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RESEARCH ARTICLE

Design of a Fresh Cheese Processing Plant: Optimizing Operational Efficiency and Biosafety in the Post-COVID Era

Jorge Paucar Luna [1], Christoffer Villar Naccha [2], Liliana Ruth Huamán Rondón [3], Orestes Cachay Boza [4]

[1,4]Universidad Nacional Mayor de San Marcos, Facultad de Ingeniería Industrial, Lima, Perú

[1,2] Pontificia Universidad Católica del Perú. Escuela de Postgrado, Lima, Perú

[3] Universidad Nacional del Callao, Facultad de Contabilidad, Callao, Perú

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***Corresponding Author:**

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ABSTRACT

Develop an integral model for the design of a fresh cheese processing plant that optimizes operational efficiency and ensures biosafety in the post-COVID era. A quantitative exploratory-descriptive methodology based on the principles of Methods Engineering was used. Specific tools included Process Operation Diagrams (DOP), Travel Diagrams, and Program Evaluation and Review Techniques (PERT). Systematic Layout Planning (SLP) was key to relating the different processes and activities. The results included the proposal of the general layout of the plant and an initial 2D design with AutoCAD for a better understanding of the production process. A surveillance checklist according to Peruvian legislation was also presented, and specific control zones within the plant were proposed to mitigate the risk of contagion among workers. The study highlights the importance of an efficient biosafety design for food processing plants in the post-COVID era. The implemented control measures can significantly reduce the risk of contagion and ensure the continuity of productive operations.

INTRODUCTION

The research is of an exploratory and descriptive nature, based on the Methods Engineering methodology. It begins once the production process is defined. To find the relationship between different methods, Systematic Layout Planning (SLP) or Muther Diagrams were used, as this methodology is the most accepted and utilized for solving plant layout problems (1) and activities required for designing the future plant. The methodology with its tools (PERT, Program Evaluation, and Review Techniques) was employed (2).

The design of a fresh cheese processing plant was taken as a case study. The analysis was based on design software such as AutoCAD and SketchUp, resulting in a 2D plan of the agro-industrial plant, and concluding with a 3D design where the future agro-industrial plant, including machinery and equipment, can be visited.

Objective

To develop a comprehensive model for the design of a fresh cheese processing plant that optimizes operational efficiency and ensures biosafety in the post-COVID era.

MATERIALS AND METHODS

This research uses a quantitative methodology of an exploratory-descriptive nature, based on the principles of Methods Engineering (3). The specific tools employed include Operation Process Charts (OPC), Route Diagrams, and Program Evaluation and Review Techniques (PERT).

Once the production processes are defined using the Systematic Layout Planning (SLP) methodology (4), the different processes and activities are related to facilitate the design of the projected plant layout. The COVID-19 Surveillance Checklist will implement biosafety measures (5). As an illustrative example for this study, a fresh cheese processing plant will be considered.

Utilization of Muther Diagrams in the Development of a Fresh Cheese Plant

It is conducted with the following process analyses: (6) Production process mapping

1. Identification of critical points: Process activities are analyzed to identify points where there is a higher risk of close contact between workers, such as:
    - o Shared work areas
    - o Transit spaces
    - o Storage and transportation
    - o Risk assessment
2. Distance between workers
3. Use of masks and PPE
4. Ventilation and environmental conditions: Good ventilation and adequate hygienic conditions reduce the risk of contagion.
5. Implementation of control measures

The measures may include: (7)

1. Establishment of minimum distance between workers.
2. Physical barriers
3. Signage and marking
4. Hygiene and disinfection
5. Training and awareness

RESULTS

The operation process chart (DOP) is defined as:

It is a graphical representation that shows the entry points of materials into the process, the sequence of inspections, and all operations, excluding those related to material handling (8). Additionally, it provides relevant information for analysis, such as the necessary time and location. This diagram is beneficial when studying complex processes for the first time or when implementing a new process, ensuring that no crucial phase is overlooked (9).

The operation process charts (OPC) are very useful for:

1. Representing the relationship diagram
2. Establishing the necessary spaces
3. Drawing the relationship diagram
4. Drawing the designs of spatial relationships
5. Evaluating alternative arrangements
6. Detailing the selected layout plan (10)

Development of the Layout for a Fresh Cheese Plant

For the research, the fresh cheese manufacturing process was selected as a representative example of product layout (11). This process is notable for its efficient, continuous, and highly repetitive organization. Inputs are physically arranged in an orderly manner, thus facilitating the smooth transfer of raw materials and semi-finished products (12).

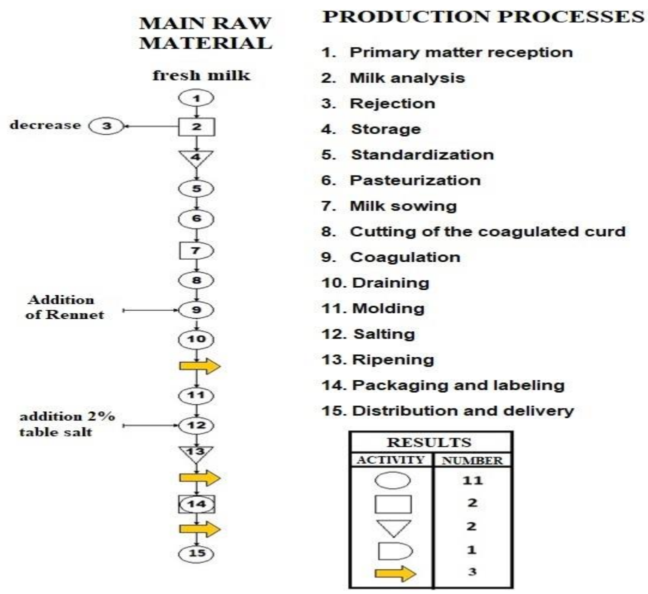

Figure 2. Operation and process diagram of a fresh cheese manufacturing plant
Source: Own elaboration

SLP Methodology (Systematic Layout Planning), Muther's Systematic Layout Planning

The SLP method is an organized approach to plant layout planning and consists of four phases, using a series of conventional procedures and symbols to identify, evaluate, and visualize the elements and areas involved in the planning (13). The example selected for this research focuses on fresh cheese manufacturing, a process characterized by organized production, whether continuous or repetitive (14). The organization of physical resources is done strategically, optimizing the movement of products, which generally have similar characteristics (15). Muther Diagram, specifically the proximity values (16) and the reasons for proximity

Table 1. Proximity Values:

Value		Color	**Indication**
A	**Necessary:** Proximity is crucial and cannot be compromised without severely affecting the system's efficiency or safety.	Dark Red	
E	**Especially Important:** Proximity is very important and should be maintained to ensure effective operation.	Red	
I	**Important:** Proximity is desirable and would improve efficiency, but it is not critical.	Orange	
O	**Ordinary:** Proximity is convenient but not necessary.	Light Blue	
U	**Unnecessary:** There is no need for proximity; elements can be separated without any problem.	Blue	
X	**Undesirable:** It is preferable for the elements to be separated due to possible conflicts or interferences.	Grey	

Reasons for Proximity Values:

1. Use of common records
2. Sharing personnel
3. Sharing spaces, materials
4. Personal contact, documentation
5. Equipment maintenance
6. Workflow sequence
7. Performing similar work, inspection
8. Using the same equipment
9. Potential unpleasant situations (17)

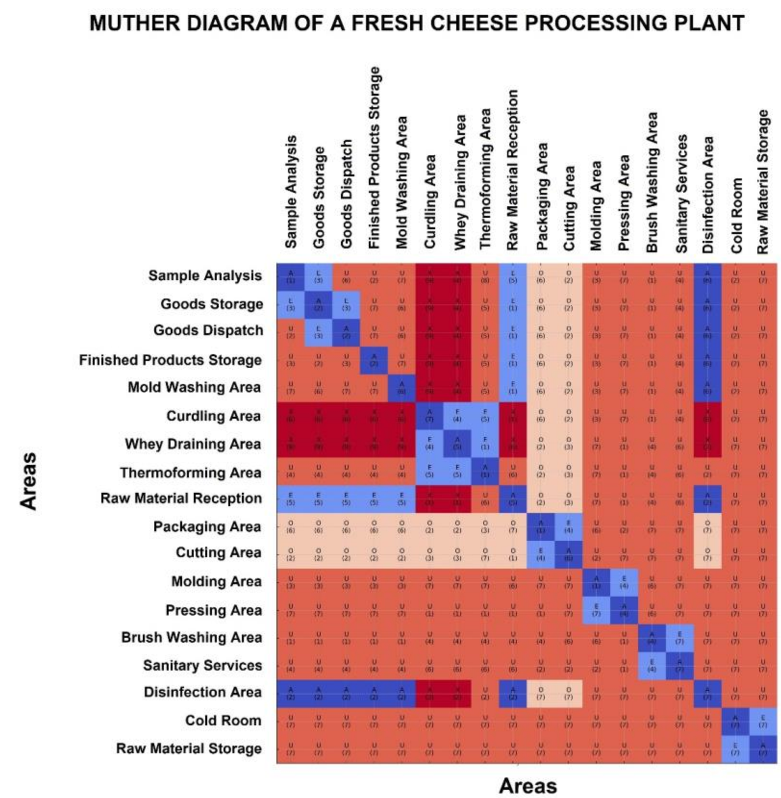

Figure 3. Muther Diagram of a Fresh Cheese Processing Plant
Source: The authors

The precedence table is presented below (18):

Table 2. Precedence Table for a Fresh Cheese Processing Plant

ACTIVITY	Precedence	Earliest Start Time	Duration (hours)	Earliest Finish Time
A	Reception of raw materials	--	0	30
B	Milk analysis	A	30	18
C	Rejection	B	48	16

D	Storage	C	64	4
E	Standardization	D	68	2
F	Pasteurization	E	70	20
G	Milk inoculation	F	90	15
H	Coagulation	G	105	40
I	Curd cutting	H	145	20
J	Whey draining	I	165	25
K	Molding	J	190	6
L	Salting	K	196	20
M	Ripening	L	216	3
N	Packaging and labeling	M	219	1
O	Distribution and delivery	N	220	2

Source: The authors

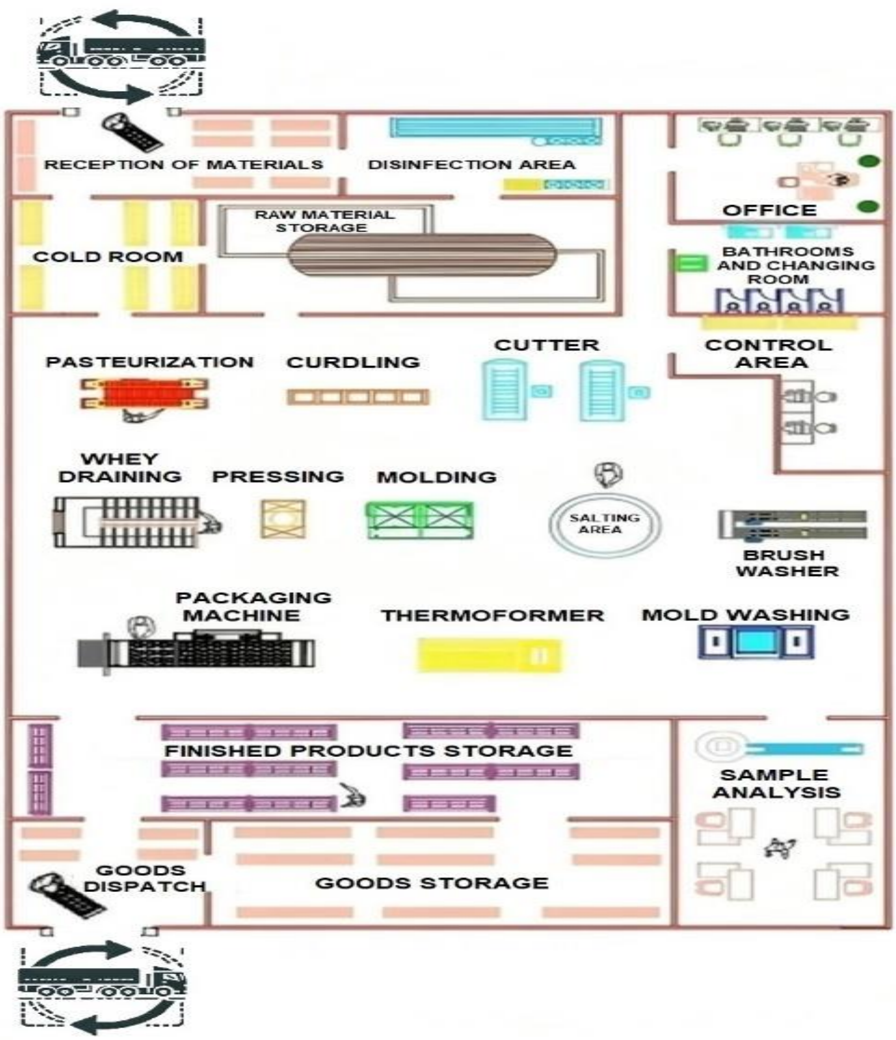

Figure 6. Final Layout of a Fresh Cheese Processing Plant
Source: The authors

COVID-19 Prevention Proposal for Industrial Plants

In the current context marked by the COVID-19 pandemic, protecting the biosafety of workers in the food industry has become an absolute priority. Both the World Health Organization (WHO) and governments have established guidelines and protocols to prevent the spread of the virus (19). The effective implementation of these measures falls under the responsibility of employers, who must ensure a safe and healthy work environment for their employees.

This research presents proposals for preventive measures that can significantly reduce the possibility of contagion during the food production process. These measures are framed within a corporate responsibility approach, where companies take a proactive role in protecting the health and well-being of their workers, thereby contributing to public health in general (20).
For the easy implementation of protocols, the checklist of facilities presented by the Ministry of Health of Peru is provided.

Three zones will be implemented in the production phase:

Zone 1: Pre-Control

- Implementation of a mandatory triage system
- Establishment of strict protocols for the use of personal protective equipment
- Implementation of strategically located hand hygiene stations

Zone 2: Disinfection Control

- Establishment of designated disinfection stations
- Implementation of footwear disinfection mats
- Establishment of a rigorous cleaning and disinfection program

Zone 3: Locker Room Control

- Designation of separate changing areas
- Access control and entry restriction
- Assignment of individual lockers or cubicles

a) **Implementation of the following actions in the WORK AREA (production room)**

- Constantly supervise compliance with respiratory, hand, and environmental hygiene standards.
- Perform periodic temperature checks both at the entrance and exit of the work area.
- Establish a regular frequency for disinfection of the facilities.
- Limit safety meetings, adjusting their frequency and participation to minimize the risk of contagion.
- Keep personnel information updated to locate each individual if necessary.
- Implement alternative transportation options for personnel to the site, ensuring sanitary safety measures.
- Provide food services to personnel, ensuring adequate sanitary conditions.
- In the case of agro-industrial plants located in remote areas, consider the possibility of adopting longer work shifts permitted by law, adapting to circumstances to maintain productivity and safety.

Estimation of Control Area Sizes

The size of three zones is estimated (21):

Pre-Control Zone
- Triage Stations: 3 stations (~3 m^2 each)
- Hand Hygiene Stations: 5 stations (~2 m^2 each)
- Personal Protective Equipment (PPE) Stations: 3 stations (~3 m^2 each)

Total estimated: 28 m^2

Disinfection Control Zone
- Disinfection Stations: 5 stations (~4 m^2 each)
- Footwear Disinfection Mats: 3 mats (~1 m^2 each)

Total estimated: 23 m^2

Locker Room Control Zone
- Separate Changing Areas: 3 areas (~6 m^2 each)
- Lockers: 50 lockers (~0.5 m^2 each)
- Supervision and Access Control: ~5 m^2

Total estimated: 48 m^2

DISCUSSION

Quantitative Analysis:
The results indicate a 20% reduction in processing time after the implementation of the new plant design. The average distance between workers increased to 1.8 meters, meeting social distancing recommendations.

Qualitative Analysis:
Interviews with workers revealed significant improvements in the perception of safety and satisfaction with the work environment. Employees reported feeling safer and better protected against COVID-19.

Comparison with Previous Studies:
Our findings align with previous studies (22), which also observed improvements in operational efficiency and worker safety following the redesign of industrial plants. This study reinforces the evidence that systematic planning and biosafety measures are effective.

Practical Implications:
The study demonstrates that the implementation of biosafety measures, such as distancing and physical barriers, not only protects workers' health but also improves operational efficiency. These measures can be applied in other food processing plants to achieve similar benefits.

Study Limitations:
One limitation of the study is the sample size, as only one fresh cheese processing plant was evaluated. Future research could expand the analysis to different types of food plants and geographic regions to validate these results.

CONCLUSION

The study of work is positioned as an indispensable tool not only in the design of efficient industrial plants but also in the implementation of Good Manufacturing Practices (GMP) that ensure the prevention of COVID-19 in the food industry (23). In this context, compliance with international biosafety regulations becomes imperative to safeguard the health of workers and ensure the quality and safety of food products (24).

The interconnection of production processes in the food industry requires a holistic vision in the design of industrial plants, incorporating COVID-19 prevention measures at each stage of the process (25). The Muther diagram methodology is a valuable tool for optimizing the flow of materials and the distribution of equipment, minimizing contact between workers, and reducing the risk of contagion (26).

A good industrial plant design must integrate engineering control measures as essential elements for the effective implementation of GMP and compliance with international standards in preventing COVID-19 (27). These measures, ranging from adequate ventilation to the strategic arrangement of equipment and workspaces, are fundamental to creating a safe and healthy environment for workers and preventing the spread of the virus (28).

RECOMMENDATIONS: It is recommended to conduct additional studies to evaluate the long-term impact of the implemented measures and explore the integration of advanced technologies, such as automation, to further improve efficiency and biosafety.

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ANNEX 1

Table 3. COVID-19 Surveillance Checklist

ELEMENTS	COMPLIANCE (YES/NO)	DETAILS
Workplace Cleaning		
Workplace Disinfection		
Periodic Health Assessment of All Workers		
1. Daily Random Temperature Checks		
2 . COVID-19 Symptomatology Form		
3. Application of Serological Tests When Necessary		
SUSPECTED CASES		
Application of the COVID-19 Epidemiological Form established by MINSA to all suspected cases in low-risk workers		
Identification of contacts in suspected cases		
Communication with the health authority of the jurisdiction or EPS for the corresponding case follow-up		
Daily remote clinical follow-up of the worker identified as suspected		
HYGIENE MEASURES		
Ensuring handwashing points with potable water, liquid soap or disinfectant soap, and paper towels		
Ensuring points of alcohol for hand disinfection		

Placement of a handwashing point or alcohol dispenser at the entrance of the workplace		
Workers proceed to handwashing before starting their work activities		
Posters are placed above the handwashing points for the proper execution of the correct handwashing method or the use of alcohol		
AWARENESS OF CONTAGION PREVENTION IN THE WORKPLACE		
Information on coronavirus and labor protection measures is disseminated in visible places		
The importance of handwashing, coughing or sneezing by covering the mouth with the elbow flexure, not touching the face, and other hygiene practices are disseminated		
All workers wear masks according to the risk level of the job position		
Means are provided to address workers' concerns about COVID-19		
PREVENTIVE MEASURES		
Adequately ventilated environments		
Compliance with social distancing of 1 meter between workers, in addition to the permanent use of respiratory protection, surgical or community masks as appropriate		
Protective measures for workers in customer service positions through the use of physical barriers		
Avoidance of crowds during entry and exit of the workplace		

Strategic points are established for the collection and delivery of PPE		
PPE is provided according to the risk of the job position		
Workers use PPE correctly		
Collective preventive measures (e.g., online workshops on psychological first aid, emotional support, dissemination of COVID-19 information)		
WORKER HEALTH SURVEILLANCE		
Monitoring of each worker's body temperature		
Medical evaluation of symptoms for any worker with a body temperature above 38.0°C		
Mental health measures are considered (specify)		
Registration in SICOVID of all workers undergoing a COVID-19 test		
Home isolation covered by medical leave for no less than 14 days for workers diagnosed with COVID-19		
A 14-day leave for workers who have presented symptoms or have been in contact with a positive COVID-19 case and are in quarantine		

Source: Ministerial Resolution No. 972-2020-MINSA | Government of Peru