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Demand flow technology as a logistic strategy in a handmade production process. The case of *Moringa oleifera* leaf capsules

Tecnología de flujo de demanda como estrategia logística en un proceso de producción artesanal. El caso de las cápsulas de hoja de *Moringa oleifera*

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Abstract

This paper presents the case study of an SME whose main turn is the spraying and encapsulation of the *Moringa oleifera* leaf through the handmade production system. The SME markets the product in five presentations and produces 6200 capsules in ten hours with a total of one multifunctional operator per shift. Its supply chain is represented in four echelons: raw material preparation, manufacturing, marketing, and the final consumer. The encapsulation process of *Moringa oleifera* was analyzed, and the problems related to the excess inventory in the process, milligram per capsule difference, lack of standards to perform processes such as weight verification were detected. As a logistics strategy, the Demand Flow Technology methodology together with the operations diagrams and Value Stream Mapping to eliminate activities that do not add value to the product was applied. As a result, the correct assignment of tasks to workers and the increment of the production line productivity were achieved.

Value stream mapping, Supply chain analysis, Encapsulation process

Resumen

Este artículo presenta el caso de estudio de una PYME que pulveriza y encapsula la hoja de *Moringa oleifera* mediante un sistema de producción artesanal. Se analizó su cadena de suministro la cual se representa en cuatro eslabones: preparación de materias primas, fabricación, comercialización y consumidor final. Se analizó el proceso de encapsulación de *Moringa oleifera* y se detectaron problemas relacionados con el exceso de inventario, diferencias de miligramos por cápsula, la falta de estándares para realizar procesos como la verificación de peso. Como estrategia logística, se aplicó la metodología de la tecnología de flujo de demanda junto con los diagramas de operaciones y el mapeo de flujo de valor para eliminar actividades que no agregan valor al producto. Como resultado, se logró la asignación correcta de tareas a los trabajadores y el incremento de la productividad de la línea de producción.

Mapa de flujo de valor, Análisis de la cadena de suministro, Proceso de encapsulamiento

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Introduction

Moringa oleifera is a tree that comes from India, its leaves and stems are used as raw material for the pharmaceutical industry because of its antiulcerous, antimicrobial, antitumorous, and anticarcinogenic properties. *Moringa oleifera* is used for the food industry, the cosmetic industry (Subramonie *et al.*, 2020) and as a food supplement for bovine and ovine livestock, fish, rabbits and chicken (Estrada-Hernández *et al.*, 2016.

In the field of alternative medicine, *Moringa oleifera* is used to reduce the side effects in diabetes (Anthanont *et al*., 2016; Magaji *et al*., 2020; Taweerutchana *et al*., 2017) and as an auxiliary in the treatment of prostate (Khan *et al*., 2020), ovary, and colon cancer in humans. Moreover, it is used in cardiovascular disease control (Vergara-Jiménez *et al.*, 2017).

In Mexico, *Moringa oleifera* is cultivated in the states of Yucatán, Chiapas, Oaxaca, Veracruz, Michoacán and Sinaloa (Valdés-Rodríguez, 2019), which are located over the intertropical convergence zone between the tropics of Cancer and Capricorn (Martín *et al*., 2013).

For both, Mexico and Latin America, the challenge for the *Moringa oleifera* production systems is the management of ecosystems sustainability and the improvement of rural communities' diet (Olson & Fahey, 2011); by means of the optimisation in the production processes (Toral *et al*., 2013; Mora & N, 2015) and the insertion of new products in the national and international market (Seifu & Teketay, 2020; Venkatesan *et al.*, 2018; Ayinde *et al.*, 2016).

This paper presents a study case of an SME dedicated to the encapsulation of the *Moringa oleifera* leaf powder, which is located in the central area of the state of Veracruz, Mexico. The diagnosis of the *current* situation of the SME is made by means of an analysis of the supply chain by a generic model to analyze processed food supply chains proposed by Stringer and Hall (2007), which was used to study field agriculture under a productive system scheme (Sánchez-Galván *et al.*, 2019).

The productive system of the SME is analyzed by means of Demand Flow Technology (DFT) methodology) (United States Patente nº 6 594 535, 2003) as a logistic strategy to identify improvement opportunities with a Value Stream Mapping (VSM) of the internal process of encapsulation of *Moringa oleifera* leaf powder. A VSM shows the inventory flow and information to generate a product or service and allows the identification of activities that do not add any value to the process (Ghushe *et al.*, 2017).

This present paper is structured in five sections: (1) introduction, (2) background, (3) materials and methods, (4) results, and (5) conclusion. The sections Introduction and Background describe the origins of *Moringa oleifera*, its applications, and its development in Mexico; additionally, the productive environment of the supply chain is described and the Demand Flow Technology methodology is included as a tool to improve the internal operations of a company, and in the first phase with the use of VSM the activities that do not add any value to the integration of the most robust systems can be visualized. Moreover, the importance of the DFT as a management logistics strategy is addressed. The section of Materials and Methods describes the methodological steps that were used to the development of this work and describes the case study. The Results section presents the analysis of the SME supply chain that is being studied, the implementation of the first two stages of the Demand Flow Technology methodology and the identified areas of opportunity. The most important characteristics of this study are emphasized in the Conclusion section.

Background

Since the '90s the industry has been subject to intense global competitiveness (Martínez Jurado & Moyano Fuentes, 2011), which has lead the SME to improve their competitiveness and aspire to new markets (Ortega & Valencia, 2017), there lies the importance of analyzing and managing the supply chains (SC) to improve the internal processes and respond to the necessities of their clients-consumers (Alarcón *et al.*, 2016; Sandoval & Arce, 2014).

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Supply Chain Management (SCM) integrates the flow of materials, information, and finances which include suppliers, manufacturers, wholesalers, retailers, and consumers (Ballou, 2004). The coordination of these flows offers strategic and competitive advantages for organizations, and its functioning depends on the correct integration of departments involved in its logistic, organizational and directional structure (Silva, 2017). The integration of SC using strategic collaboration allows reducing costs, improving client satisfaction, and dealing with the challenges of global competitiveness (Delgado *et al.*, 2017). The collaboration seeks a win-win relationship between the SC parts when planning, working and carrying out operations together to increase their competitive advantages (Abeysekara *et al.*, 2019).

The benefits associated with the integration of the SC focus on decision making and taking advantage of the flows between operations (Bautista *et al.*, 2015). Correctly implementing the supply chain implies making the internal operations of a company efficient, and to achieve it, the support of continuous improvement tools is necessary (Socconini, 2013). In this case study, the two first stages of Demand Flow Technology (DFT) are developed as a logistics tool that would allow improving the internal operations of the company.

The DFT methodology focuses on improving the quality of the product in short time production, at the lowest cost, and directly focused on accomplishing the client's request (Ramírez-Santaella & Molina, 2004). The DFT focuses on minimizing the work that no added value to the production process emphasizing in the quality of the resources; it is based on the daily production programming with which the inventory is eliminated, both in the material in process and the finished process in a way that DFT involves all the supply chain from the productive echelon to the raw material suppliers (Kampouris & Miller, 1994).

DFT supported by a VSM in the first implementation phase allows the understanding of the production process through mapping the process in a graph (Villaseñor *et al.*, 2009; Rajadell & Sánchez, 2010). VSM identifies the flows of processes and waste (Razali & Ab Rahman, 2019), which allows dealing with problematic situations related to the efficiency of people's communication, materials, equipment and processes (García & Amador, 2019).

A VSM focused on a company of lean manufacturing is developed in eight steps; (1) defining a commitment, (2) choosing the process, (3) lean manufacturing learning, (4) mapping the process of the current state, (5) defining the key performance indicators, (6) map of the process of a future state, (7) creating Kaizen plans, and (8) implementing Kaizen plans (Villaseñor & Galindo, 2009).

A VSM focused on emphasizing the use of the tool as a way of making the improvement opportunities visible in any process. It can be made in five steps: (1) mapping the current state, (2) measurement of performance indicators, (3) identification of opportunity areas, (4) choice of techniques to improve the process, (5) mapping the future state (Paredes, 2017).

A VSM can also be done in four steps as a mechanism to know the opportunity areas of a process or system: (1) establishing product families, (2) mapping the current state, (3) mapping the future state, and (4) making improvements during the implementation of Kaizen events (Socconini, 2013).

The study of the supply chain allows the identification of the materials flow, information, and finances of an organization. At the same time, the correct study of the SC allows establishing strategic advantages, as well as correctly integrating the different departments involved in the logistic structure. The improvement of the internal processes directly impacts the SC and continuous improvement methodologies like DFT supported on tools like VSM with its four steps that allow identifying activities that add value to the product while exposing those that do not.

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The harmonization of these two continuous improvement tools allows on one hand studying the current state of the process, and at the same time they show the opportunity areas for the company, and supported by Kaizen events it is possible to intervene these opportunity areas in benefit of the company and the clients that make use of the products and they pay for them.

Materials and methods

Methodology

This is qualitative research, based both on moderate observation and in face-to-face interviews to identify individual and collective activities in regards to the economical causes that interact within the organization. The qualitative analysis will help to understand the SME context and determine the structure of the productive process (Hernández-Sampieri, 2018).

The methodology used for carrying out this research is shown in Figure 1.

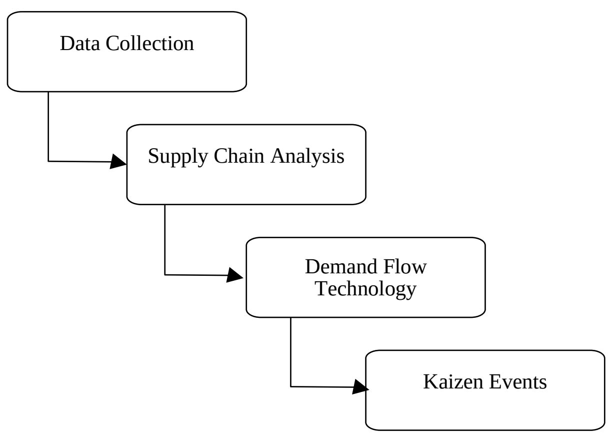

Figure 1 Methodology to improve the Moringa oleifera encapsulation process
Source: own elaboration

Data collection

The data collection was carried out through face-to-face interviews with the owner of the company, technical person, and process operators. To achieve the correct description of the activities, the people in charge of the process were interviewed directly, who through their experience were able to provide the information for general documentation and they explicitly helped for the construction of flowcharts of each of the main processes (encapsulation, tea leaves, and food supplement).

Supply chain analysis

It was defined with face-to-face semi-structured interviews to integrate a generic model of the agro-food supply chain proposed by (Stringer & Hall, 2007), which analyzes the productive system through supply chain decomposition into hierarchical components (stages, operational steps, and unit operations).

Demand Flow Technology Methodology

Two methodology stages were implemented. Stage 1 describes the family products through a flowchart of the process, determination of the time cycle, mapping the process (Value Stream Mapping), and Takt time calculation. Stage 2 describes the resources requirements, the standard operations development, and the distribution of the factory (United States Patent number 6 594 535, 2003).

Kaizen events

The Kaizen events were gradually implemented and in an orderly manner in each operation where the areas of opportunity were identified. The proposals with an improvement approach were made with the help of the people in charge of the process and the management. Additionally, the experience of a team member with decision-making ability was considered, the members of the team participated and the logistic was prepared, with the project agenda, all the members were notified of each event and at the end, the Kaizen event was defined in a standard way, with the objective that when each Kaizen event is finished it can show measurable changes in the results of each operation (Ramírez Alvarado & Alvarado Pumisacho, 2017).

Case Study

The study is centered in an SME from Veracruz dedicated to processing *Moringa oleifera* leaves, under the scheme of Rural Production Society of Limited Liability and Variable Capital, properly constituted in a public deed dated on February 2nd, 2017, and it is properly registered in the Public Registry of Commerce in the city of Veracruz, Mexico and with a valid Commercial number.

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The SME is classified as a micro-enterprise based on the workers number (4 employees) according to the established stratification in section III, article 3 from the Law for Competitiveness Development published in the Federal Official Gazette (Ley para el Desarrollo de la Competitividad de la Micro, Pequeña y Mediana Empresa, 2019).

The SME grinds products in three presentations: capsules, tea leaves, and leaf powder as food supplements. The grinding of these products is carried out with dried leaves of *Moringa oleífera* (delivered by only one supplier) and the production processes are adapted to the necessities of the product presentation and the aimed market.

The SME uses a handmade process of raw material transformation, which is its main characteristic. The SME in this study belongs to the agro-food industry, and it's dedicated to the production of Moringa oleifera capsules under the food supplement market.

Its productive system depends on the facilities and the owner's abilities. A "Push" system is used as a production method with a lot size of approximately 5 kilograms. The works are done according to the availability of raw material and based on the availability of workmanship. There is no documentary evidence of the work in process is not available.

Results

Supply chain analysis

In this study, four echelons related to the *Moringa oleifera* leaf are identified: production in a farm, manufacturing, commercialization, and purchase (Figure 2).

The SME is the one that produces and uses its supply and distribution infrastructure. This makes it seem like a logistic vertical type chain 1PL. The 1PL logistics operators also known as First Party Logistics are characterized by managing a self-sufficient logistics function, which mainly buys and sells in the same place or area (Ramírez Castellanos, 2015).

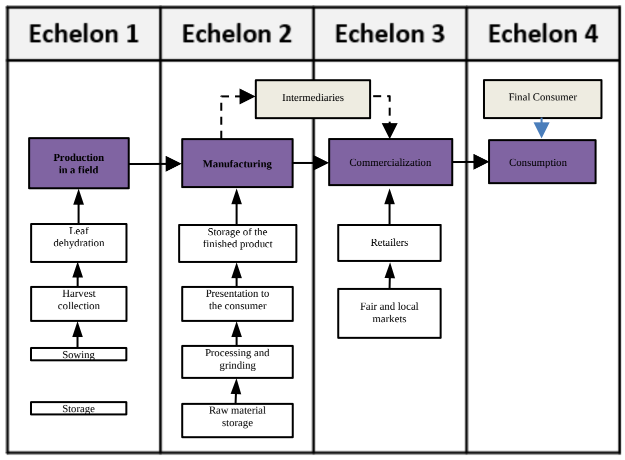

Figure 2 Moringa oleifera leaf supply chain
Source: own elaboration

Economical agents: With the information obtained from face-to-face interviews, three economical agents in the chain supply have been identified: the producer, the intermediary, and the final consumer.

The producer refers to the landowner where the plant *Moringa oleifera* is cultivated, and to the one who manufactures the *Moringa oleifera* leaf. For this specific case, the owner is the one in charge of the echelons 1 and 2 (production in fields and manufacturing). The intermediary is the one who acquires the product directly in the facilities of the company and distributes and/or commercializes to thirds. The final consumer is the one who benefits when acquiring the product.

Echelon 1. Production in a field

The production is the first echelon of the supply chain, there, the land preparation activities, cleaning, sowing, harvest collection and dehydration of the *Moringa oleifera* leaf are held. The land preparation consists of plowing for sowing using mechanical and manual tools, in a way that the earth (means of sowing) is as soft as possible to take advantage of the environment humidity or the irrigation. The cleaning consists of taking away the weed in the cropland.

The harvest is done by the use of a calendar, to determine the maturity of the leaves; furthermore, the size, color, and maturity degree of the sprouts and stems are examined.

The leaf collection is done manually using basic supplies like plastic buckets, a special bag used to carry crops, and textile bags.

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The leaves are detached by using the fingertips (thumb and index), sliding from the upper part to the lower part, being careful not to hurt the plant stem, and the leaves are placed in the collection utensils.

The dehydration process of Moringa oleifera leaves takes 4 to 6 days depending on the weather conditions and season of the year. This consists of placing the only just cut and collected leaves in stretcher frames (built with wood frames and plastic net), organized inside a handmade dehydrator (PVC structure covered in black plastic material, inside it has plastic shelves where the stretcher frames are placed).

To store and take products from one supply chain echelon to other bags and plastic boxes (containers) are used, in a way that humidity is kept in the *Moringa oleifera* leaf. The plastic bags are color black so that the *Moringa oleifera* leaf is protected from the sunlight, and they are put inside the plastic boxes to keep the humidity of the leaves. Through containers are how the leaves are transported to the second echelon in the supply chain.

Echelon 2. Manufacturing

The raw material transformation process is handmade and is part of a basic characteristic of the company. The products that are manufactured are *Moringa* 5 milligrams capsules in a presentation of 30, 60 and 100 units, *Moringa* tea in 50 grams presentation, and supplement in jars of 30 grams.

The capacity of the company allows producing 6200 capsules in one work shift at a normal pace, taking into account the operators' abilities, in a 10-hour shift and a constant pace we could expect 62 jars of *Moringa oleifera* capsules in a presentation of 100 units. That is, if the company would want to increase the production capacity, it needs to intervene in its current production system and based on that, make decisions to increase its production levels.

In the raw material storage room, the *Moringa oleifera* leaf is received and labeled, which is stored in plastic material containers. In the reception process, the raw material is weighed, examined, labeled and stored temporarily until the raw material is needed for production.

The storage and use of *Moringa oleifera* are done through the FIFO (First-in First-out) method. In the area of processing and grinding, the raw material is prepared, there the *Moringa oleifera* leaf is selected and visually examined.

The examination is done when the product is needed for the production of capsules, tea leaves or food supplements. The product is examined so that it meets the requirements of the process. The examination is understood like taking off the husk, dry leaves, and pieces of stems from the product, and all flaws that the raw material may have from the dehydration process in the field.

The sanitizing process refers to the innocuousness of the *Moringa* leaf, as well as taking off the excess of humidity that the leaves may have. In this case, the sanitizing process not only refers to maintaining the necessary conditions so that the leaves are processes, but also establishing a standard that can be part of the process of grinding and pulverization. In this stage, the leaves go through a process of dehydration using applying heat and maintaining a sterile environment of the product, in a space that is free of external pollutants.

The grinding process not only applies to two processes: food supplement and encapsulation. The grinding consists of processing the *Moringa oleifera* leaf through different sieving to obtain a specific powder, but approval tolerances have not been defined. In the case of the encapsulation process, this is repeated during three cycles until the expected results are obtained. In this sense, the process greatly depends on the expertise of the operator and there is no documented process, nor established control for the acceptance or refusal of the product. This is why the acceptance or refusal criteria are defined by the operator's experience to be able to continue into the next operation.

The encapsulation process is a handmade process in which the powder of *Moringa oleifera* is encapsulated, the operator is the one in charge of executing it. When the encapsulation has finished, a sampling by acceptance of 5 capsules is done, and in which, each capsule must weigh 5 milligrams. In case the five capsule samples taken randomly from the lot do not weigh that amount, they are all processed again.

The activity called consumer presentation refers to the packaging, labeling and boxing up of the product. Filling the containers is done manually and it is done in different presentations: 30 capsules, 60 capsules and 100 capsules in plastic containers. The Packing is done in boxes, each box holds 30 jars for its storage.

The intermediary and producer are who transport the product between the second and third echelon. The producer transport small amounts of product to local fairs, local markets, and retailers.

Echelon 3. Commercialization.

According to the typology of commercialization schemes proposed by Rodríguez y Riveros (2016), the SME in the study is found in a short circuit commercialization scheme.

The SME is an individual producer organized informally, it does not have certified products and it does not make any previous agreements in the product's buying and selling negotiations.

Between the second and third echelons (manufacturing and commercialization) the intermediary as agent economy appears. The negotiation is done directly and not based on a sales forecast. There are no signed contracts and the relationship between them is based on trust.

The producer also does the commercialization process in local fair markets, local markets, and retail distributors (inside and outside the city). In the local markets, the producer makes the product known (flyers, pamphlets, and presentation cards) and sells the product to the general public. The fair works as a type of advertising and point of sale.

The local markets and retailers are their main clients, dedicated to alternative medicine and food supplements; the product is left on consignment and it depends on resupply (when the product is sold, the product is supplied) which is done based on the delivery calendar through established routes.

Echelon 4. Consumption

The final consumer is in the last echelon, who uses and benefits from the product (*Moringa oleifera* capsules) through its purchase. Concerning the client's specifications and necessities (CTQ), the SME has not defined nor specified those quality requirements formally. Nevertheless, the minimum requirements in regards to good practice and manufacturing and the ones related to food innocuousness are met. In regards to the sale registers, these are calculated monthly based on the deliveries of the producer to the clients.

Opportunity areas

Analysis of the supply chain allowed five areas of improvement to be identified: (1) Inexact product dosage, (2) Unnecessary transportation and storage, (3) Underused workforce, (4) Excessive inventory in process, and (5) Manufacturing practices.

Inexact product dosage. The encapsulation process (echelon two) is handmade and it is done through a manual encapsulation where the operator with his experience and ability calculates the amount of *Moringa oleifera* powder that each capsule is made up of which is manufactured in lots of 200 units.

The calculation of *Moringa oleifera* powder is done empirically, and the result is only known at the end of the operation when 5 capsules are taken and weighed, if the weigh is adequate then they go on to the next operation if not, the capsules are disassembled and they are processed again.

Unnecessary transportation and storage. It occurs in the second echelon when the dehydrated *Moringa oleifera* leaf is transported to the preparation, encapsulation, verification, and packaging areas. The distribution and arrangement of these operations in the current facilities were organized according to the producer's experience, and they do not follow the linearity in its distribution which causes the number of rounds to be multiple and of long distances. In the process, there is an excess of movements and in-process material transportation and it implies a constant relocation of the product when processed in five kilogram lots.

Underused workforce. Since the process is handmade, it implies a high dependence on the workforce, thus having two operators allows an assurance that the product will flow into the market. The company has four people that work there formally, however, the ability of these operators is limited to only one part of the process. They do not get involved in additional activities, so the process, in general, is fragmented. This suggests the possibility of having multitasked operators to guaranty that the process does not stop in case any of them is absent, even when there is a person in charge of the process who knows the general functioning.

Excessive inventory in the process. On average there is a two-month inventory for raw material, material in-process, and finished product. Also, there is machinery distributed in work areas from raw material reception, going through the powder and sanitation area, which results in a working system that uses lots. The problem starts in the processing, then the process of packaging the product, then the final result. This represents for the company a waste of time and causes deficiencies, directly affecting the client deliveries and thus the utilities for the company.

Manufacturing Practices. In regards to the facilities and necessary regulations, the company has determined activities related to good manufacturing practices; however, there is no documentary evidence related to these activities. Moreover, there is no evidence of established procedures that allow the company to guaranty repeatability and reproducibility both in operations and in activities the operators do.

Demand flow technology application

Stage 1. Product Families Definition

The information collected from a face-to-face interview allowed identified the product's families from this case study (Table 1).

Products	Presentation
Moringa capsules (30 capsules)	Jar
Moringa capsules (60 capsules)	Jar
Moringa capsules (100 capsules)	Jar
Food supplement	Jar 30 grams.
Tea leaves	Bag 30 grams.

Table 1 SME Product families in the study
Source: own elaboration based on information collected from the SME

The study of time required for the activities that involve the process of *Moringa oleifera* leaves encapsulation allows determining the time it takes for the processing of capsules cycle in the SME. In this study pieces/second as a measurement unit were defined.

The strategy to find a representative sample when elaborating *Moringa oleifera* capsules mainly consisted of two steps:

The first step consisted in identifying if the product sample of 1 capsule taken randomly from the lot weighs according to the sale reports provided by the SME owner, those are the *Moringa oleifera*. This in addition to having support in the production program that the company has and that coincides with the production of capsules due to high demand.

The second step allowed the identification of activities and materials needed to manufacture the *Moringa oleifera* capsules using Bills of Material (BOM). The product BOM is shown in Figure 3 and it shows graphically the necessary components to make one piece (1 Jar with 100 capsules) which allows the estimation of the amount of raw material and necessary components for the demand programming, according to the clients' needs and requirements.

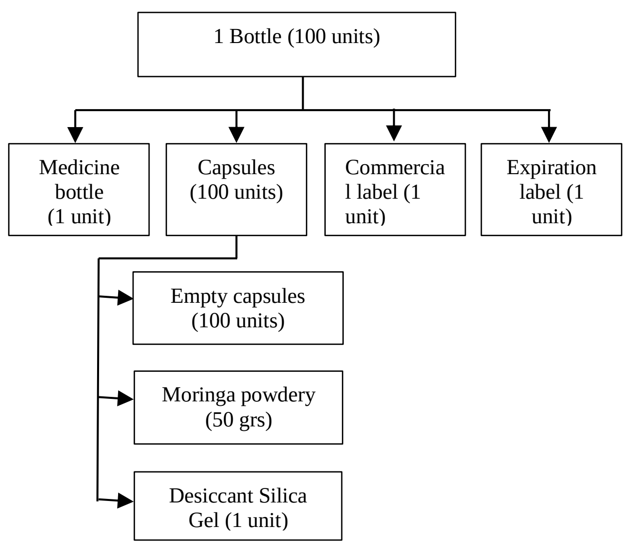

Figure 3 Bill of Materials (BOM) for Moringa oleífera encapsulation
Source: own elaboration

For the study case and in accordance with the central limit theorem it was decided to observe the process during an 8 hour shift and register the time to process a 5 kilogram lot to achieve a total of 62 jars of 200 capsules in one day of work with one operator, and to achieve this level of production 10 hours of work were required, thus in average 6.2 units per hour were achieved and each finished unit was achieved in 9.67 minutes. Table 2 shows the time of cycle for the processing of *Moringa oleifera* capsules including the time for storage which was calculated based on the amount of finished product that is not sent to market.

No.	Activity	Time (seconds)
1	Raw Material Reception	10139
2	Cleaning of moringa leaf	227
3	Selection of Moringa leaf	11212
4	Sterilization (1)	8327
5	Milling	2342
6	Powdery	2580
7	Sterilization (2)	8640
8	Capsule Process	12230
9	Packaging	1162
10	Commecial Labeling	481
11	Expiration Labeling	212
12	Storage of the finished product	2592000
	Total	2649553

Table 2 Current cycle time for the Moringa oleifera capsule processing
Source: own elaboration based on information collected from the SME

Indicators measurement

The current situation state would not be complete without the development and explanation of three specific concepts: effective capacity, cycle time, and takt time.

The effective capacity of the company corresponds to the 63% which shows that it is capable of achieving satisfactorily, in the proper time and form with 63 out of 100 units required by the market, while the process efficiency is 43.5% which is why the company requires an extra time of workforce, increase their days of production, and hire temporary staff to be able to reach the market necessities. The current cycle time to produce 2 consecutive units corresponds to 25820 seconds, without considering the 90 storage days of the finished product.

In contrast, Takt time corresponds to 221.76 seconds, which means that the market demands one unit of product (jar with 100 capsules of *Moringa*) during this time. As a result of these indicators, it is shown that it is necessary to intervene in the production process to decrease the current cycle time and take it as closely as possible to Takt time.

The sequence of events with the operations classification and the work in process, work and mobility (transportation), the contributions allow evaluating that the preparation activities take up 62.03% of the effective time, in work it represents a total of 36.7% and the transportation contributes 1.30%. In this sense, the actions involve working with the preparation activities so they considerably decrease and this implies changing the production system to lots of 5kg for only one piece (200 capsules) considering that the encapsulation is the most time-consuming of the process.

Table 3 shows the flow matrix of the current process, which presents in detail the sequence of events for each product. This presentation is limited to only the encapsulation process to show the usefulness of the tool when the 10-hour shift is finished with one operator 62 units (each unit with 100 capsules) is finished and each unit is processed in 426 seconds.

#	Activity	Lote Size	Time (in second)		
			Capsule process	Food enrich-ment	Tea leaves
1	Raw Material Reception	5 kg	2399	2399	2399
2	Cleaning of moringa leaf	5 kg	227	227	227
3	Selection of Moringa leaf	5 kg	3532	3532	3532
4	Sterilization (1)	5 kg	3600	3600	3600
5	Milling	5 kg	2342	2342	
6	Powdery	5 kg	2400	1440	1152
7	Sterilization (2)	5 kg	7200	7200	7200
8	Capsule Process	100 gr	1310		
9	Packaging	2 pieces	1903	1142	913
10	Commecial Labeling	2 pieces	542	542	542
11	Expiration Labeling	2 pieces	364	364	364
	Total		25820	22789	19930

Table 3 Current process flow matrix
Source: own elaboration based on information collected from the SME

With the data of the time required per work station and process, the next step is to calculate Takt time. To do so, two variables are required: work time and the client's requirements. For the case that is being analyzed which is the encapsulation, the data and the calculation of Takt time are the ones shown in Table 4. As a result, it was found that for a 2500 jars demand of 100 capsules, the client is willing to buy each piece every 221.76 seconds. When comparing takt time with the average cycle time of the process it is noticeable that the current 581 seconds to supply one unit is much more than what the market demands.

Description	Total	Units
Hours per day	8	Hours
Lunch	30	Minutes
Morning break	30	Minutes
Minutes per shift	420	Minutes
Seconds per shift	25200	Seconds
Monthly Demand	2500	Units
Number of shifts per month	22	Days
Demand per shift	113.64	Units
Takt time in seconds	221.76	Units

Table 4 Takt time calculation
Source: own elaboration based on information collected from the SME

Improvement opportunities in the process

VSM analysis identified four activities that do not add any value: (1) Raw material reception, (2) Raw material selection, (3) Sterilization area, and (4) Grind-pulverize process.

Kaizen event 1

Raw material reception. The raw material reception activity does not have a procedure to receive the raw material nor does it have a system that allows guaranteeing the useless life of the product before it enters the production line. The food industries seek to offer their consumers innocuous and good quality products, thus incorporating traceability ensures food safety and it should be developed throughout the supply chain (Castillo Ramos, Maldonado Astudillo, & Solis Navarrete, 2019). The corrective action consisted of placing a label to identify the lot and reception date to start the traceability process. The traceability will allow having the record of the product and give guarantee to the client that all the added value obtained during the production process and through the normative requirements and that the product and innocuousness will be handled the best way.

Kaizen event 2

Raw material selection. The raw material selection requires personal safety equipment. The selection method is handmade using the operator's criteria. One of the current limitations to guarantee the repeatability in the process is the actual staff rotation. Since there is no documented method to carry out this activity, it was proposed to make these documented proceedings to generate the critical to quality (CTQ) of the process. Moreover, it is necessary to establish a measurement system analysis (MSA), to ensure that the inspectors have the same acceptance criteria according to an established standard. Establishing criteria to select material these must include when inspection and classification activities proceed before its production, and if necessary, lab tests must be done to establish if they are ideal to be used. Only healthy and adequate materials should be included (De calidad, S., 2002).

Kaizen event 3

Sterilization area. The sterilization area is fundamental for the final phase of the process because it is where sterilization of equipment and necessary material for the *Moringa oleifera* leaves, specifically for encapsulation, takes place. Indeed, this area does not add value to the product, but it is necessary to guarantee the innocuousness of the product, it is a technical process requirement. Currently, protection equipment is used to enter and remain in the area. The access is registered in logs where the current state and people that enter are registered to maintain a controlled environment, but it does not have documentary information related to good manufacturing practices (GMP) for controlled environments. Good practices starting at primary production is an echeloning strategy to guarantee the quality and innocuousness preservation from the production to food consumption. How it is carried out is through rational and documented processes to ensure the quality of the products, from production, transformation, transportation, preparation, to food consumption (Garzón, 2009).

Kaizen event 4

Grinding-pulverize process. The grinding process is done through an operator, a mill and different sieving. In the process, the *Moringa oleifera* leaves are crushed. Nonetheless, since no system allows knowing how this is done appropriately, the acceptance of the product is based on the operator and production supervisor's experience. The lack of evidence in the performance analysis, along with the absence of defined criteria both in individuals and in the organization, does not allow the organizational efforts to be turned into accomplished goals. This is why having defined criteria in an internal measurement system will have as a consequence the improvement of the performance of each process (Fernandez *et al*, 2012). The action that was taken consisted of the development of the procedures to generate critical to quality and a method to determine the grinding with maximum and minimal acceptance (quality standards) and performance indicators. This event is decisive to guarantee the quality and standardisation of the product.

Stage 2. Line production design

The amount of people that are needed in the line of encapsulation is obtained from the Takt time which is the pace in which the demand for the products in the market must be achieved. Using the formula Number of people (NP) where the standard time and the Takt time are related. The standard time is the total amount of time per station for each product, and it is taken from the sequence of events. The number of people that result from the arithmetical operations is not rounded, while the ones for work stations, being that they are discrete variables, are rounded. The number of people and work stations for the process of encapsulation will remain as follows:

Encapsulation process

Number of people = (Standard time/Takt time)
Number of people = (581 seconds/221 seconds)
Number of people in encapsulation process = 2.62 people

Work stations = 2-3

In summary, between 2 and 3 people with 2 to 3 work stations are required to accomplish the market demand. However, since the encapsulation process is the operation that requires more time in the productive system it was initially decided to have a line of design with only two operators.

There is a breakdown of each of the operations involved in the encapsulation process of the *Moringa oleifera*. The process to produce 200 capsules is described, it is done by using 105 grams of *Moringa oleifera* dehydrated leaf and considering two operators in the process from which in an 8 hours day with 7.5 effective hours of work 82 jars with 100 units each is obtained.

Some of the processes that were intervened were bottling and labeling. For bottling the time was reduced by suggesting that if capsules weigh in average 5mg and each jar contains 100 capsules, then weighing them would facilitate the bottling process (50 grams per unit). The labeling process decreased time considerably when incorporating a manual labeling machine both for label 1 and label 2.

The physical distribution of the plant is shown in figure 4 where it can be seen that the processes are separated and there are long distances to be covered to carry out the activities related to the encapsulation process.

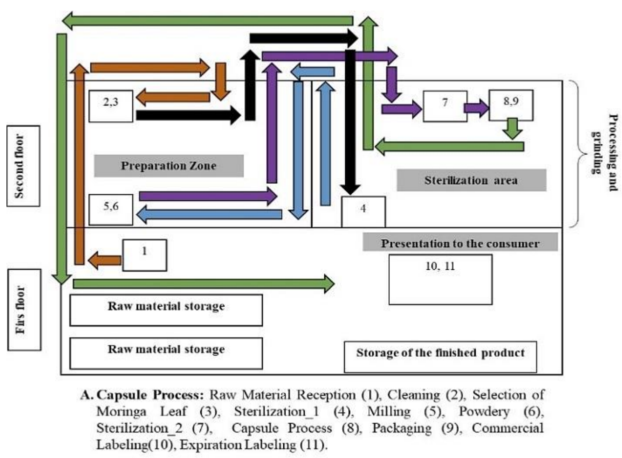

Figure 4 Plant distribution for Moringa oleifera encapsulation process
Source: own elaboration

The map of future value built based on the Kaizen events identification, and the improvements that are foreseen for the encapsulation process, which include the replacement of processes, this reflects how which material flows between the operations.

Based on the future VSM for the encapsulation process there were some adaptations to show the sequence of logical steps in the design of the production line. First, a redistribution of the plant was suggested to minimize the distances covered. The change consisted in adding equipment (a microwave oven), used to sterilize and standardize the process of drying the leaf, to the preparation zone (3) and maintain the equipment in the sterile area to use the equipment to prepare the other necessary utensils in the encapsulation (3a). The design representation of the line is shown in figure 5. In the proposal of the line for *Moringa oleifera* encapsulation two operators were considered according to the requirements and calculated resources. Two IPK were determined. The first one of 100 grams placed before the encapsulation process, and the second before the bottling process with an amount of 200 finished capsules. The size of Kanban was made considering the processing time for encapsulation, which is the most time-consuming process and which generates 200 capsules per time cycle in the process.

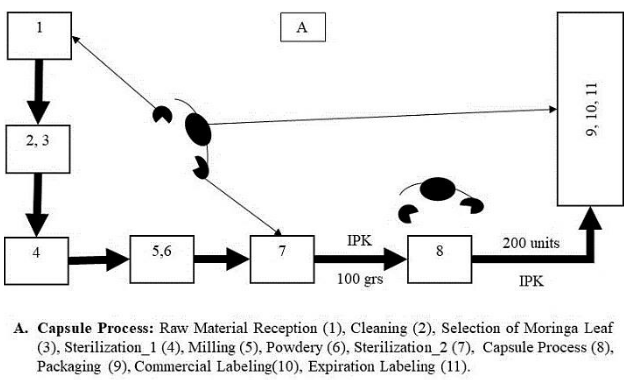

Figure 5 Line suggested for Moringa Oleifera encapsulation process
Source: own elaboration

DFT as a logistic strategy

The DFT application allowed determining areas of opportunity within the production process: demand, production flow, and technology.

In regards to the demand, the process now can adapt to different amounts that the market demands, commit to delivery dates, and above all plan the resources the production process requires.

In regards to the production flow, the heart of the DFT is centered in the continuous flow in a way that the operator-process interaction is harmonious, which decreased the material transportation and the distances covered, as well as a decrease of work in the process derived from the action of planning the operations to use the most limited resource.

In regards to technology, since it's a handmade and traditional process in its operations, the level of technology is low, and to migrate to the automation of the process it should be done gradually and according to the economical possibilities of the organization. Below, there is a summary of the corrective arrangements applied to the process.

It was decided to change the current lot system (5 kilograms) to a continuous flow system where amounts are managed per 105 grams cycle, obtaining a finished product in 655 seconds that, compared to the 25820 seconds of the initial process, show a significant improvement, which allows giving response to the market in less time.

The reduction of the amount of inventory between operations in terms of timing was notable, derived from a lot of 105 grams instead of 5 kilogram lots, which meant improving the waiting time between processes to 35400 seconds. The improvement in the flow of materials and information had an impact on the quality of the product because of the inspection in place that the operators do between operations.

Eliminating covered distances between operations as an effect of the organization of the line of production made it possible to decrease 40 meters and 750 seconds.

The improvement in acceptance and refusal criteria because of the implementation of documented procedures.

By providing the operators with documented procedures, in which it was included: methods of visual inspection, visual comparison tables for acceptance and refusal of the product, along with the rules of operation for each task and activity, allowed considerably improving the level of acceptance of the product, and lowered 10% the reprocessing derived from the refusal between operations.

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Preparation activities were identified and those in which there is man-machine interaction were broken down, determining that 83% of the process is handmade, and 16.85% is done along with a machine. The fact that the process is not automated is highlighted.

Regarding the production programming, it was identified that this leads the production to the market, which causes a shortage in the delivery of products, or noncompliance by the company.

The study of timing was not only a tool to measure the time of cycle in the process, but it was also strengthened as a way of seeing the whole system and being able to find improvement opportunities within it.

After the observation process, four main problems were found. These affected the system performance. They are listed below:

Lack of an inventory control system in the reception stage. When the time was measured for the study, a fact that is continually repeated was made evident, in the reception stage: the person who unloads the *Moringa oleifera* leaves opens the bags to inspect the product, then he seals them, but he does not label the product with the characteristics proper of inspection, he just separates. This causes him to stop the process to walk in the storage room looking for the much-needed supplies for this stage.

A lack of a defined area for the temporary storage of the raw material, this causes the raw material to be left in a place waiting for the arrival of the missing components from the storage room. The problem is that this temporary storage area is randomly selected and does not have a fixed place inside the storage room which causes a mess and unnecessary movements by the operator in charge in the unification phase.

Pulverization process. The pulverization process makes sense for two products in a particular way: the food supplement and the encapsulation. For the first one, a thick grinding is needed, while the encapsulation needs a very fine grinding, as a consequence the operator's experience is what defines the quality of the product to be processed. In this sense, there is no raw material separation process (*Moringa oleifera* leaves).

Everything is used and goes on to the milling and pulverization. However, the fact that the *Moringa* leaves come in different densities and particles (different sizes) causes the grinding not to be uniform and so it has to be processed and re-processed until the operator's acceptance criteria define it as acceptable. In consequence, even if the process has the help of machinery, it still relies on qualitative acceptance criteria.

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Conclusions

The consumption of *Moringa oleifera* has increased in the last ten years, either because of its nutritional properties or for its use as alternative medicine in the treatment of the disease. This makes it relevant to evaluate the production process of the *Moringa oleifera* to improve the materials flow and the information starting from the production process to the client. The materials flow and the information influences the SME profitability and it is reflected in each part of its supply chain. The impact of the Supply Chain of the SME is seen mainly in two aspects: one related to the market (ensuring the quantity and quality of product) and the other in the producer's income through its business profitability.

Nowadays, the SC of *Moringa oleifera* has increased its participation both in the national market and in local markets. However, the problems and challenges that this sector faces are not only centered on the production process but are also reflected in all the levels of the chain.

The first echelon shows the production in a field with agricultural practices defined by the farmer's experience, and with opportunity areas in the level of making the farm technological. Having adequate agricultural practices to farm and exploitation of the *Moringa* will allow improving the leaf production efficiency per hectare.

The second echelon shows that with the implementation of the two steps of the DFT methodology (Product family definition, line production design) the operations of the SME were improved. In the first phase, the integration of product families allowed focusing the company’s effort on the product that provided more profitability, because the capsules are the ones that have a larger profit margin. Moreover, the *Moringa oleifera* encapsulation process has been documented through flow charts, and the production process characteristics identified.

The process operations documentation allowed making the VSM of the actual process. Firstly, it is emphasized that the production process is highly dependent on the workforce and a low level of automation, therefore, it is mostly a handmade and traditional process. Secondly, from the first step, two objectives and goals were clarified which were followed to improve internal operations of the process as part of the benefits of the DFT. In the second phase, the design of the production line allowed us to know the necessary resources to design the line according to the real demand on the market and not based on a sale forecast.

The development of standard operations allowed us to have documented procedures and to plan the plant distribution according to the requirements of the product, taking into account the current conditions of the facilities using the design of production line under the DFT approach improved the flow of materials and information starting from the raw material reception to the delivery of the product to the client as an effect of the production planning improvement, also, the process can be adapted to different market conditions.

The study of the productive processes in the small and medium enterprises through the study of its supply chain allows knowing the relationships the company has with its economical agents. Intervening the process of *Moringa oleifera* encapsulation through DFT improved the flow of materials and information guaranteeing that the productive chain is strengthened and responds better to the markets and their requirements.

Implementing the DFT with a focus on responding the demand with an internal capacity of the company and developing VSM in its first stage, shows that when identifying the activities that do not add value, and when the areas of opportunity are identified, the time to respond to clients were reduced and the quality of the products was considerably improved. Designing the production line under the DFT approach provided the company a strategy not only productive but also logistic to face the challenges that the agricultural market requires in scenarios of more demand and better quality products, above all in traditional production processes.

The supplier's evaluation will allow these to understand the internal needs, designs, and specifications of the company to reduce the investment in the inventory through more frequent, programmed deliveries; material delivery with higher quality and the elimination of inspection in the reception process so that it is possible to have a manufacturing flow system that involves all the supply chain. The idea of developing the suppliers is to turn them into an extension of the production buyer process.

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