MAPP working paper no 19
March 1994
ISSN 0907 2101

QFood

Optimal design of food products

Anne C. Bech
Erling Engelund
Hans Jørn Juhl
Kai Kristensen
Carsten Stig Poulsen
Project no 9

Executive Summary

1. QFood is an acronym for Quality Function Deployment in the Food Industry. On the basis of House of Quality, the project seeks to combine traditional socio-economic factors with a more technical analysis in a common modelling framework which can be used to illustrate consumer reactions to new and modified food products. Sensory analysis has been important in the development of food products, but it is characteristic that sensory analysis has often been carried out independently of the more market-based analyses.

2. Sensory analysis is a method which uses human senses - the sense of sight, hearing, smell, taste and touch - as instruments of measurement. The report gives an introduction to sensory analysis in general. The QFood project uses both descriptive and affective tests and the methods used are described.

3. As a rule, market analysis uses a combination of qualitative and quantitative methods. The QFood-project focuses on the quantitative part and two common methods, multi-dimensional scaling (MDS) and conjoiont analysis are briefly described.

4. Integration between sensory analysis and market analysis on the basis of House of Quality is the central part of the project. House of Quality is described with special reference to the development of food products.

5. An MDS-based model for use in the evaluation of an optimal product is developed. The model is based on the profit function from classical micro-economic theory. The imputed price is defined as a function of a Customer Satisfaction Index which is inversely proportional to how "close" the product is to the consumer's ideal.

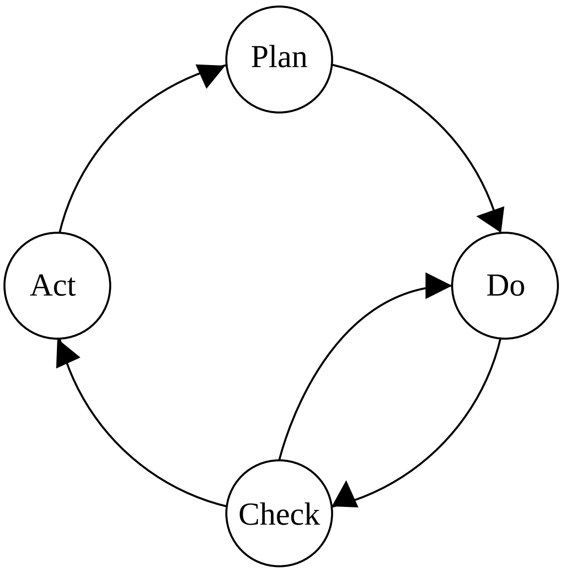
Table of Contents

1. Introduction

Quality plays an increasingly important role in western consumers' choice of food products. This is due, among other things, to the growing abundance of food products in the West, the intense competition between producers, and the increasing awareness of nutritional and environmental issues. The aim of the QFooD project (project 9 of the MAPP programme) is to determine those factors which consumers attach most importance to in evaluating the quality of a food product. QFooD is an acronym for Quality Function Deployment in the Food Industry.

The project seeks to combine traditional socioeconomic factors with a more technical analysis in a common modelling framework which can be used to illustrate consumer reactions to new and modified food products. The challenge for food producers is to identify consumers' demands for quality, measure whether existing products live up to them, identify possible improvements or new products, and develop and test the new products and launch them onto the market. This process can be described within the framework of Shewhart's classical quality control model (Shewhart, 1931), which is shown in Figure 1 below.

Figure 1. Shewhart's classical quality control model



In the planning phase, consumers' demands are identified through market surveys. In the do phase, this results in modifications to existing products or ideas for new ones. The check phase ensures that the prototypes contain all the product specifications aimed at. Finally, the product is marketed in the act phase, during which consumer reactions can be revealed through market surveys.

Product and process development in the food industry differs from that of other industries in the central importance given to taste in overall consumer preferences. A number of methods have been developed over the past 20-30 years, collectively known as sensory analysis, which are distinguished by the fact that human senses, in particular the sense of taste, form the basis of the measurements. While sensory analysis has naturally been important in the development of food products, it is characteristic that it has often been carried out independently of the more market-based analyses, sometimes even replacing them. The problem with this separation is that, unless product development is related to consumers' demands, it risks leading down a blind alley. One of the major aims of the QFooD project is to clarify the natural dividing line between market analysis and sensory analysis, and, through an integrated understanding of product development, make (Danish) food processing companies more competitive.

The two forms of analysis are discussed separately in the following two sections. Section 4 examines the possibility of integrating the two through Quality Function Deployment (QFD), while a more formal model is presented in section 5. Finally, section 6 gives a brief description of the four sub-projects of the QFooD project.

2. Sensory analysis

What is sensory analysis?

Sensory analysis is a method which uses human senses - the sense of sight, hearing, smell, taste, and touch - as instruments of measurements. In other words, differences between products, the intensity of a quality, or the degree of preference for a product, are measured by the senses.

It is the extreme sensitivity of our senses that enables them to be used in this way. For some smells, the human sense of smell is more than 100 times as sensitive as the most advanced analytic methods of gas chromatography (Meilgaard, 1991). In some cases, the sense of smell is also superior to chemical analysis, eg in detecting oxidized flavourings (Sinesio et al., 1990). Another reason is that human senses can distinguish and measure a wide variety of stimuli. Added to this is the fact that sensory analysis measures perception, ie how individuals perceive a difference, a quality, or a preference for a product. This can be illustrated by the fact that, while sensory analysis measures the perceived intensity of sweetness in a foodstuff, chemical analysis measures the sugar content. Therefore sensory analysis can, eg, be used to compare the sweetness of different types of sugar or artificial sweeteners in a given product category. In this respect, sensory analysis is unique.

Since perceptions cannot be read directly, it is necessary for the individual to respond to the received stimuli on a scale chosen or constructed specially for the purpose.

The aim of sensory analysis

The basic aim of all forms of sensory analysis is to furnish information for the decision-making process. As regards food products, this means all kinds of decisions about a product's sensory attributes, appearance, smell, taste, and consistency. In an industrial context, sensory analysis is often used to help minimize the risks associated with the introduction of new products and maintenance of existing ones. Eggert (1989) sees sensory analysis in a strategic perspective, and expresses its purpose as follows:

> "A complete knowledge of a product's sensory properties from a scientific/-technical viewpoint and a broader understanding of the ultimate consumer relative to product acceptance, product optimization and product satisfaction are needed."

Eggert's broad interpretation thus involves both production and marketing perspectives. Put another way, it is both necessary to know which demands consumers make regarding a product's sensory attributes and how a product with these attributes can be produced. While this may sound simple, it conceals a complex set of problems. On the product side, the sensory attributes are influenced by both the processes employed and the ingredients, which in turn are dependent on the process. On the consumer side, the demands made on a product's sensory attributes are influenced by a variety of factors which can be related to the product, the consumer, or to the surroundings (Shepherd, 1985, 1990). Last, but not least, it must be remembered that the process is dynamic. Consumer demands change, as do product technologies and processes.

Sensory methods of analysis

Altogether, there are three different categories of sensory analysis, all of which can be applied to product development in the food industry. As Figure 2 shows, each method is suitable for different problems.

Figure 2. Sensory methods of analysis in relation to overall problems

Analysis category	Overall problems
Discriminative analyses (difference test)	The analysis can determine whether the difference between two products is significant. If it is not, the risk of the consumer being able to tell the difference is assumed to be minimal.
Descriptive analyses (descriptive test)	The analysis can provide a detailed description of the product's attributes. The analysis determines both whether there is a significant difference between two or more products and what that difference consists in.
Affective test (preference test)	The analysis can identify which product the consumer prefers and how it is evaluated compared with the consumer's ideal. The analysis can either be carried out separately or as part of a market analysis.

In practice, it will often be necessary to carry out several different sensory tests as a basis for making the necessary decisions (see, for example, Lawless & Claassen, 1993). An outline of which analytic method can be employed in different situations is shown in Figure 3.

Figure 3. Different uses of sensory analysis

Purpose	Discriminative test	Descriptive test	Affective test
Product development			
Product maintenance	x	x	x
Product optimization	x	x	x
New products	x	x	x
Correlation with physical attributes		x	
Correlation with consumer preferences		x	x
Competitor surveillance		x	x
Quality control			
Product specification		x	x
Specification of raw materials		x	
Storage stability	x	x	x
Quality control	x	x	

Figure 4 shows some characteristics of the three different analysis categories, each of which contains numerous different techniques (see, for example, Stone & Sidel (1993), Meilgaard et al. (1991), and Hootman (1992)).

Figure 4. Characteristic test conditions for the three different analysis categories

<table>
<tr><th>Test</th><th>Discriminative</th><th>Descriptive</th><th colspan="2">Affective</th></tr>
<tr><td rowspan="3">Partici-
pants</td><td colspan="2" rowspan="3">Trained panel
(8-16 participants)</td><td rowspan="3">From target group</td><td>Panel (>50) of staff without expert know-ledge of the product</td></tr>
<tr><td>Consumer panel (>50)</td></tr>
<tr><td>Consumers chosen at random (>50)</td></tr>
<tr><td rowspan="3">Premises</td><td colspan="2" rowspan="3">Under near-laboratory conditions</td><td colspan="2">The laboratory</td></tr>
<tr><td colspan="2">Hall-test</td></tr>
<tr><td colspan="2">In home test</td></tr>
</table>

The QFooD project uses both descriptive and affective tests. The descriptive tests employ the QDA method (Quantitative Descriptive Analysis), since this method is used by both private production and service firms (Lundbye & Møller, 1991) and researchers at Danish institutions of higher education (Laustsen, 1993). The affective tests will be carried out as an integrated part of the market survey, using randomly selected consumers from the target group, who evaluate each product according to a scale of preference. The methods used in the project are briefly described below.

The QDA method

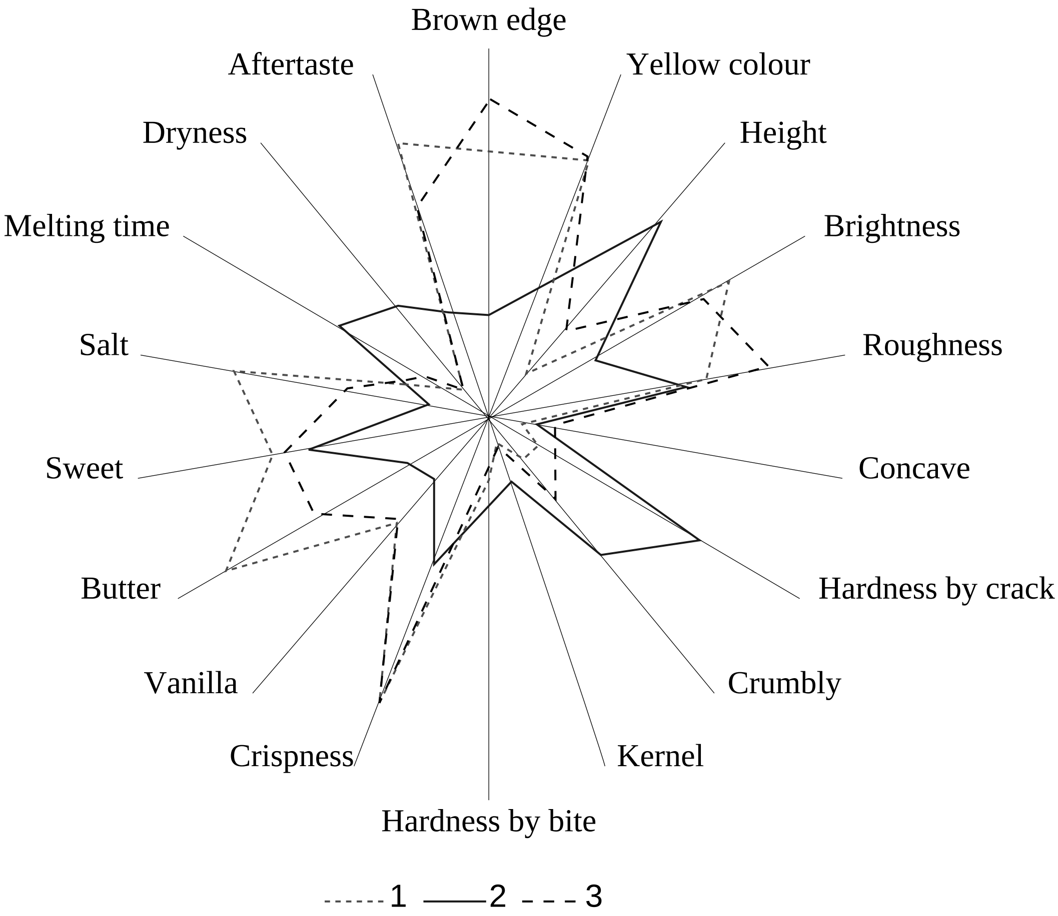
The QDA method was first described in Stone et al. (1974), and later in Stone (1992) and Stone and Sidel (1993). One of the reasons for developing the method was to achieve closer contact with the market, and it should be emphasized that the method can be understood by both marketing and R&D (Stone et al., 1974).

The method is based on the principle that participants in a panel must be able to express their perceptions of a product both objectively and reproducibly. In addition, a usable sensory terminology must be developed, and the products must be evaluated several times in order to obtain a quantitative description (Stone, 1992). According to Stone (1992), the QDA method contains the following elements:

- a complete list of sensory attributes (based on perceptions),
- the order the attributes appear in,
- repeated measurements of the intensity of each quality, and
- statistical analyses of the data.

The panel leader has a coordinating role only, and does not take part in the evaluations. The overall results are produced on the basis of the statistical processing of the results of the individual panel participants. These are selected on the basis of their knowledge and use of the product, their ability to distinguish between products, and their ability to understand the purpose of the exercise (Stone, 1992). It is recommended that each product is evaluated by the panel 3-4 times (Stone & Sidel, 1993). The scale used is an intensity scale in the form of a horizontal line with two anchors, named in pairs, eg a little/a lot. Participants indicate the intensity of each attribute vertically on the line (Stone, 1992). Numerous statistical analytical techniques can be used, including variance analysis, regression analysis, and other multi-variate methods. The results of the sensory evaluations are often presented in the form of a sensory profile (see Figure 5). The figure shows that the panel percieves products 1 and 3 as very similar and product 2 is perceived as being very different from the two other products.

Figure 5. Profile of three prototype butter cookies;(unpublished project results)



Preference measurements

These measurements are used partly to find out how consumers evaluate certain pre-determined attributes and partly for measuring consumer overall preferences.

The attributes are chosen on the basis of both market knowledge and those attributes which consumers value most. If this proves insufficient, qualitative surveys are carried out in the form of focus group interviews. The attributes are evaluated on a "just right" or "relative-to-ideal" scale, the principle being that consumers indicate whether the attribute in question corresponds to the consumer's idea of the ideal, or whether there is too little or too much of it. This method is recommended by several authors, eg Shepherd (1985, 1990), Meilgaard et al. (1991), and Lawless and Claassen (1993).

Consumers' preferences are measured using a 9-point hedonic category scale, ranging from the value 1 (don't like the product at all) to the value 9 (the product is exceptionally good).

3. Market analysis

For a product to be successful, it must (from the consumer's point of view) give more value for money than competing products. The development of such products is based not on luck, but on a thorough knowledge of the market.

Any product can be described by a set of attributes which together fulfil a number of the consumer's needs. One of the main tasks of market analysis is to identify those needs which are not met by existing products. These needs are often latent. Another aim of market analysis is to determine which attributes are the most important for the consumer's choice of product. Finally, market analysis must also include competing products, identify potential consumers, and thus help determine the demand function of the new product.

As a rule, market analysis uses a combination of qualitative and quantitative methods. In many cases, focus groups have proved to be an effective qualitative instrument in obtaining an overall picture of the market. While focus group interviews can lead to a deeper insight into consumers' use and expectations of a particular product, the small number of consumers interviewed can also prove to be highly unrepresentative. Nevertheless, the results of such interviews can give new product ideas, and will in any case be a valuable input of the necessary quantitative survey.

On the basis of the focus group interview, the market analysis is able to put forward a number of hypotheses about the market and also get ideas for new questions.

Over the past 20 years, multidimensional scaling (MDS) and conjoint analysis have become widely used in marketing as part of the decision basis in the design of new products. These two quantitative techniques are briefly described below.

Multidimensional scaling

The fundamental assumption in MDS analysis is that consumers' perceptions of product quality can be depicted diagrammatically in a chart. The products can be either existing products, prototypes of newly developed products, or product concepts, ie a description of a new product describing what the product is and can be used for, and which also defines the target group.

Typically, the consumer has to give an overall evaluation of the products on a scale of preference. The chart's dimensions correspond to the most important of the consumer's latent needs which the product satisfies. Both products and consumers can be positioned in the chart by dots. Any product can be placed on the chart according to the extent to which it satisfies latent needs. Since consumers' perceptions can very often be represented in 2 or 3 dimensions, the chart makes an important contribution to understanding the competitive structure of the market.

Supplementing the chart with an assumption about individual decision-making increases its predictive power to indicate how a new product should be made up. The usual assumption is that a consumer's position on the chart corresponds to the product composition which will give him/her maximum satisfaction of needs. The greater the consumer's preference for a given product, the less the distance from his/her ideal point to the product's coordinates. Concentric circles can then be drawn with a centre in the consumer's ideal point. The consumer has the same preference for all products which lie on the same circle.

In most cases, the firm is more interested in the behaviour of market segments than that of individual consumers. If the market can be segmented on the basis of brand loyalty, preferences, or desired product attributes, then ideal points are determined for each segment. The expected behaviour of a whole segment could then be evaluated, and, to round off the analysis, each segment could be described by a number of background variables.

The chart enables the firm to make various decisions about the introduction of a new product. For example, the firm could choose to market a product which appeals to a niche of consumers with unfulfilled needs, or it could choose a product which closely resembles competing products. Urban (1975) is an example of a heuristic solution of the positioning problem, while Shocker and Srinivasan (1974) probably represent the first attempt in marketing literature at an analytic formulation of the problem. Shocker and Srinivasan (1974) employ non-linear programming to determine the composition of new products. The object function is specified on the basis of an assumption that the probability of a consumer choosing a given product is inversely proportional to the distance from the product to the consumer's ideal point. One of the most recent contributions to MDS modelling comes from Horsky and Nelson (1992), who construct a model for identifying the profit-maximizing price and positioning of a new product in an oligopolistic market, where competitors are expected to react to penetration.

The first problem in an MDS analysis is to identify the latent needs from the products' respective position on the chart. This often requires a very thorough knowledge of the product, and with it cooperation between several functions within the firm. The next problem is to convert these perceptual dimensions to product attributes, thereby enabling R&D to create a product to match the product concept. This is often the weakest point of the analysis, and once again emphasizes the necessity for cooperation between functions in the firm, from the planning of the market analysis to the final reporting of the results. All attributes of the product which are considered to be important for the consumer's preference must be fully described. An experimental design based on the presumed most important attributes is often produced at this point, so that the degree of variation in the actual products can be as large as possible. However, the consequences of varying the products' attributes can only be evaluated to the extent that the products in the market analysis have these attributes. For example, the introduction of a non-butter cookie cannot be evaluated on the basis of a chart generated from an analysis of butter cookies.

Conjoint analysis

Conjoint analysis was introduced to marketing by Green and Rao (1971). The first step in a typical conjoint analysis is to present consumers with a number of product descriptions and ask for a ranking of them. Product descriptions, defined via a set of physical attributes, are often hypothetical, but can also be actual products, produced according to an experimental design. The advantage of conjoint analysis over MDS analysis is the direct relation to the manipulable attributes. Since these attributes are chosen in advance, however, they also constitute the greatest problem of this technique. It is therefore by no means certain that the chosen attributes are the most important for the consumer's choice of product. The results of the analysis are, of course, only as good as the input they are based on.

A conjoint analysis is based on the principle that individual utility functions are calculated for each attribute. If the utility values are basically the same for all levels of a given attribute, then it has very little importance for the consumer's choice. The opposite will of course be true if the utility values are widely different across the levels of a given attribute. The overall utility of a given product is calculated by summing the utility values across attributes. It will then be possible to calculate the utility which the consumer assigns to each different product.

The choice of product also requires a behavioural model. Either the product with the highest utility value is assumed to be the chosen product or a stochastic model is defined so that alternative products are chosen with an estimated probability. By aggregating across consumers, the number of individuals who prefer a given product can be found, and thus also an estimate of the product's expected market share. The last steps, which included the evaluation of alternative products and their potential market shares, are traditionally carried out by simulation.

An example of a newly developed product optimization model using conjoint analysis can be found in Green and Krieger (1992).

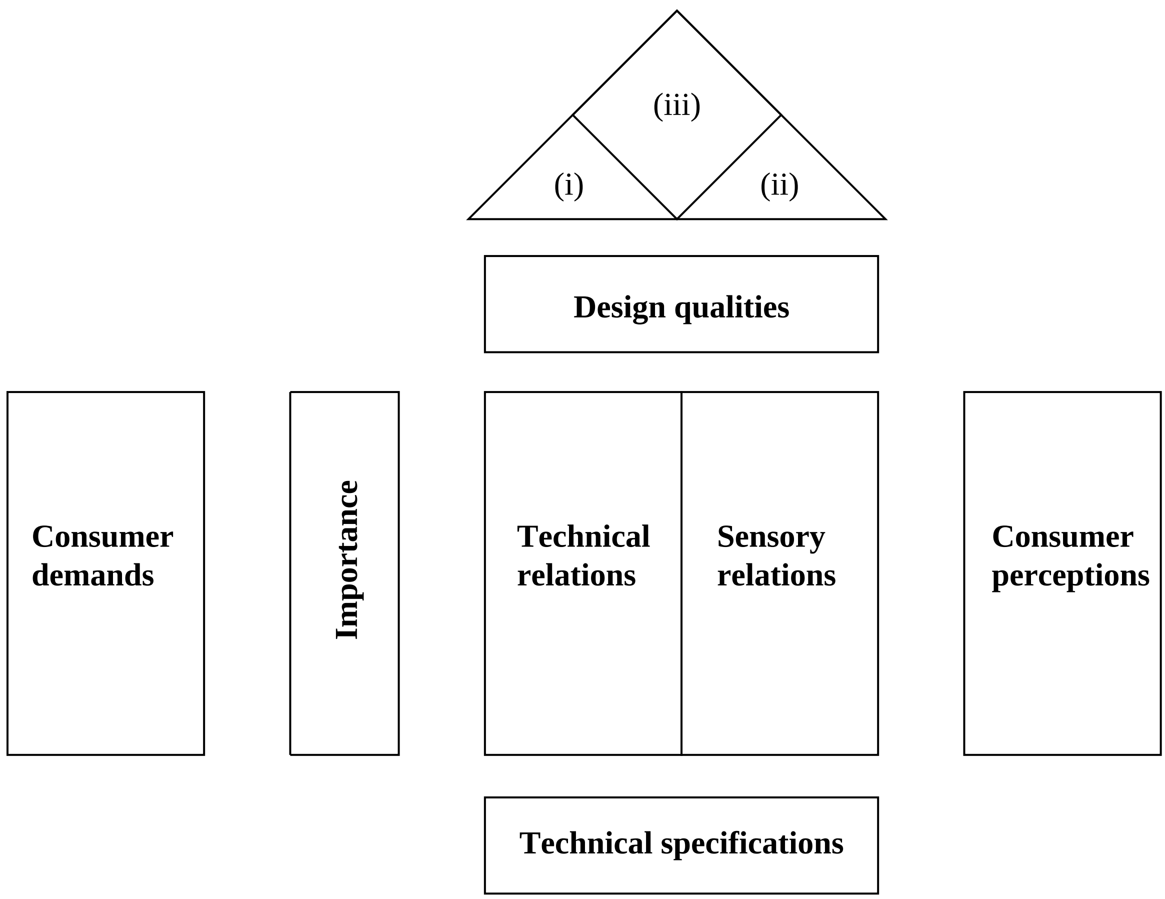
4. Integration between sensory analysis and market analysis

By tradition, sensory analyses and market analyses are each carried out in their respective departments in the firm, often in a quite uncoordinated way (McBride, 1990). R&D is responsible for the former, while marketing carries out the latter. The obvious thing to do would be to integrate the two, of course. With a starting point in an MDS analysis of consumer preferences, a sensory description of the products included in the market analysis would constitute a possible, and very probable, link between the latent needs of the consumer and the physical attributes of the product. In one of the larger empirical studies, Souder (1987) has demonstrated a clear connection between the success of newly developed products and the degree of integration between the two departments. The degree of integration is defined as the extent to which there is a continuous exchange of information between departments and departments agree on decisions and decision-making powers.

There can be many reasons for the lack of integration between the two departments. Gupta et al. (1987) identify three main groups of reasons: Firstly, it can be attributed to the firm's organizational structure. If decision-making is highly centralized and the organization of work very rule-based, there will be a low degree of integration. Secondly, top management can directly encourage teamwork, eg by means of joint bonus systems for the marketing and development departments. Thirdly, the lack of integration could be due to the big differences in the two departments' personnel. The technical staff in R&D might tend to regard their marketing colleagues as frivolous, because the guidelines which the R&D department receive have no direct connection to the product's physical properties, while marketing perhaps has a tendency to regard the engineers as vapid, because they communicate in technical terms which have no immediate relevance for the consumer.

Greater acceptance and understanding could be achieved if the sensory and market analyses were planned jointly, so that the preference evaluation via the sensory properties could be traced all the way back to the physical properties. Generally speaking, the lack of integration is the responsibility of top management. The literature on Total Quality Management (TQM) emphasizes management's commitment as being crucial for favourable changes in the organization. The introduction of cross-functional management was precisely one of Deming's 14 points for getting out of the crisis which has afflicted large parts of European and American industry (see Deming, 1986).

Figure 6. House of Quality (with special reference to the development of food products)



The name QFooD includes the acronym QFD - Quality Functional Deployment - which is a management technique developed at Mitsubishi's Kobe shipyards in 1972. QFD is expected to strongly improve communications and understanding between the two departments. QFD actually consists of four "houses" for integrating the flow of communication in the firm, of which the first - the House of Quality - is the best known.

The idea behind the House of Quality is to place consumers' desires for products together with the technological possibilities in a simple figure. The left-hand side of the figure, which shows consumer preferences, is the starting point. These preferences include partly a qualitative element - which attributes does the consumer evaluate the product on - and partly a quantitative one - what is the relative importance of these attributes. The right-hand side of the figure expresses the consumer's perception of how far existing products fulfil the criteria. Both sides of the figure can be covered through traditional market analyses.

The middle part of the figure shows how consumer desires can be translated into objective product specifications. For present purposes, these have been divided into two groups: technical and sensory. The reason for this is not just to place sensory analysis in relation to the firm's other production criteria, but also to draw attention to the difference between sensory analysis and traditional market analysis. The sensory variables are seen as part of the internal product specifications, while the market analysis, through the expression of consumer desires, provides an external specification.

The centre of the middle block shows the connection between the two sets of descriptions. The roof of the house represents the mutual connections between the internal product specifications, and since there are two types, it shows three types of relations: (i) mutual relations between technical specifications, (ii) mutual relations between sensory specifications, and (iii) relations between technical and sensory specifications. These relations are important as regards the plan-do-check-act model described in the introduction. As we see it, the plan phase reflects consumer desires expressed through the market analysis. In the do phase, these desires are then converted to sensory and technical specifications. After the development of a number of prototypes, the sensory analysis in the check phase can replace consumer measurements and thus functions as an internal quality control. The do-check part of the model can be carried out internally several times, until the product has the required composition. Next, the product can be marketed in the act phase, in which market analyses can confirm whether or not the product lives up to the consumer's expectations. This brings the process full circle. If the product does not live up to expectations, a new plan phase starts.

The House of Quality can be expanded in a number of respects. Existing products can be described both technically and sensorily, and the costs associated with changes to each product specification can be estimated. One interesting possibility, which seems to have been overlooked in the literature, is to expand the middle block with a part to represent other marketing parameters. These are then placed on an equal footing with the other parts of "technology" as determinants of the consumer's product experiences. This also opens up the possibility of the consumer's preferences being influenced through marketing, which is not altogether unrealistic.

Griffin and Hauser (1992) describe an experiment which they carried out in an American company in which two teams of employees were put to work on two very similar product development projects. One of the teams used the QFD approach, while the other used the more traditional phase-review process. By recording both the degree of communication among team members and between teams and what they talked about, Griffins and Hauser (1992) came to some very interesting conclusions, which strengthen our expectations of QFD as a link between sensory analysis and market analysis. They concluded that, compared with the phase-review team, the QFD team thought of themselves as being more integrated. There is more communication in the team, and it is of a more horizontal, non-administrative character. A possible warning signal is that the QFD team tended to see itself as self-sufficient, which, however, could also just be an expression of more effective internal communication.

There are, of course, certain methodological problems connected with linking market and sensory analyses. Sensory analysis consists typically of about 20 sensory dimensions per product, which it is totally unrealistic to expect the consumer to evaluate. The first problem, therefore, is to reduce the number of dimensions before carrying out the market analysis and without forfeiting the possibility for integrating the results of the two analyses.

Another obvious problem which makes the integration of the two forms of analysis more difficult is the difference in the units of analysis of the two methods. Sensory analysis uses the product as the unit of analysis, while in market analysis it is the respondent. Differences between the evaluations of panel participants are undesirable, while the identification of differences between consumers is interesting and opens up the possibility of more precise marketing. This gives food for thought about analytic techniques. One possibility is to regard all consumers in the market analysis as homogeneous, but another possibility is to use multimode analysis (See Law et al., 1984).

We have designed an MDS-based model for use in the evaluation of an optimal product. This is presented in the following section.

5. A model for optimal product design and price determination

The starting point of our model construction is the profit function from classical micro-economic theory. Consider the following well-known equation:

(1) $\Pi = (p-c)x(p)$

where

Π = the profit, p = the price, c = the variable unit costs, and x = the volume in demand of a given product.

While we can determine the optimal number of units to produce in order to maximize profit, the equation tells us nothing about what the product should look like. Fixed costs are not included, but are naturally relevant should the firm decide to enter a market. In this connection, there will be a number of start-up and overhead costs to take into account. If product development is related to existing markets and the modification of existing products, the fixed costs will be irrelevant. The profit function in equation (1) is static, and furthermore assumes that each product can be described independently of the firm's other products (Kristensen & Juhl, 1989). As for the variable unit costs, it is a condition that they are independent of the scale of production, and as such are identical with the marginal costs. A final limitation of the model is that it takes no account of the reactions of competitors (Kristensen & Juhl, 1989).

For the purposes of the project, equation (1) must be expanded so that an optimization of the function can indicate both the most appropriate composition of the product and the optimal price. This is achieved by assuming the following price and cost functions for the product:

(2) $\tilde{p} = p + \Phi_1(CSI/p)$

(3) $\tilde{c} = c + \Phi_2(CSI)$

(4) $\Pi = (\tilde{p} - \tilde{c})x(\tilde{p})$

It can be seen from equation (2) that the firm should not only employ the market price (p) in computing its profit, but also include a measure for goodwill. The amount can be seen as an invisible revenue, which, while not appearing in traditional accounts, agrees well with the management philosophy in TQM. This goodwill is defined as a function of CSI, which is short for Customer Satisfaction Index (Kristensen et al., 1991). It would be natural to define CSI as a measure which is inversely proportional to how "close" the firm's product is to the consumer's ideal.

(5) $$CSI = \sum_{i=1}^{N} \frac{b_i}{(s_i - s_i^*)^2}$$

Parameter b_i is a measure of the importance the consumer attaches to the i'th sensory attribute, while the denominator is a measure of how far the product is from the ideal at this point. The attributes s_i cannot be directly controlled, but it is possible to link consumer measurements s_i with the technical and sensory specifications in the firm via the House of Quality. Competitors are indirectly included in the model via their influence on CSI. The heterogeneity of consumers' preferences is built into the model by virtue of the fact that each segment has its own ideal set of attributes, and CSI will then be calculated as a weighted sum of CSI for each segment, using the segment parts as weights.

The estimated price ($\tilde{p}$) is made up of the market price and a discounted value of the future payments. These types of prices are called imputed prices in economics, and have a structural resemblance to Friedman's "permanent income" concept (Friedman, 1957). From (2), it can be seen that the discounted value is defined as customer satisfaction measure per krone - reflecting the natural assumption that the customer is only willing to pay more for better quality if the increased satisfaction more than outweighs the price increase. This being so, it is conceivable that it would be optimal for the firm not to change the composition of the product.

The estimated variable unit cost ($\tilde{c}$) also consists of two components - the usual unit costs plus a term which is conditional on CSI. The latter is based on the assumption that continuous monitoring of the market to determine whether consumers' ideal perception of the product changes will incur a number of costs. It is also expected that the costs of producing a product "close" to the ideal will be greater than making products of lower quality.

Before the model can function in practice, however, it will first be necessary to specify and measure the functions for the invisible revenues and costs. The model could also be expanded to include the consumer's perception process and the linkage between the sensory attributes and the physical/chemical properties of the product.

6. Joint projects

An important part of the QFooD project consists of joint projects with Danish food processing companies. These projects also form the empirical basis for our model. Four projects were initiated, involving widely different vegetable and meat products. The overall aim is the same for all the projects, which allows us to successively test and optimize the methods used. The collected experiences and results of the projects will be published in Spring 1995.

The aim is as indicated by the title of this report, ie "Optimal Design of Food Products", the framework of the project being the "House of Quality" (see section 4). The following stages are common to all the projects:

1. Consumer demands on the product are identified through focus-group interviews.
2. An experimental design is developed in collaboration with the firm, either with a view to production or to selection of products for the consumer survey. The factors which are presumed to have the greatest importance for consumers' preferences and perceptions of product quality are systematically varied. This ensures both product variation and the possibility of analyzing relations between production factors and consumer preferences. The test design typically involves 10-20 products.
3. The chosen products are analysed sensorily using the QDA method. In addition to this, relevant technical analyses of the product are carried out in accordance with the aim of the project from the firm's point of view.
4. A quantitative consumer analysis is carried out, which both measures consumers' perceptions of the products and collects demographic information and information on consumers' use of and attitudes to the product. This will typically involve 2-500 consumers, each evaluating up to four products, which are systematically chosen according to an experimental design (balanced-incomplete-block design).

5. Analysis of the results, which consist of three sets of data: (a) Data from consumer analyses; (b) Data from the sensory analysis; and (c) Data from the technical analyses. Integration of the information in the three sets of data, such that the optimal design is determined on the basis of the consumer analysis while, at the same time, the sensory/technical product specification is also specified. This is the context in which the elaborated model is tested.

Intergoods Bakery

Intergoods Bakery is a manufacturer of butter cookies. The aim of this project is to develop and implement a systematic approach to product development in international markets, which makes it eminently suitable for testing of the model described above. The aim of the QFooD project is first and foremost to analyse the relation between sensory attributes and consumer preferences for butter cookies. The project is now entering its final phase. An internal report has been drawn up for the firm, the material of which has so far provided the basis of an article entitled: "A sensory analysis of butter cookies - An application of Generalized Procrustean Analysis" (Juhl, 1994).

Frigodan, Danisco

This project concerns frozen peas. The aim of the project is to improve the firm's competitiveness by developing "optimally designed" peas based on consumer preferences. The QFooD project is responsible for carrying out the necessary market analyses, and also participates in the steering committee. The project involves several partners, since the results are to be used in processing. The other partners are the KVL Centre for Food Research at the Danish Royal Veterinary and Agricultural University, the Danish Institute of Plant and Soil Science in Aarslev, and Maribo Seed. This is a 5-year project, ending in 1998. A consumer survey has been carried out in Denmark, and the results of this will appear in the final report of the project.

Danish Institute for Fisheries, Technology, and Aquaculture (DIFTA)

This project deals with the breeding and processing of eels, and its aim is to ensure that as much of the processing as possible takes place in Denmark. The main function of the QFooD here is ascertain consumers' preferences for eel products. This is done by means of a 3-stage series of market analysis: lifestyle analysis, focus group tests, and quantitative consumer surveys. The results of these surveys must be able to be related directly back to the processing of the products, breeding, and the feedstuff used. The lifestyle analysis is carried out in cooperation with project 14: "Food-related lifestyle", Grunert et al., (1993).

Danish Meat Research Institute

This project deals with a consumer survey of pork, and is part of a much bigger project on male pigs. There has been a lot of controversy in the (Danish) press about an unpleasant after-taste in meat from male pigs, and the very characteristic smell it has when being cooked. The aim of the project is to analyse the factors responsible for the smell and taste of the meat of male pigs by looking at the relation between chemical measurements and consumer evaluations. A pilot study has been carried out, in which 72 households were asked to cook and eat meat which had been selected especially to contain all the presumed variables. The project is somewhat untraditional in the sense that we are trying to uncover the effect of a potential negative taste experience. It also sets a limit on the extent to which the presumed variables can be varied, of course.

7. References

Deming, W. E. (1986). *Out of the crisis*. MIT, Center for Advanced Engineering.

Eggert, J. (1989). Sensory strategy for success in the food industry. J*ournal of Sensory Studies, 3*, 161-167.

Friedman, M. (1957). *A theory of the consumption function*. Princeton: National Bureau of Economic Research.

Green, P. E. & Rao, V. R. (1971). Conjoint measurement for qualifying judgmental data. *Journal of Marketing Research, 8*, 355-363.

Green, P. E. & Krieger, A. (1992). An application of a product positioning model to pharmaceutical products. *Marketing Science, 11,* (2) 117-132.

Griffin, A. & Hauser, J. (1992). Patterns of communication among marketing, engineering and manufacturing - a comparison between two new product teams. *Management Science, 38,* 360-373.

Grunert, K. G., Brunsø, K. & Bisp, S. (1993). Food-related life style: Development of a cross-culturally valid instrument for market surveillance. MAPP working paper no 12.

Gupta, A. K., Raj, S. P. & Wileman, D. () A model for studying R&D-Marketing interface in the product innovation process. *Journal of Marketing, 50,* 7-17.

Hauser, J. & Clausing, D. (1988). The house of quality. *Harvard Business Review, 66*, 63-73

Hootman, R. C. (1992). *Manual on descriptive analysis testing for sensory evaluation.* Philadelphia: American Society for Testing and Materials.

Horsky, D. & Nelson, P. (1992). New brand positioning and pricing in an oligopolistic market. *Marketing Science, 11*(2) 133-153.

Juhl, H. J. (1994). A sensory analysis of butter cookies - An application of Generalized Procrustes Analysis. MAPP working paper no. 20.

Juhl, H. J. & Kristensen, K. (1989). Multiproduct pricing: A microeconomic simplification. *International Journal of Research in Marketing,* 175-182.

Kristensen, K. & Juhl, H. J. (1989). Some aspects of pricing in practice. In: G. J. Avlonitis, N. K. Papavasilliou & A. G. Kouremenos (Eds.). *Marketing thought and practice in the 1990's,* pp. 1273-1284.

Kristensen, K., Kanji, G. & Dahlgaard, J. J. (1992). On measurement of customer satisfaction. *Total Quality Management, 3* , 123-128.

Laustsen, A. M. (1993). KVL Center for Fødevareforskning. Personlig meddelelse.

Law, H. G., Snyder, C. W., Hattie, J. A. & McDonald, R. P. (Eds.) (1984). *Research methods for multimode data analysis.* New York: Praeger.

Lawless, H. T. & Claassen, M. R. (1993). Application of the central dogma in sensory evaluation. *Food Technology, 47*(6),139-146.

Lundbye, U. & Møller, S. (1991). Chokolade i profil. *Bromnyt, 14(*6-7) 27-32.

McBride, R. L. (1990). Three generations of sensory evaluation. In: R. L. McBride & H. J. H. MacFie (Eds.). *Psychological basis of sensory evaluation.* London: Elsevier.

Meilgaard, M., Civille, G. V. & Carr, B. T. (1991). *Sensory evaluation techniques* (2. ed.). Boca Raton: CRC Press, Inc.

Souder, W. E. (1987). *Managing new product innovations*. Lexington Books.

Shepherd, D. (1985). Dietary salt intake. *Nutrition and Food Science, 96,* 10-11.

Shepherd, R. (1990). Attitudes and beliefs as determinants of food choice. In: R. L. McBride & H. J. H. MacFie (Eds.), *Psychological basis of sensory evaluation*. London: Elsevier.

Shewhart, W. E. (1931). *Economical control of quality of manufactured product,* Van Nostrand, New York.

Sinesio, F., Risvik, E. & Rødbotten, M. (1990). Evaluation of panelist performance in descriptive profiling of rancid sausages: A multivariate study. *Journal of Sensory Studies, 5,* 33-52.

Stone, H. (1992). Quantitative Descriptive Analysis (QDA). In: R. C. Hootman (Ed.), *Manual on descriptive analysis testing for sensory evaluation*. Philadelphia: American Society for Testing and Materials.

Stone, H., Sidel, J., Oliver, S., Woolsey, A. & Singleton, R. C. (1974). Sensory evaluation by quantitative descriptive analysis. *Food Technology, 28,* 24-34.

Stone, H. & Sidel, J. L. (1993). *Sensory evaluation practices* (2. ed.). San Diego: Academic Press, Inc.