

Analysis of the Operational Risk of the Process Pasteurization and Mixing in a Dairy Processing Plant, Using the HAZOP Methodology

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The realization of PHA (Process Hazard Analysis) as an evaluation of all those elements that are part of management programs for safety in industrial processes that can generate an impact on the profitability of the company, is a matter to highlight. Given the above, industries need to identify the variations that occur concerning normal parameters in the process. During the development of the study, operational risks are analysed in the process of a dairy plant, located in Cundinamarca, Colombia. For this analysis, the HAZOP methodology is used, which will allow the identification of hazards, operability study, and mitigation of the risks related to the investigated process. For the analysis, the pasteurization and mixing stage as the subsystem was determined. In this operational stage, the node to study was the reactor. The different diagrams of the node for the analysis were established. The specifications at the equipment and instrumentation level were used. Previous information, plus the contributions regarding the operation of the plant by staff, the inputs are compiled for the development of the mentioned methodology. Once the deviations in the studied node were identified, the possible origins and effects of each deviation were determined. The measures and corrective actions necessary for improvements in the production process were proposed.

1. Introduction

For a manufacturing company, it is essential to keep control of each process in order to keep the profitability rates stable and the mitigation most significant possible number of operational risks. In the case of dairy companies, considering that their products categorized as high risk to public health, these controls must be more exhaustive to ensure the total quality of the products to the customer. One of the most critical processes in the industry is milk safety before it converts into a finished product, microbial safety must ensure to increase milk life; therefore, the pasteurization is the heat treatment for used to guarantee the milk safety in this industry. (Aouanouk, et al., 2018). With the main to ensure the continuous improvement of the company and the supervision of the procedure of pasteurization of the milk, it is necessary to implement the risk analysis process commonly known as PHA. For the realization of the PHA, there are different methodologies, among the most recognized and implemented is the technical what-if checklist, the analysis of the failure tree (FTA), modal analysis of failures and effects (FMEA), analysis of cause and consequence (CCA), analysis of event tree (ETA), preliminary analysis of risks (APR) and the functional analysis of operability (HAZOP) (Kunte and Sakthivel, 2016). The analysis mentioned above is functional; however, it is of vital importance to understand the resources available to be able to run it, the scope that it wants to give to the possible outcomes, the complexity, and stage of development of the facilities, among other factors. For this study, was chosen as methodology the HAZOP because of its easy application and contribution in the processes of the dairy industry, this analysis is based on the standard IEC 61882:2016 (IEC, 2016).

The technique HAZOP focuses on identifying and analysing the risks and also in the methodical and systematic tracking of the operational deviation. Besides, this analysis achieves to determine the different stages that can affect the employees, environment, infrastructure, inputs, machinery, production, and other factors. In the same way, it is establishing the principal components that cause risks as the process

distribution, the equipment, the design, human actions, lack of preventive methods, external methods, for these reasons is necessary to count on teams of experts that known and understand the process with the different risks in functioning. Later is analysed the probability and severity when the problem happens and then to pose a sequence of recommendations and suggestions that mitigate the damages and dangerous situations. Additionally, this technology is of human reasoning, and for this reason, there is not a success or exact solution, it depends on the knowledge and experience of human resource who applies the methods (Freedman, 2003). Therefore, in this case, is showed as an example of a dairy factory located in Colombia, where the control of operational parameters is not constant, only the factory realizes an initial inspection and other of the tentative way in the course of the process of pasteurization the milk. Different variables condition this process of integrating into all systems, and it requires a combination of time-temperature that achieves adequate heat treatment from microbiological and organoleptic perception milk suitable for its final treatment. (Gonzalez, 2013). As a result, with the methodology HAZOP, the factory can determine the operational risks for establishing preventive measures but also to realize a cost budget of the process and its failures. Finally, it concludes that this technique applies in any company and process with positive results in the identification of the deviation of the variable and the operational parameters of the process that carry in risk situations and difficulties in operation.

2. Material and methods

The analysis of operational risk performs at a plant of dairy, located in the municipality of Subachoque, department of Cundinamarca, Colombia. The method employed for the analysis, as mentioned previously, it was the HAZOP. It determinate as the principal subsystem for the analysis, the stage of pasteurization, and mixing. In this operational phase, the node-to-study was the reactor. The description of the process makes using a diagram P&ID shown in Figure 1.

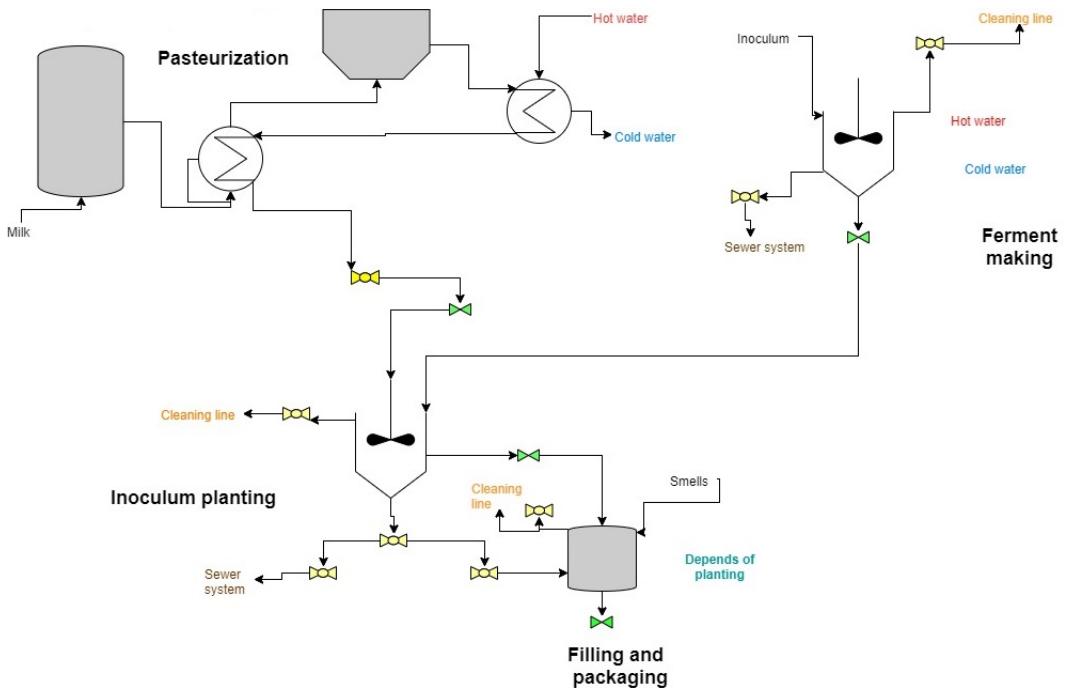


Figure 1: P&ID Process Pasteurization and Mixing

The identification process of deviations and possible causes are made considering parameters such as the pressure, temperature, flow, among others. A matrix with further improvements to the model proposed by Marhavilas et al., 2019, was created.

3. Results and discussion

Table 1 shows the risk matrix produced, considering the parameters for severity (S) and probability (L), and in Table 2, the parameters that define the probabilities of events where failures occur are presented.

Table 1: Risk matrix

Ranking Severity(S)	Consequences			Likelihood(L)				
	Environmental damage	Clients - Business Economics	Personnel injury	1	2	3	4	5
5 Catastrophic/ Fatal	Multiple environments affected	Loss of market share > 10 million	Single fatality or multiple fatalities. Permanent disability	M	M	H	H	VH
4 Severe/ Serious	Major localized effect	Loss of sensitive or priority market customers. > 1 Million and <= 10 Million	Fracture, hospitalisation >24 hrs, incapacitation >4 weeks	L	M	M	H	H
3 Major	Localized effect	Shortages and / or loss of customers. > 100,000 and <= 1 million.	Strain/twist, sprain/ cramp/ dislocation, incapacitation >= 3 days	N	L	M	M	H
2 Small/Minor	Minor effect	Complaints and / or Claims. > 10,000 and <= 100,000	Minor injury (without disability), basic first-aid need, no-hospitalization	N	N	L	M	M
1 Trivial/Only Minor	Slight	Specification non-compliance fixed. <10,000	Minor injury, discomfort, slight bruising, self-help recovery	N	N	N	L	L
0 No impact	No effect	None	No injury	N	N	N	N	N

Risk (R): * VH:"Very High"; H:" High"; M:" Medium"; L:" Low"; N:" None"

Table 2: Likelihood parameters definition]

Code	Definition
1	Remote (almost never). It has not happened in the industry. Once per 100 years
2	Unlikely (occurs rarely). It has happened in the industry (once per 25 years)
3	Possible (could occur, but uncommon). It has happened in the last 10 years
4	Likely (recurrent but not frequent): once per year. Probable occurrence in a period between 1 and 5 years
5	Very likely (occurs frequently). It can occur throughout the year. Several times a year (once per month)

Based on the risk matrix developed, we identified the main perturbations and deviations that have the process. There we found that the main risks are relational with systems of flow, temperature, agitation, and lack of maintenance programs. Set out the consequences that can generate each risk, and the most critical were related to shutdowns of the process, fire, and explosions, which would imply much harm to the personal as economic the evaluation of the previously mentioned evidence in table 3. Besides, inside the table are set out the possible recommendations or solutions to mitigate the risks mentioned.

Table 3: Evaluation of the risk of the node (continue)

Parameter	Deviation	Possible Cause	Consequences	Safeguards	Risk Matrix			Recommendations
					S	L	R	
Flow	Low Flow	The flow is varied, where it is necessary that the retention time is to the effect of 18 - 20 sec evenly	The reduction of microorganisms and bacteria is not achieved due to the effect of the pasteurization temperature. Delay in the process.	Regulate the flow. Process the milk again.	3	3	M	Have a follow up maintenance program
	Reverse flow	Blockage / Breakage of check valves	Blockage / Breakage of check valves	Change of periodic check valves and preventive inspections to avoid production stoppage	4	3	M	Generate a change of valves in order to minimize obstructions in the process

Maintenan ce	Less Level control valve failure, Level control probe failure	Liquid inlet control valve failure, Level control probe failure	Variation of optimal operating conditions, Decrease or increase of the output flow	Routine valve checks, Regular probe calibration	5	2	M	Automate the process with electrovalves where they are controlled by the signals emitted from the probes to avoid the variation of the optimal conditions of the process.
	High pipe temperatu res	Uncalibrated temperatu measuring instruments	Failures in the piping system	Check in detail the operation of each part of the steam system	4	2	M	Entities trained to maintenance. have personnel experienced in the handling of the tools
	Delay in mixing	Breakage in the feeder mixer.	Decreases capacity and product quality	Repair mixer and review maintenance plan	5	2	M	Purchase machinery of quality, have personnel experienced in the handling of machines and the tools. planning of maintenance programs
Pollution	Microorganisms	Loss of the final that interact with milk due to poor cleaning of heat exchange		Standardized preventive maintenance and control programs for cleaning of heat exchanges by process operators	5	3	H	Establishing a timeline with activities and responsible people of cleaning of each area. Creating a program of preventive maintenance of each machine and its components
High / low temperatu re	Temperature decrease in the heat exchange due to the malfunction of the pneumatic valves	customer poisoning		Check and calibrate the pneumatic valves	5	2	M	Checking the calibration parameters frequently. Creating a preventive maintenance program, with prevalence in the critical components
No agitation	Power supply failure, Failure in the agitation system	Decreased conversion, imperfect mixture		Routine checks of the agitation system, routine Maintenance of the agitation system, Installation of an emergency generator for power failure.	5	3	H	Having at least two sources of electric power generation for an emergency. Creating a program with preventive and corrective activities that permit an assertive reaction in an emergency
No flow of milk	Compressor failure / obstruction, valves closed, pipe leak		It paralyzes the production process. Production costs increase	Review periodic state of the flow of the milk and the ducts to prevent breakdowns, obstructions and leakage of pipelines.	5	3	H	Implement a comprehensive valve system to prevent breakdowns, obstructions, and periodically carry out preventive maintenance.
Reverse flow	Pump failure		Production stopped	Constant revision of pumps	5	3	H	Perform pump maintenance, in addition to maintaining flow and process control
Agitation	Loss of control	Movement of the Preventive			5	4	H	Periodic change of the

Temperature	Thermal inactivation	General pasteurizer failures	High microbial load in the final product	Safety integrity level mass flow control	5	4	H	Tension pulleys. To Acquire an electric power plant
Heat transfer	The deviation of 5 °C with respect to the water outlet of the unit hot water	Greater resistance to heat transfer in the heat exchanger due to fouling in the equipment. Delay in the process.	Requires cleaning by qualified personnel and quality inputs.	5	2	M	Controlling the time and temperature and to implement a system of random sampling with microbiological tests that guarantee the quality levels in the pasteurization process. Planned maintenance programs are optimal to the periodicity of the process	
Low and high temperature and control of the pasteurization process.	In which a temperature must be managed of 70 to 75 °C for a period of 10 to 15 seconds.	The lack of standardization of agents pathogens in the final product for the short period of time of exposure of the milk to the temperature, The loss of nutrients or vitamins for a long time of temperature	Control the process by means of instruments such as thermometers and timers. Implementation of a control that opens an air valve triple that switches when the product has reached the temperature of pasteurization	5	3	H	Implement a system of indirect heat. Controlling and document the parameters like time and ranks of maximum and minimum temperature in the thermal process with traceability records	
No heat extraction from reactors	Inefficient design of reactors that increase the risk of explosion	Explosion accidents	Increased monitoring of component status, replacement of critical components with higher reliability components, Improving reactor power Installation of protective walls	5	3	H	Maintain a follow-up maintenance programs. have experienced staff in the training and handling of machinery.	
Cooling system failure	Cooling system failures	Fires, explosions	Reaction leak identification software based on energy balance	5	3	H	Periodic verification of the functioning machines through control charts	
Critical temperature threshold	Emergency discharge system malfunction	Fires, explosions	Risk prediction analysis	5	5	VH	Creating an emergency protocol with corrective measures	
Transfer	Transfer of heat	Insufficient inhibition of the microbial load	Intoxication of customers, and total loss of the	Implement a system of recirculation of	5	1	M	Standardize and document the parameters like time

due to improper product heat treatment	the milk to increase inhibition of the microbial load	and ranks of maximum and minimum temperature in the thermal process. Delegating responsible people in the control of critical parameters
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4. Conclusions

The use of HAZOP allows us to conclude that the method is appropriate when identifying the existence of risks within the mixing and pasteurization process. The identification of faults in the systems that generate alterations and lack of precision, especially in the operational parameters (temperature and pressure), warns of the need for measures such as detailed inspections and maintenance. Also, it allows the recognition of the repercussions that could be had, such as the deterioration and performance of the machinery, safety risks to employees, and the quality of the final product, which could influence consumer satisfaction and well-being. It is noteworthy that many of the risks can mitigate through operational controls such as the anticipation of failures of each machine based on evaluation tools such as the documentation of maintenance activities, generation of schedules with functions aimed at responsible persons, statistical sampling methods that allow evaluating consequences and preventive and corrective measures at different stages. In conclusion, the technique allows the increase in safety levels within a process in which it is crucial that the milk meets the appropriate microbiological parameters, avoiding situations where the health of consumers can be affected.

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