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Implementation of QFD method in quality analysis of confectionery products

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Abstract The paper presents the possibility of the application of QFD method as an effective tool to identify consumer preferences for a new characteristic of a sponge-fatty cake as well as designing of the high quality products of food industry. The consumer expectations were examined in relation to these products, and then translated into technical specifications, important from the point of view of the manufacturer of sponge-fatty cakes. The analysis showed that there is a chance of producing a type of sponge-fatty cakes that will meet the requirements of consumers, and at the same time meet the requirements of nutritionists and technologists. Results of the current study indicated that the main parameters responsible for the quality of the final product, preferred by consumers, are: the appropriate content of liquid and solid fat in the form of crystalline β', and the presence of refined fats. This means that consumers prefer a product that has a high volume and a suitable color, and does not have any perceptible "sandy" or "gritty" texture. The analysis showed that the resulting final product meets the respondents' most rigorous requirements in terms of sponginess, product volume, humidity, brittleness; the analysis also revealed the additional health benefits of our product in comparison to two other products of competing food companies. However, delicate modifications of aroma, smell, and color were necessary. Besides, this paper showed how customers' voice can be heard in order to reduce development and manufacturing costs, improve product quality, provide features that satisfy customer needs, and reduce development time. Furthermore, to give more insight into the problem, in this paper we have adopted a new approach by extending the quality function deployment matrix beyond the house of quality.

Keywords QFD method · Foodstuff quality · The house of quality

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Introduction

The need for continuous improvement of manufactured goods quality is a stimulus for manufacturers to continuous product innovation. This issue is affecting more and more fields of industry, including production of foodstuffs. Searching for new better products and their further development aims to introduce to the market goods, best suited to consumer preferences, which exhibit the characteristics and levels of these traits, which will be widely accepted by consumers.

Continuous striving for the fulfillment of the expectations of the customers is necessary to maintain position in the market and compete with other companies operating in the given branch of industry (Kutschenreiter-Praszkiewicz 2013). The customer orientation should be the basis of any organization's strategic plans in the sphere of the production process.

Thus, the statement "the customer is king" became the motto of any success-oriented company. In this context, it is particularly important to focus on designing of quality (called Design for Quality), which analyses every action related to obtaining and maintaining a predetermined level of quality of

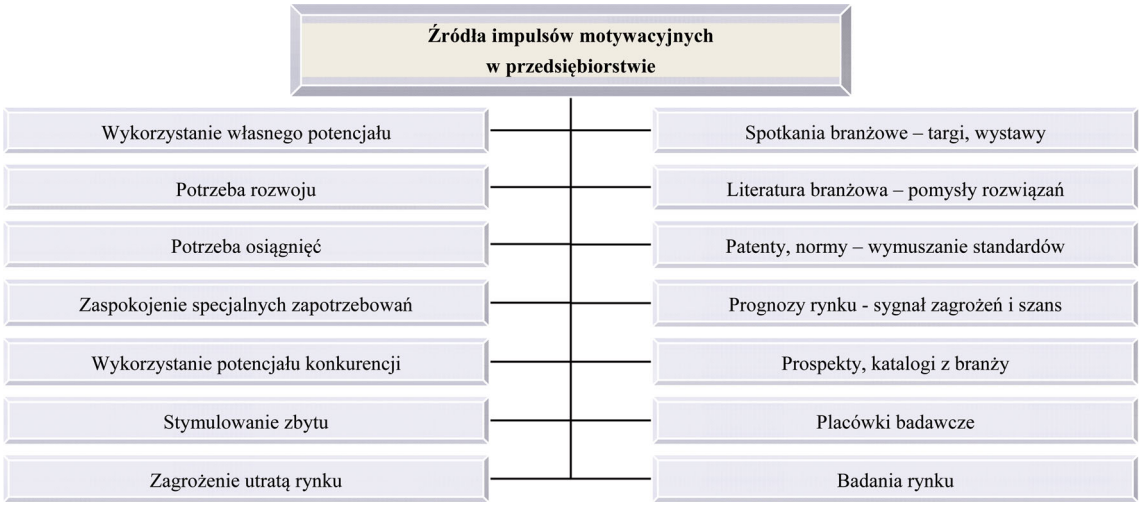


Fig. 1 Sources of motivation in an enterprise. Own elaboration based on (Penc 1995)

the product during its entire life cycle (Hamrol 2011). This is an important issue for the food industry, whose clients belong to a diverse, in many respects, community and defining the quality characteristics of consumer food products is a subject of their judgment. The market of food industry is shaped by a wide range of customers having different requirements and preferences, which clearly define and standardize the basis of both product design and manufacturing process. The quality requirements determine the life cycle of products and control the management activities and regulations of the company. A company that cares about the health of the consumer attempts to create the product for which the customers, at the next choice, will return and buy again.

QFD method is a cross-functional planning tool, which ensures that the voice of the customer is systematically deployed throughout the product planning and design stages (Pable et al. 2010; Shin and Kim 2000). This method improves the communication process between producers and clients, and is used to adjust the level of quality of the products according to customers' requirements (Mehrjerdi 2010a). According to Shen et al. (2001) QFD is a powerful system for quality improvement and product development, which assures that quality is an essential concern of the new products and services.

The presented method has been developed by Japanese engineers to ensure product quality already in the design phase of the product (Chan and Wu 2002).

Product innovations in the food industry

- In the customer-oriented quality systems, particular attention should be paid to: examination of the requirements and expectations of customers,
- survey of customer satisfaction with products and services.

The basis for the design and manufacture of new or modified food product should be to examine the customer preferences. The difficulty of this study stems from the frequent inability to formulate the client's future expectations with respect to product, depending among others on the variable taste preferences, seasonality of products, consumer age, the achievements of science and technology, and sometimes a combination of several aspects of solving the problem of defining the expectations of the consumer in relation to a new food product. Improvement and further development of already manufactured products is considered to be one of the following forms of management innovation (Penc 1995):

- strategic—related to innovative projects with long-term nature, affecting a significant impact on the entire company,
- tactical—for any type of ongoing changes to the product, its production methods or in the organization in order to more fully meet the needs of the market.

Figure 1 shows the most common source of information for motivational processes in an enterprise.

In practice, the development of new or a modification of an existing consumer food product occurs through planning processes, selection of raw materials and additives for the product (food) of the desired quality (sensory, nutritional and dietary). The food industry is highly segmented market in which manufactures and retails need to be able to respond quickly to the changing nature of customers preferences and tastes (Haq and Boddu 2014). In view of the need to ensure the technological quality of food is important for a trader to take into account the factors affecting its nutritional value and sensory factors limiting the shelf life of the product in the planning process.

In the evaluation and planning of product quality, the manufacturers use a different language than consumers. Recipients of food products describing their requirements are generally asked to determine the description of the related sensory attributes, and do not use the names of the quality parameters nor their specific numerical values. However, in the course of food production planning the designers and technologists use the precise technical language. QFD method, representing extended version of the matrix data analysis, is helpful in translating the user requirements into technical quality indicators.

Subject of research

As a subject of the current study, in order to present the applicability of the method of QFD as a tool to streamline the process of merging customer requirements and technical parameters of the manufacturing process of the product, the sponge-fatty cakes were chosen from a diverse range of products of the food industry. Sponge-fatty cake is a popular confectionery, which is the base for an assortment of pies and cakes.

Consumers of confectionery products form a very diverse community, which makes the diagnosis, systematization and interpretation of their expectations an extremely difficult task. In addition, in a sponge-fatty cakes technology it is possible to model their quality by applying different raw materials and technological parameters. These are goods to produce which it is necessary to add quite large amounts of fats, even up to 100 % in relation to the weight of the flour. Beside, an ingredient functionality is difficult to assess in complex systems, such as cakes, because several ingredients may interact and affect the sensory quality. Therefore developing new cake formulations that are perceived as fresh and, which retain freshness during storage is a complicated process (Heenan et al. 2010).

The quality of the crumb is a parameter having a significant impact on market acceptance of these products. Its evaluation is an important parameter of its specific weight—the higher it is, the worse sensory features are presented by an article. There are various possibilities of modeling of this quality parameter. For example, a large addition of fat in the dough makes the structure of the crumb more delicate than typical sponge products (Żbikowska and Krygier 2004). In addition, there are other factors which impart appropriate characteristics to pastry products. For example, the addition of lauric acid is responsible for the stronger flavor, the addition of refined fat gives the product the desired color (Żbikowska et al. 2012a). The presence of liquid fat makes the structure of the product more plump and elastic (Żbikowska et al. 2012b).

Modification of the dough composition also influences the physicochemical characteristics and organoleptic properties. An example may be the results of studies on the effects of saccharin addition on the physical properties of sponge-fatty cake (Kusińska and Starek 2012) as well as the correlation of the rheological properties of the intermediate and the quality features of the final product (Rutkowska and Neryng 2002). Basic quality parameters of sponge-fatty cake are characterized by the following mechanical properties of texture: 18.51–20.01 N hardness, elasticity 0.52–0.58, 0.26–0.29 cohesiveness, chewiness 2.93–3.05 N and humidity 38.6–38.8 % (Kusińska and Starek 2011). The texture dictates consumer perceptions of quality and acceptability of food products (Szcześniak 2002; Wanga et al. 2013).

From sponge-fatty base dough many types of pound cakes, biscuits, tree cakes, biscuits (interleaved, non-interleaved) biscuits, mazurkas and layer cakes are produced. The above data indicate that this type of dough can be used for different purposes, therefore, the aim of the study was to find those technological parameters that could be responsible for meeting the highest demands of consumers of sponge-fatty cakes.

Materials and methods

In this paper, the quality function deployment method, QFD, was used as an effective tool to support pro-quality action. The method allows for determination of a new characteristic of sponge-fatty cakes from customer's demands. Application possibilities and usefulness of this method within the many important aspects of the quality of food industry products have been tested on the example of a food product, i.e. the sponge-fatty cake. Although this method is both time- and labor-intensive, however, it brings tangible benefits to the manufacturer because it gives greater assurance of customer satisfaction, reduces the number of changes that need to be incorporated into the design and manufacturing process, shortens the product development cycle and reduces costs (Ayağ et al. 2013; Ayoola 2013).

The study was conducted in two stages: in the first stage the consumers determined their preferences with regards to sponge-fatty cakes. The material was collected by direct interview and based on surveys in which respondents evaluated the suggested parameters determining the quality of the cakes. The next stage of the study was to determine the relationship between technological parameters and requirements of consumers in relation to this type of confectionery products. For this purpose the results of the brainstorming session, as a way of group exploration of new ideas to solve problems, were employed. During the study session, participants were free to raise any number of custom solu-

tions, and then evaluate all of the proposals and make their selection.

The result of this step is a matrix of links between technical parameters and technical requirements, which is one of the areas of QFD method. In addition, the organoleptic assessment of the prepared sponge-fatty cake was carried out to make a comparison of its properties with the features of two other sponge fatty cakes that are already on the market. This evaluation was made by a team of 100 randomly selected respondents—students from Economics Faculty (specialty: Commodities and Food Technology), University of Technology and Humanities in Radom (UTH). The respondents were asked about the quality parameters, which should characterize the sponge-fatty cakes. Respondents were also asked to evaluate their preferences with respect to the features mentioned in the scale of 1–5, where 1—corresponded to the lowest and 5—to the highest grade of the given feature. A comparison of the own product "A" with two competing products "B" and "C" in terms of assessing consumer needs was conducted at the Laboratory of Sensory UTH Radom. Customer assessment of the degree of consumer acceptance of individual products was carried out using a five-hedonic scale.

Discussion and results

Application of QFD method allows determining the parameters (properties) of the product and its components, and then the parameters of raw materials and the processes leading to its production on the basis of information from the market (consumers) expressed in the language of clients. The requirements can be transformed by a sequence of houses of quality relating to product, process design, process, and organizational projects to ensure the quality expected by the customer (Sikorski 2002; Jyothi and Rao 2011).

In the literature and in practice many different types of houses of quality are presented, both in terms of their visualization, as well as the proposed scope of the information included therein (Szafrański 2011). In general, the appearance of the scheme depends on the product and the team that addresses this need. It is assumed that the house of quality is composed of six to nine components (fields). The number of its parts and the interpretation may vary slightly depending on the literature (Mehrjerdi 2010b).

QFD takes into account the highest possible degree of consumer expectations and enables technologists to obtain a modified or new products with wholesome food composition, minimized amount of controversial ingredients and the desired organoleptic properties. However, the house of quality is the prime planning tool used in QFD (Chan and Wu 2002).

The project of the house of quality for a sponge-fatty cake

QFD analysis involves a sequence of interrelated actions, so that they can systematically take into account the requirements of the more participants of the product life cycle. Application of this method for sponge-fatty cake is presented in Fig. 2. The primary tool for QFD method is a diagram commonly referred to as the "house of quality", which contains specifically defined fields covering (Hamrol 2011):

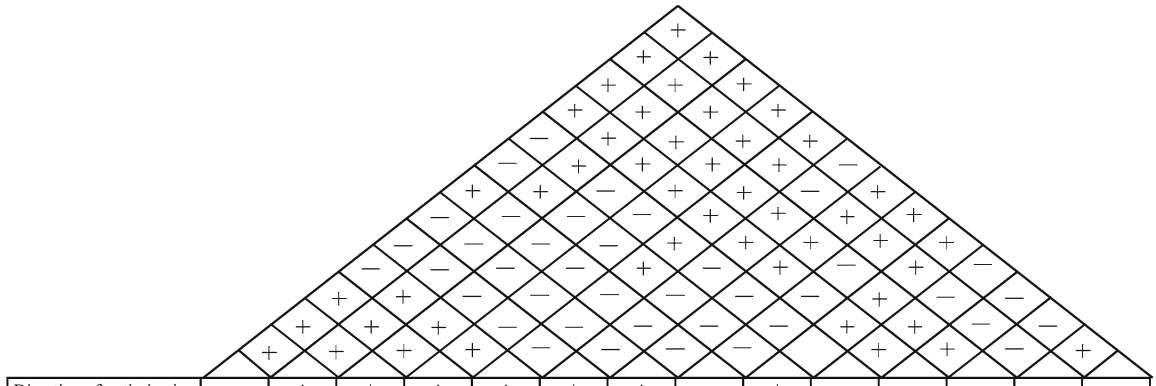
I customer requirements - articulated in everyday language preferences and needs of users,
II validity requirements by customers - to assign individual features of validity coefficients for the adopted scale, for example, from 0 to 5 points,
III list of technical parameters established within the company to meet consumer demands while being measurable (e.g., to determine the ↓ or – for minimum, ↑ or + for maximum, • to nominal) and possible to meet in the course of production,
IV the relationship between consumer requirements and technical parameters in three-point scale by specifying dependency ratio in a progressive scoring,
V the validity of the technical parameter as the sum of the products of validity coefficients of successive requirements and coefficients of their relationship with the given technical parameter,
VI determination of the mutual influence on each individual attributes of the product,
VII comparison of the own product with the products of competing companies.

In the QFD diagram the following areas can be found (Hamrol 2011):

I targets that must be achieved by measurable technical parameters defined in the third field, so as to meet customer requirements or increase the competitiveness of the product,
II indicators as a measure of technical and organizational difficulties, the occurrence of which would be expected for achieving the set target values of technical parameters.

The individual fields of the diagram summarize the results of research (Fig. 2).

The first step in the construction of the diagram QFD was to determine the consumer requirements, written in the "language of our customers." Due to the importance of the diagram, among the features of sponge-fatty cake indicated by consumers, the following basic groups can be distinguished:



Direction of optimization		•	↑	↓	↑	↑	↓	↑	•	↓	•	•	•	•	•					
technical parameters / customer requirements	assessment of validity	the use of lauric fats	the use of liquid fats	the use of solid fats (β crystalline form)	the use of liquid and solid (β' crystalline form) fats	the use of refined fats	the use of sugar or other sweeteners	the use of raising agents	the use of flavorings	the use of preservatives and antioxidants	the use of dyes	baking temperature	baking time	the use of appropriate packaging materials (smart packaging)	the application of a reclosable package	Image profile				
pleasant smell	4		1	1	1	3			3			2	1	2	2			A	B C	
good taste	5	2	2	1	3	3	3	1	1		1	2	2	2	2		C		A	B
appearance	5	1	1	2	2	2	2	3			3	2	2	1	2			A	B	C
sponginess	3	1	1	1	1	1	1	3				2	2	1	2		B	C	A	
product volume	1						1	2				2	3	2		B	C	A		
color	4		1	1	1	2	2	2			3	2	2	1	2			A	C	B
humidity	1	2	2	1	1	2	1	1	1			2	2	3	2		C	B	A	
not crumbling	3	2	2	2	2	1	1	2	1					2	1		C	B	A	
harmless to health	5		1	3	3	2				1	1							C	B	A
containing substances beneficial to health	4		3	2	2	1					1			1			A B C			
no effect on cholesterol level	4		1	3	3	2	1					1					B C	A		
consumability time	5		2	2	2	2		1		3			1	3	2				A B C	
Validity of technical parameters		26	65	78	88	85	45	51	21	20	41	50	52	60	57					
Critical parameters					1	2														

1	2	3	4	5

A comparison of own product to the competitive

A	B	C
155	156	137

Fig. 2 The house of quality for a sponge-fatty cake

- essential features required—related to the organoleptic features of the cakes (such as a pleasant smell, good taste, appearance and color). It is believed that color perceived an object as food via their visual perception system before tasting it and predict its taste before making a decision about whether or not to purchase or eat it. Therefore, color is sometimes the most decisive element as an indicator for food selection and evaluation (Abdullah 2004; Fernández et al. 2005).
- qualities expected subconsciously—sponginess, product volume, moisture, lack of crumbling,
- innovation parameters associated with the product - not harmful to health, the content of substances beneficial to health, with no effect on cholesterol.

In the field (I) all the more important, highlighted by consumer traits of the sponge-fatty cake, assigned by respondents with validity coefficients on a scale of 1–5 points (Field II), were collected . The next stage of the work was carried out with the participation of specialists from pastry plants. The aim was to develop the technical characteristics of the sponge-fatty dough, containing specified by the user measurable technical parameters (field III), which constitute the content of the columns of the house. The prepared matrix also indicates the degree of relationship between the technical requirements and the demands of consumers in a progressive three-level scale of numbers:

- 3—direct relationship,

- 2, 1—indirect relationships,
- 0—no relationships.

The value "3" are reached by a direct dependence, such as a link with the use of fragrance aromas and refined fats. An example of the lack of relationship between consumer requirements and technical characteristics is the absence of such relationship between the appearance and use of flavorings. Indirect relationships are marked by values "1" or "2". In Fig. 2—the matrix forming part of the diagram presents the results of analysis of this stage of QFD method.

The data summarized in the matrix allow us to conclude that all the requirements defined by the consumer of sponge-fatty cakes are reflected in the concept of the product being developed. A large number of dependencies, defined as strong—3 points, and intermediate—2 points testifies to the fact that the parameters of the planned food product are due to the requirements of its consumers.

Then, to assess the importance of individual quality characteristics in the general concept of the product, the computations of validity of technical parameters were performed (box V). As in the fields II (requirement validity according to customers) and IV (dependency ratio between the customers' requirements and technical parameters) the numerical values were used, we were able to determine the validity of the given technical parameter as the sum of the products of the weighting factor of the requirement "i" and the dependency ratio between the requirement "i" and the technical parameter "j" according to the following equation:

$$T_j = \sum_{i=1}^{n} W_i Z_{ij}$$

where: T_j—validity coefficient of the technical parameter "j"; W_i—weighting factor of the requirement "i", for "i" = 1, 2, . . . , n; Z_{ij} dependency ratio between the requirement "i" and the technical parameter "j".

Table 1 contains the summary of the calculations. It was found that the critical parameters for the sponge-fatty cakes are:

- the use of liquid and solid (β' crystalline form) fats
- the use of refined fats.

Considering these two parameters, we can conclude that the requirements of consumers are directed mainly towards product characterized by high volume, correct color and at the same time require that products characterized by lack of feel "earthiness" while eating. Besides, in order to define the image profile of the product being developed, the analysis of competitiveness was performed. To this end, a comparative evaluation of the proposed sponge-fatty dough with two other similar products produced by two competing companies that are already on the market has been carried out. The products were compared in terms of the degree of meeting the individual customer requirements, expressed at the stage of development of the validity assessment of the proposed technical parameters of the product. In the evaluation process a five-point scale was used, where:

– grade 1 meant insufficient meeting of the requirement,
– grade 5 meant the satisfactory meeting the requirement.

The evaluation was performer by a group of 10 arbitrarily chosen respondents. The result of this phase of the QFD method was a map of customer perception (Table 2, Box VII).

In the next stage, based on data collected in Table 2, it has been quantified how good is the designed product A in relation to comparable products of competing companies B and C, which is defined as the profile image of the product. Finally we have calculated the total number of points for the own product A using the following formula:

$$P_{wA} = \sum_{i=1}^{n} W_i S_{iA}$$

where: P_{wA}—profile image for product A; W_i—weighting factor of the requirement "i", for "i" = 1, 2, . . . , n; S_{iA}—individual grade to meet the customer requirements for product A.

The profile images for the competitive products B and C were determined the same way and results of the analysis are collected in Table 3.

Competitiveness analysis showed the advantage of the proposed own pastries (company A—Fig. 2) with respect to the needs of consumers in terms of bulk, product volume, humidity, fragility, and the health benefits. The developed product collected lower scores compared with the products of competing companies in terms of parameters associated with the smell, appearance and color. There is therefore a need to modify the proposed product in terms of odor, smell and color. According to Lee et al. (2013) food-color preference has fundamentally interesting aspects as well as industrial importance therefore the fine-tuning of these parameters provides an opportunity to obtain consumer acceptance and perhaps advantage over similar products from other companies already existing in the market.

Table 1 Assessment of the validity of the technical parameters of the designed product

i Customer requirements	Technical parameters—j														
	Weighting factor of the requirement W_i	Dependency between the requirement "i" and technical parameter "j" ratio Z_{ij}													
		The use of lauric fats	The use of liquid fats	The use of solid fats (β crystalline form)	The use of liquid and solid (β' crystalline form) fats	The use of refined fats	The use of sugar or other sweeteners	The use of raising agents	The use of flavorings	The use of preservatives and antioxidants	The use of dyes	Baking temperature	Baking time	The use of appropriate packaging materials (smart packaging)	The application of a reclosable package
1. Pleasant smell	4		1	1	1	3			3			2	1	2	2
2. Good taste	5	2	2	1	3	3	3	1	1		1	2	2	2	2
3. Appearance	5	1	1	2	2	2	2	3			3	2	2	1	2
4. Sponginess	3	1	1	1	1	1	1	3				2	2	1	2
5. Product volume	1						1	2				2	3	2	
6. Color	4		1	1	1	2	2	2			3	2	2	1	2
7. Humidity	1	2	2	1	1	2	1	1	1			2	2	3	2
8. Not crumbling	3	2	2	2	2	1	1	2	1					2	1
9. Harmless to health	5		1	3	3	2				1	1				
10. Containing substances beneficial to health	4		3	2	2	1					1			1	
11. No effect on cholesterol level	4		1	3	3	2	1					1			
12. Consumability time	5		2	2	2	2		1		3			1	3	2
Validity of technical parametrs T_j $T_j = \sum_{i=1}^{12} W_i Z_{ij}$		26	65	78	88	85	45	51	21	20	41	50	52	60	57
Critical parameters					1.	2.									

Table 2 Map of customer perception (comparison of the designed product-A with competitive products C and B)

Customer requirements - i	Weighting factor of the requirement W_i	Customer perception (individual grades to meet the customers' requirements S_i)[a]				
		1	2	3	4	5
Pleasant smell	4			A	B C	
Good taste	5		C		A	B
Appearance	5			A	B	C
Sponginess	3		B	C	A	
Product volume	1	B	C	A		
Color	4			A	C	B
Humidity	1		C	B	A	
Not crumbling	3		C	B	A	
Harmless to health	5			C	B	A
Containing substances beneficial to health	4		A B C			
No effect on cholesterol level	4		B C	A		
Consumability time	5				A B C	

[a] "response scale"—a quantitative expression of customer requirements for products A, B, C in scale (1–5)

Table 3 Profile image of the compared products

Product	A (own)	B (competitive)	C (competitive)
Profile image of the product	155	156	137

Conclusions

Analysis using QFD method, showed that there is a chance of producing a food product, a sponge-fatty cake being a type of pastry, which will meet the demands of consumers, and at the same time meet the requirements of nutritionists and technologists.

The analysis also showed that the parameters responsible for the quality of the finished cake sponge-fatty preferred by consumers is adequate content of liquid and solid (especially crystalline β' form) fat, as well as the presence of refined fats in the product. This means that consumers need a product, which is characterized by a large volume, the right color, and at the same time require that product characterized by lack of feel "earthiness" while eating.

The study also assessed the features of final product by comparing it with two other products of competing companies. The evaluation was performed by a group of arbitrarily selected 100 respondents. Product evaluation showed that the final product meets the highest degree requirements of respondents in terms of bulk, product volume, humidity, and the fragility of the health benefits with regards to the products of two other competing food companies.

It should be noted, however, that there is a need for a delicate modification of the product in terms of odor, smell and color to get the product fully accepted by consumers, considerably better than the products offered by other companies. The study shows that the QFD method is the proper tool for the design of products or processes, especially when we have to deal with constantly changing fashions and continuous progress in the field of applied materials and technology. The modern approach to the quality of the final product is the most important measure of customer satisfaction and meeting their needs. Method of quality function deployment is an apt tool for translating market requirements into technical language used by the designers, engineers and technologists.

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