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Ergonomic Model to Reduce the Development of Musculoskeletal Disorders in the Process of Production of Empanadas in a SME

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Abstract

Nowadays, ergonomics is implementing new methodologies across various sectors, including workplaces, production facilities, and common areas, in order to maximize productivity. This research focuses on conducting an ergonomic analysis using RULA and REBA techniques in a bakery business to reduce the development of musculoskeletal disorders. After conducting a systematic literature review to understand the evolution of ergonomics in organizational settings, the analysis was performed using Ergonautas website, where data were recorded to assess the risk levels of activities. A diagnosis of the company was carried out, focusing on the workstations that are part of the production process, in which several opportunities for improvement were found. Through the Nordic questionnaire, it was possible to identify the main discomforts of the operators, which are hands (100%), followed by the elbow (85.71%), and lastly, the shoulders (71.43%). The production activities posing ergonomic risks are mixing, cutting, and baking. This was identified using the REBA and RULA techniques, which indicate that mixing represents a high risk, followed by cutting, which has a medium risk, as well as baking. In the case of mixing, it is recommended to intervene at the station as soon as possible.

Keywords
Bakery industry, ergonomics, RULA, REBA, musculoskeletal disorders.

1. Introduction
To promote the growth of the bakery sector, companies must carefully analyze their processes to improve them and, consequently, remain competitive in the market. Bakeries and other flour-based food production companies are exposed to risks either due to the nature of the activities performed or the design of their machines (Vásconez and Jama, 2022).
Musculoskeletal disorders are a group of preventable disorders that affect nerves, tendons, and muscles (Yazdanirad et al., 2022). The main ergonomic risks in the bakery industry include lifting heavy objects, repetitive activities,

incorrect postures, twisting, and prolonged standing (Beheshti, 2014). This makes it possible to detect problems earlier, such as muscle contraction and intense joint pain, which can harm both workers and the production process. By obtaining more information about the current situation, immediate action can be taken. For example, to improve the quality of life for workers, frequent breaks, schedule modifications, and workplace reorganization can be implemented (Vera et al., 2019). Additionally, a new evaluation can be planned, which involves adopting a systemic approach that promotes ergonomics by considering individual risk factors, evaluating the current work plan, and identifying possible improvements within the processes (Rodríguez et al., 2019).

1.1 Objectives

The present work aims to develop an ergonomic improvement proposal in the empanada production process to reduce the development of musculoskeletal disorders in a small and medium-sized enterprise (MSE). The specific objectives of the following work are:

a) Perform a diagnosis of the postures adopted by the operators during the production process.
b) Identify production activities that represent ergonomic risks for the operator.
c) Obtain anthropometric data to adapt the workstation to the operator and thus optimize working conditions.
d) Determine the main illnesses in operators during their work activities.

2. Literature Review

2.1 Ergonomy

According to the International Ergonomics & Human Factors Association (2000), ergonomics is defined as a scientific discipline that studies the interactions between humans, the work they perform, and the elements of the system to reduce physical, mental, and psychological loads on the worker and increase productivity.

2.2 REBA

Using the Rapid Entire Body Assessment (REBA) technique, the postures adopted by the upper body members (arm, forearm, and wrist), neck, and legs can be evaluated. In addition to assessing posture, other aspects such as the load or force handled and the type of muscle activity performed by the operator are also considered (Diego Mas, 2022).

2.3. RULA

The Rapid Upper Limb Assessment (RULA) specifically targets the upper limbs of the body, considering the posture adopted, duration, repetitions of the posture, and the force exerted by the operator during the activity. With this information, we will determine whether the adopted posture necessitates immediate corrections or redesign of the workstation (Diego Mas, 2022).

2.4 Small and Medium Enterprise (SME)

A Small and Medium-sized Enterprise (SME) is defined as a company that has a limited number of employees and whose financial income or total assets fall below certain thresholds. Typically, SMEs are businesses with a limited capacity for production and operations compared to large multinational corporations ((OCDE), s.f.).

2.5 Case Studies

A study was conducted in a company to gather qualitative data about the knowledge that workers have regarding ergonomics. The result was that the employees had basic knowledge about modern ergonomics. This demonstrates the possibility of the existence of companies that apply basic ergonomics knowledge, causing operators to lack facilities to carry out productive tasks (Gómez-Salazar, 2022).

In another study conducted in a mining company, the following techniques were employed: Individual Risk Assessment (ERIN) and Rapid Entire Body Assessment (REBA). These techniques were useful for evaluating exposure to risk factors including lifting heavy objects, handling, and weighing logs, which can cause musculoskeletal disorders. The results of the ERIN application for the tasks of face drilling and laboratory cleaning indicate a high level of risk, thus necessitating changes to be made in a short period of time in both tasks. A total of 13 critical and common postures for the tasks were evaluated using REBA: rock loosening, support, face drilling, and blasting. Of these, three presented a very high risk, four a high risk, two a medium risk, and four a low risk. The tasks of rock loosening and support generally presented the highest risk levels, while the blasting task presented the lowest risk levels (Rodríguez et al., 2019).

In 2018, a study was conducted on 150 workers in the construction sector in Spain, applying a multi-methodological approach where various methods and techniques such as flow diagrams, simplified process representation, REBA, RULA, Nordic questionnaire, and Borg scale were employed. The study findings suggest that activities posing a high-risk level, such as lifting, manual handling, pushing, and pulling, may contribute to the development of Work-related Musculoskeletal Disorders (WRMSD). A clear correlation exists between these risk factors, documented injuries, and the indicators of WRMSD. Analysis of the questionnaire responses from workers reveals that biomechanical risk factors predominantly impact individuals aged 25-54. If this population remain exposed to ergonomic risk factors, there is a significant probability of them developing musculoskeletal ailments associated with their occupational conditions in later years (Zorrilla et al., 2018).

In a recent study about the chassis assembly line employees puts together components weighing over 8 kg on average beneath the car's body, impacting workers with complaints of Musculoskeletal Disorders (MSDs). This line comprises 30 assembly tasks grouped into six categories (A, B, C, D, E, and F) based on the work posture. The study used REBA and RULA to assess and analyze MSD. Of these methods, REBA is deemed the most suitable as it comprehensively evaluates all aspects of limb usage during work. Groups A, C, D, E, and F revealed that 83.33% of complaints were classified as moderate to severe, necessitating corrective measures. In contrast, Group B reported 16.67% of complaints categorized as very high and highly dangerous, requiring immediate corrective action (Nelfiyanti and Mohamed, 2022).

3. Methods

3.1 Study model

The execution plan begins with the description of the empanada production process and the collection of anthropometric data from the operators, such as gender, age, elbow height, shoulder height, eye height, and stature. Additionally, the measurements of the machines used, such as the mixer, cutter, and oven, will be considered. Following this, a 3D description of the current workstation will be created, followed by a diagnosis of the station, and finally, the formulation of a 3D proposal for the workstation (Table 1).

Table 1. Stages of the methodology

Steps	Techniques	Tools
1. Description of the process		Process Operations Diagram
2. Operators perception recording	Interview	Nordic Questionnaire
3. Collection of anthropometric data and machinery dimensions	Instrumental measurement Observation of operator's postures	Measuring tape Metric tape Anthropometric measurement form
4. Workstation diagnosis	RULA REBA	
5. Formulation of a 3D proposal		Autodesk Inventor Professional 2023

3.1.1 Description of the process

Phase 1 allows for a schematic representation of a process to identify activities and operations. Additionally, the Flowchart was used to identify activities that produce defective empanadas, enabling intervention in said activity to ensure compliance with required ergonomic conditions. Both tools (Operations and Processes Diagram and Flowchart) facilitate verification of critical aspects for the production process (Zorrilla Muñoz et al., 2018).

3.1.2 Operators perception recording

In Phase 2, the interview technique was applied using an adaptation of the Nordic Questionnaire to identify signs of musculoskeletal disorders which was based on the assessment of these operators. Furthermore, the question guide was divided focusing on different body parts such as the neck, back, elbows, hands, and spine.

3.1.3 Collection of anthropometric data and machinery dimensions

Phase 3 consists of collecting anthropometric data from operators such as height, elbow height, shoulder height, shoulder width, knuckle height, sex, and weight. Operator data will be collected using an anthropometric form, while

equipment measurements will be taken with a metric tape to assess operator effort and discomfort. Additionally, workstation photos will be taken from various angles during production.

3.1.4 Workstation diagnosis

Phase 5 involves utilizing REBA and RULA techniques through the Ergonautas website, a platform dedicated to occupational ergonomics and workstation analysis. With the application of these techniques, we will determine if the adopted posture requires immediate corrections or workstation redesign. The following are the steps for the approval of the REBA and RULA technique (Table 2):

Table 2. Steps for REBA and RULA

Steps	REBA	RULA
1. Introduce general data	Workstation Description Company Department Area	Workstation Description Company Department Area
2. Choose the type of assessment	Single side of the body Both sides of the body	Single side of the body Both sides of the body
3. Enter data for posture analysis	Group A (legs, trunk, and neck) Group B (arms, forearms, and wrists) Group C (type of muscle activity performed and applied force)	Group A (arms, forearms, and wrists) Group B (legs, trunk, and neck) Group C (type of muscle activity performed and applied force)

Additionally, REBA and RULA techniques have the following scoring scale considering the level of risk and corrective measures to be applied (Table 3).

Table 3. Scoring and Action Scale for REBA and RULA

	Score	Level	Risk	Action
REBA	1	0	Inappreciable	No intervention necessary
	2-3	1	Low	Low intervention may be necessary
	4-7	2	Medium	Medium intervention necessary
	8-10	3	High	High intervention needed as soon as possible
	11-15	4	Very high	Very high intervention required immediately
RULA	1-2	1	Inappreciable	Low risk
	3-4	2	Low	Task changes may be required
	5-6	3	Medium	Task redesign is required
	7	4	High	Urgent task changes are required

3.1.5 Formulation of a 3D proposal for the workstation

In Phase 5, a workstation redesign will be conducted, taking into account ergonomic analysis, to provide a suitable environment for the operator performing the task. This redesign aims to enhance productivity, reduce defective products, and prevent the development of musculoskeletal disorders. The redesign will be executed based on the existing 3D model of the current workstation (Table 4).

3.2 Research variables

Table 4. Research variables

Variable	Dimension	Indicator
Ergonomy	Anthropometry	Height
		Elbow height
		Shoulder height
		Eye height

		Working angle
	Machine measurements	Height
		Broad
		Long
Musculoskeletal disorders	Workers with illnesses	% of workers with pain
		% of workers who left their activities

4. Results and Discussion

4.1 Description of the process

The process begins with the measurement of flour, salt, sugar, and shortening in the required quantities, followed by their mixing with water in the mixing machine until obtaining a uniform dough of 1.9 kg. The operator, when removing the dough, repeatedly leans due to the low height of the machine. The dough is then taken to the cutting machine, where it is divided into two equal parts and cut into 30 pieces each. Subsequently, the pieces are manually given a round shape and placed on trays for molding and filling. Finally, the empanadas are taken to the oven and removed to rest on trays before being taken to the counter. In the present investigation, 6 operations, 6 inspection activities, and 1 combined activity were identified, where the empanada is cooked simultaneously with the worker controlling the oven temperature (Figure 1).

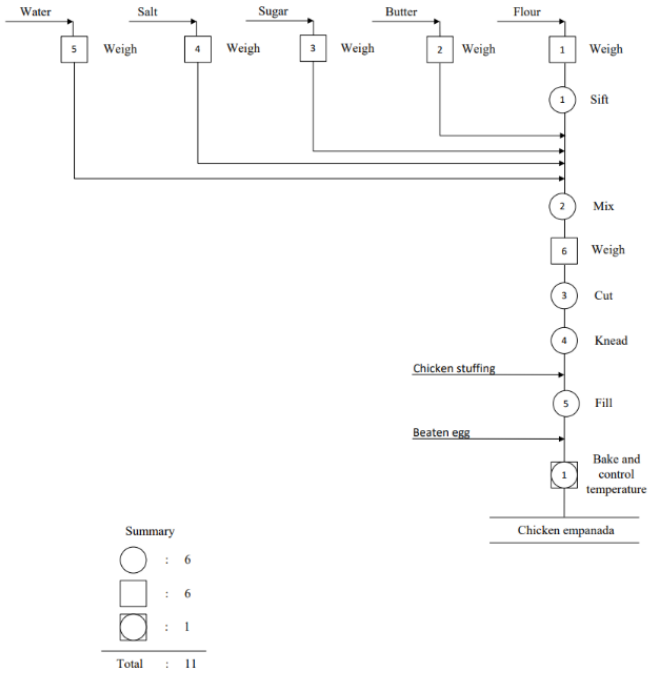


Figure 1. Process Operations Diagram for Empanada Production

4.2 Operators perception recording

A total of 7 bakery workers participated, all of whom are involved in the empanada production process. The questionnaire is divided into 5 sections, considering various body parts such as the neck, shoulders, elbows, hands, and spine. It was found that workers mainly experience discomfort in their hands (100%) and elbows (85.7%). It was also determined that the pain in their hands prevented workers from ceasing their tasks (28.6%). Similarly, 16.7% of the workers stated that elbow pain prevented them from carrying out their daily activities (Table 5).

Table 5. Results of questionnaire

Parts of body	Results	Description
Neck	28.6%	Workers reported experiencing neck pain for 7 days in the last 12 months.
Shoulder	71.4%	Workers reported experiencing shoulder pain.

	57.1%	Workers stated that they experienced pain for 8 to 30 days straight.
Elbow	85.7%	Workers experienced discomfort in their elbows,
	16.7%	Worker mentioned that the pain forced them to stop their work activities.
Hands	100%	Workers reported experiencing hands pain.
	28.6%	Workers were compelled to stop their activities due to the pain in their hands.
Spine	71.4%	Workers experienced discomfort in the last 12 months.
	16.7%	Worker indicated that the pain caused them to stop working.

4.3 Collection of anthropometric data and machinery dimensions

Anthropometric data from two operators were collected using a measuring tape and recorded in an anthropometric chart. This decision was made to facilitate the design of the improvement proposal. One female worker and one male worker were selected based on their measurements, chosen for their similarity to other workers of the same gender (Figure 2).

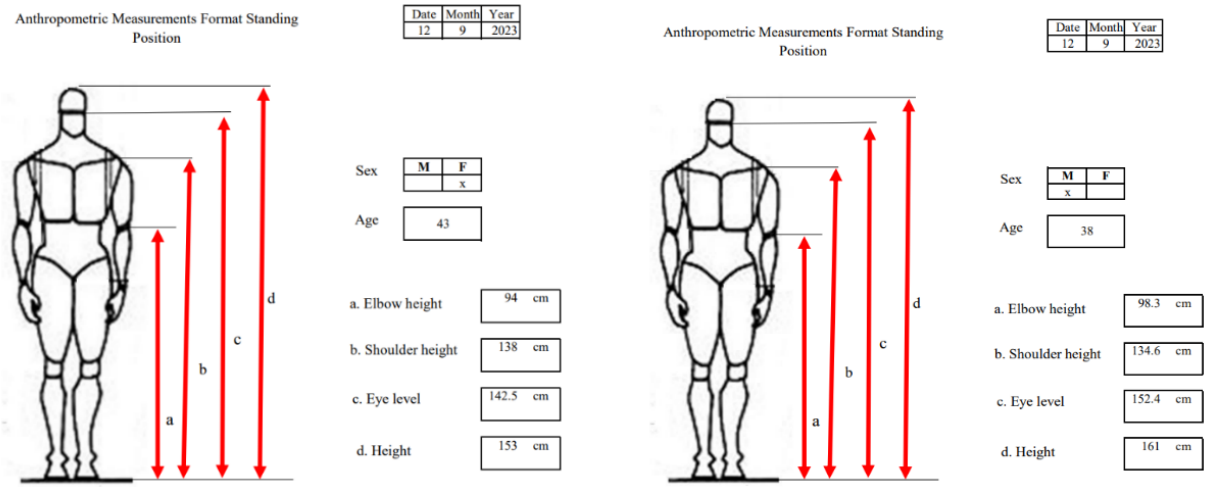
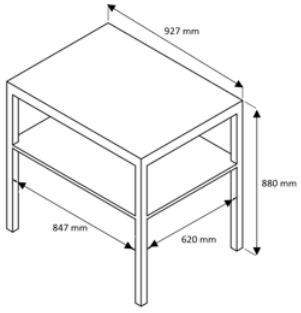
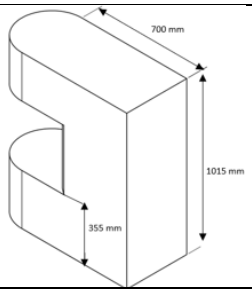
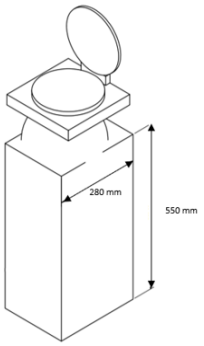
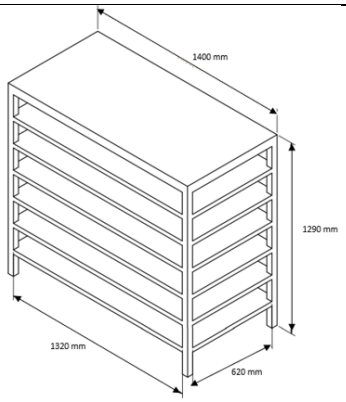
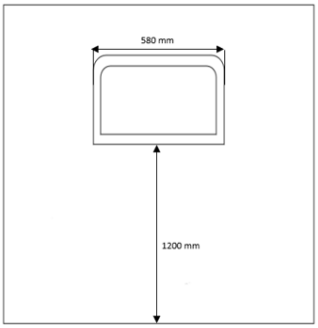


Figure 2. Anthropometric data

Additionally, measurements of the dimensions of the machinery used in the production process (table, mixer, cutter, and oven) were taken (Table 6).

Table 6. Machinery dimensions

Work table	
Machinery	**Dimension**
	
Mixing machine	
Machinery	**Dimension**

	
Cutting machine	
Machinery	**Dimension**
	
Shelves	
Machinery	**Dimension**
	
Oven	
Machinery	**Dimension**
	

4.4 Workstation diagnosis

The stages of mixing, cutting, kneading, and baking were considered because they were the activities that took the most time and effort. To do this, the Ergonautas tool will be used to conduct the analysis.

4.4.1 REBA

4.4.1.1 Mixing

In this case, a score of 10 was obtained, indicating a high level of risk, so intervention in the workplace area is necessary as soon as possible. Regarding the surveys, it can be interpreted that the mixing stage lacks ergonomic conditions, as workers experience neck, spine, and shoulder pain, resulting in the absence of 2 workers for 7 days.

4.4.1.2 Cutting

A score of 7 was obtained, indicating the need to intervene in the workplace area so that the cutting machine adapts to the measurements of the worker. This coincides with the questionnaire result as workers experience back pain, resulting in one worker being forced to stop performing their activities.

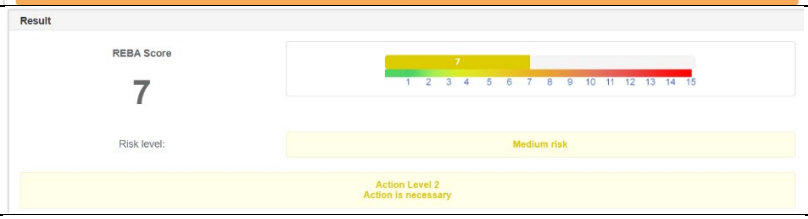
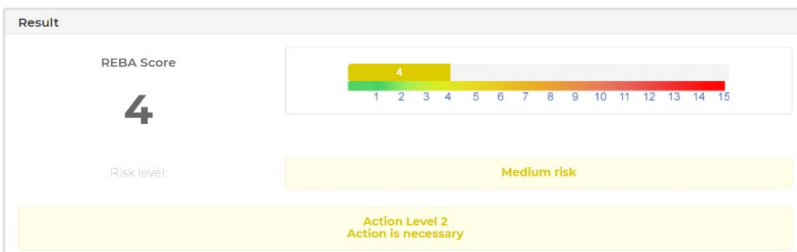
4.4.1.3 Kneading

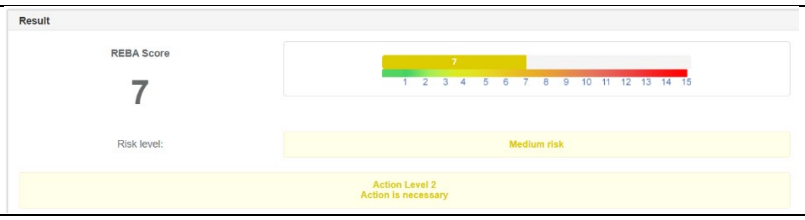
Kneading is a repetitive activity as the worker makes circular movements for the 60 dough portions. Additionally, the worker proceeds to flatten the 60 dough portions with the rolling pin. There is a clear need to improve the current working conditions in the kneading activity, which aligns with the survey results. In this case, they indicated experiencing hand pain due to the repetitive movements performed by the workers, followed by flattening it with the rolling pin.

4.4.1.4 Baking

A score of 7 was obtained, indicating the need for immediate measures to correct the current workstation conditions. It is worth noting that in this activity, the worker exerts effort when inserting the tray because the oven is above shoulder height. This aligns with what the workers indicated, experiencing shoulder and hand pain (Table 7).

Table 7. REBA Score

Activities	Score
Mixing	
Cutting	
Kneading	

Baking	

4.4.2 RULA

4.4.2.1 Mixing

In the mixing stage, a score of 7 was obtained, indicating the need for urgent changes in the task. In comparison to REBA, where a score of 10 was obtained, indicating a high level of risk.

4.4.2.2 Cutting

A score of 7 was obtained, signaling the need for changes in the conditions of the activity. In this case, the score aligns with the results in the REBA technique, where a score of 7 was obtained, indicating a medium level of risk.

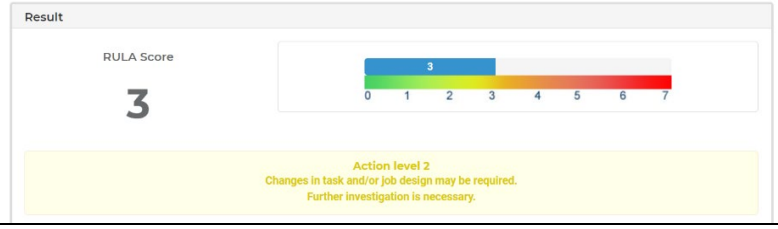
4.4.2.3 Kneading

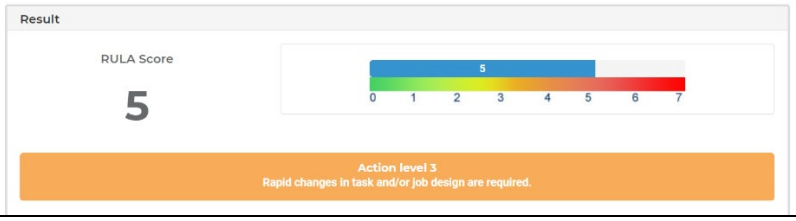
In this activity, a score of 3 was obtained, suggesting potential changes in the conditions of the activity to prevent musculoskeletal disorders. It is noteworthy that in REBA, the same score of 3 was obtained, indicating potential changes in the activity, which is at a medium level.

4.4.2.4 Baking

A final score of 5 was obtained in the baking stage, suggesting the redesign of the task. With this score, it can be concluded that this activity requires rapid changes in the workstation design. In this case, baking received the same score as in the REBA technique (Table 8).

Table 8. RULA Score

Activity	Score
Mixing	
Cutting	
Kneading	

Baking	

For those activities that do not have the same score in both techniques, we chose to consider the most unfavorable scenario. This is the case for mixing, kneading, and baking, where the most urgent level of action was considered.
Through the Nordic questionnaire, the prevalence of musculoskeletal disorders (MSDs) was determined by adopting inadequate postures at work. Thus, it was found that the most predominant discomfort occurs in the hands (100%), followed by the elbow (85.71%), and lastly the shoulders (71.43%).

The mixing stage lacks ergonomic conditions, which could be related to the 28.6% of workers experiencing neck pain. Similarly, the results regarding the spine demonstrate discomfort in 71.4% of workers, which is also related to this activity. The need to improve current working conditions in kneading is evident, aligning with the results of questions concerning the neck due to the repetitive movements performed by workers.
If we correlate the results of Ergonautas with the survey, it can be inferred that baking lacks ergonomic conditions, thus being associated with the 71.43% of workers experiencing shoulder pain.
This proposal offers a potential solution thanks to the diagnosis of REBA and RULA so that it can be implemented by the company in the future.

4.5 Formulation of a 3D proposal for the workstation

In this case, the height of the machinery was adjusted by installing an adjustable platform, allowing them to be tailored to the height of the operators based on anthropometric measurements. As a result, postures can be improved by reducing the bending angle of the operators (Figure 3).

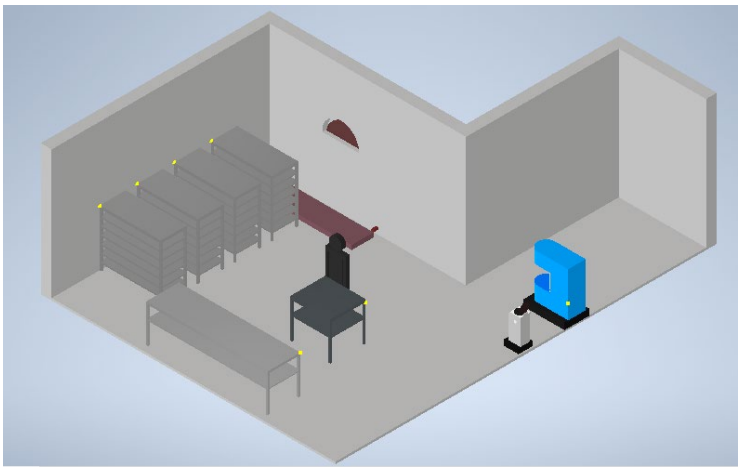


Figure 3. 3D plane

It is worth noting that the height of the platform can be controlled through a lifting system that adjusts according to the machine dimensions and the requirements of the activity. For mixing, a platform with dimensions of 60 x 60 x 28 cm (length, width, and height) is proposed. For cutting, a platform with dimensions of 20 x 20 x 16 cm is used. For baking, a platform with dimensions of 70 x 30 x 14 cm is proposed, which will have the option to be removed if the oven is not in use, avoiding obstruction during activities (Figure 4).

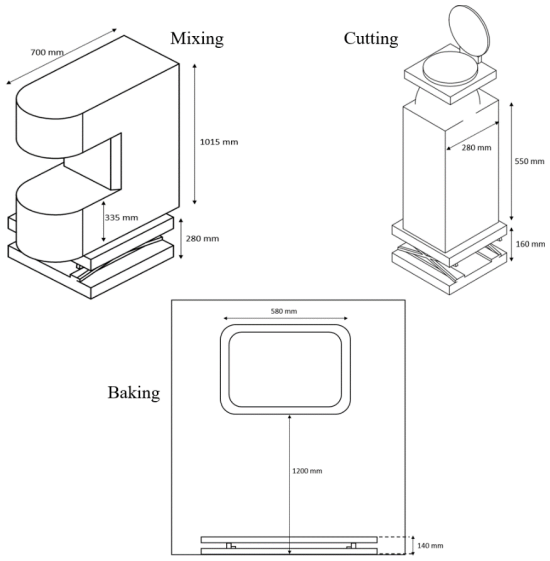


Figure 4. Adjustable machinery with platform

5. Conclusion

Through posture diagnosis using REBA and RULA, it was determined that the postures adopted by operators during the production process are harmful. The bending angle of the operators is inadequate for the type of work performed (mixing, cutting, and baking). Production activities posing an ergonomic risk are mixing, cutting, and baking. This was identified using the REBA and RULA techniques, which indicate that mixing poses a high risk, followed by cutting with a medium risk, similar to baking. In the case of mixing, it is recommended to intervene at the station as soon as possible.

Anthropometric data of the operators were obtained, allowing for a proposal for improvement considering the results of REBA and RULA. Thus, if the improvement proposal is implemented, it could prevent the development of musculoskeletal disorders as each station adapts to the anthropometric measurements of the operators.

Through the Nordic questionnaire, the main ailments of operators during the production process were identified, which are hands (100%), followed by the elbow (85.71%), and lastly the shoulders (71.43%).

Among the limitations for future research are the time and cost of implementing ergonomic designs in the machines, since specialized labor is required to guarantee correct installation. Also, data collection during the production process can affect worker performance. Research could be conducted on the effectiveness of worker ergonomics training to improve work practices, increase productivity, and reduce the cost of personal injury.

The application of REBA, RULA, and the Nordic questionnaire allowed us to recognize the discomfort of the operators and, consequently, identify activities with a higher ergonomic risk. These techniques can be applied in SMEs from different sectors in order to counteract discomfort and improve the ergonomic conditions of the activities they present.

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