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Research paper

DMAIC methodology application in bakery for French bread-quality standardization purposes

Aplicação da metodologia DMAIC em uma panificadora para padronização da qualidade do pão francês

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ABSTRACT: French bread is one of the food items mostly consumed in Brazil, as well as Brazilian bakeries' core product. Its growing demand forces bakeries to adopt strategies to speed up the production of Brazilians' "favorite", without losing its typical taste and quality. The current study was carried out in a traditional bakery in Araraquara City, São Paulo State. Its aim is to reduce the number of non-conformities in the French bread-production process. The DMAIC cycle was herein adopted as main methodology, although other tools, such as data collection and analysis, brainstorming and Pareto charts, 5W1H and risk mapping, were also used. Results have evidenced that more than 50% of the investigated production was not in compliance due to labor issues, raw material type and the adoption of non-standard processes. Finally, an action plan comprising bakery-intervention proposals was prepared and it evidenced the need of standardizing the used chemical yeast, of training the bakery's employees and of standardizing the time of each production stage.

Keywords: DMAIC. Bakery. French bread. Continuous improvement. Action plan.

RESUMO: *O pão francês é um dos alimentos mais consumidos no Brasil, além de ser o carro chefe das panificadoras brasileiras. Com a crescente demanda, é vital que as panificadoras adotem estratégias para agilizar a produção do "favorito" dos brasileiros sem perder o sabor e qualidade característicos. O presente trabalho foi desenvolvido em uma panificadora tradicional de Araraquara, São Paulo, com o intuito de reduzir as não conformidades da produção de pão francês. A metodologia principal utilizada constitui o ciclo DMAIC, onde foram utilizadas outras ferramentas: coleta e análises de dados, brainstorming, gráficos de Pareto, 5W1H e mapeamento de riscos. Após cada uma das etapas apresentadas, foi constatado que mais de 50% da produção não estava conforme e as causas raízes dos problemas que a panificadora enfrentava foram identificadas: mão-de-obra, matéria-prima e processos não padronizados. Por fim, foi elaborado um plano de ação com propostas de intervenção para a panificadora evidenciando-se a necessidade de treinamento dos colaboradores, padronização do fermento biológico e dos tempos de processo em cada etapa de produção.*

Palavras-chave*: DMAIC, panificação, pão francês, melhoria contínua, plano de ação.*

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INTRODUCTION

The growth of different industrial sectors in the current global scenario has forced entrepreneurs to continuously improve their products and services, based on adopting efficient quality management, among other reasons, to help increasing their competitiveness in the market (TELLES, 2014).

A traditional bakery from Araraquara City, hinterlands São Paulo State, remains operational in the market for more than 45 years; therefore, it was chosen for the present investigation. French bread is one of the several typical bakery products provided by the bakery, whose production is based on storing the dough in a cold chamber. It is done to supply consumers based on the local demand and to avoid wearing out employees due to excessive working hours. According to this process, the bread dough is prepared and placed in cold chamber at the resting and fermentation stage to cool out and to slow down the fermentation process. This procedure helps preserving its sensory features, so it can be baked the following day (cooled dough).

The quality of bread subjected to cold rooms often fluctuates, since this product presents varied features in each batch. Thus, it is not possible guaranteeing the final product’s pleasant sensory quality, and it ends up harming both the bakery and its customers. Assumingly, this dough cooling process is the main management issue causing the poor quality observed for bread produced in the investigated bakery.

The acronym DMAIC refers to the initial letters of each of the five stages of the methodology used as roadmap to guide the development of different processes, namely: define, measure, analyze, improve, and control. This methodology aims at improving products, services, and processes, based on problem-solving strategies. It derived from the PDCA cycle, whose name also derives from the initial letters of its steps, namely: plan, do, check and act. Both methods have the same purpose; they are well-known worldwide, as well as used by companies that adopt the Six Sigma strategies (AGUIAR, 2012).

According to Carpinetti (2016), the definition stage aims at defining the project to be developed. To do so, it is initially necessary to define the object of study, the problem and the undesirable effect to be ruled out. According to Werkema (2012), this stage is duly finished when both the project scope and the process to be analyzed are clearly defined, when the history of the problem is surveyed and when likely project constraints are addressed.

The measurement-taking stage comprises the application of statistical tools to diagnose and analyze the process leading to the definition of goals and results to be achieved. This stage is quite important, since the longer it lasts, the easier it is to solve the problem; moreover, it enables the research team to gather information about the investigated process, based on substantial evidence collected through the adopted tools (ARAÚJO, 2012).

The third stage comprises the analysis of data collected in the previous stage; statistical software can be used to calculate data; graphs can be plotted to help identifying issues and variations in the investigated process (SLACK, JOHNSTON, BRANDON-JONES, 2015). Both the process and its variables should be clear at the end of this stage to enable finding effective solutions, as well as to suggest improvements, at the following stage (COUTINHO, 2011).

According to Werkema (2012), the improvement stage is the one when the suggested solutions are tested at smaller scale, i.e., when a pilot test followed by data analysis is carried out. The solution presenting the best results - i.e., the approved one - is the one to

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be implemented at large scale. According to Araújo (2012), using statistical tools for process improvement purposes is a quite common strategy adopted to propose corrective actions to be applied to the target problem.

The main aim of the control stage is to ensure that the implemented improvements are not lost. Then, parameters used to monitor the progress of the adopted procedures were herein defined and procedures were reviewed. It was done to find new standardization strategies, such as elaborating standard operating procedures (SOP), making records, elaborating instructions, among others (CARPINETTI, 2016).

The aim of the current study was to apply a methodology to standardize the quality of French breads, based on comparing breads produced based on the conventional process to those subjected to cooling to the delay fermentation process. It was done to help standardizing the production process to prevent further variations in the product from happening and to guarantee its sensory quality. Accordingly, the DMAIC methodology was adopted as quality management tool to achieve this goal. The tool was used to reduce variability, defects and waste in the bread production process, as well as to increase its speed, and to make it more efficient and effective.

PROCEDURES

Definition

A meeting with the bakery manager was initially held to collected information about all adversities associated with the defective production process to make French bread based on using cooled dough. The flowchart of the French bread production process is shown in **Figure 1**, according to which, the production of cooled-dough French bread subjected to fermentation in chamber stands out in the bakery's production process cold to be supplied later and the uncooled dough with fermentation in cabinets to be supplied immediately.

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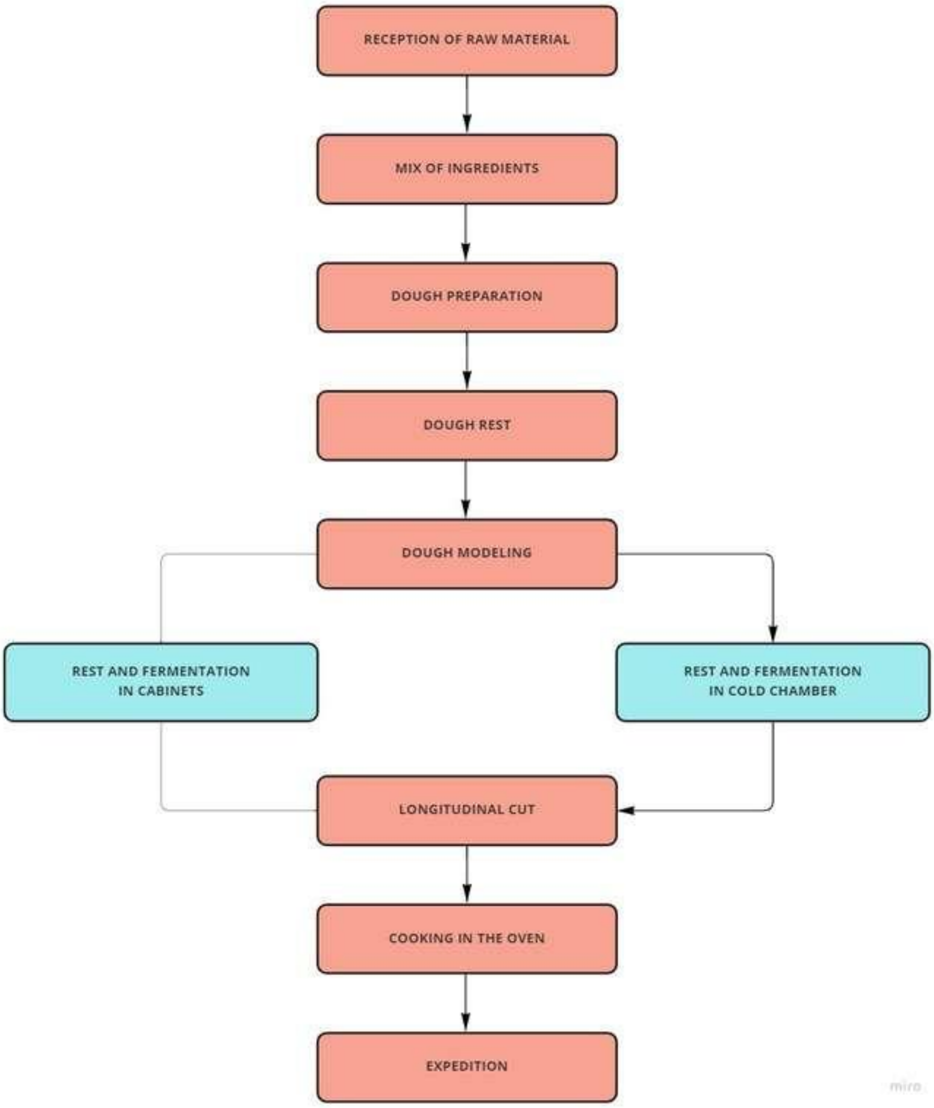
Figure 1. French Bread Production Flowchart



During the meeting, the bakery manager was asked about any other adverse conditions in the production process. He mentioned that the ice machine used in this process was defective and that it released ice water along with ice. In addition, the cold chamber was filled, and some modeled dough batches had to go to the chamber because the maximum capacity had been reached. He also mentioned that raw material brands (flour, flour improver and yeast) used in the production process often changed.

Measurement

A Control Form was elaborated to help better understanding the problem and identifying likely root causes for it. The form was handed out to the bakery's employees in order to register non-conformities in the bread production process. They were asked to remove a sample (one bread unit) from each bread batch, as well as to assess its external and internal features, to identify non-conformities and to fill in the Control Form. The form also comprised parameters used to identify dough ingredients, the person who made it and

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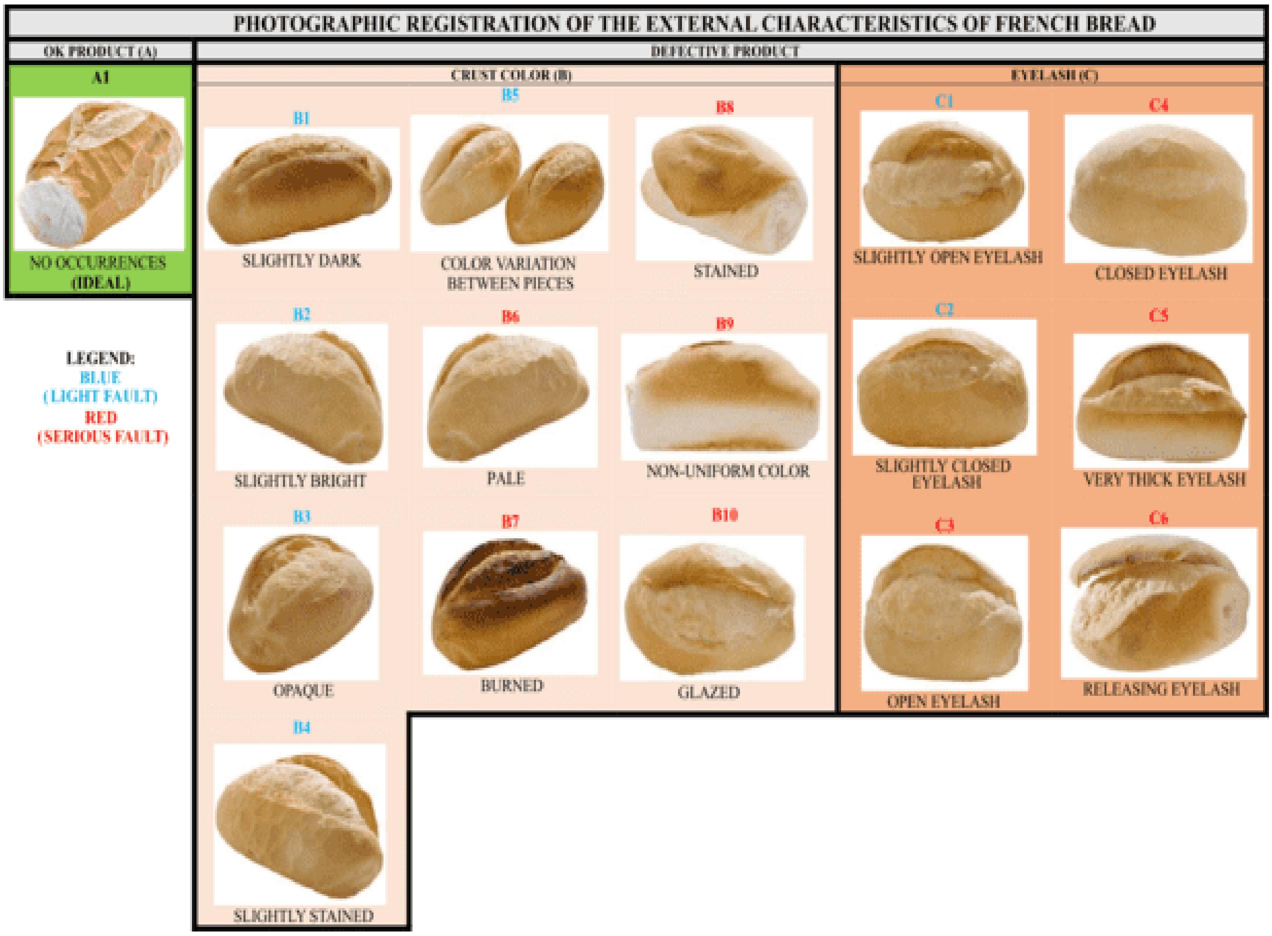
when it was produced, in addition to other adverse conditions of the production process mentioned at the definition stage.

The control form was initially filled in daily from May 17th to 22nd and from July 9th to 30th, 2022. In total, 55 batches of bread produced based on using cooled and non-cooled dough were measured.

A three-page Characteristic Photographic Record of French Bread was also elaborated in compliance with NBR 16170:2013 (ABNT, 2013), based on photographs taken from the standard to be used as reference in the process to identify non-conformities with two assessment parameters proposed in the standard, namely: external and internal features. This record was prepared to help identifying both internal and external pathologies capable of affecting the final product, as shown in **Figures 2, 3** and **4**.

Figure 2. Characteristic Photographic Record of French Bread (page 1)



Source: Adapted from NBR 16170:2013 (ABNT, 2013).

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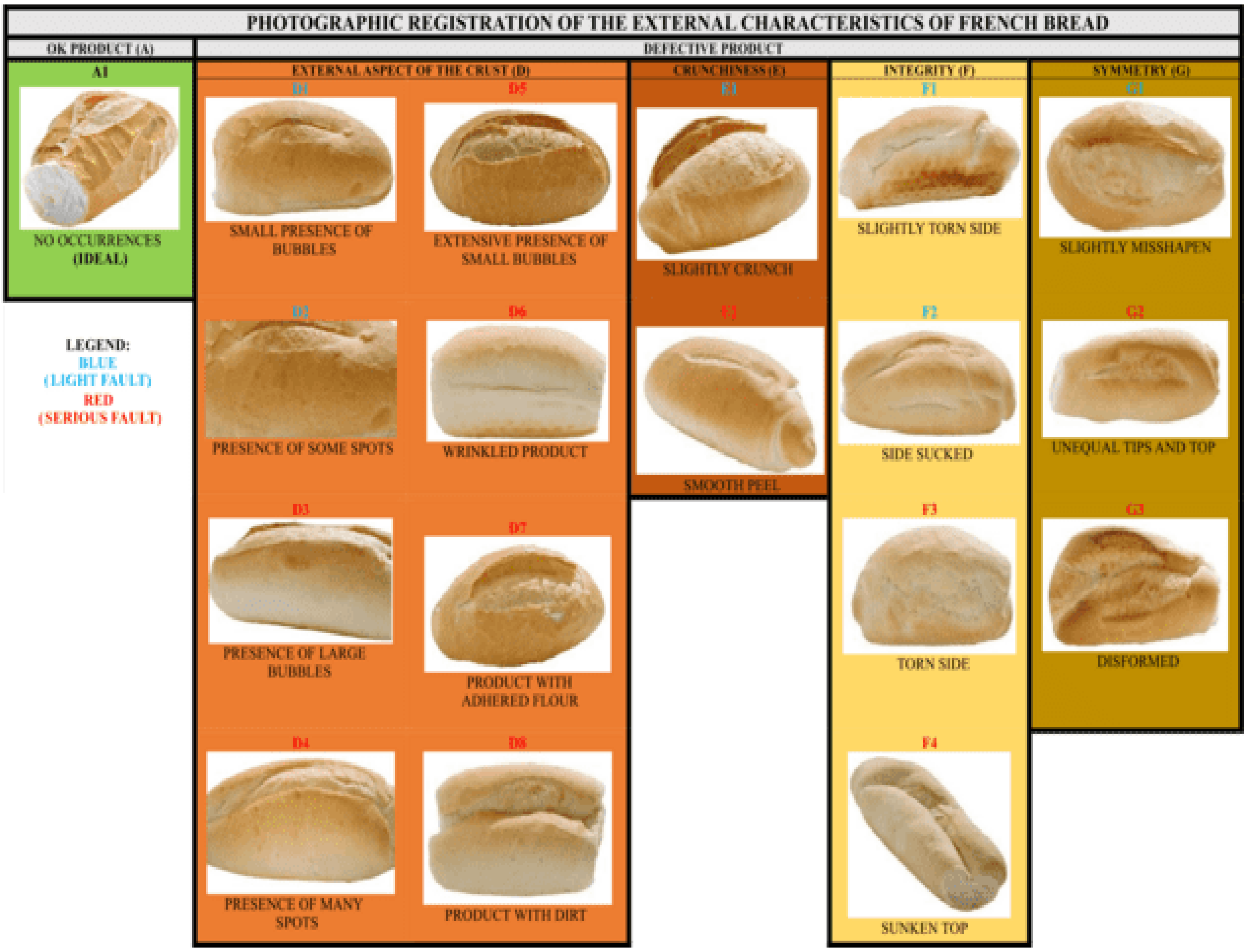
Figure 3. Characteristic Photographic Record of French Bread (page 2)



Source: Adapted from NBR 16170:2013 (ABNT, 2013).

The record was elaborated based on using the photograph of a defect-free French bread as ideal reference; it was highlighted in green (A1 and J1). This sample was compared to the produced breads and different colors were used for each type of problem found in different categories to make the identification process easier. Each photograph was labeled with a code comprising a letter and a number - as if it was a game board -; then, they were separated into two color categories (blue for light faults and red for severe faults). It was done to make it easier to collect samples from the production batch and to compare them to the photographs taken based on the ABNT standard. Each letter (between B and G) in this code was linked to a different external defect: crust color, eyelash, external crust appearance, crispness, integrity, and symmetry, respectively. Letters from K to M were linked to internal defects, such as internal crust appearance, crumb color and crumb texture, respectively.

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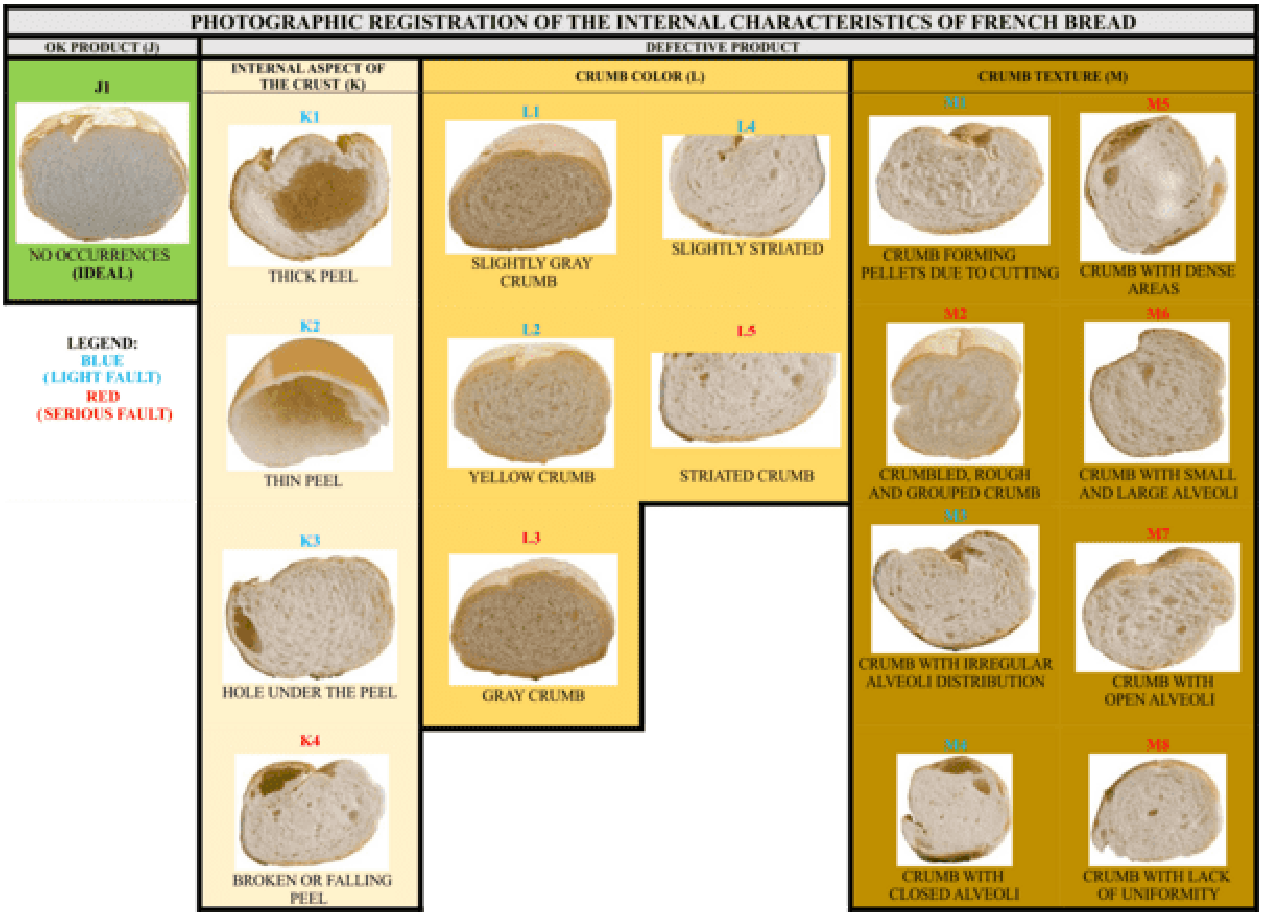
Figure 4. Characteristic Photographic Record of French Bread (page 3)



Source: Adapted from NBR 16170:2013 (ABNT, 2013).

Data Analysis

After the data collection process was over, information in the forms were digitized and data were tabulated. Brainstorming tools were used as starting point to analyze the likely root causes of the problem. Pareto chart in Microsoft Excel software was used to check and analyze the collected data. Raw materials and collaborators' names were replaced by random two-letter identification codes for secrecy purposes.

Improvement and Control

The likely causes of the reported issues were mapped after data analysis and a 5W1H action plan was developed to implement the intervention proposals to standardize the quality of French bread.

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RESULTS AND DISCUSSION
Data Analysis

Data from the control sheets were digitized and subjected to a first analysis, according to which, conventionally processed bread, i.e., and bread produced with non-cooled dough, have also shown defects. In total, 29 non-compliant batches, which accounted for more than 50% of the total production (55 batches), were identified, as shown in **Table 1**.

Table 1. French Bread Batch Comparison

	Conforming Batches	Non-Conforming Batches
Cooled Dough Breads	16	19
Non-Cooled Dough Breads	10	10
Total	26	29

This scenario was unknown at the bakery, since defects were always associated with breads subjected to dough cooling; data analysis has shown that 50% of batches produced through the conventional process also presented defects. Subsequently, a second analysis was carried out to identify likely variables capable of contributing to the non-compliance observed in the production process. It was done by splitting the completed form into small samples and by developing a diagram aimed at classifying suspect variables into three different levels of risk to the process (potential, undefined and null), which were defined via Brainstorming, as shown in **Chart 1**.

Chart 1. Diagram of Likely Process Risks Variables

VARIABLE	RISK LEVEL	JUSTIFICATION
Environment Temperature (ºC)	NULL	Mean temperature reached approximately 22°C ± 2.6 ºC and it oscillated between conforming and non-conforming batches.
Water with Ice	NULL	The ice machine was repaired before data collection; only ice was used in the production process.
Oven Temperature (ºC)	NULL	Mean temperature reached approximately 201.4°C ± 3.6 ºC and it oscillated between conforming and non-conforming batches.
Time Delay to Go to the Cold Room (Hours)	INDEFINITE	Wide variation in time between conforming and non-conforming batches.
Time Interval Between Manufacturing and Cooking (Hours)	INDEFINITE	Wide variation in time between conforming and non-conforming batches.
Yeast Brand	POTENTIAL	Direct raw material used to manufacture dough and the main variable of the French bread fermentation process.
Collaborator Who Made the Dough	POTENTIAL	Direct labor to produce French bread.

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The diagram enabled easily guiding the following analysis steps. Two tables were prepared: **Table 2**, for yeast brands and **Table 3**, for employees who made the bread dough. Results have shown that the bakery always used the cheapest yeast brand to produce bread; thus, the used brands changed based on the raw material price.

Table 2. List of Used Yeast Brands

	Batches produced with each brand	Conforming Batches	Non-Conforming Batches	Non-Conforming Percentage
LN Brand	15	6	9	60%
PA Brand	31	11	20	55%
IA Brand	9	9	0	0%
Total	55	26	29	

Table 3. List of Collaborators Who Made the Bread Dough

	Batches produced by each Collaborator	Conforming Batches	Non-Conforming Batches	Non-Conforming Percentage
AX Collaborator	28	9	19	68%
LS Collaborator	18	13	5	28%
BO Collaborator	9	4	5	56%
Total	55	26	29	

Based on data analysis, more than half of the batches produced by collaborators AX and BO, as well as of batches produced with yeasts belonging to brands PA and LN, presented defects. On the other hand, the yeast belonging to brand IA did not result in any defective batches. In addition to the charts plotted for collaborators and yeast brand, two other Pareto charts were plotted to help better understanding how each observed problem affected the whole production; it was done to investigate the specific reasons for each observed defect, as shown in **Figures 5** and **6.**

Based on the charts, most breads presented issues, such as lash and external crust appearance. Upon consulting the French Bread Implementation Guide (SEBRAE, 2015), it was found that issues associated with breads' external features mostly result from improper handling during the production process, as well as from non-adherence to good manufacturing and handling practices, and from defective flour using.

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Figure 5. Pareto Chart plotted for Cooled-Brough Bread Defects

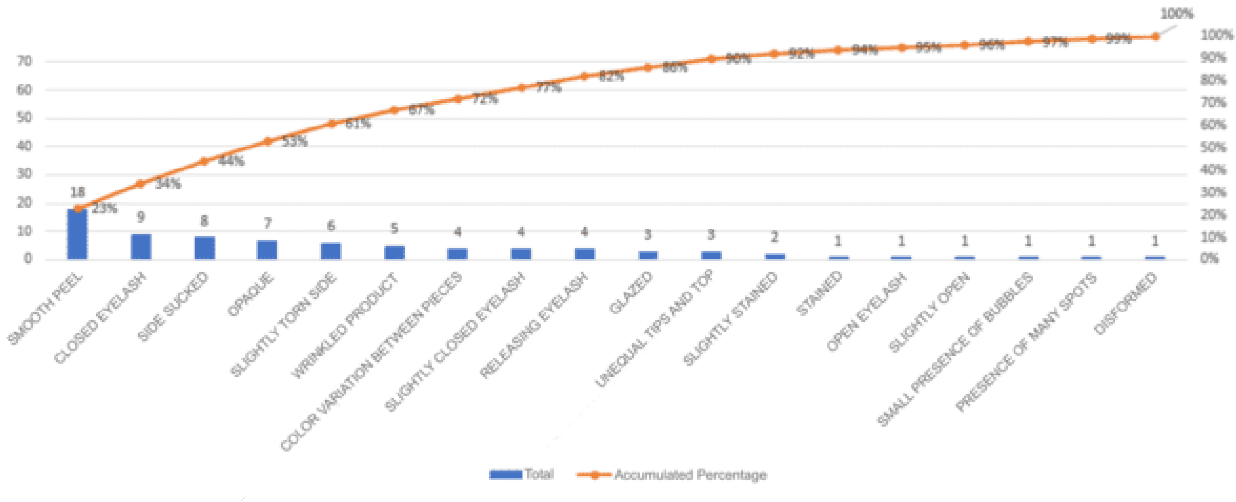
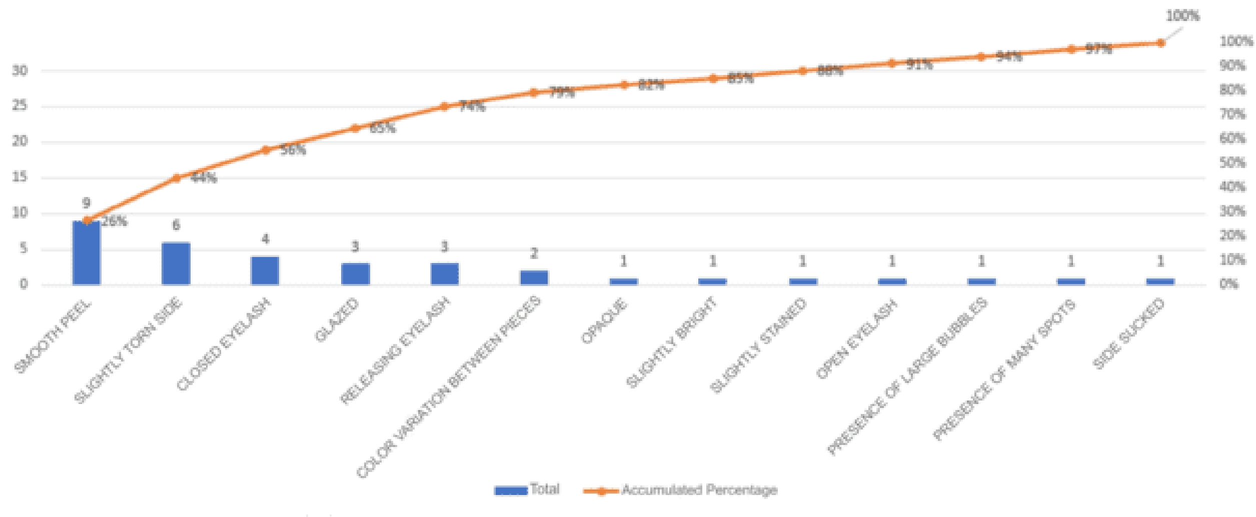


Figure 6. Pareto Chart plotted for Non-Cooled-Brough Bread Defects



Improvement and Control

According to Faust (2019), it is important reviewing the standardization of baking processes, as well as improving control and increasing the demand for quality.

Therefore, an action plan was prepared based on using the 5W1H tool after analyzing the current results and instructions provided by the herein adopted Guide, it was done to enable approaching the likely causes of the observed issues in order to standardize the French bread production process and quality, as shown in **Chart 2**.

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Chart 2. Action Plan with Intervention Proposals for the Investigated Bakery

What will be done? (What)	Who will do it? (Who)	Where will it be done? (Where)	Why will it be done? (Why)	When will it be done? (When)	How will it be done? (How)
Only using yeast belonging to brand IA	Collaborator	In the French bread dough productio n process	Because, despite other factors, this yeast did not present any production defect	In the production of the following French bread batches	Only yeasts belonging to the IA brand will be purchased; employees will not use another yeast brand in the bread production process
Employee training	Management	In the productio n line	Ensuring good manufacturing and handling practices	In the production of the following French bread batches	A specific dynamic will be applied to train all three employees about each production stage
Standardizatio n of schedules to produce and cook each French bread type	Management	In the productio n line	Because schedules were messy and production was disorganized	In the production of the following French bread batches	Schedules will be selected to produce cooled and non-cooled dough breads in order meet customers' demands

According to Faust (2019), besides reaffirming baking procedures, employee training avoids the emergence of errors in the bread production process.

Yeast brand, the employee who makes the dough, resting and fermentation time, and the cooking time necessary to produce each bread type were considered at the time to prepare this intervention. Although the last two parameters were not seen as potential root causes for the problem, they can cause confusion and production queues; thus, they were included in the action plan because errors generated at the supply stage affect product quality; not only its appearance, but, also its texture, durability and taste, as also observed by Faust (2019).

This plan was presented to the bakery manager so each of these actions could contribute to significantly decrease the number of non-compliant occurrences in the French bread production process. However, for financial reasons, the manager decided to do not implement these proposals in the short term, and it hindered the implementation of Improvement and Control stages.

CONCLUSIONS

The manager of the herein investigated bakery believed that only cooled-dough breads presented issues and that they happened sporadically; however, the application of the herein adopted methodology has evidenced that more than 50% of the total production

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based on both processes presented daily defects. Results enabled concluding that the observed issues stemmed from the use of yeasts belonging to different brands (due to financial issues) and from the fact that untrained employees were carrying out the whole bread production process without following a single standard.

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