QFD Implementation with the contribution of Sensory Analysis on product development in baking industry

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ABSTRACT: The main purpose of this thesis consists in the implementation of QFD (Quality Function Deployment) in free crust sliced bread production line.

The deployment of quality function allows deploying customer requirements into process stages and process variables. An online survey was conducted in order to define the most significant customer requirements related to sliced bread. The sensory analysis was used to choose the product technical specifications. A pilot panel of untrained assessors was set up, a test room was scaled-up and a procedure for sensory tests was set up. The first matrix was built and the product technical specifications were ranked through the sum of relations intensity with the pre-defined requirements.

The technical specifications and the process stages were deployed, the process stages were ranked and then were deployed in its most important operative variables through the construction of the second and third matrix.

Through the obtained results of the quality deployment, QFD was integrated with FMEA (Failure Mode and Effects Analysis) in order to understand the deviations of the product quality. Failure matrixes of the product specifications with more quality deviations were built and the related causes were established.

Based on the results, improved solutions were submitted in order to fix free crust sliced bread specifications and optimize the most important process stages.

INTRODUCTION

QFD – State of the Art

In any organization with an implemented quality management system various tools, called quality management tools, are used to control, monitor and track the desired quality. In these tools, the double entry matrixes, also called quality matrixes, are highlighted by their usefulness which relate product and process specifications to customer requirements, to process stages risk and to possible causes and their derived failures; which define the prioritization of process stages and prioritize projects among themselves and among other functions. [1] One of these most useful tools in new product development and which best represents the mentioned relationships through matrixes is QFD.

This tool was born in Japan, in the 60s and was created by teachers Akao and Mizuno [2] with the purpose to help and ensure compliance of customer requirements during product development. From there on, there were several methodological developments and changes.

In parallel to this development carried out in Japan, from 1986 there was in USA an intense diffusion of QFD although there were different methodologies similar to those developed by professor Akao team. [3]

The QFD versatility is such that different types of application methods have been developed: the QFDr (restricted QFD), the QD (just Quality Deployment) and QFD standard – the most widely used.

The application of this tool enables the deployment of customer requirements into product specific technical characteristics and identifies the strong and weak points in product and process, failures and deviations from the initial target. However, the risk associated to each failure and its possible causes are not accounted for. [3]

Another tool used in the development of products is FMEA (Failure Mode and Effects Analysis), which consists in the systematic analysis of the failure history.

This analysis enables to evaluate aspects related to the product failures and its reliability, prioritizing and eliminating faults, problems and potential errors through a quality matrix where relationships between failures and possible causes help to see which continuous improvement actions can be implemented to control the process.

QFD and failure analysis have different purposes and therefore are not usually used together. [4]

Nevertheless, nowadays efforts are made to integrate both quality tools in the same project thus to deploy customer requirements in product and process technical specifications and analyze the possible failures that endanger its reliability. [4], [5]

Therefore, it is possible to integrate both methods through QFD matrixes results using their indicators of importance prioritization to quantify potential or existing errors in a failure analysis matrix.

This new approach allows to understand the intensity of the relationship between customer requirements and development risks at the beginning of a project in order to avoid committing faults and mistakes that can increase associated costs. Besides, this has already been used in important projects of great companies such as NASA and US Air Force. [6]

METODOLOGY AND APPLICATION

Quality Matrix

Quality Function Deployment is an easy method whose characteristics are listening to what customers think about a product and what customers really want, need and expect and then use a logical system in order to determine the best way to satisfy those requirements with available resources.

It consists in the conversion of customer requirements into product quality characteristics through successive deployments of matrixes composed by relations and correlations between the same variables.

In addition to being able to obtain the customer satisfaction, the use of QFD when applied to the product development phase allows to reduce possible modifications and change processes thus reducing the risk and associated costs.

Finally, the most important advantage is undoubtedly getting data from the customer perception that allows the identification of changes in social values and the detection of new business opportunities. If the needs of different customers are taken into consideration and are satisfied, then the competitive advantage will on the side of the contestant who best meets the market trends. [7]

The House of Quality was used as a starting point and was obtained through crossing the customer requirements –what they express – the "Whats" of the matrix with the quantitative parameters to product quality designated "Hows". [8], [9]

The quantitative parameters correspond to the product technical requirements, are measurable and are defined by the organization to ensure market competitiveness.

Customer Requirements ("Whats")

Online Survey

A survey online about the habits of sliced bread consumption was developed and performed with the marketing department in order to try to reach all possible customers in a short period of time.

This survey was conducted in October 2014.

In one of the survey parts, questions focused on prioritization of the sliced bread characteristics, which were selected with the marketing department and in the opinion on the advantages and disadvantages of this product.

The relevance was rated from 1 to 6, where 1 is the least relevant and 6 is the most important characteristic to the customer.

The results are shown in Figure 1.

Looking at Figure 1 it is clear that the customer chose the taste as the most important characteristic with 95 votes. Considering the most relevant ratings above average, the expiration date is the second characteristic with the most votes.

Following the same philosophy of interpretation the less relevant for the customer was the shape with 88 votes followed by the size defined as the number of slices per bread packaging with 58 votes.

For the two remaining characteristics, odor and texture were considered to have a medium relevance, i.e. texture in position 4 and the odor in position 3.

The characteristics of sliced bread in ascending order of relevance for the customer are prioritized as follow:

Shape < Size (no. of slices/packaging) < Odor <Texture < Expiration Date < Taste

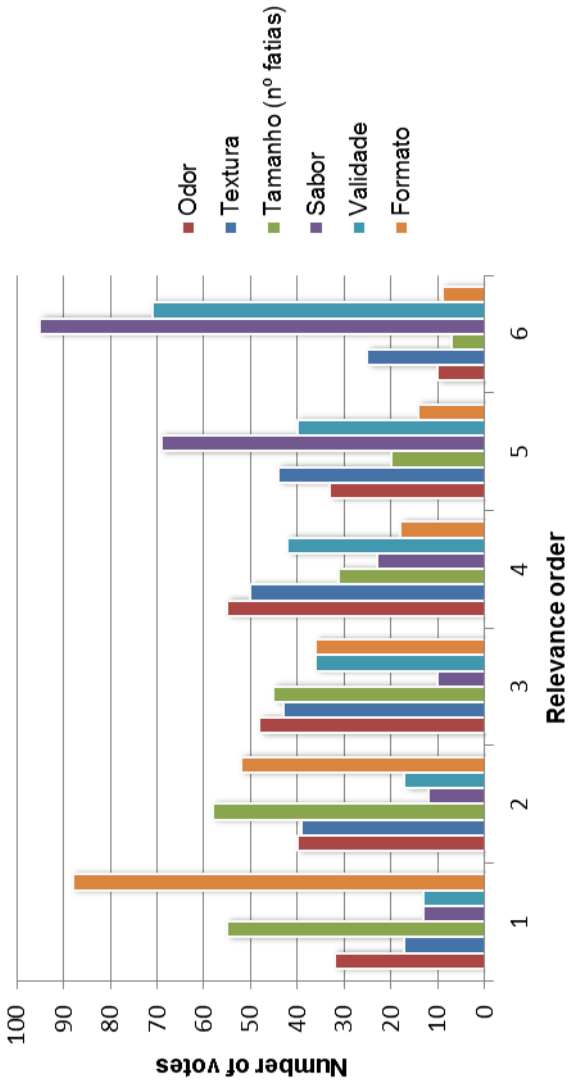

Figure 1 – Relevance order through customer opinion about sliced bread characteristics.

In the final part of the survey, customers were asked to indicate an advantage and a disadvantage which they thought more relevant. Table 1 shows the customers' replies.

Besides the shape, size, odor, texture, expiration date and taste, the price of the product was also highlighted in the customer selection criteria.

Texture, odor and taste are important parameters in the sensory evaluation of the products and are directly related to the freshness and softness of sliced bread throughout its expiration date.

Despite not being very relevant for the customer, the shape is one of the parameters that defines the choice of sliced bread because it is related to the product appearance which is why it may get a relative importance of 2.
Based on what was previously said, each requirement was prioritized using a scale of 1 to 5 with 1 being insignificant and 5 being very important as presented in Table 2. [9], [10]

Table 1 – Advantages and Disadvantages of sliced bread, in costumer insight.

Advantages	Disavantages
- Pratical; - Softness texture; - Long expiration date; - Easy storage after opening of the package; - Appropriate consumption to suit all ages.	- High price(racio price/quantity and quality); - Additives (unhealthy chemical and preservatives; customer view); - Artificial; - Flavor does not compare to the traditional bread; - Weak package.

Table 2– Prioritization of customer requirements through importance level.

Customer Requirements	**Importance** (1 – Minor important 5 – Very important)
Price	5
Taste and odor (Aroma)	5
Expiration date	4
Texture	3
Format	2
Size (no. of slices)	1

Competitive Evaluation

The competitive evaluation is part of the house of quality with the purpose of evaluating and comparing product requirements through the customer's point of view with similar products of market competitors.
The evaluation is performed based on a scale between 1 and 5 where 1 is the worst rated and 5 is the best rated for each requirement. [7], [9]

Product Technical Specifications ("Hows")

Sensory Analysis

In food industry, sensory analysis can be defined as "the examination of the organoleptic characteristics of a product by the sense organs" where organoleptic is defined as "the qualification of a property of a product perceptible by the sense organs." [11]
It means that it is an area of science used to summon, measure, analyze and interpret reactions to food and materials characteristics as they are perceived through the five senses: sight, smell, taste, touch and hearing.
Sensory analysis allows to obtain a consensus on which product technical characteristics should be selected in their sensory description.
The customer can often distinguish and understand the sensations during product testing experience but cannot express himself due to lack of this knowledge on sensory analysis.

Assessors Panel Definition

The main purpose of sensory analysis within the project is to check the acceptability in the customer market i.e. if a product pleases or displeases or if it is preferred to another.
This method, referred as affective, should be conducted with an assessors panel composed by a number of assessors between 20 (usually the minimum number to analyze a product in laboratory, called pilot panel) and 600 (called customer panel and usually used to mass assessment). [11] A pilot panel made by available employees in the facility was used in this project.
Therefore, once the approved assessors list is composed of more than 200 employees, a schedule and a proper timetable was established to avoid weariness.

The scale used to product evaluation was a hedonic scale. It is a bipolar mixed scale where number and strings are linked at each scale division only with 5 categories. (Figure 2) Since there is no specialized training, it becomes easier for the assessors to rank the study parameters on time, avoiding indecisions and bad judgments caused by the extension of categories.

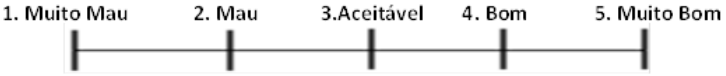

Figure 2 – Hedonic mixed scale of product evaluation.

Procedure of Sensory Tests

• Test format:
The assessors shall have at their disposal the product sample for evaluation, an evaluation sheet to fill in as indicated and a support label.
The test consists of a technical evaluation of packaging followed by a product sensory analysis based on the general descriptor parameters defined together with the marketing department (texture, taste, odor, crumb and freshness).
Relating used scale categories with the support label, the assessor should classify the descriptor parameter between 1 and 5 evaluating the product sample characteristics;

• Number of assessors per session:
Each session will be composed of 18 assessors divided into three groups and selected from a staff list of the HR department and sensory panel selection criteria; [12], [13]

• Products per session:
A maximum of 3 samples of different products will be evaluated by the assessors;

• Session duration:
Each assessor will have 15 minutes to perform the evaluation (experimental phase), becoming 10 minutes after they get used to it;
Each session will last 1h30min;

• Schedule:
In each week three different product samples should be collected and evaluated to avoid employee tiredness because an assessors specialized training will not be carried out; [14]

• Results record:
The results for each product must be inserted in a specific Microsoft® Excel software sheet in order to monitor product development during sensory evaluation time.
Each question in the product evaluation sheet must be registered in the proper field;

• Results treatment:
The product sample in evaluation should be compared qualitatively to the standard product by plotting a polar coordinate system of average ratings for each attribute of the sensory profile.
The standard product should have all the sensory attributes on the average of hedonic ratings, specifically 3 as shown in Figure 3.

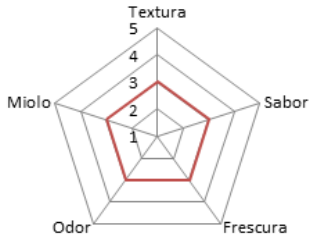

Figure 3 – Sensory profile of the standard product.

The results treatment should be complemented by another statistical test to compare the scores averages and set a level of importance among them.

Variance analysis is used to compare the averages of the ratings and confronts the variance among the various products to the variance within each product.
This analysis is based on two fundamental principles: the subdivision into total variability components determined by total sum of squares (TSS) and their degrees of freedom and in the estimation and comparison of the variance, σ^2, of these estimation.
It is also based on three assumptions: the independence of the results guaranteed through random sensory tests, the normal distribution of the results and variances homogeneity. [15]

Thereafter, the seven main specifications of free crust sliced bread produced by Panrico® were defined and selected:
• Texture: Soft, Regular crumb and crumb cohesiveness;
• Natural bread taste;
• White color;
• Regular/uniform shape slice;
• Natural bread odor.

Correlations between Product Specification

The correlations are represented in the “roof” of the house of quality through a nomenclature which must be defined *a priori* after the choice of specifications.
These relations are established in order to determine potentially positive and negative interaction using symbols to classify and distinguish strong, medium or weak, positive or negative relations. [16]
It should be take into consideration that too many positive interactions may suggest a potential redundancy in which there are no critical points and thus the focus should be on negative interactions considering the used technology to overcome the possible implications and consider the advantages and disadvantages when technical targets are established.
Correlations are defined in Table 3.

Table 3 – Product technical specifications correlations.

	Soft	Taste	Color	Crumb	Slice shape	Cohesiveness	Odor
Soft							
Taste							
Color		+					
Crumb	+ +						
Slice shape	+			-			
Cohesiveness	+ +		-	+			
Odor		+ +					

Label	
+ +	Strongly Positive
+	Positive
-	Negative
- -	Strongly Negative

Technical Difficulty

The product specification changes also have different technical difficulties and should be included in the matrix. The difficulty to obtain, maintain or modify a characteristic was defined by the sensory analysis team assuming a scale between 1 and 5 where 1 represents an easy characteristic to obtain and 5 is a difficult characteristic.

Being softness a very important sensory attribute of the texture in sliced bread, it is at the same time hard to be kept constant in a product, once it depends on various parameters throughout the production process. So, this was the unique specification classified with 5 in Table 2.12.

Table 4 – Product specifications technical difficulty.

Product Technical Specifications	**Technical Difficulty** (1 – Easy 5 – Hard)
Soft	5
Taste	3
Color	1
Crumb	4
Slice shape	2
Cohesiveness	4
Odor	2

Competitive Technical Evaluation

The competitive technical evaluation of product specifications consists in comparing the product technical characteristics with competitor products conducted by QFD team.

A monitoring comprising several weekly evaluations was performed for different life product days until expiration date, together with the marketing department in order to study the behavior of various technical characteristics of the product and the differences between them.

A scale of 1 to 5 was also set, where 1 is the minimum and 5 is the maximum. [12], [14]

"Whats" vs "Hows" Relations

The relations matrix is represented in the center of QFD matrix and has a heavily weight on the possible conclusions to be drawn. It comprises the establishment of relations between customer requirements (Whats) and product technical specifications (Hows).

Relations are usually defined using symbols which correspond to scores and their intensity should be distinguish as strong, medium and weak in order to identify the project requirements with the greatest influence on customer satisfaction and also the absence and/or unsuitable relations.

These relations have been defined in department meetings, in which several ideas and ways to approach each of them were discussed. The conclusion reached showed that the best method would be to see relations through a production perspective by setting the intensity of each relation based on the technical specification importance on the customer requirement.

For example, the product price depends heavily on the raw materials price, production costs and

profit margin set by the company. These factors are the great responsible for sliced bread characteristics, this way strong relations were established between price and softness, price and taste, which are very important product sensory characteristics.

Technical Specifications Importance

The technical importance for each specification is defined as the sum of the scores of the relations matrix strength with the value of the importance defined by the customer.

The sum value is the Absolute Technical Importance (Eq. 1) being the Relative Technical Importance (percentage) obtained by dividing the sum value by total amount. (Table 4)

$$\mathrm{TI}_{\mathrm{Abs}} = \sum(\mathrm{Importance} \times \mathrm{Strength\ Relation}) \quad \text{Eq. 1}$$

First QFD Matrix

Table 5 – OFD 1st Matrizx.

Product Specifications Correlations	
Soft	
Taste	
Color	+
Crumb	+ +
Slice shape	+
Cohesiveness	+ +
Odor	+ +

Label				
Hows vs Hows		Whats vs Hows		
+ +	Strongly Positive	●	9	Strong Relation
+	Positive	○	3	Medium Relation
-	Negative	Δ	1	Weak Relation
- -	Strongly Negative			

		Product Technical Specifications							Competitive Evaluation	Customer Claims per year	
		1	2	3	4	5	6	7	(1 - Minimum 5 - Maximum) X - Our company A - Competitor A		
Improvement Directions		↔	↔	↔	↑	↔	↑	↔			
Customer Requirements	Importance (1 - Less important 5 - Very important)	Soft	Taste	Color	Crumb	Slice shap	Cohesiveness	Odor	1 2 3 4 5	2014	2015
Price	5	●	●			○	Δ	○	X A	a)	a)
Expiration Date	4	●	○		●		Δ	○	X A		
Aroma	5		●	○				○	A X		
Format	2					●			A X		
Size (no. Of slices)	1	○			○	○			A X		
Texture	3	●			○		●		A X		
Technical Difficulty 1 - Easy 5 - Hard		5	3	1	4	2	4	2			
	Product Specifications Units	a)	a)	a)	a)	a)	a)	a)			
Technical Competitive Evaluation (1 - Minimum 5 - Maximum)		1 A 2 A 3 X 4 X 5	A	X	XA	A	X	A	A X		
Technical Importance	Absolute	111	102	15	48	36	36	42	TOTAL 390		
	Relative	28,5%	26,2%	3,8%	12,3%	9,2%	9,2%	10,8%	100%		
	Ranking	1	2	7	3	5	6	4			
Technical Targets		a)	a)	a)	a)	a)	a)	a)			

a) classified values

DEPLOYMENT

The QFD methodology consists of a set of matrixes that are developed in order to guide and coordinate actions within the team that develops the product so that customer complaints are not only eliminated but they can also provide an active response to customer wishes and future expectations.

In the first matrix customer requirements are related to the measurable product specifications.

In the project second phase these technical specifications will be related to the various production process stages.

In the third and final QFD phases the process stages will be deployed into operative variables used in the sliced bread production.

Product Technical Specifications Importance

Table 6 – Product specifications importance degrees.

Product Technical Specifications	**Relative Technical Importance (%)**	**Ranking (1st Matrix)**	**Importance** (1 – Minor important 5 – Very important)
Soft	28,5	1	5
Natural bread taste	26,2	2	5
Color	3,8	7	1
Regular crumb	12,3	3	4
Regular/Uniform slice	9,2	5	3
Cohesive slice	9,2	6	2
Natural bread odor	10,8	4	4

Process Stages – Technical Difficulty

The definition of the various process stages technical difficulty was made in a similar way to that performed for product technical specifications in the first matrix using the same scale of 1 to 5, where 1 represents easy and 5 represents difficult. The process stages where more parameters should be controlled and where there is a higher risk of nonconformities were taken as maximum difficulty, as the case of fermentation and oven baking. The formulation and weighing and cooling stages were classified with 2 and 1, respectively, because the instruction is already defined and the control is easy to achieve and maintain. In Table 6 chosen technical difficulties are shown.

Table 7 – Technical Difficulty of process stages.

Process stages	**Technical Difficulty** (1 – Easy 5 – Hard)
Formulation and Weighing	2
Mixing	3
Dividing	4
Rounding	2
Intermediate proofing	3
Rolling	4
Molding	4
Proofing	5
Baking	5
Depanning	4
Cooling	1
Crust removal	4
Slicer	3
Packaging	4

Process Stages Importance

Table 8 – Process stages importance degree.

Process Stages	**Relative Technical Importance (%)**	**Ranking (2nd Matriz)**	**Importance** (1 – minor important 5 – Very important)
Formulation and Weighing	16,7	3	5
Mixing	11,4	4	4
Intermediate proofing	10,2	5	3
Rolling	10	5	3
Proofing	18,5	2	5
Baking	22,1	1	5

Operative variables – Technical Difficulty

The R&D department defined the most important operative variables for each stage. Some of them were related to various process stages at the same time. This factor is rather relevant because relations between process stages are important and demonstrate that the process is interlinked.

The chosen variables were selected and ranked according to the technical difficulty as shown in Table 8.

Table 9 – Operative variables technical difficulty.

Operacional variables	**Units**	**Technical Difficulty** (1 – Easy 5 – Hard)
V1	u1	3
V2	u2	4
V3	u3	2
V4	u4	4
V5	u5	1
V6	u6	1
V7	u7	3
V8	u8	4
V9	u9	5
V10	u10	4
V11	u11	5

FMEA

Possible Causes

Through QFD it was possible to identify the most relevant customer requirements, the main product specifications and its current situation in the market compared to the other competitor, the process stages and the most important operative variables in sliced bread production and so figure out the causes of quality deviations and also where such failures could be.

In the first matrix the most deviated specifications from the standard ones have been identified. They are the crumb regularity, the slice cohesiveness and the taste and odor of bread.

To detect the possible causes related to nonconformities there was a systematic and logical analysis through troubleshooting.

The crumb is considered not regular when it has internal holes with diameter larger than 1cm and the possible causes are shown in Table 9.

Table 10 – Causes to crumb regularity failures. [17], [18]

Failure	Main Cause	Possible Causes
No regular crumb	Holes in Bread	Old Dough
		Improper Mixing
		Lack of Moisture in proofer
		Improper Moulding
		Humidity too high in Proofer
		Proofer temperature too high
		Excess dusting flour
		Excess Divider oil
		Insufficient Intermediate Proof
		Dough to stiff
		Cool Oven
		Rough handling at/in Oven
		Short residence time at Oven

The cohesiveness depends on crumb texture to endure deformation without breaking.
Table 10 presents possible causes for the lack of cohesiveness

Table 11 – Causes to cohesiveness failures. [17], [18]

Failure	Main Causes	Possible Causes
Lack of Cohesiveness	Hollow Bottom	Overmixing
		Moisture in bottom of pans
		Use of hot pans
		Proofer humidity too high
		Underscalling
	Loaf brusts on the side	Improper moulding
		Overproofing
		Mixing too weak
		Quality loss in the dough
		High temperature at intermediate stages
		Cool Oven

The taste and odor deviate from the desire quality when the bread has poor flavour of which possible causes are shown in Table 11.

Table 12 – Causes to poor flavour. [17], [18]

Failure	Main Causes	Possible Causes
Taste and Odor	Poor Flavour	Old Dough
		Unbalanced recipe
		Improper mixing
		Too low or too high a salt ratio
		Short mixing time
		Improper storage of flour
		Poor quality raw materials
		Overproofing
		Product contact with unsanitary equipment
		Careless lubricating of equiment
		Baked product stale
		Burned dough stuck to the forms
		Absorption external odours

QFD Integration

In order to integrate the QFD with failure analysis, it was decided to use the third matrix prioritized operative variables, its technical difficulty and the relation intensity with process stages (prioritized in the second matrix).

For each variable it is identified how the control is currently done, the control method, the used equipment, documents and reference values.

To perform the failure analysis the same nomenclature and symbolism was used for differentiating the relation intensity in QFD matrixes.
The prioritization of the matrix results was performed through the sum of the products of operative variables technical difficulty with the respective relations intensity defined by the main causes of detected faults.

$$\text{Priorization} = \sum(\text{TD} \times \text{Intensity relation}) \qquad \text{Eq.2}$$

Where TD represents the technical difficulty.

CONCLUSIONS

In new product development the VOC is essential in requirements establishment and prioritization through customer interviews as well as meetings with marketing department during the project.
QFD is undoubtedly a huge valuable tool for any kind of industry and provides those responsible for it a wide view during the conception, anticipating the view of possible errors in advanced parts of the project and reducing associated costs related to product development.
The food industry has the peculiarity of being a constantly changing industry due to the evolution of customer requirements such as the inherent variability to production processes.
Therefore, it is important to use sensory analysis as a control method of the technical parameters defined as very important. It is a method that helps in technical specifications failures detecting throughout product life time and it can be used in different ways allowing also to locate the product on the market comparing it to the competitors'.
Through QFD the free crust sliced bread proved to be one of the industrialized bakery products best known and consumed in the market with a long expiration date that ensures the product consumption conditions although it has a high price per unit. The first relations matrix highlights the product price importance and its strong influence on the most relevant characteristics like softness and taste. Being the product produced by a brand leader company, the customer has no problem to pay the set price and meet their requirements.
The technical characteristics were deployed in the process stages and, as expected, it was concluded that the oven and fermentation processes are the most important of all the production line, not forgetting the raw materials used in the formulation step. These unit operation are by far the most important stages to obtain ideal sliced bread with the most important technical specifications such as softness, taste and crumb regularity and they must be operated with maximum possible accuracy. This rigor was verified by defining the technical objectives for each process stage and through weekly assessments with the help of sensory analysis.

In the QFD final matrix the most relevant stages were deployed in its operative variables. It was clear the highlight of each stage temperature as the most important variable, also expected, followed by the added water as the second operative prioritized variable. The previous variable may be overlooked in the operating conditions of each stage but it has an important role in defining the mass internal temperature, helps to mix all ingredients and allows to obtain the desired final weight according to the operating conditions.

To understand the detected improvement opportunities in the product technical specifications the QFD was integrated with failure analysis thereby building matrixes for each of the characteristics with more improvement opportunities using prioritization, relations intensity and technical difficulty resulting from quality deployment. This tool was not used in its fullness but it was an important method for the detection of general possible causes responsible for the variability found in crumb cohesiveness and regularity and flavour. The overproofing, the improper process time in the oven and fermentation chamber or temperature values above the set-point were the factors that showed more relations with operative variables prioritized through QFD and they can have a negatively influence on the texture and crumb cohesiveness, the appearance of air bubbles inside the crumb and the flavour.

So after identifying the product improvement study points, the QFD integration with FMEA enables the definition of continuous improvement solutions in the production line which are capable of correcting and prevent deviations from the ideal free crust sliced bread and monitor with greater accuracy all stages of production and process variables.

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