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Supply chain in the food industry in the meat sector

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Abstract. - The meat industry is one of the largest and most important today due to its high consumption, especially in meat from animals such as cows and the derivatives obtained from their processing. This is why it is of utmost importance to design a supply chain that ensures the flow of raw materials efficiently, safely, and humanely. This is how, in this document, the simulation of the beef slaughter and processing process is generated in the FlexSim software to obtain process performance dashboards. In addition, a cleaner production proposal has been included that contains wastewater treatment and the system's energy optimization. This will not only help reduce waste and the use of energy and water but is also intended to ensure the quality of the products and the conservation of the environment.

Keywords: Supply chain, food industry, simulation, meat sector.

Cadena de suministro de la industria alimentaria en el sector cárnico

Resumen: La industria cárnica es una de las más grandes e importantes de la actualidad, esto debido al alto consumo que se presenta, especialmente en carne de animales como la vaca y los derivados que se obtienen de su procesamiento. Es por esto por lo que es de suma importancia el diseño de una cadena de abastecimiento que asegure el flujo de materia prima de una forma eficiente, segura y humanitaria. Es así como en el presente documento se genera la simulación de proceso de sacrificio y procesado de carne de vaca en el software FlexSim para obtener tableros del rendimiento del proceso. Además, se ha incluido una propuesta de producción más limpia que contiene el tratamiento de agua residual y la optimización energética del sistema, esto no solo ayudará a reducir desperdicios, disminuir el uso de energía y agua, se pretende asegurar la calidad de los productos y la conservación del medio ambiente.

Palabras clave: Cadena de suministro, industria alimenticia, simulación, sector cárnico.

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I. INTRODUCTION

The Food Industry is one of the most potential sectors in Ecuador, as it brings economic and social benefits to the country. This industry has grown exponentially, representing 6.6% of the Gross Domestic Product (GDP) and 42.8% of the income generated in the country. It represents 45% of manufacturing activity, creating five out of ten jobs in the country [1].

The food industry encompasses industrial activities focusing on the treatment, transformation, preparation, preservation, and packaging of food products [2]. For this reason, it is essential to direct efforts towards continuously improving processes to optimize production management in general, reduce energy consumption and greenhouse gas emissions, and optimize water use in this industry.

There is a broad diversification of sectors in the food industry, which includes the meat industry, the poultry industry, the dairy industry, the chocolate industry, the fishing industry, and the beverage industry. For this study, priority will be given to the meat industry, and points of improvement in the use of water and energy resources will be analyzed to obtain benefits for the company and reduce the negative impact on the environment [2].

The meat industry represents a significant part of the Ecuadorian economy. Currently, it ranks 20th among 47 industries nationally. In 2019, this industry contributed approximately $1,176.5 million. In addition, global demand for meat products is estimated to grow at an annual rate of 1.3% between 2007 and 2050 [3]. It is also important to note that around 220,000 metric tons of meat are processed annually in Ecuador. This previously mentioned industry has several meat sources for human consumption, which are cattle, pigs, and sheep, that strengthen this industry.

This project aims to collect data from the meat industry and analyze it to develop a simulation model. This model will enable the identification of the critical points within the supply chain concerning optimizing resources such as water and energy. In addition, simulations will be carried out in various scenarios to determine the best option in terms of improvement for this industry.

II. DEVELOPMENT

The supply chain is essential for the proper functioning of companies since it is not only responsible for the relationships between suppliers, manufacturers, and distribution centers until they reach the final customer since it associates all the activities of the flow to transform them into goods and services, from the inputs of raw materials to consumption to the final customer [4]. For this reason, communication between the parties involved is necessary to achieve a horizontal integration of the supply chain because the groups or individuals involved in this business may be affected by the fulfillment of the objectives of the organization. This includes employees, customers, suppliers, shareholders, environmental banks, and governments [5].

On the other hand, the study of logistics is essential for the realization of supply chain activities optimally, or called the green chain. For this, it must be considered that logistics refers to all the processes of planning, carrying out, and controlling, efficiently, the flow of raw material, inventory, finished products, services, and information involved. This is monitored from the point of origin to consumption, which includes movements of transfers for importing and exporting goods to meet customer needs. Therefore, the supply chain's comprehensive value proposition aims to optimize its total performance at all chain stages while separately comparing the resulting complete performance with each link [6].

Currently, the food industry is one of the most polluting, so there must be effective control of the supply chain to reduce the pollution they generate. In the particular case of the meat industry, it is responsible for producing, processing, and distributing all animal meat to distribution centers such as markets, warehouses, and department stores [7]. However, meat is a livestock product of more excellent value. It has proteins and amino acids, minerals, fats and fatty acids, vitamins and other bioactive components, and small amounts of carbohydrates. From the nutritional point of view, the importance of meat derives from its high-quality proteins, which contain all the essential amino acids, as well as its minerals and vitamins of high bioavailability [8]. The objective of optimizing the supply chain of the meat industry starts from the animal processing plants or slaughterhouses, where it benefits the species of animals that were declared, authorized, and registered for human consumption [9] and then involves the process to the other participants of the supply chain until reaching the final customer.

III. METHODOLOGY

This research work is based on a mixed approach, that is, a process of collection and analysis of qualitative and quantitative data from primary, secondary, and tertiary information sources obtained from electronic libraries such as Scielo and Dialnet, among which stand out Cleaner production procedure in the Obdulio Morales slaughterhouse in the province of Sancti Spiritus, Cuba; Guide to Clean Production in the meat processing sector and Benchmarking and Energy Saving and Efficiency Measures in the Meat Industry. This is to learn more about the meat supply chain and propose cleaner production initiatives. In addition to this, an interview was conducted with an operator who works in the area of the cattle slaughter process in the Camal Metropolitano of Quito, who provided information and data on the process, from the reception of the animals to the refrigeration stage and distribution of the meat. On the other hand, for developing the simulation model, the use of FlexSim software is proposed, which simulates the performance and behavior of the AS IS and TO BE model of the production process in the meat industry. Therefore, the different hypotheses propose that:

1. Automating the equipment significantly reduces Energy consumption during the slaughtering process.
2. Implementing a water collection system allows water recirculation throughout the production process, reducing water consumption.
3. Pollution from spills decreases when the actual waste of livestock is reused in other production processes, such as dog food.

IV. RESULTS

A. Production process

The meat industry's supply chain starts with input suppliers. At this stage, inputs may include standing animals, i.e., farmers who raise and sell them when they reach the right weight and age, vaccines, medicines, and even food. Then, the reception and marking of the animal are included in the processing stage. In this phase, the animals are received from the truck and taken to the pens, resting for 4 to 8 hours. Subsequently, they pass through a corridor in the washing the animal stage and are bathed. Then, the animal stage is slaughtered, where they enter the knockout box. Desensitization, bleeding, removal of legs and head, skinning, sternum cutting, leather removal, and cleaning of viscera are performed.

It then follows the post-mortem process, which analyzes the animal's relevant parts to evaluate the meat's quality. Then, the animal stage is divided, where a cut is made in half of the animal. At the end of this process, the inspection stage continues, in which a veterinarian reviews the animal to determine if it has any disease or stroke. In case of any illness, tumor, or blow in the meat, it is not intended for human consumption. It is confiscated and transported to a plant called digester, where it is incinerated.

Next, the cut meat goes through the washing process, where it is washed from side to side, and then continues to the quartering process, where cuts are made in the meat to divide it into quarter portions. Finally, it undergoes refrigeration while waiting to be distributed. Importantly, distribution must be done in refrigerated trucks to maintain meat quality. The meat is distributed to processing companies, which treat it to make sausages or other cuts. It is also distributed to specialized butchers that meet the needs of the business sector, restaurants, hotels, and finally to retail distributors, which can be stores or minimarkets that sell meat at retail. Next, the supply chain of the meat industry will be presented [8]:

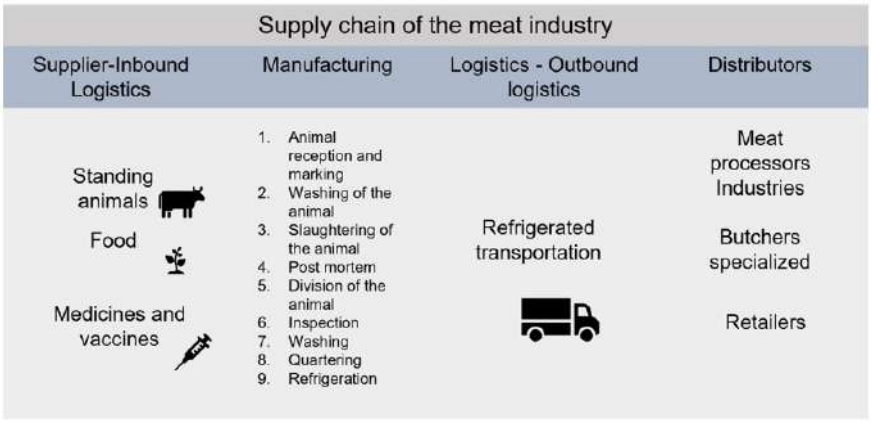

Fig. 1. Meat Industry Supply Chain
Source: Authors.

B. Flujo de materiales

Es necesario tomar en cuenta el proceso de producción para así conocer el flujo de materiales desde la cadena de suministro, de igual manera se considera los controles pertinentes para así lograr cumplir con los controles de calidad de la carne y las necesidades de los clientes.

1. Ganado (Recepción de materia prima).
2. Beneficio, desposte, refrigeración (tantos productos de carácter comestible y no comestible) [8].
3. Carne (Resultado).
4. Industrialización y procesamiento de cárnicos (Transporte – Distribución).

Table 1. Material flow.

Phases	Materials
Reception of raw materials	Animals, food and medicines
Slaughter - cutting	Blood, fat, viscera, flesh
Processing	Packaging, labels, condiments
Storage - distribution	Refrigerants, packaging, processed meat
Derivative products	Chopped seasonings and spices

Source: Authors.

C. Waste

The meat industry is characterized by the execution of the process in which some types of waste and scrap are obtained in the solid and liquid environment. This is why you should think about correctly managing these wastes since, if not, they damage the environment.

The waste includes meat by-products during the slaughter process. They are divided into blood, viscera, bones, and skin. These are organic wastes that, if not appropriately treated, become contaminants. Understanding these wastes, a percentage can be specified for the animals entering the process. For blood, you have approximately 12 liters, viscera is 10.8%, skin is 8.8%, and bones represent 20%.

D. Cycle time

The process in the plant begins with the arrival of the cows, which are placed in a coral for 4 to 8 hours to calm down after the trip. After this, they can move on to the washing phase, which takes about 8 minutes per beef. On the other hand, evisceration is the most important since the meat quality is endangered when the animal dies. It is necessary to process the animal quickly, that is, remove all the organs in at least 1 hour since the internal tissues begin a physiological process that causes the bacteria to migrate. There is a sanitary regulation on animal slaughter, where maximum times are established to execute the evisceration, and depending on the country, it can vary between 30 and 45 minutes. Removing the most significant amount of heat from the animal, in the long run, represents a substantial improvement in the quality of the carcass, with an adequate cold and pH curve [10]. According to the data collected in the interview, approximately 70 and 80 cattle are processed per hour.

E. Transport routes

The transport of meat products must be quality, and food safety is the main factor to be considered. The vehicle of raw material from the supplier to the producing company and the movement of this within the company and to the distribution centers must be considered. It is also necessary to have a cold chain to keep the products in good condition. This implies the optimal design of route packaging and ensures that no variations compromise the quality and state of the product.

F. Development of the simulation model

The software chosen for the simulation is FlexSim since it has a broad functionality and range of tools to make the simulation as close to reality. In addition, it has an excellent graphical interface that allows one to know the process in a precise and intuitive way, and, above all, it has a wide range of variables of machinery and operators that allow one to use control panels to know the development of the process, and also to carry out the simulation of the hypotheses raised to propose improvements of cleaner production in the meat industry.

G. Calibration and Validation

Generation of simulation model variables:

For the proposal of good, cleaner production practices, the variables of processing time were considered since the possibility of automating the process to reduce energy consumption could be evaluated. Likewise:

- Processing time: Machinery cycle times were defined to identify the number of kilowatts spent.
- Liters of water: The highest water waste during washing was identified.

H. Optimization and analysis of scenarios

As for the water system proposed for harvesting, the importance of water in the cow washing area was taken into account because it is in this process that most of the water is used. However, it is essential to note that this resource is used in all procedures carried out in the meat industry. In this way, considering the care of it, the system above was raised. A P&ID diagram was used to represent the essential elements for the collection system operation.

There is the presence of an expansion joint, which fulfills the objective of providing flexibility and thus achieving an expansion or contraction of the system if necessary. This is related to the water that passes through there regarding the needed amount. Similarly, a control valve next to the passage pipe is required when leaving the tank with a filter so that the amount and pressure the water returns to the initial source to restart the process can be regulated. Finally, a filter is used to separate the solids from the water and thus purify, as the solids extracted will be used as fertilizer and in the nutrition of the land.

I. Implications for industry in terms of cleaner production

In the results of the FlexSim simulation, the priority of cattle entry into the model was controlled by the date of arrival, the time it had been in line, and the level of urgency based on labels for the products. As well as the capacity of the pens before and after the meat process, which allowed us to define the number of resources that can enter the processing and the times in which they must intervene. Also, bottlenecks in the machinery during the slaughter process were determined, as well as water and energy waste.

The proposal for improvement in the meat industry consists of minimizing pollution from discharges, adopting energy-saving measures, and reducing water consumption since, during cattle washing, around 10.000 liters of water are used, with 1.500 liters per animal, and during slaughter for the separation of parts are used 2.400 liters, which are converted into wastewater; for this, the dry cleaning of animals and the recirculation of water, the use of water is significantly reduced. On the other hand, the most significant waste of energy in the meat industry occurs thanks to cold machines. For example, the average electricity consumption in Spain is 155 kWh / ton of channel, where 45% of this consumption occurs in complex generation plants and 10% in the conditioning of equipment; so, the strategies proposed in the table will help improve the energy consumption of meat companies.

Tabla 2. Variables asociadas a la propuesta de mejora.

Proposal to improve cleaner production		
Variable	**Objective**	**Strategy**
Processing time	Minimize pollution from spills.	Adapt the contact surfaces to have a more hygienic design that is easy to clean and inclines the evacuation of liquids.
		Implement the use of stun guns as the primary method of immobilizing cows.
		Install a double drainage system for the post-mortem process of the animal, and thus, the blood is directed to a storage tank and another for the discharge of cleaning wastewater.
	Energy saving	Replace low-efficiency motors with high-performance EFF1/EFF2
		Install motion sensors in low-traffic areas to avoid energy waste.
		Automate the use of pumping equipment in slaughtering and refrigeration processes.
Liters of water	Water saving	Install automated water use systems in the washing and cracking process
		Installation of water recirculation systems for washing the animal
		Perform dry cleaning of the animal before the washing process.

Source: The authors.

After the analysis carried out by simulation, the following results were reached:

By automating the process, mainly slaughtering, process cycle times were considerably reduced by reducing waste and unnecessary tasks or movements. With automation, energy consumption was significantly reduced since the machine is only on for the processing time, and the facilities are not constantly working.

Implementing a water repository system allows the water content to be stored and increased constantly. This water is processed and re-entered into the production process. As you can see, the water content reaches up to 15,000 liters at the end of a shift, of which around 6,000 liters can be treated, so it is a significant saving for the company to re-enter the water already used through a treatment system.

Concerning the waste found in the process, it can be seen to accumulate throughout the day. However, the control panel expresses it only when they are already collected at the end of the shift, reaching a final weight of 1 ton of waste. This waste produces dog food and fertilizer in fruit and vegetable cultivation processes. For this reason, the waste is much less since most of the parts of the cow are used.

CONCLUSIONS

First, it is essential to know the process that is being treated, which can only be achieved by researching academic and reliable sources to contrast data and understand how the way of doing the same activities has evolved. Similarly, interviewing a direct operator in this industry was of utmost importance to know the process firsthand and know the primary wastes that are presented.

It must be taken into account that when a cleaner production proposal is made, attention must be paid, and efforts must be focused on reducing the damage or impact that the chosen industry currently has. Considering this, proposing something that goes according to the leading cause will be easier. Care must be taken since the impact caused on the environment must be minimized, but without affecting the productivity and performance of organizations.

The use of control panels is of utmost importance in generating a process simulation model. This is because, in this way, you can know the circle's performance and identify bottlenecks and productive problems through data. This will be of utmost importance for realizing a proposal for improvement based on results.

REFERENCES

[1] "The food and beverage sector, a market that continues to grow in Ecuador.," 29 June 2022. [Online]. Available:https://muchomejorecuador.org.ec/elementor-26163/#:~:text=The%20sector%20of%20food%20and%20beverages%20is%20one%20of%20the, (GDP)%20in%20the%20Ecuador. [Accessed June 24, 2023].

[2]M. Malagié, G. Jensen, J. Graham, and L. Donald, 'Food Industry,' [Online]. Available: https://www.insst.es/documents/94886/161971/Capítulo+67.+Industria+alimentaria. [Accessed June 24, 2023].

[3] F. Mayorga, "Elaboration and conservation of meat in Ecuador," Technical University of Ambato, Ambato, 2022.

[4] D. B. Garza, "Definition and implementation of indicators in the supply area for the performance analysis of the supply chain of the resale department," 2018. [Online]. Available: http://eprints.uanl.mx/21949/.

[5]M. A. G. Vidales, "Supply Chain Management," 2020. [Online]. Available: https://elibro.net/es/ereader/udla/176583?page=58.

[6]J. M. Trejo, "Supply Chain Fundamentals: Theory and Applications," 2023. [Online]. Available: https://elibro.net/es/ereader/udla/227743?page=17.

[7] J. L. Garza Gastro, M. Blanco Jiménez and M. M. Terán Cazares, "Strategic factors that improve the quality of the meat industry supply chain in Mexico," 2021. [Online]. Available: file:///C:/Users/azele/Downloads/2032-Texto%20del%20art%C3%ADculo-7424-1-10-20220328.pdf.

[8]C. López and R. García, "Characterization of the beef supply chain in Colombia," Colombia, 2020.

[9]M. J. Flores Cabrera and L. M. Otero Rodríguez, "Strengthening solid waste management in the Colombian meat industry," 2022. [Online]. Available: https://hdl.handle.net/11323/9127.

[10] BM Editores, «BM Editores,» 19 October 2021. [Online]. Available: https://bmeditores.mx/ganaderia/vital-el-tiempo-en-el-proceso-de-eviscerado-animal/. [Accessed July 1, 2023].
[11] S. P. C. Coronel, "Achiote (Bixa Orellana) as an antimicrobial and natural antioxidant for the meat industry.," 2021. [Online]. Available: http://dspace.espoch.edu.ec/handle/123456789/17064.
[12] Z. Gil Unday, H. M. Pérez Fariña, E. López Bastida and E. Bravo Amarante, «Cleaner production procedure in the Obdulio Morales slaughterhouse in the province of Sancti Spiritus, Cuba,» Revista Universidad y Sociedad, vol. 10, nº 5, pp. 109-199, 2018.
[13] Á. Cruz Trujillo, «Benchmarking and Energy Saving and Efficiency Measures in the Meat Industry,» University of Seville, Seville, 2016.