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Article

Supply model in academic workshop of coffee bean roasting

Modelo de suministro en taller académico de tostado del grano de café

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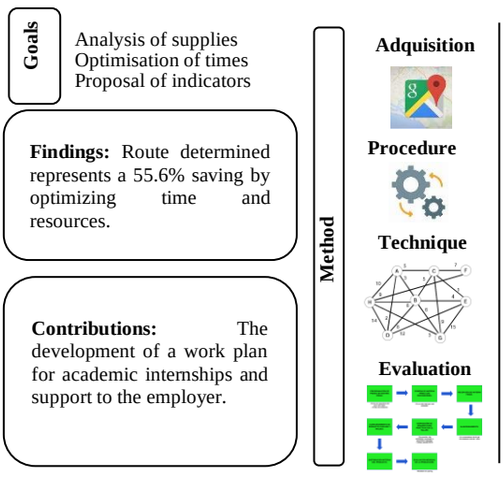
Abstract

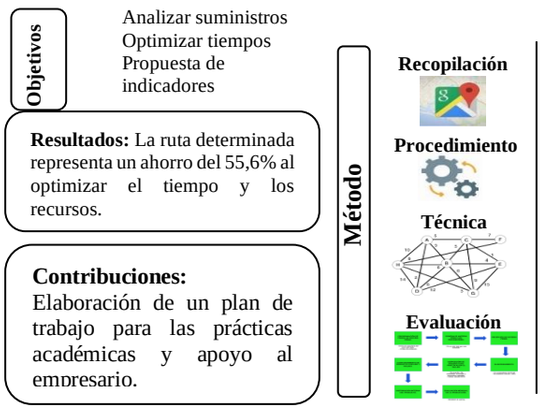
In the international market, companies encourage the generation of ideas to enter the environment and gain competitive advantage. Consequently, supply models are the combination of technology and good business practices from the industrial sector, including the information systems required to check activities. The aim of this study is to analyze the supply of operations in the production process of a coffee roasting workshop. Indicators and operations strengthen the development and execution of supply chain planning, organization and management. With field work in coffee farms, profits and companies found in the main producing regions of central Veracruz: Coatepec, Ixhuatlan del Coffee, Huatusco and Cordoba.



Supply chain, coffee bean, process optimization

Resumen

En el mercado internacional, las empresas fomentan la generación de ideas para entrar en el entorno y obtener ventaja competitiva. Como consecuencia, los modelos de suministros son la combinación de tecnología y buenas prácticas de negocios del sector industrial, que incluye los sistemas de información requeridos para monitorear las actividades. Con la finalidad de analizar el suministro de las operaciones del proceso productivo de un taller para el tostado del café. Los indicadores y las operaciones fortalecen el desarrollo y ejecución de la planificación, organización y gestión de la cadena de suministro. Con trabajo de campo en fincas Cafetaleras, beneficios y empresas ubicadas en las principales regiones productoras del centro de Veracruz: Coatepec, Ixhuatlán del Café, Huatusco y Córdoba.



Cadena de suministros, grano de Coffee, optimización del proceso

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Introduction

Supply activities involve the movement of goods from the supply of raw materials to the final consumer. This includes choice, buying, production scheduling, order processing, inventory control, transportation, storage and customer service. (Hernandez-Marquina et al., 2024).

In the Faculty workshop has a mortar machine, toaster, mill, sealant, and tools for roasting, grinding and packaging coffee bean. It is a proposal for standard operations to be conducted for the workshop supply chain, from planning to execution, The availability of machines and tools for use and process optimization (Ratanasanya, et al., 2022).

The coffee processes in the farm include pulping, fermentation, washing, drying, and storing. Among these, fermentation requires special attention given that the biochemical changes that occur in the coffee mucilage affect the flavor and aroma precursors of the final product (Rosero & Pantoja, 2021).

In this paper, we present the identification of an analysis model through the Dijkstra algorithm. Refers Edsger Dijkstra, who first described it in 1959.

“Dijkstra's algorithm uses the greedy principle, which is looking for the shortest path from one node (point / vertex) to another in the same direction (directed graph) starting from the origin node to the destination node. The calculated nodes are obtained from several strategic locations that can be known in general, such as offices, crossroads or public locations that are easily remembered by the public. The supporting data for the calculation of the Dijkstra's algorithm uses data derived from the user information about the user's name and location, while the location coordinate data is obtained from Google Maps” (Jason, et al., 2023).

There are studies, consider a vertical coffee supply chain where processors buy the raw coffee beans from planters, process them to convert them into green coffee beans, and sell them to firms or retailers who in turn sell the roasted or powdered coffee to consumers. Farmers or planters are price takers, and processors may enjoy oligopsonistic power vis-a-vis farmers.

The retailers may exercise oligopsony power vis-a-vis processors, or processors could also enjoy oligopoly power over retailers (Tanushree Haldar, 2022).

The impact of exports on economic development is more than imports as it is more closely related to domestic activities. The world growth significantly depends upon export share of the world. The export share has a close connection with the growth of a country as well (Sultan & Munir, 2015).

Historical data on coffee bean

The worldwide spread of the genus Coffea started in the African tropics, but it was not until the 14th century that the Arabs brought the plant to Yemen and there appeared the first plantations. By 1510 its production and consumption had already spread to Cairo and in 1555 to Istanbul, so that its advance continued in the Islamic world between periods of prohibition and tolerance.

By the early 17th century coffee had already been introduced into India and by the end of the same century, the Dutch brought the Yemeni coffee to the island of Java, where the climatic conditions and fertility of the land allowed coffee to adapt perfectly in the East Indies (Granados, 2018).

Although coffee was known in Europe from 1450, only until its arrival in Venice in 1615 and Marseille in 1644, its consumption expanded, and its commercial importance increased. By the mid-18th century, coffee consumption had become widespread throughout Europe and even coffee trees had been planted in the main botanical gardens.

But, in America, coffee was introduced during the eighteenth century by the French Captain Clieu, who was commissioned to bring a bunch of coffee to the island of Martinique, to propagate its production and consumption in the French colonies. From that island in the Antilles, the plant spread through the Caribbean and the Continent.

In 1727 coffee was introduced to Brazil and in 1731 to Jamaica and Santo Domingo, from where its cultivation spread to the rest of the present producing countries of America. With the industrial revolution and the growth of the world population during the 20th century, coffee became practically a universal drink (Díaz, 2015).

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Before entering Mexico, coffee travels from the Guyanas through the Antilles, Martinique, and finally Cuba. It is known that in 1796, it was Don Juan Antonio Gómez who brought from Cuba to the region of Córdoba, state of Veracruz, the first coffees that existed in the country, and that on May 16, 1808, coffee arrived in Coatepec, Veracruz, coming from Havana, Cuba, as described by Mariano Contreras (Ruiz-López & Calleja, 2021).

The coffee-growing region of Veracruz is distributed in 842 communities and 82 municipalities, where there are about 86,000 producers, some of them indigenous inhabitants belonging to the Nahuatl, Totonac and Popoluca ethnic groups.

Most processes including Source, Manufacturing, Delivery and Return have a small performance value with a lower class. Costs and Agility have the lowest score. (Nguyen, et al., 2021)

Box 1

Figure 1

Coffee-producing regions in the state of Veracruz

Source: Pronatura México

Where the northern zone involves Huayacocotla, Papantla and Zozocolco; in the central zone Atzalan, Misantla, Coatepec, Huatusco, Ixhuatlan del Coffee, Cordoba and Zongolica; and in the southern zone Tezonapa and Los Tuxtlas.

Although the "local demand for specialty coffee is growing, however, and coffee-cherry products are increasingly traded and consumed. This bears potential for retaining more value in origin countries and among farmers. However, how farming families can better profit from specialty coffee and its by-products, such as dried coffee cherries (also known as cascara or sultana), remains poorly understood" (Jacobi, et al. 2024).

During roasting, the grains undergo significant transformations due to the gradually reached temperatures. At 100°C, they double in size, and it is then that the grain loses its moisture and changes color to a deep yellow tone. Progressively between 150 and 180°C the grains get tones ranging from light brown to brown. When the temperature inside reaches around 200°C, the oils come out of the grains. Generally, higher oil results in changes in taste (Severin & Lindemann, 2024).

The chemical composition of green coffee beans is not only determined by species and variety, but also influenced by a few different factors including the terroir, harvesting methods (handpicked or mechanical), seed processing (wet, dry, or semi dry) and storage (Kath, et al, 2021).

Supply Chain Management (SCM) is the key unit of action for the implementation and success of the analysis of the algorithm (Hernández-Marquina, et al., 2024).

Traditional literature on linear SCM extensively discusses collaboration and its impact on performance, along with strategies to improve collaboration and enhance Supply Chain (SC) performance (Boughzala & De Vreede, 2015).

For example, there are studies that describe the measurement of supply chain performance using the Supply Chain Operations Reference (SCOR) method with the Key Performance Indicator (KPI) validation phase, the calculation of the actual KPI values and the weighting of the metrics for each level using the Analytical Hierarchy Process (AHP) method. (Suryaningrat, et al., 2024).

Also, with research exploring the significant growth in Honduran coffee production and productivity, while contrasting these achievements with growing concerns about environmental and social sustainability. (Ceballos-Sierra, et al., 2024).

Methodology

Study area

The selected suppliers are from Farm Monte Azul (FMA), farm Coffee-Tal Apan, and farm Xico. For the study, the arabica type green coffee grain with 5% defects, 12.5% moisture, harvested at 1100 meters above sea level is used.

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Box 2

Figure 2
Arabica coffee
Source: Farm Monte Azul

Farm Monte Azul, a company originally from Huatusco, Veracruz, Mexico. Located in the mountainous area and mesophilic forest, harvesting its coffee at more than 1,200 m above sea level and dedicated to marketing green, roasted, ground and soluble coffee (Finca Monte Azul, 2024).

Equipment

The areas and machinery in the faculty industrial workshop are distributed according to the following figure 3.

In other studies, a drum coffee roaster is a basic type of roasting machine that consists of a horizontal drum rotating over a heat source which could be supplied by fuels or electricity. The most common employs indirectly heated drums, where the heat source is under the drum (Klaidaeng, et al., 2023).

Where the following equipment is found, first, toaster machine for coffee beans, cereals such as peanuts and cocoa. It has the largest load capacity of 3 kg per roasting cycle and a minimum of 1.5 kg.

The duration of each cycle varies according to the type of grain, but ranges between 15 and 25 minutes.

The product is fed into the top hopper, the mixing or beating takes place inside the cylinder and the toasted product is discharged through the central gate directly to the cooling tank. Process smoke is distributed through the chimneys to the outside.

Box 3

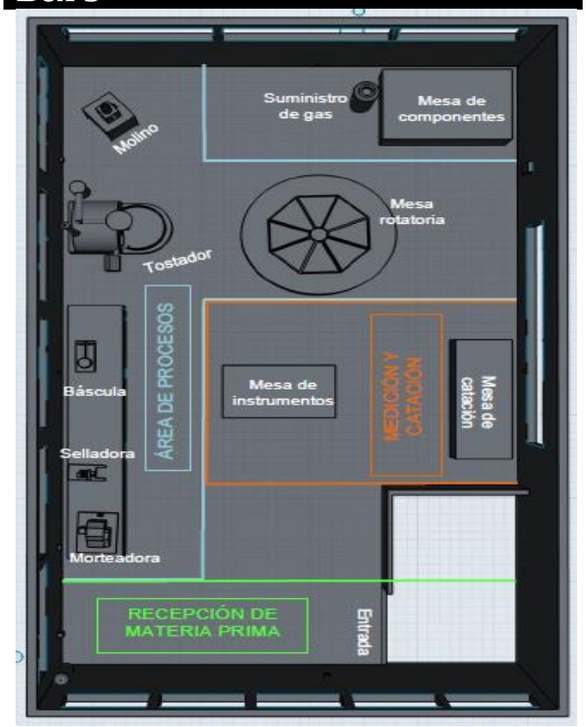

Figure 3
Distribution of the working area (Lay out)
Source: Industrial workshop of the faculty

Box 4

Figure 4
Toaster machine
Source: Industrial workshop of the faculty

Coffee grinder for roasted grain, "Use Rough" classification. It has a grinding capacity of 1.2 kg/min, just like those deposited in the transparent hopper. Once the grain is in the hopper, the side door is released to pass through the body where the blades are found, with the Swiss discs. It has 9 levels of coffee granulation adjustable to the operator's taste. The ground coffee leaves the front nozzle into the pre-placed container, the waste falls into the waste tray.

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Box 5

Figure 5
Machine for grinding
Source: Industrial workshop of the faculty

Morteadora machine, which consists in removing the grain husk that covers the coffee bean washed and dried.

Consists of a horizontal screw that rotates inside an adjusted cover, the bottom of the cover is perforated, through the perforations and by means of a fan a suction force is applied, originating friction and pressure between the grains, the husk is torn off and passes through the holes, a fan produces air flow in the discharge to remove the husks not removed by suction.

Box 6

Figure 6
Mortero machine for grain
Source: Industrial workshop of the faculty

Analysis of information

Travel times and distances to suppliers via sedan type transport.

Box 7

Table 1
Travel times and distances

Destino	Total distance (round trip)	Total travel time
Company Don Coffee	266 km	4 hours
Farm Monte Azul	251 km	4 hours and 25 minutes
Farm Coffee-tal Apan	231 km	3 hours and 45 minutes
Farm Xico Inn	248 km	4 hours and 15 minutes

Source: Own elaboration

The distances proved can be ratified as the shortest from point A to point B with a Dijkstra algorithm, it is this same algorithm that uses the Google Maps™ platform to calculate its travel routes. To check this, the algorithm is then used considering alternate routes to those used, comparing them with the original to corroborate or find the shortest route. Where, as point A is the destination, and point B is the workshop of the faculty.

Application of the Dijkstra algorithm

The analysis of current routes to the workshop suppliers is applied the smallest path algorithm or Dijkstra algorithm, which allows showing the smallest paths to be used.

If you analyze the available routes reported by Google Maps™, by default the platform points to the fastest route considering factors that can only be evaluated through satellite technology, such as traffic, tolls and other variables.

The algorithm finds the shortest route in terms of distance and distance travelled, each supplier will be contacted to compare both results, The necessary analysis is then made with the inclusion of the factors mentioned above for the selection of the best route.

Results

Dijkstra chart for the Apan Coffee

Towns or intermediate towns on the routes are represented by nodes from A to H, is shown in figure 7:

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Box 8

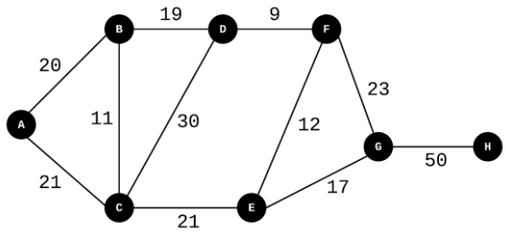

Figure 7

Dijkstra chart for the Apan Coffee

Source: Own elaboration

Interpreting nodes

- Node A: Workshop, Boca del Río, Ver.
- Node B: San Julian, Ver.
- Node C: Santa Fe, Ver.
- Node D: La Antigua, Ver.
- Node E: Tolome, Ver.
- Node F: Salmoral, Ver.
- Node G: National Bridge, Ver.
- Node H: Coffee-tal Apan, Coatepec, Ver.

Therefore, the distances between them are set in kilometers and specified with numbers on the edges. The resolution of the algorithm is described in the following table.

Box 9

Table 2

Iterations of the algorithm Coffee-tal Apan.

Node	Iter. 1	Iter. 2	Iter. 3	Iter. 4	Iter. 5	Iter. 6	Iter. 7	Iter. 8
A	**(0, -)**	*	*	*	*	*	*	*
B		**(20, A)**	*	*	*	*	*	*
C		(21, A)	(31, B)	*	*	*	*	*
D			**(39, B)**	(51, C)	*	*	*	*
E				(42, C)	(90, D)	(60, F)	*	*
F					**(48, D)**	*	*	*
G						**(71, F)**	(77, E)	*
H							(127, E)	**(121, F)**

Source: Own elaboration

Then, the shortest path found by the Dijkstra algorithm is shown in figure 8:

Box 10

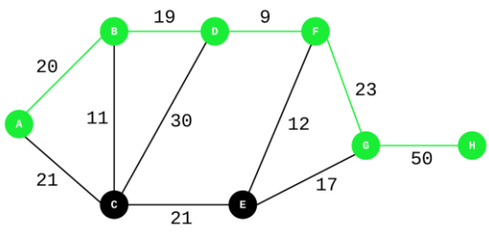

Figure 8

Route found by Dijkstra

Source: Own elaboration

Dijkstra chart for the Xico Inn

Finding then the Dijkstra graph is similar the route of the Coffee-tal Apan. Changing only the destination node "H", is shown in figure 9:

Box 11

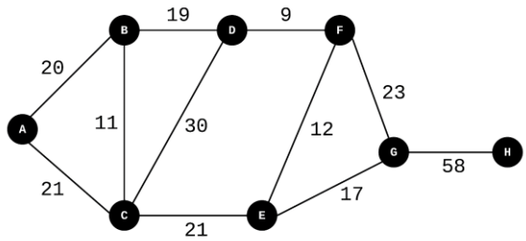

Figure 9

Dijkstra chart for the Xico inn.

Source: Own elaboration

Applying the same procedure as table 2, a similar close result of the routes is obtained.

Box 12

Table 3

Iterations of the algorithm Xico Inn

Node	Iter. 1	Iter. 2	Iter. 3	Iter. 4	Iter. 5	Iter. 6	Iter. 7	Iter. 8
A	**(0, -)**	*	*	*	*	*	*	*
B		**(20, A)**	*	*	*	*	*	*
C		(21, A)	(31, B)	*	*	*	*	*
D			**(39, B)**	(51, C)	*	*	*	*
E				(42, C)	(90, D)	(60, F)	*	*
F					**(48, D)**	*	*	*
G						**(71, F)**	(77, E)	*
H							(135, E)	**(129, F)**

Source: Own elaboration

Then, shortest route found by Dijkstra algorithm is shown in figure 10:

Box 13

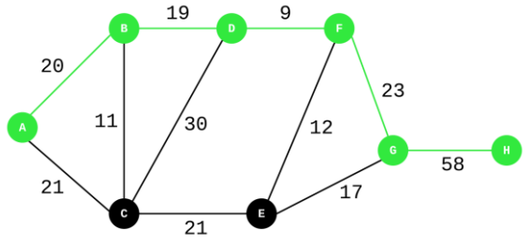

Figure 10

Route found by Dijkstra

Source: Own elaboration

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Dijkstra chart for the Monte Azul

The nodes correspond to the following cities, is shown in Figure 11:

Box 14

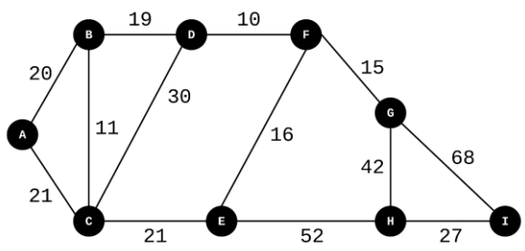

Figure 11
Dijkstra chart for the Monte Azul
Source: Own elaboration

Interpreting nodes,

- Node A: Workshop, Boca del Rio, Ver.
- Node B: San Julian, Ver.
- Node C: Santa Fe, Ver.
- Node D: La Antigua, Ver.
- Node E: Tolome, Ver.
- Node F: Jose Cardel, Ver.
- Node G: National Bridge, Ver.
- Node H: El Encinal, Ver.
- Node I: Finca Monte Azul, Huatusco, Ver.

Then, solving the algorithm at figure 12.

Box 15

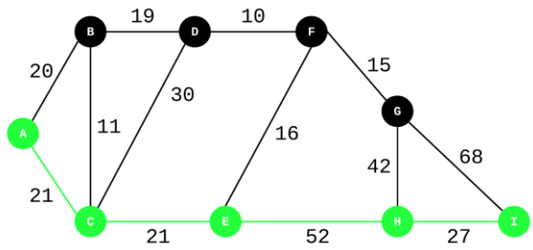

Figure 12
Route proven by Dijkstra
Source: Own elaboration

A vehicle is a motor vehicle for the transport of the raw material. The numbers of inputs are 50 kg of green grain with up to four passengers. This data is important in proven fuel expenditure, which is a principal factor when considering costs.

Comparison of transport costs between separate route and unified routes, is shown in figure 13:

Box 16

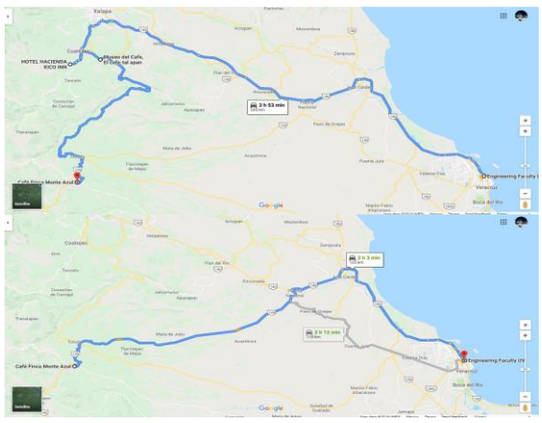

Figure 13
Unified route for suppliers found
Source: Own elaboration

Box 17

Table 4
Transports costs. National currency

Coffee-tal Apan + Xico Inn + Monte Azul	Unified route
Fuel consumption (litres)	
47.11	21.71
Distance (km) Total	
716	330
Fuel cost	
$857.32	$395.13
Cost of stands	
$392.00	$160.00
Total cost	
$1,249.32	$555.13

Source: Own elaboration

As a process description, the flow diagram of the workshop supply chain is found, is shown in figure 14.

Box 18

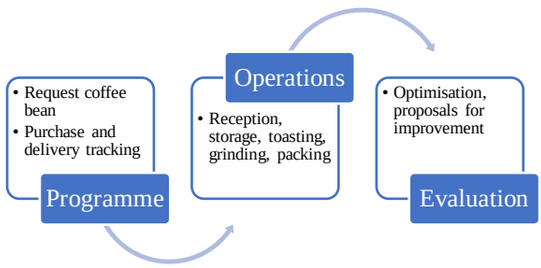

Figure 14
Flow diagram
Source: Own elaboration

Discussion of results

Combining the routes of Coatepec and Xico, also noting the proximity of the city of Huatusco, generates unified route for suppliers found in the region, is shown in figure 13.

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As a short road is the route formed by I, H, E, C, A with 121 km, is shown in table 2.

Generating the minimum distance H, G, F, D, B, A with 129 km from the point of origin is shown in table 3.

Then, the route determined is a 55.6% saving by improving time and resources.

Although, consumers demand assurance in their consumed products, starting from their composition and safety.

Also, categorize actors or stakeholders in the coffee industry supply chain into 6 groups. They are farmers, processors, manufacturers, national government agencies, markets/retailers/cafes, and the end consumer. Each stake holder has a specific role, either to write and read data or only to read the information. There are 3 functions in the system; input data, which acts as process information, transaction or process confirmation, and tracing information (Alamsyah, et al., 2023).

Conclusions

The information from the workshop field work, supply chain indicators are decided.

Visits to farms are important to define the processes used in cultivation, wet or dry profit process, storage and distribution of this important product for the economy of the state of Veracruz.

However, coffee is one of the most consumed beverages worldwide. Like other agricultural products, coffee is susceptible of colonization by mycotoxin-producing fungi and therefore, the presence of mycotoxins. These chemical hazards can pose a risk for consumers, as them are potentially carcinogenic, neurotoxic, or immunosuppressive (Rubio-Lopez, et al., 2023).

Supply chain management (SCM) practitioners currently face multiple challenges, ranging from eradicating supply chain disruptions to improving the flow of goods, and from increasing the need for supply chain flexibility to mitigating bullwhip effects. To address these growing challenges, firms are developing novel capabilities in digitalization or Industry 4.0, sustainability, servitization, and e-commerce, among others (Sandberg, et al., 2022).

Box 19

Figure 9

Project academic and students on visits

Source: Own elaboration

The tools applied in the project helped demonstration of results, showing operations that generate a positive assessment of supply.

Production and buying indicators were proposed for resource management and supply planning. The indicators are savings in transport costs of up to 60% compared with first expenditure and ensure the availability of raw material for internships during the academic semester.

Future work includes the possibility of marketing the product as roasted or ground coffee, proving a business register for the support of the entrepreneur.

Box 20

Figure 10

Project academic and students on visits

Source: Own elaboration

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Box 21

Figure 11
Academics and researchers from the University of Veracruz

Source: Own elaboration

Conflict of interest

The authors declare no interest conflict. They have no known competing commercial interests or personal relationships that could have appeared to influence the article reported in this article.

Authors' Contribution

Ramírez-Roman, Adolfo: Contributed to the project idea, research method and technique. Supported the development of the visit to coffee farms. He analysed the data and systematized the results; he worked the article.

Rodríguez-Rodríguez, Luis Alberto: worked on the development of graphs and diagrams, coffee bean roasting tests and systematization of results; also worked on the drafting of the document.

Suárez-Álvarez, Ángel: Contributed to research design, type of research, approach, use of equipment and writing of article.

Chabat-Uranga, Jacqueline: Done the systematization of the background for the state of the method. Supported the field study. Also contributed to the writing of the article.

Availability of data and materials

The map images for the sign of routes were obtained from the free platform google maps. Data from associations and museums related to coffee.

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Abbreviations

FMA	Farm Monte Azul
SC	Supply Chain
SCM	Supply Chain Management

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