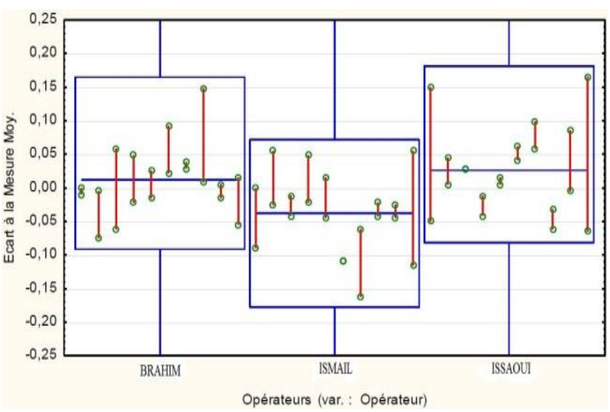

Fig. 5 Box plot of the measurement tool study

This result obliged the team to change the balance and carry out an action plan to make the instrument a source of credible and reliable data. The realized plan includes:

- Training for operators on the use of electronic and digital scales.
- The realization of a series of procedures concerning the use of the scale and its calibration
- The integration of a rubric in the IT system to monitor all the company's resources disposes of for the control of quality.

After the scale was changed and all the plan's actions were completed, the team re-verified the conformity of the measurement system, which gave a value of 7.08, judging the current measurement system as acceptable. The correction of this equipment has allowed the calculation of the quality level, which is essential to be situated regarding the objective; the result obtained a Z process corresponding to a proportion of nonconformities of 14.49%.

Current state map VSM:

The VSM realization is supreme in a Lean Manufacturing project and also provides the same added value for LSS projects because it allows:

- Identification of LSS projects
- Early detection of flow improvement opportunities
- Visualization of flows, duration, and timing of operations, resources, a process in which multiple information is gathered in a unique map.
- Identification of non-value added activities and the different waste in the flows.

Figure 6 provides an overview of the cookies manufacturing process's current state, which allows the identification of several improvement opportunities that are marked. Under each process on the map, we found the Machine Capacity (MC), the Cycle Time (CT), the Batch Size (BS), the Scrap Ratio (SR), and the Operational Efficiency (OE). This information has been used to extract further findings and quick results, where the most important are mentioned below:

- high waiting time
- A very significant gap between machine capacity and cycle time
- A very high proportion of scrap

c) Analyze:

According to the analysis of the control charts that represent the process behavior as well as the results of the Cp and Cpk indicators, it was found that the process is capable but badly centered, which justifies the presence of the special causes that pushed the production to be decentralized towards the target (see Figure 7).

A rating analysis was also carried out to compare the actual and theoretical rates for each workstation, where the actual rate was significantly lower than the theoretical rate. For this reason, the organization of the workstations and an adjustment of the theoretical rates must be considered as part of the improvement actions.

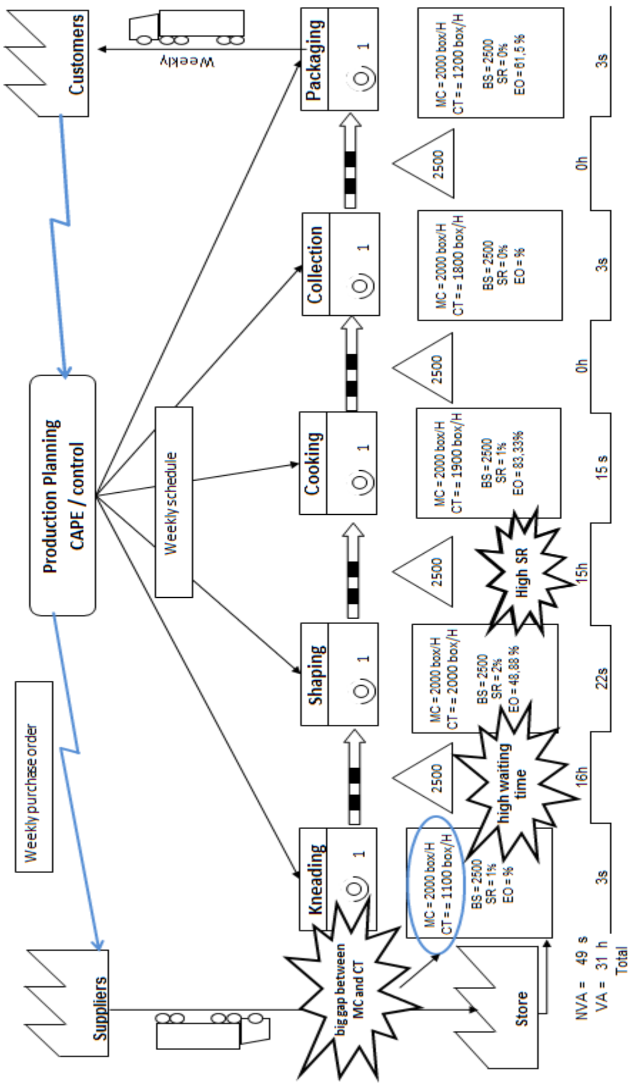

Fig. 6 Current Value Stream Mapping

In addition to production rates, the operational efficiency dedicated to each station (see figure 8) where the enrobing and spreading station does not reach the objective of 65% by 2020. This comes back to the system's database's poor use, which does not include operational downtime and breakdowns when calculating this performance indicator.

d) Improve:

Confirmatory test and control charts:

After changing the scale and the other actions related to its functioning, validation tests were required to validate the performed change. A set of tests and controls were executed where the team agreed on 5 samples every 30 minutes to validate the solutions' relevance.

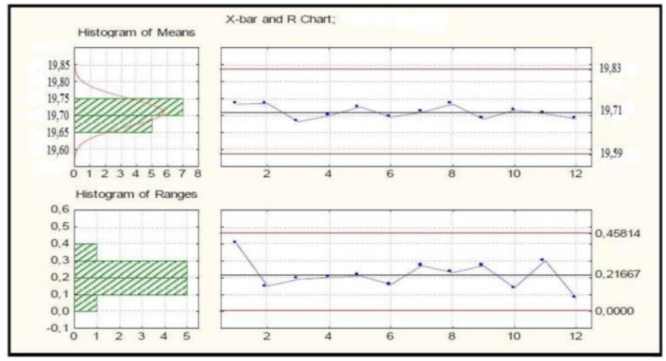

Fig. 7 The process control chart

In this context that we proceeded to implement control charts in the company's system where these charts will not be just used to improve the process controls but also to :

- Identification of released enhancements
- Tests for process stability
- Visualization of process anomalies (special and common causes)
- Creation of a KPI linked to the performance of the process

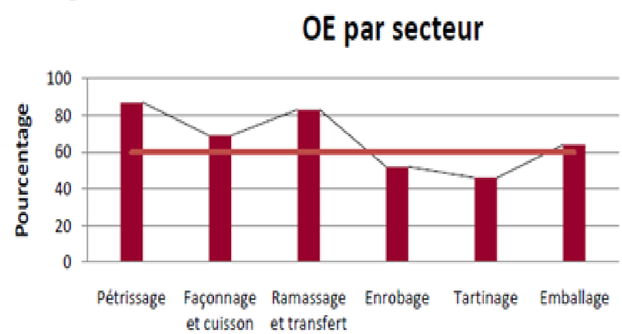

Fig. 8 Operational efficiency on every workstation

However, these control charts will allow the production managers to monitor better and visualize the process and predict the quality of the products, which was not possible before, which means monitoring the process instructions and the processes capability.

Reorganization of workstations:

To apply all the "improve" phase solutions, the workstations' reorganization will facilitate the success of the other tools of the LSS methodology as a sort of site preparation. In this project, we employed the spaghetti diagram to prepare the production workshop to reveal the most optimized circuits and movements to be considered in the 5S application and visual management.

The spaghetti diagram has allowed proposing various flow optimization solutions, either for the movements for finding tools and parts, operators' movements, and improving the flow through efforts minimization to move the items among the workshops.

5S application: Sort, Set in Order, Shine, Standardize, Sustain are the 5 steps of the 5S methodology implementation; they spontaneously rethink tidiness, cleanliness, and order. Such characteristics reflect the constraints in the agribusiness sector, which requires high hygiene specifications.

The 5S implementation in this company has allowed a more optimized flow due to:

- The significant reduction in space required for operations
- The organization of workstations with labeled, stored, and arranged tools in designated locations.
- The creation of a daily cleaning culture among the operators.
- The elimination of clutter caused by tools, equipment, and parts that are not used or are only used occasionally.
- The optimization of time allocated to the completion of tasks.

These benefits have increased productivity and physical flow transparency. In addition, the cleaning schedule and its instructions guarantee safe contact with food, which is important in the food industry.

Visual Management: Visual management is a key element for successfully implementing and pursuing 5S actions and programs. Its tools reinforce the detection of anomalies like Scoreboards were used to implement and to share visual indicators (production rates, machine status, measurement instrument control, ...), nameplates and workshop floor tracing were also added to facilitate the identification of anomalies and to avoid production interruptions. Visual management and 5S produced a radical change in the workshop's condition, and employees were satisfied to work in a new, colored and clean environment.

The 5S approach and visual management implementation coincided with the appearance of the Coronavirus. in fact that a set of actions for the staff and food sanitary protection has been taken into consideration both in the displays and the controls actions where these two tools have facilitated the communication and the protection between the team members.

Performance Indicators:

Performance indicators play a very important role in determining the company's progress towards its overall strategic objectives and goals. A set of performance indicators has been designated for a useful dashboard for controlling the production units' performance and monitoring process status, where the most important are operational performance and production efficiency. For this reason, operators are supported to help them identify the shutdown types, associate a specific code with each shutdown type and easily record these shutdowns in a file, which helps the shutdowns classification by category. In addition, to facilitate each workstation's task, a sheet of possible shutdown types has been developed to minimize the error rate during the data filling process. This line performance monitoring and the shutdown records will allow for immediate intervention in case of a drop in performance.

SMED Application :

The SMED method is extremely important in Lean projects. It is used to minimize changeover time between one product to another, optimize cycle time, and improve product quality, flexibility, and productivity. These advantages are a part of the objectives defined by the company.

The SMED application allowed a significant reduction in the changeover time since it performs 17 changes per month. Previously, the changeover was performed with an average duration of 109 minutes, and now the production team can achieve the changeover in 71 minutes. Therefore we optimize 38 minutes in each change.

e) Control: The LSS project's main objective is to correct the deviations and improve the situation and ensure that these improvements and results are long-term sustainable. Once all improvements are achieved, it was desired to conduct continuous evaluations to maintain the new situation. A number of control actions were suggested, which are :

- Training for the quality department staff on the respect and monitoring of the "control plan" related to improvement actions while integrating counter-actions.
- Periodical inspection and audit for the different measures of the actions proposed in the improvement phase.
  - Monitoring of the operational efficiency indicator
  - Audit on the SMED instructions monitoring
  - 5S audit via a checklist
  - Audit on the SOPs compliance
- Control cards piloting to maintain the control of the products out of specification

Finally, the standard in an LSS project aims to minimize the variation in the achievement of different tasks, which is a basic element for continuous improvement. Furthermore, the use of standard leads to uniformity and cost savings[59].In this project and especially for the different actions, a set of standards has been created to maintain the solutions and involve all employees. Some of the standards created are :

- Standard SMED methodology instructions for an optimal changeover procedure
- Standard of the scale's operating instructions.
- The standard for first-level maintenance.
- The standard for operators' operation sheet.

IV. RESULTS AND DISCUSSION

It concerns an LSS application in an SME; for the implementation, we followed the DMAIC cycle. This application allowed quantifiable gains such as an annual gain of 870.204 Dirhams, a decrease in a scrap rate of 5.96%, an improvement in operational efficiency of about 5.6%, and an increase in productivity. In addition, through this application, the company has benefited from several improvements in the organization and visual management of the entire process, hygiene, and working environment.

During the LSS implementation, we have encountered several difficulties, and the most important is that the project was launched at the beginning of the containment due to the coronavirus, where the company was not willing to invest in the project, which has been reflected in the financial amount allowed for the different actions, even though the government will reimburse up to 90% of the investment amount. For example, the solution of the scale variation and the incapability that we just proceeded to change it. However, we could orient to more credible, technical and even automatic solutions without involving the operators, creating standards, and realizing training pieces for adequate scale use. The confinement and the country's situation also influenced the project's progress, as a series of meetings were held at a distance. The consultants were unable to visit the workshops continuously to follow the project's progress better.

In addition, the human factor still posed difficulties starting from the top management, who was not convinced to accept the project in terms of gain and return on investment. Also, most employees were not trained for the LSS implementation, where much time was allocated to this project is spent in the coaching and internal training, especially since we met difficulties in their implications to understand the project's goals and their roles to ensure its success.

V. CONCLUSIONS

This article is a government program that supports small and medium enterprises to improve their performance, especially in logistics. After several meetings with top management and consulting firms, they decided to apply the LSS concept because it improves its operational performance through waste and variation reduction within the manufacturing process.

The LSS application framework is carried out following the DMAIC standard cycle using the tools of the two toolboxes, lean manufacturing, and Six Sigma, in each phase, and in our case, we deployed different types of tools and methods (SMED, 5S practice, control charts, R&R, Visual Management, standardization, Pareto, Process capability analysis, VSM, ISHIKAWA, ...). The LSS implementation has enabled the company to improve the production flow by minimizing several kinds of waste such as transportation, waiting time, changeover time. This implementation also improved the quality of the product, as the company encountered a variation in the oil quantity used in each mix, which influences one of the essential characteristics of the cookies, namely the dough cracking.

To maintain the innovation phase solutions, standards have been created in continuous improvement and action control. These solutions have produced an annual gain of 870204 Dirhams and an improvement in operational efficiency of about 5.6%, and a decrease in a scrap rate of 5.96%.

From a research perspective, we plan to survey interviews with operations management consultants to uncover all the factors that inhibit the Moroccan SME sector from successfully implementing LSS and other operations management approaches.

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