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The Product Design of Puffed Snacks by Using Quality Function Deployment (QFD) and Reverse Engineering (RE) Techniques

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ABSTRACT

Quality function deployment (QFD) and reverse engineering (RE) techniques were used to design a new product that consumer wants. To prepare the information, the consumer test and quantitative descriptive analysis (QDA) were conducted to obtain liking scores and QDA attributes of commercial products. QFD was applied to relate consumer liking and QDA attributes of products, and to identify the priority and the direction of goodness for each QDA attribute. For a consumer group, it was found that flavours, both potato and seasoning flavours, were the most important attributes, followed by saltiness and sweetness. This target consumers wanted the product that was strong in seasoning aroma, but optimum in seasoning taste and saltiness, and slightly in sweetness. RE was then utilized to create the profile of the target product. The RE results showed that the target product should be stronger in seasoning flavours and saltiness, and slightly in sweetness. To compromise the results from both QFD and RE, the flavouring compound should be reformulated to include less salt to make puffed snacks strong in flavours but optimum in taste.

Key words: food product design, puffed snacks, quality function deployment, reverse engineering

INTRODUCTION

The food industry relies heavily on new products to rejuvenate and maintain its business. The effective and successful new product development has to start with the customer (Saguy and Moskowitz, 1999). The quality function deployment (QFD) is a structured approach for integrating research of consumer needs and descriptions of the competitive environment with technical realities into a unique product specification. QFD methodology evolves around the "house of quality (HOQ)" a graphical representation of the interrelationships between customer wants and associated product characteristics (Rudolph,1995). The implementation of QFD in the food industry was started with a three day workshop arranged by the American Supplier Institute (ASI) in 1987 (Charteris, 1993). However, there are few published applications of QFD for the improvement of food products. Most of the relevant information has only been published in the form of scientific working papers, or as reports, and so much of this

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information is therefore not so readily available to people in general (Costa *et al.*, 2001).

Benner *et al.* (2003) criticized that the QFD approach ensures that the product is developed according to the wants of the target consumer group, but it is suitable for product improvements and not for truly innovative product. Moreover, it takes a large effort and a lot of time to conduct QFD for the first time, but once it has been executed it will speed up the time-to market and enable the company to improve the product at less cost. These authors suggested that if QFD was going to be used for food product development, it was important that simplifications were made to the product and its characteristics and interactions in order to keep HOQ matrices manageable. Another suggestion is the target values in matrices may be replaced by target intervals because of the fact that food ingredients are often still physiologically active materials that hence are subject to changes.

An example of HOQ modification for food product development was proposed by Bech *et al.* (1994) to consider the relationships between sensory attributes, technical attributes, and consumer requirements. This new structure has been applied during market-based studies to improve the quality of smoked eel fillet (Bech *et al.*, 1997), frozen peas (Bech *et al*., 1997), and chocolate couverture (Viaene and Januszewska, 1999). Another sample was done for a Danish butter cookies company by Holmen and Kristensen (1996). They used the HOQ approach to identify the incompatibility between retailers and consumers, and transmit this information to internal departments and external suppliers for solving problems together. This modification has been called "the city of quality"

To estimate the target value of each product characteristic, reverse engineering (RE) technique may be used. It is a way to identify the levels of one set of variables, given the levels of another set of variables by the task of inter-relating the data sets coming from products that have been systematically varied, or from products that are unrelated to each other but have been mapped in a coordinate system (Moskowitz, 2000). One of the benefits of using reverse engineering is to generate a specific sensory profile of product for maximizing consumer preferences or meeting the constraints of product development process. This techniques has been applied in some products such as ready- to-eat cereal (Moskowitz, 1997), juice (Moskowitz, 1998), and pasta sauce (Moskowitz, 2000).

In 2004, the value of savoury snack market in Thailand was expected to be worth 10-12 billion baht and this market consisted of puffed snacks (40 %), potato chips (30 %), puffed rice (9 %), prawn crackers (8-9 %), fish snacks (8 %), and others such as nuts and popcorn (Tansattakij, 2004). Wangcharoen *et al.* (2002) showed that 47.3 % of Thai respondents in urban areas ate snacks on a daily basis and the main reasons for consuming snacks were that they were delicious, they stopped hunger, and they are fun to eat. Good snacks should be good in sensory attributes (taste, smell, and texture), inexpensive, convenient to consume, nutritious, and low in fat, and they should have long shelf-life, as well. This research was aimed to apply QFD and RE techniques in sensory attribute designs of 7 Thai snack categories for each target consumer group. But only results of puffed snacks for a target consumer group would be presented in this paper.

MATERIALS AND METHODS

1. Collecting data

1.1 Preference data

Forty three Thai consumers, who were 18 – 45 years of age and ate snacks daily, were recruited for 1.5 hour sample evaluation which was splitted into 7 sections. In each section, they were asked to taste 3 brands, the leading brand and two main competing brands, from each of 7 snack categories including puffed snacks, potato chips, dried squid, popcorn, fish snacks, nuts, and prawn crackers. Before starting the first section, all panelists were advised how to evaluate samples. The 9-point hedonic scale was used for preference ratings (appearance, aroma, taste, texture, and overall liking), and there was a 10 minute break between each section.

Data were then analyzed by SPSS 10.0. Cluster analysis was used to classify respondents by their overall liking scores for each product category. Overall liking of each respondent group for each product category was estimated from their attribute liking scores by multiple regression (stepwise) as the equation below.

Overall liking = A (Appearance liking) + B (Aroma liking) + C (Taste liking) + D (Texture liking)

1.2 Quantitative descriptive analysis (QDA) data

Thirty semi-trained panelists were used to obtain QDA data for the same 21 snack products. They were selected and trained by the modified methods of ISO3972:1991 and ISO4120:1983, respectively.

2. Quality function deployment

A HOQ was built for each snack category to translate the attribute liking into QDA attributes. The importance scores of each attribute liking were considered from its coefficient in the multiple regression between the attribute liking scores and the overall liking scores.

The impact between each pair of attribute liking and related QDA attribute, and the relationship between each pair of QDA attributes were considered by Pearson correlation. Cohen (1995) suggested that impacts in the middle of HOQ should be considered into 3 levels consisting of possibly related which was valued as 1, moderately related which was valued as 3, and strongly related which was valued as 9. In the study, therefore, if a correlation coefficient was ≥ 0.9 or was an inverted U curve, then it was defined as being strongly related and scored as 9 for the impact of attribute liking and related QDA attribute (in the middle of house), and as + + or -- for the relationship between a pair of QDA attributes (on the roof). 0.6 ≤ correlation coefficient < 0.9 was defined as being moderately related and scored as 3 and as + or –, respectively. In case of 0.4 ≤ correlation coefficient < 0.6 it was defined as being slightly related and scored as 1. The contribution (priority) for each QDA attribute was then computed by summing the multiplication of impact and importance scores.

The direction of goodness for each QDA attribute was considered from the sign + and – of the correlation coefficient; + meant high intensity is good and vice versa in case of minus. For the inverted U curve, it meant the intensity of that sensory attribute should be optimized.

3. Reverse engineering

3.1 Creating a set of equations

The preference scores and QDA data were transformed to z-scores. The 21 products were then mapped in a coordinate system by reducing their QDA data with principal component analysis (PCA). The products' PC scores and their square terms were used as independent variables in the equations for estimating the degree of preference for each of the sensory attribute as well as the overall liking, and the equations for evaluating the intensity of the QDA attributes by multiple regression (stepwise).

3.2 Finding the target

The overall liking equation was maximized for each product category by using the solver command in Excel 2000. These maximized PC scores were then used in the QDA attribute equations to get the target product profiles.

RESULTS AND DISCUSSION

In this paper, the product design of puffed snacks for a target consumer group would be presented only.

1. Collecting data

1.1 Preference data

For puffed snacks, the respondents could be clustered into 2 different groups. The first group preferred puffed snacks 1 rather than puffed snacks 2 and puffed snacks 3 and the second group was vice versa. Only the first group data is shown in Table1 and presented in this paper. The overall liking equation under Table 1 showed that the overall liking scores for this target group were highly affected by taste liking scores and moderately affected by texture and aroma liking scores. This result seemed to be agreed with Williams (1999) who mentioned that flavours and seasonings were very important for snack products.

1.2 QDA data

Semi-trained panelists generated 29 QDA attributes for describing the sensory characteristics of 7 snack categories but the number of attributes used for each snack were different, such as there were 14 QDA attributes for puffed snacks. The QDA results showed that puffed snacks 1 were a bit milder in flavours and saltiness than puffed snacks 2 and both of them were significantly stronger in flavours and saltiness than puffed snacks 3. In addition, puffed snacks 1 were a bit hotter than puffed snacks 2 and both of them were significantly hotter than puffed snacks 3, whilst puffed snacks 2 and puffed snacks 3 were significantly sweeter, harder, and more cohesive than puffed snacks 1 (Figure 1).

2. Quality function deployment

The HOQ for puffed snacks (Figure 2) shows that the important quantitative descriptive attributes for puffed snacks were flavour both potato and seasoning flavours (7.65), saltiness and sweetness (6.12), cohesiveness of mass (1.71), hotness (0.68), and hardness (0.19), respectively. Clearly, the consumers wanted puffed snacks that were more flavoured (positive correlation coefficient) and had a lower potato flavour (negative correlation coefficient) in the case of aroma liking. However, the care for flovour was needed as the results showed that there was a particular optimum flavour, and that if the flavour was increased or decreased from this level, then consumer acceptance would decrease, i.e., the graph produced an inverted U-shaped curve for taste liking. The product needed to be less sweet, less cohesive, rather hot, and not hard, and the care for saltiness was needed as this attribute also showed an inverted U-shape when liking plotted against intensity. This finding was agreed with Booth and Conner (1990) and Moskowitz and Bernstein (2000) who mentioned that factors or

Table 1 Mean preference scores for 3 puffed snacks.

Attribute	Mean ± S.D.		
	Puffed snacks 1	Puffed snacks 2	Puffed snacks 3
Appearance	7.41 ± 1.40 [a]	6.64 ± 1.65 [b]	7.09 ± 1.23 [ab]
Aroma	7.36 ± 1.05 [a]	7.05 ± 1.29 [a]	6.18 ± 1.59 [b]
Taste	7.36 ± 1.14 [a]	6.41 ± 1.65 [b]	6.45 ± 1.53 [b]
Texture	7.77 ± 0.69 [a]	7.59 ± 1.01 [a]	7.09 ± 1.38 [b]
Overall	7.59 ± 1.05 [a]	6.68 ± 1.46 [b]	6.59 ± 1.53 [b]

[a, b] Means with different letter in same raw are significantly different ($p \leq 0.05$)
Regression equation ($R^2 = 0.994$):
Overall liking = 0.170 Aroma liking + 0.681 Taste liking + 0.193 Texture liking

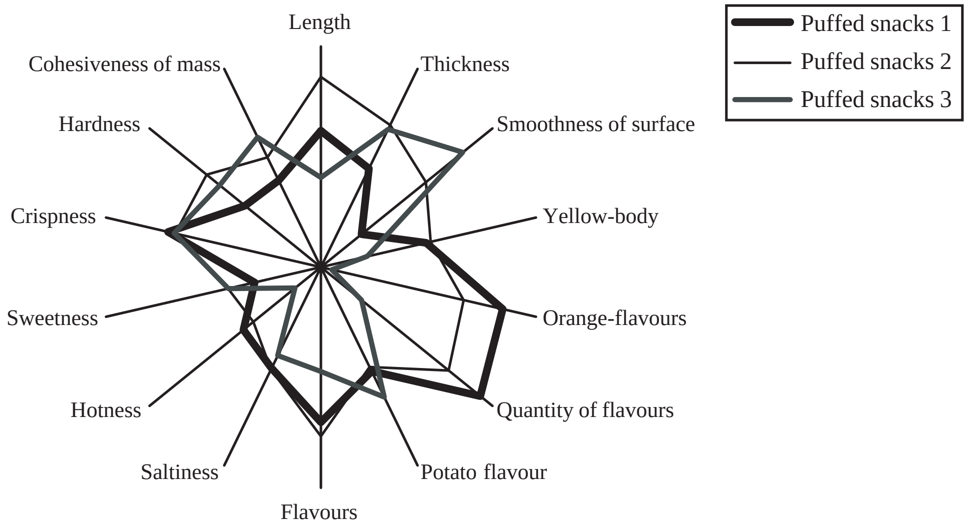

Figure 1 Quantitative descriptive analysis of 3 puffed snacks.

attributes which showed an inverted U-shaped curve against liking scores would be more important for the product acceptance of consumers.

The correlation on the roof of the matrix of the HOQ showed that the colour of the products (yellow and orange) were influenced by the quantity of flavourings and the types of flavour added, and depending on the combinations could have an influence on the perceived hotness, saltiness and sweetness of the products. The analysis also indicated that hardness and cohesiveness were dependent on the thickness and surface smoothness of the products and that hardness and cohesiveness increased with the thickness or surface smoothness of the products.

3. Reverse engineering

3.1 Creating a set of equation

The PCA reduced 29 QDA attributes to 8 PCs with 90.35 % explained variance. The multiple regression for estimating the degree of preference and the intensity of QDA attributes were created. For example the overall liking score equation was:

$$\text{Overall liking} = 0.131\,PC1 + 0.226\,PC2 - 0.202\,PC3 + 0.123\,PC4 - 0.104\,PC5 - 0.211\,PC6 - 0.373\,PC8 - 0.060\,PC7^2 + 0.063\,PC8^2 \qquad [\text{Adjusted } R^2 = 0.808]$$

3.2 Finding the target

The overall liking equation was maximized for each snack category. The QDA profile of the target product was computed by the PC score set obtained from maximizing the overall liking equation. For the target puffed snacks, it should be an intenser yellow than the existing commercial puffed snacks and that the dusted flavouring should be pale orange in colour. The length should be nearly equal to those of the third most important brand of Puffed snacks defined as Puffed snacks 3. The thickness should be in the middle between Puffed snacks 1 and Puffed snacks 2. The smoothness of the surface and the quantity of flavours should be closer to Puffed snack 1. The flavours should be stronger whilst the potato flavour should be moderate. The taste should be more salty but less sweet and hot as Puffed snack 1. The texture should be moderately hard and cohesive (Figure 3).

This target product profile that was

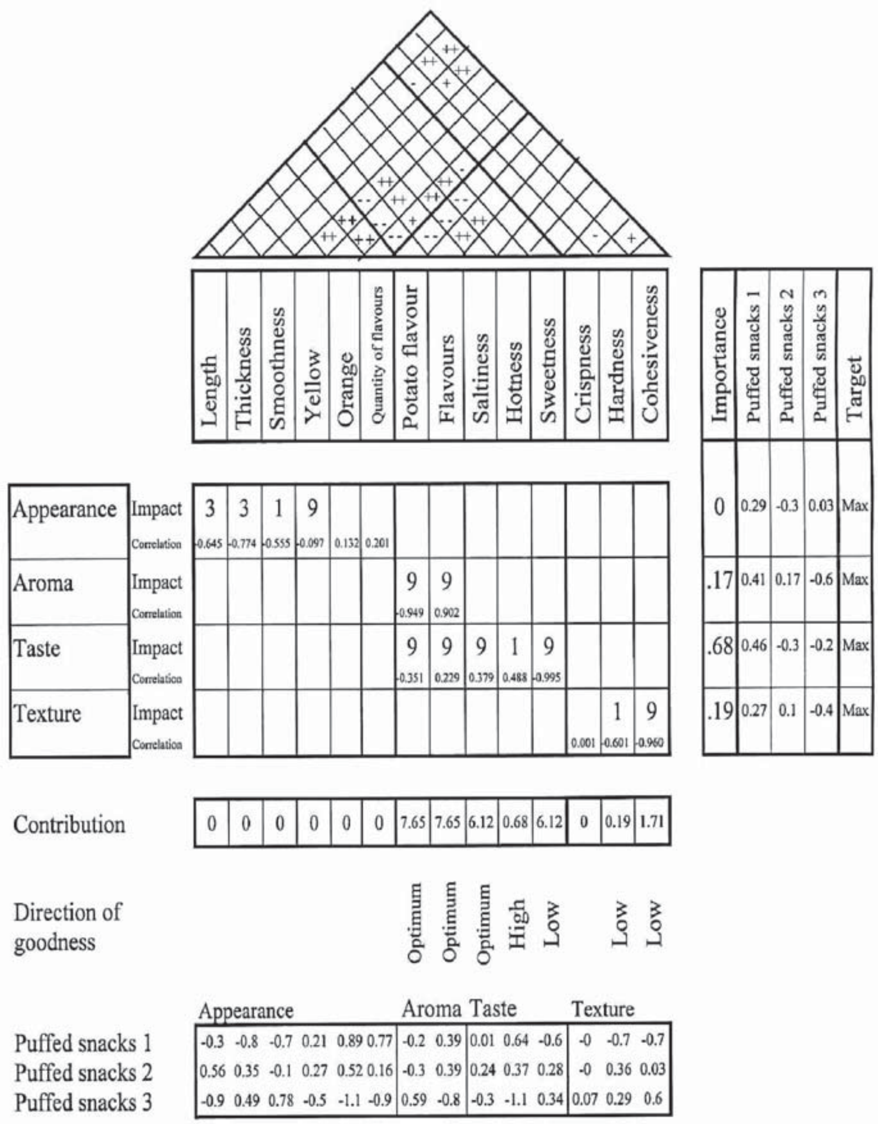

Figure 2 The HOQ for puffed snacks.
(Plus and minus values in the right and below sections of HOQ were Z-scores of attribute likings and QDA data of 3 puffed snacks to show differences of products and would be used for reverse engineering in the next step.)

produced by the reverse engineering approach for puffed snacks produced an almost identical solution to the HOQ approach for the important product requirements (Figure 2), except the seasoning flavours and saltiness where the direction of goodness from HOQ suggested that they should be optimized, whilst the reverse engineering approach proposed that these attributes should be increased. This incompatibility could be explained by the strong relationship between yellow colour and flavours, and between flavours and saltiness, of the existing products on the roof of HOQ showing that the flavouring agents currently used might be a yellow flavouring

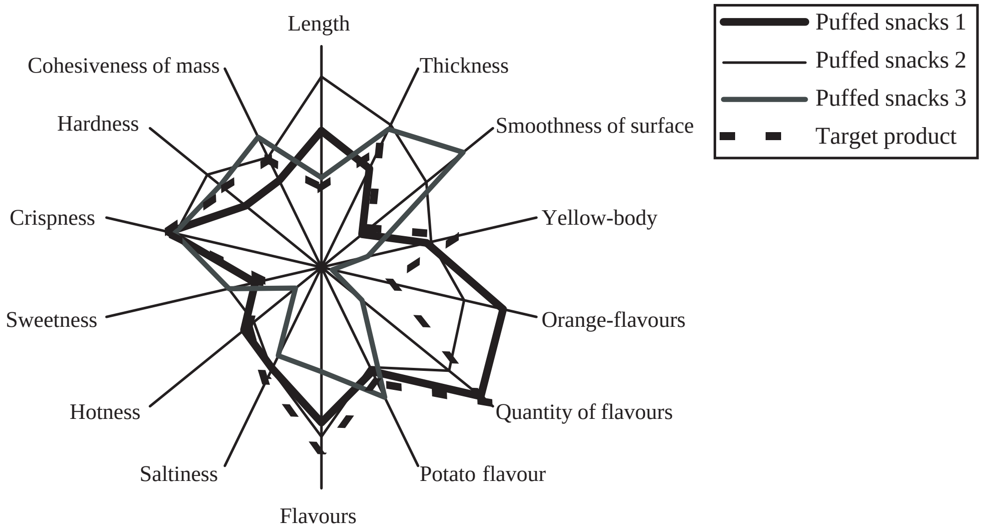

Figure 3 Quantitative descriptive analysis of 3 puffed snacks and a target product.

agent with added salt. The more flavouring the agents, the yellower and saltier the product. To compromise the results from both QFD and RE, the flavouring compound should be reformulated to include less salt to make puffed snacks strong in flavours but optimum in taste. Since QFD and RE had never been used together before, this research showed that they might disclose more useful information in product designs.

Strong flavoured and hot puffed snacks, a result of the QFD and RE application for product designs in this study, might be a product which met consumer wants in a survey conducted by Wangcharoen *et al*. (2002) who showed that Thai consumers wanted functional puffed snacks with hot pungent flavoured Thai herbs. Uhl (2000) also mentioned that Thai people preferred foods with flavour blends which were hot, pungent, sweet, aromatic, and might be sour and salty depending on types of foods.

CONCLUSION

This work showed that the application of QFD and RE techniques could provide the useful information to product developers. QFD helped the product developers to identify the importance of product attributes and the direction to improve them, whilst RE was beneficial in the intensity estimation of the target product's attributes. The compromise of QFD and RE results might give the better result to product developers.

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