

Quality function deployment in the food industry: a review

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This paper presents a detailed literature review on the topic of the application of quality function deployment (QFD) in the food industry. This review is extended with a thorough description of the methodologies involved in the practice of QFD within food companies, exemplified with the help of a case study on ketchup quality improvement. The benefits, drawbacks and challenges of QFD's application in food Research and Development (R&D) are presented and discussed. © 2001 Elsevier Science Ltd. All rights reserved.

Introduction

Today's food business arena can be best characterized as a mainly technology-driven environment whose survival is constantly challenged by a highly consumer-oriented market, demanding the continuous development of evermore innovative products that meet expectations. The shortening of products' life-cycle and an increasing consumer demand for more variety and quality have led to a pressing need for tools that can help plan, structure and systematize food quality improvement and new product development [1,2].

Quality function deployment (QFD) is an innovative approach bringing quality—as demanded by the

customer[†]—upstream in the product development process. In a R&D context, QFD can be seen as a *set of planning tools* that help introducing new or improved products/services faster to the market by controlling their development process and focusing on customer satisfaction [3–6].

QFD is said to have been first proposed in Japan by Yoji Akao in 1966. However, it did not emerge as a viable and formalized approach to quality control in planning until 1972, when Akao developed a quality control chart previously introduced at Mitsubishi Heavy Industries and instituted the QFD quality tables. This led to the rapid increase in QFD applications in Japan and to its introduction in the US in the early 1980s. Throughout the following years, the use of QFD became increasingly popular both in Japan and the US, namely due to a series of publications and symposia promoted by several institutes [3–5,7–9]. However, the first European symposium on QFD only took place in 1992, in the UK. Early users of QFD include Toyota, Ford Motor Company, Procter and Gamble and 3M Corporation, but many other companies, including some European like Phillips Corporation, have meanwhile followed their lead [3–8,10][‡].

QFD has been in use in the food industry since 1987 [6,11]. Meanwhile, many authors have advocated it as a planning tool to help in the management of food product/process development, subject to some adaptation to meet the specific requirements of the food industry [1–3,6,11,12]. However, there are not many published applications of QFD in the improvement of food product development processes, especially on an industrial level. From the analysis of the literature published so far, both at an industrial and a scientific research level, three main conclusions can be made:

1. Within the limited amount of literature available, most of the relevant information has only been published in the form of scientific working papers, theses and reports, and is therefore not so readily available to scientists in general.

[†] A 'customer' in a QFD project can be another manufacturer and/or a wholesaler, a retailer, a regulatory body, a consumer market segment, etc. [3].

[‡] For a more detailed review of QFD's history, the reader can refer to ASI [3] and Cohen [4].

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2. Scientists in the food area are probably still not much aware of the main ideas of QFD, its methodology and its potential for food product development and research guidance.
3. Up to date, there are no structured accounts of the applications of QFD in food product/process development, either at an academic or at an industrial level.

The aims of this paper are, therefore, (i) to describe QFD and its practice in the context of the food industry, (ii) to review the published material, giving a structured account of QFD's applications in food product development so far, and (iii) to discuss the benefits, drawbacks and challenges of QFD's application in food R&D.

We will begin with a description of the methodology involved in the implementation of a QFD project in a food company, accompanied by some practical examples taken from a case study on the improvement of tomato ketchup [2,13,14].

The implementation of Quality Function Deployment

Once the decision of using QFD to manage product development activities has been made, the next step should be to obtain the necessary executive commitment and organisational support to the project. Then, decisions have to be made regarding the project's objectives (quality improvement, new product development, increased customer satisfaction, etc.), time-span and schedule. The next step is to define which concept or existing product (or product category) is going to be the object of the QFD project and which customers will be targeted. Finally, a cross-functional team containing members from all functions involved in the product development and market introduction process—market research, product and process design, engineering and production, quality management, marketing, sales and distribution—is assembled. The facilities, materials and time necessary to carry out the project are made available by management and the team can start [4,7,15,16].*

There are two types of team activities involved in a QFD implementation project [9]:

- The *Product's Quality Deployment*, referring to the activities needed to convert customer-required quality (as the customer defines it) into a product's specific attributes;
- The *Deployment of the Quality Function*, concerning the activities needed to assure that the customer-required quality, once put into the product, is actually achieved.

Basically, these activities link customer-required quality to the whole of product development and market intro-

* More detailed descriptions of the QFD start-up process and team assembly can be found in several publications [4,7,15,16].

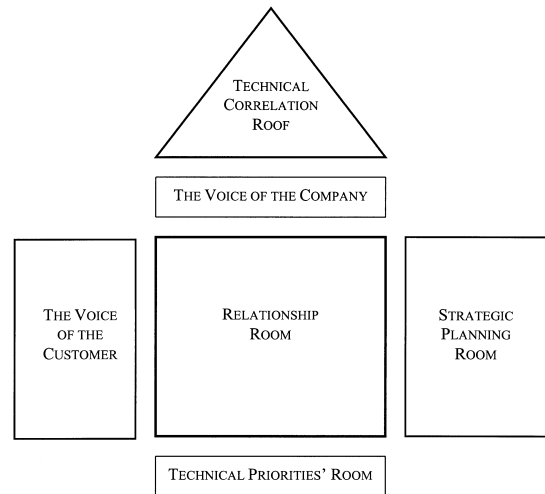


Fig. 1. The House of Quality.

duction functions downstream by generating a cascade of matrix-shaped charts [3,5]. This matrix-generation process has been combined in a *four-phase approach* [8], a focused approach which consists of four matrixes involving the product planning, product design, process planning and process control planning phases.

Product's quality deployment—the house of quality

In QFD's *four-phase approach*, the first matrix to be built is the *Product Planning Matrix*, also called 'the *House of Quality*' (HOQ) [8] due to its house-like shape. Its purpose is to translate important customer requirements regarding product quality into important end-product control characteristics. The HOQ comprises several different parts or 'Rooms' that are sequentially filled in order to achieve an actionable translation from requirements into characteristics (Fig. 1) [3,5–6,11].

The HOQ's first room concerns the *Voice of the Customer* [17]—a structured list of requirements regarding the product and its attributes as the customers describe them (also called "customer Requirements", "wants" or "WHATS"), together with a measure of the importance the customers attach to each requirement [3–8,17].† The customer requirements are loose, vague qualitative statements in the customer's own words, like 'easy to use' or 'with a fresh taste'. They indicate which benefits the customer expects to be fulfilled by the product or service. There are several possible sources of customers requirements: market research data, sales data, customer complaints, retailers, focus groups, toll-free lines, opinion surveys, in-depth interviews, etc. [3–7,11,17].

After their identification, the customers' requirements are compiled and structured by the QFD team (and/or

† Even in QFD projects where the consumer requirements are the main issue, the requirements of other customers or external regulations may still have to be taken into account. In order not to confuse one type of requirements with other, the last can be listed in a separate room—the *Important Control Items* [6].

THE BEST TO EAT	EASY TO SERVE	Flows easily from the bottle	4
		Pours without scattering	4
	HEALTHY	Still sweet but no sugar	3
		Contains less salt	3
	TASTY	There must be a tomato aroma	4
		Should have a salty taste	3
		Not too acidic	3
		Should be spicy	4
		Can feel the vinegar taste	3
		Can feel the tomato taste	5
		It is thick in the mouth	3
	NO DEFECTS	Manufacturing waste is reduced	3
		It never spoils	4
No water at the surface		3	
GOOD PACKAGING AND LABELLING	CLEAR INFORMATION	Proper storage indications	4
		Innovative usage suggestions	2
		Tomato content information	4
		“Green” practices information	3
	BEST PACKAGE	Can see the product inside	4
		Different sizes are available	3
		Can be squeezed	2
		Easy to handle and use	4
		Can be re-used or recycled	4
		No ketchup on the lid	4

Fig. 2. The *Voice of the Customer* in a case study regarding the quality improvement of tomato ketchup. The targeted market segment was the Dutch student population, aged between 20 and 26 years old. Results displayed are the outcome of the qualitative (focus group) and quantitative (survey with 75 respondents) research performed [13].

by the customer), using the so-called “*Quality Tools*” [4,8,17]. Finally, relative importance weightings are attached to each customer requirement by the QFD team based on quantitative market research—the *Customer Importance Rating*. This helps establish priorities in the product development process and to allocate the necessary resources [3–8,10,11]. Figure 2 shows the *Voice of the Customer* in a case study regarding the application of QFD in the quality improvement of tomato ketchup [13].

The establishment of the *Voice of the Customer* is the most critical step in a QFD project [3,6,17]. On one hand, it requires obtaining and expressing what customers require of a product or service—and not what the company thinks they require—and how important this is for them. On the other hand, since these prioritized customer requirements are guiding the whole development process, a misinterpretation at this stage may seriously compromise the outcome of the process [4].

Once the QFD team has established the customer requirements, the next step is to understand where the company and its competitors stand in terms of satisfying these requirements in the marketplace, by filling the *Strategic Planning Room* (Fig. 3) [3,8,15]. Based on

qualitative and quantitative market research, the customer’s perception of how the company’s product or concept satisfies his or her requirements in comparison to other products—*Customer Competitive Assessment*—is rated and graphically depicted. A *Customer Complaints* column may also be added. An *Improvement Ratio* is calculated based on the company’s current and planned levels (*Goals*) of customer satisfaction. Finally, the *Strategic Planning Room* provides a link between the QFD project and the company’s strategic vision by identifying market opportunities—the *Sales Points*-, and priorities for R&D based on the *Weight* of each *Customer Requirement* for the company [3–8,15–17].*

At this stage, the QFD team should have a clear picture of what the customer requires from the product or concept and how this can be related to the company’s strategy. The team has now to decide how these requirements can be incorporated into the final product so that the customer is satisfied. This is represented in the HOQ by the *Voice of the Company Room* [3,11]. Here, the end-product’s technical characteristics directly

* For a detailed description of these activities, the reader can refer to Cohen [4] and King [15].

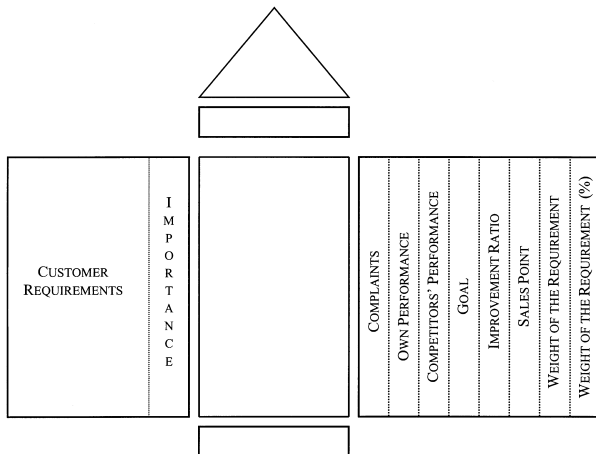


Fig. 3. The Strategic Planning Room and its components.

related to the customer's requirements are listed, that is, the "design requirements", "quality functions" or "HOWs". They must be measurable parameters that will be used to evaluate objectively the product's quality, since their outputs are going to be controlled and compared with target values to ensure customer requirements are being met [3–8,11,15]. Often these parameters are correlated in a product, therefore in the *Technical Correlation Roof* [11] the QFD team has to specify their degree of interdependence. This step helps to determine the effects of changing one product characteristic on the others attributes, enabling the team to identify and react to synergistic (positive interdependence) or trade-off (negative interdependence) situations. Trade-off situations often point out R&D needs and should always be solved in the way that most favours the customer [3–6,10,11,17].

The QFD team must now fill the core of the HOQ—the *Relationship Room*—where the relationships between each customer requirement (*Voice of the Consumer*) and the product characteristics (*Voice of the Company*), as well as their intensity, are depicted [3–8,15]. The team seeks consensus on how much each product characteristic affects each customer requirement based on their own expertise, customer surveys or data from statistical studies and controlled experiments. This widely recognized complex task is another critical stage in the HOQ building process [1,3,5,8]. On one hand, it shows whether or not the company is adequately addressing the customer requirements from a technical point of view. On the other hand, it is an important project checkpoint. Blank rows in the *Relationship Room* indicate customer requirements that are not being addressed by any of the product's technical characteristics. Therefore, a product characteristic may be missing or may have to be modified in the final product. An empty column indicates either a waste of resources, by showing that there is a product characteristic not satisfying any of the listed customer require-

ments, or missing customer requirements [3–8]. Figure 4 shows a simplified account of the *Voice of the Customer*, the *Voice of the Company*, the *Relationship Room* and the *Technical Correlation Roof* in the ketchup improvement case study [13].

The last task in building the HOQ is filling the *Technical Priorities Room* (Fig. 5). It starts with a *Technical Competitive Assessment* of the end-product's characteristics (*Voice of the Company*) in currently marketed products [4]. In this way, the QFD team can view the competitors' and their own technical performance level regarding product characteristics directly affecting customer requirements [3–8,11,15]. 'In-house' product testing usually provides the data necessary for this assessment, which again should be expressed in measurable terms. For each product characteristic, the comparison between the company's and the competitors' technical performance level is depicted in a graph. A row indicating the level of organizational difficulty related with realising each end-product characteristic can also be added [3–6,8,11].

The *Technical Competitive Assessment* is then compared with the *Customer Competitive Assessment* (*Strategic Planning Room*). This is done to determine inconsistencies between how the customers and the company are evaluating existing products [3–7,15]. For example, let us say that the *Customer Competitive Assessment* indicates that a competitive product is best meeting a certain requirement from the customer's point of view. Meanwhile, the *Technical Competitive Assessment* and the *Relationship Room* indicate that due to the company's current performance level in a certain end-product characteristic that requirement is better fulfilled. This contradiction points out to one of the following situations: (a) the *Technical Competitive Assessment* may have been inadequately performed; (b) there was a mistake in filling the *Relationship Room* and the end-product characteristic is not related with the customer requirement; (c) the customer's evaluation of the product has no real substance and the product suffers from an image problem [1–8]. In the last situation, an advertising effort actually showing that the product's characteristic satisfies better the requirement than the competition should be envisaged [1,5].

The *Customer and Technical Competitive Assessments*, the *Sales Points*, the *Relationship Room* and the *Customer Importance Ratings* all contribute to determine the *Target Values* or *How Much's* [3–7,15]. The *Target Values* represent, in measurable terms, the level of performance for each end-product characteristic the company has to provide in order to maximize customer satisfaction. These performance levels are critical control points to be measured at each stage of the product development and market introduction processes. Therefore, the *Target Values* provide not only an objective means of assessing requirements' compliance

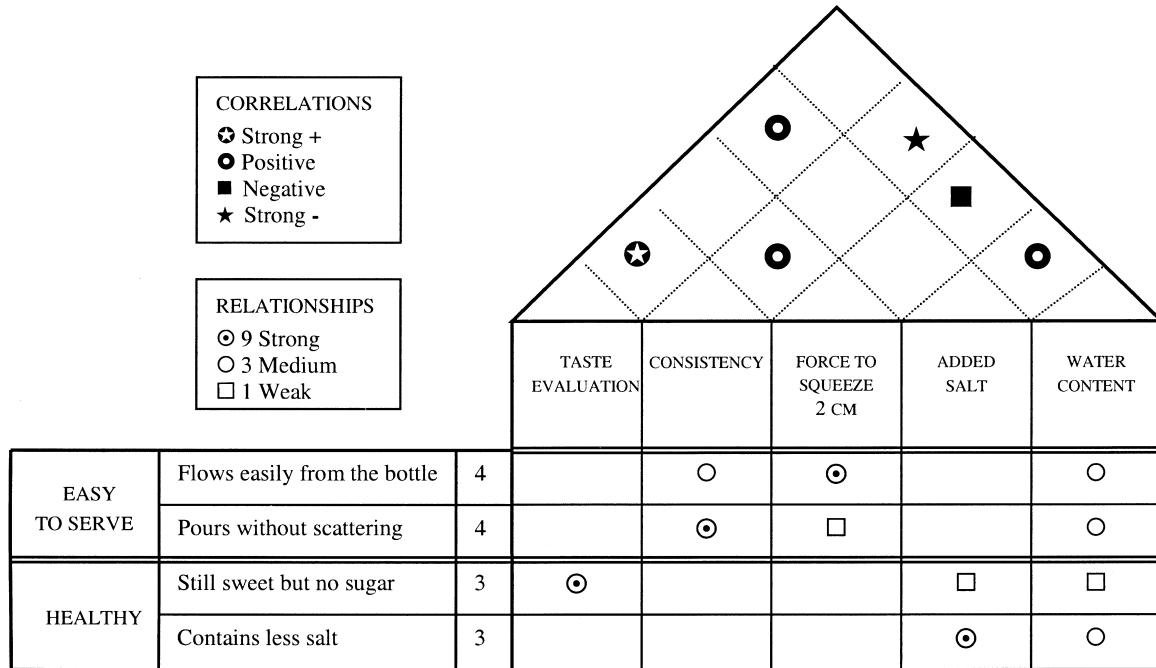


Fig. 4. The Voice of the Customer, the Voice of the Company, the Technical Correlation Roof and the Relationship Room in a case study regarding the quality improvement of tomato ketchup (simplified) [2,13,14].

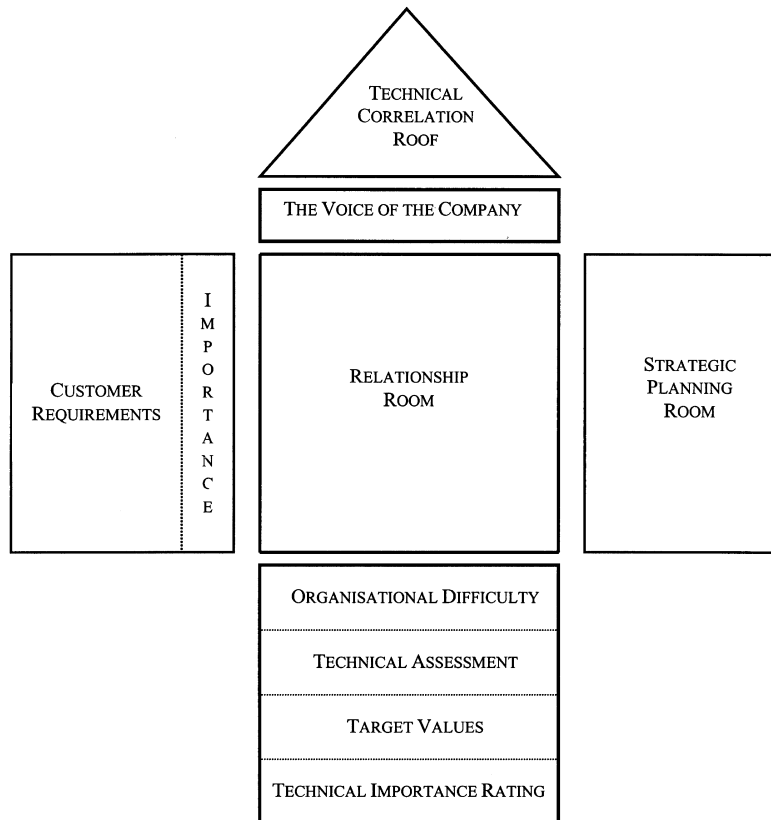


Fig. 5. The Technical Priorities' Room and its components.

but also specific goals for further R&D [3–7,11]. A final *Technical Importance Rating* for each end-product characteristic can also be calculated based on the *Customer Importance Rating* for each requirement and the strength of the relationships between that characteristic and each customer requirement (*Relationship Room*). These ratings indicate the relative importance of each end-product characteristic in achieving the collective consumer requirements. As the absolute values are meaningless, they are often expressed as a percentage [3–7,15].*

The HOQ has been the main focus of QFD-related literature, because it contains the most critical information a company needs regarding its relationships with customers and its competitive position in the marketplace. However, and in order to truly drive the whole product development process, the *Voice of the Customer* must be still systematically cascaded into the remaining product/process design activities and marketing stages through the use of additional matrices [3–8,10,15].

Deployment of the quality function

Based on the information depicted in the HOQ, the QFD team has now to select the end-product characteristics that are to be deployed through the remainder of the R&D and market introduction activities [3,5,6]. End-product characteristics showing a *Technical Importance Rating* above a pre-determined threshold (indicating a strong relative importance in achieving the collective consumer requirements) are selected for further deployment. The same happens to end-product characteristics related with customer requirements, which are strong *Sales Points* or have poor *Competitive Performance*. End-product characteristics having a high level of *Organisational* or *Technical Difficulty* may also be selected [3,5,6].

The selected end-product characteristics are now going to be carried from the overall product level to the component level through the building of the *Deployment Matrix*, *Product Design Matrix* or *Parts Deployment Matrix* [3–5,8,10]. This matrix shows whether and to what extent the relationships between component and product characteristics are critical. Its structure is similar to that of the HOQ: the rows are the selected end-product characteristics, which have now become design requirements, while the columns list the components' characteristics directly affecting these design requirements. The relationships between both types of characteristics are depicted at the matrix's core. Critical component characteristics are selected based on the strength of these relationships and are to be deployed further into the production planning and the control system [3,5,10].

The critical component characteristics become the rows of a third relationship matrix—the *Process Plan and Control Chart* or *Process Planning Matrix*, in which the columns are related processing operations. If a critical component characteristic is strongly affected by a process operation, that characteristic becomes a control point in the quality control plan. Moreover, if a process operation parameter must be monitored to achieve the specified level of a component characteristic, this parameter becomes a checkpoint in the process control plan [3,5,10]. In the last matrix—*Operating Instruction Chart* or *Production Planning Matrix*—the control points and checkpoints originating from the preceding matrix are related to operating instructions carried out during production [3,5,10]. Fig. 6 shows a guide for the *Deployment of the Quality Function* process in the food industry [2,3,6].

Through the *Deployment of the Quality Function* activities, the QFD team has established the operational means of controlling key product and component characteristics (control points) and monitoring process parameters (checkpoints) during product development and market introduction. This information can now be integrated in the company's quality assurance system, bringing customer guidance and quality assurance upstream to product development [3–5,10,17].

Quality function deployment in the food industry—a review

To our knowledge, there are only three papers documenting the development and commercial introduction of new products or processes making use of QFD [18–20]. With the exception of one paper describing the main ideas of QFD and giving a simplified example of its first implementation stages [20], the referred publications have focused on the description of the organisational benefits and technical quality improvements achieved, rather than on the implementation process itself. Yet, the Danish R&D programme for the food sector (*via* the research programme MAPP—Market-based Process and Product innovation) has since 1992 produced a significant number of working papers and publications on QFD, some of which describe tailored applications for food product and process development innovation [12,21–23].

Holmen and Kristensen [12] described the partial structuring of a product development process according to the HOQ structure in a Danish butter cookies company. They also suggested some upstream and downstream extensions to the HOQ that may bring more realism to QFD's application in food product development. These extensions incorporate the retailers' specific requirements and link end-product characteristics to the integrated development of ingredients and packaging.

To create a better integration between sensory analysis and market analysis in food product development,

* For a more detailed description of these activities, the reader can refer to ASI [3] and Cohen [4].

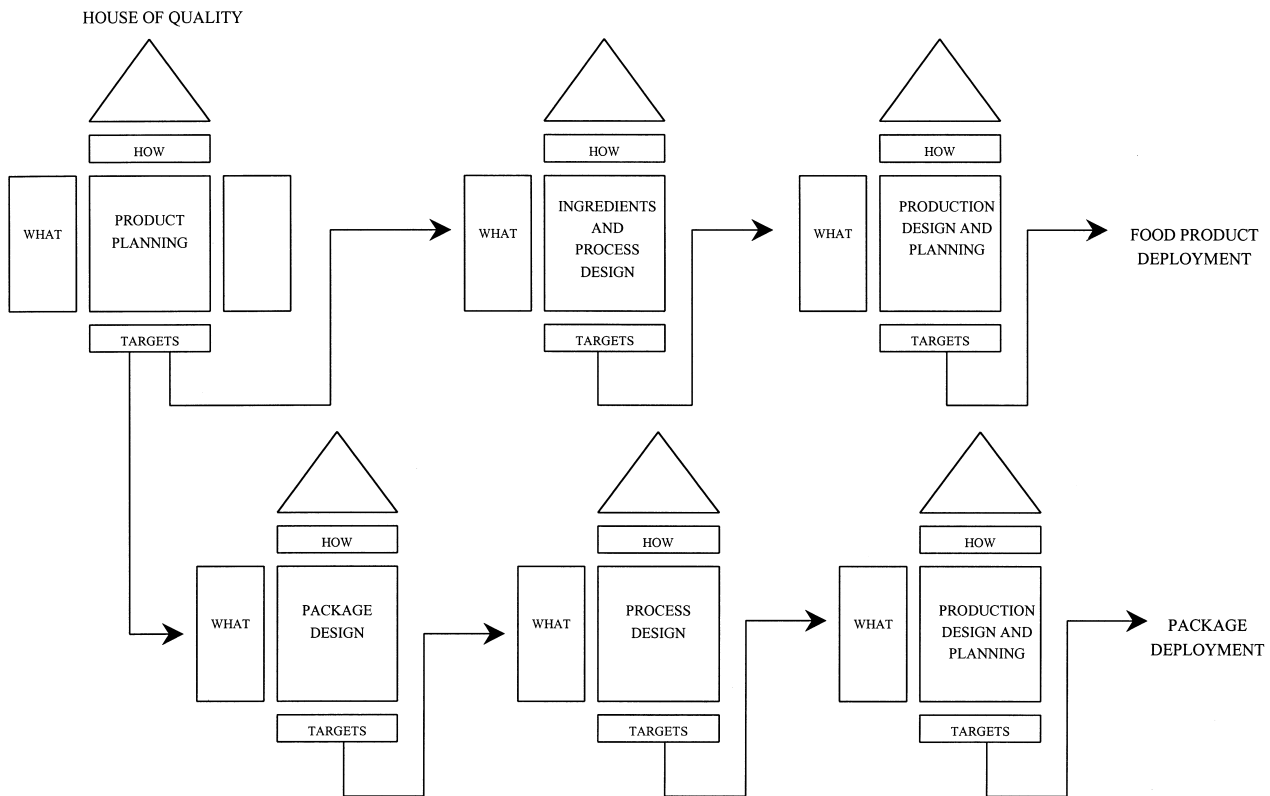


Fig. 6. Deployment of the Quality Function in the food industry [2,11].

Bech, Englund *et al.* [21] proposed a new structure for the HOQ in which relationships between sensory attributes, technical attributes and consumer requirements are highly detailed (Fig. 7). This new structure was later applied in the market-based quality improvement of smoked eel fillet [22], through the building of a modified HOQ in which relevant customer requirements

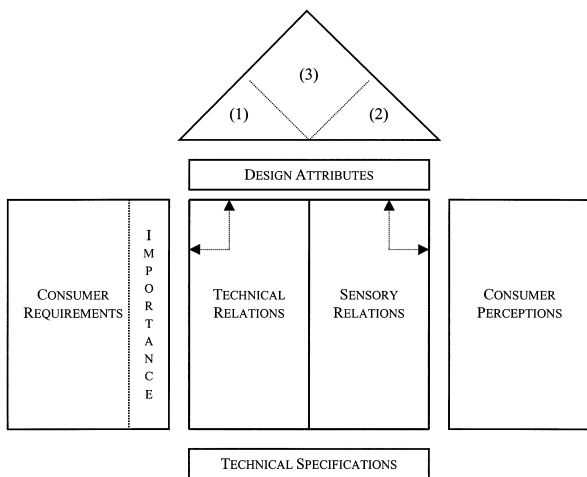


Fig. 7. Modified House of Quality for food product development: (1) interactions between technical attributes; (2) interactions between sensory attributes; (3) Interactions between technical and sensory attributes [21,22].

were related to breeding and manufacturing characteristics, as well as to attributes generated by a sensory panel. Bech *et al.* also used this modified HOQ to optimise the translation of consumer requirements into sensory attributes measurable by descriptive sensory analysis [23]. Data regarding a research project aiming at the development of pea varieties for freezing was used to build a modified HOQ and propose a model for sensory quality screening of new pea varieties. The modified HOQ is expected to better reflect the specificity of food product development (namely of the food’s sensory properties) in QFD projects [21–24].

The application of QFD in food product development has been recently subject of several research projects at the Wageningen University in The Netherlands [1,2,13,14,25]. Costa [13] and de Vries [14] conducted a case study regarding the practical implementation of QFD in the quality improvement project. The conclusion was that the *Relationship Room* lacked truly quantitative relationships between the consumer requirements and the food product characteristics, both intrinsic (physical) and extrinsic (brand name, price, origin). In view of the complex nature of consumers’ relationships with foods and of food matrix interactions (*Technical Correlation Roof*), multivariate statistical methods and statistical design of experiments [11] were recommended for their quantification. Korsten [25] developed a model

through which food technological innovations can be quantitatively evaluated and compared in terms of how well they meet pre-defined consumer segment requirements. This model can be used for new concept selection (a pre-requisite to the building of the HOQ), in an approach similar to the *New Concept Selection Chart* [15].

To our knowledge, the last published research concerning QFD's application in food product development refers to the chocolate industry [26]. In this paper, a modified HOQ [21] is used to improve the sensory quality of a chocolate couverture. More recently, a representative of Unilever Research has also reported the use of QFD for the development of table sauces [27].

Benefits and drawbacks of quality function deployment for food R&D

In spite of its considerable benefits to the product development process itself, QFD was clearly not developed having in mind the food industry or the consumer. This situation can be readily understood by viewing the summary of its benefits and drawbacks of the application of QFD in product development depicted in Table 1. QFD does not address certain aspects that are vital for food R&D [2,12,16].

Foods are complex products with which people have equally complex relationships. Ingredients in foods display intricate interactions that affect the way processes should be designed and optimised. Moreover, raw materials show a natural predisposition for variation that does not suit with the somewhat inflexible character of QFD charts regarding changes [2]. Consumer requirements concerning food can be very diverse and variable, and it is likely that they can only be satisfied if both the food product attributes and its interactions are taken into account during development process [2]. Therefore we do not share the opinion that food products can be described as a set of attributes, which together fulfil consumers' needs [21]. Interactions between attributes can play a decisive role in achieving consumer satisfaction. Finally, and taken into consideration the research reviewed in this paper, QFD (in its standard format) seems to be more suitable for the ingredients' and food packaging industries than for food manufacturers. Hopefully, this situation will gra-

dually improve with the development of QFD approaches more tailored to the specific needs of the food industry.

Challenges remaining for QFD practitioners in food R&D

In essence, QFD encompasses exactly the same activities that development teams perform in conventional product development processes. Its main contribution is to replace informal, intuitive decision-making processes by a structured methodology that compiles all relevant information and company expertise for use in product development and market introduction activities. Any future progresses of QFD in food product development are therefore highly dependent on the progresses and the results of fundamental research in several areas of food sciences.

We are still missing considerable knowledge about how different factors influence food choice and how they interact with each other [28]. Moreover, it seems that food choice behaviour is mostly not based on a rational decision-making process, but rather characterised by a low involvement and a limited search for information, which may increasingly difficult its understanding [1,29]. It also is widely recognized that the most powerful consumer requirements—features whose presence in the product consumers view as necessary but not sufficient for their satisfaction ('*dissatisfiers*' or basic needs) or enticing features that are not expected (delighters)—and its self-attributed importance are hardly ever verbalised by consumers. This demands from QFD the use of elaborate consumer research techniques, which must be further improved in order to better reflect the specificity of consumers' food choice processes [1,3,15–17].

The development of models establishing quantifiable relationships between consumer requirements and food attributes has traditionally focused on the so-called *psychophysical relationships*, the relationships between consumers' quality perception at the sensory level and foods' intrinsic characteristics. We are still missing truly integrative models for consumer-oriented product development that encompass both the food's physical properties and its effects, as well as other elements of the marketing mix [1,13].

Table 1. Benefits and drawbacks of QFD's application in product development [12,16]

QFD benefits	QFD drawbacks
Simultaneous development across functions	Process-related improvements more difficult to achieve than product-related ones
All functions participate from the start	Benefits service developers more than product developers
Team empowered to make decisions	Improvements increasingly difficult with increasing product complexity
Tasks shared across functions	Improvements more difficult to achieve in projects seeking true innovation
Consensus decisions about trade-offs	More suitable for products which are assemblies of individual components
Working meetings to develop results jointly	

Although the QFD process is considered to be mainly consumer-driven (*via* the determination of the *Voice of the Customer* and its downstream deployment), it does not specifically support feedback from consumers at the later stages of product development like prototyping or market introduction [30]. Approaches like the *Lead Users* method [31], targeting segments more likely to accept innovative technologies, or the *Consumer Idealised Design* [32], which aims at involving consumers in the actual design of products and services, may be worthy of further investigation.

It is now, therefore, up to food scientists and technologist to develop the methods by which the food industry may also make use of QFD and benefit from its potential for successful product development.

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