

Development of Japanese Rice - Cooker with a Focus on Enhancing the Flavor Profile of Cooked Rice: A Case of Mitsubishi Electric Home Appliance

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Abstract

The study aims to clarify the technology integration approach adopted by a company in the development of a rice cooker, by exploring consumer needs that might be ambiguous during the product design stage of development. The development process involves making a series of decisions to define the subtle flavor of cooked rice. A rice cooker is considered beneficial as it enhances the flavor of cooked rice. It is understood that flavor is a personal preference that cannot be always evaluated quantitatively. Securing the flavor profile of cooked rice is a major consideration in the design of a rice cooker, which is intended for large-scale commercialization. To this end, companies invite evaluators to participate in the trial run of rice cookers during the development process who share their assessment on the flavor of rice prepared using the trial product with designers. The effectiveness of such product evaluations depends on the dialogue between the designers and evaluators. Since defining the subtle flavors of cooked rice is a complex process, both evaluators and designers sample the rice prepared in the trial product to discern the flavors and have a shared sense of flavor. At this stage, the communication between evaluators and designers becomes important as it enables them to gain a mutual understanding and develop a shared sense of flavor. The process of enhancing the sensory properties of food items, such as the flavor of rice prepared using a rice cooker, is an organizational ability that makes the product developed through the process difficult to imitate by competitors. This shared sense is accumulated and refined through the product development cycle, which eventually becomes the evaluation criterion for the product. Currently, most products are being designed using the modular architecture approach. Japanese companies have been proficient in integrated product development, and they stringently manage the development of products that require the optimization of assembly efficiency. However, Japanese companies must utilize their proficiency for developing value-added consumer products like rice cookers that intend to enhance the flavor profile of rice while rice preparation.

Keywords: Product development, Consumer electronics, Product innovation, Rice cooker, Mitsubishi Electric Home Appliance

1. Introduction

Several studies refer to the technology-push and demand-pull models to describe

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innovation processes (Stefano, Gambardella & Verona, 2012)¹. Additionally, product development can be defined as the process of adopting technology to develop a new product or improve an existing product that can cater to market needs (Ulrich & Eppinger 2012, Wheelwright & Clark 1992). During product development, customer needs often remain ambiguous to the manufacturers. It can be argued that a product's success in the market suggests that the manufacturing company has clear understanding of customer needs (Maidique & Zirger 1985). Besides, customers often fail to recognize and discover their exact needs until the time of purchasing and using a product. It is important for customers to assess the value of the offerings.

However, despite this ambiguity in customer needs, manufacturers must develop new products and must base their decisions related to each development process on a temporary definition of customer needs for gaining competitive advantages in the markets. This decision-making activity is referred to as a bundle of decision-making processes (Krishnan & Ulrich, 2001).

Motivated by previous studies, this study examines the development of a rice-cooker. This development process involves making a series of decisions to define the subtle flavor of cooked rice, prepared in the rice cooker, which is easily influenced by personal preferences. Specifically, I attempt to clarify not only the process involved in evaluating the flavor of rice cooked in the rice cooker but also the sustainability and robustness of the development process.

2. Research Method

To investigate the process of developing the sensory properties of rice cooked in this rice-cooker, I use a case study and analyze it using a qualitative approach. It is well known that this method may provide little basis for scientific generalization. Based on this approach, like the lifecycle model implemented in an organizational process, this study proposes sustainable product development through a sustainability and iterative lifecycle model. The theoretical implications of these principles are considered valid. Accordingly, it would be important to clarify the theoretical implications of developing a product like a rice cooker, which commands a high market share in the long-term.

This research is mainly based on interviews of people who participated in the product development process and on articles published in newspapers and company websites. The interview process started in 2012; major Japanese rice cooker manufacturers were contacted

¹ This study explains the role of demand as a source of innovation by examining the frequency of keywords such as technology-push and demand-pull in 100 most highly cited papers from 1956 to 2010.

through their company websites and sent interview. The Mitsubishi Electric Home Appliance Co., Ltd. accepted the interview request.

Subsequently, before the actual interview, a questionnaire was sent to the company via e-mail. The questions were grouped under the following three categories: how to identify the market needs, how to earn technological advantages, and how to retain these advantages. The answers were analyzed during a face to face interview with development managers and administrators that lasted for approximately 4 hours. Several unclear inputs on the development process were clarified via e-mail after the interview.

3. Case Study: Mitsubishi Electric Home Appliance²

3.1 Overview

Mitsubishi Electric Home Appliance Co., Ltd. develops home appliances, such as vacuum cleaners and cooking appliances including rice cookers and induction heating (IH) cooking heaters. It took the company more than 40 years, since the initial launch of its electronic jar rice cooker (electric rice cooker with an electronic jar) in 1972, to develop an upgraded rice cooker (fig. 1).



Figure 1. Rice cooker: The general home appliances in Japan
Adapted from the website of Mitsubishi Electric Home Appliance

The product development period for rice cooker spans across 2-3 years. The first one year is spent on basic research, and new product research begins in the second year. Since the selling price of a rice cooker gradually declines after the introduction of the product in the market, it becomes necessary to introduce new products consistently for maintaining prices or profits. Owing to such decline in the selling price, both the manufacturers and mass electronics retailers find it imperative to introduce new products annually to the

² Interviews with the director, deputy manager, and staff of the home appliance engineering department on February 22, 2013, January 19, 2017, and November 2, 2017.

market.

The product development process has the following four stages: (1) product planning, (2) prototype development, (3) mass-production prototype development, and (4) mass production. Design review (DR), which is similar to software DR or substrate DR, is performed, and internal meetings are conducted during each product development stage for understanding the progress made in each stage. Depending on the extent of product development—whether the development involves a full-model change or cosmetic level improvements including a color change—one among the three types of development ranks is assigned to the product development. Based on these ranks, the attendees are selected for the aforementioned internal meetings.

3.2 The *Kamado* method

The design and development team of the company was primarily responsible for the development of the rice cooker. The objective of Japanese rice cooking is to recreate the flavor of rice cooked on a “*Kamado*,” which is a traditional Japanese cooking furnace that can be found in old Japanese households. Japanese people believe that the flavor of rice cooked on a *Kamado* is unquestionable. However, the earlier version of the rice cooker manufactured by the Mitsubishi Electric Home Appliance used a different method to recreate the flavor of rice prepared on a *Kamado*. In the *Kamado* cooking method, the sticky “*Oneba*” soup that overflows from a hot *Kamado* contains the α -starch that contributes to the flavor of the cooked rice; this flavor is referred to as “*Umami*.” The content of α -starch increases in rice, when raw rice which usually has β -starch, and water are heated together at 98°C for 20 minutes or more. This principle of enhancing the flavor of rice by cooking it on a high temperature became the basis for the rice cooker development. Unlike *Kamado* cooking, the conventional cooking method of rice-cookers is mainly based on steaming that neither requires water nor entails a waiting time after heating. This cooking process differentiates the rice cooked on *Kamado* from the rice cooked in a rice cooker.

3.3 Decision-making on the subtle flavor of cooked rice

The flavor of rice tends to change under varied cooking conditions, such as air temperature, humidity levels in a kitchen, and the quantity of rice used for cooking. These conditions may influence the cooking temperature while rice is cooked in the rice cooker, and result in diffusing the partial heterogeneous moisture over whole rice in the cooker’s pot.

Additionally, the conditions in which rice is grown, namely, the rice growing district, breed, and harvest time, may also affect the flavor of cooked rice. Especially, these rice

growing conditions may influence the cellular structure of rice, quality of starch, or water absorption, and consequentially lead to a variation in the texture, appearance, and flavor indexes of rice that are assigned by the evaluators.

Moreover, although many customers feel that cooked rice has a simple and subtle flavor, different customers have different preferences in Japan. It is difficult for developers to define a standard flavor for cooked rice.

To check whether the planned flavor is realized, the company evaluates the rice cooked in the trial product in terms of indexes, such as texture, appearance, and flavor. First, the texture of cooked rice in terms of hardness and stickiness is qualitatively measured by evaluators and quantitatively by Mitsubishi's original rheometer. This instrument specifically measures the texture of cooked rice by measuring the force required to compress and crush approximately 200 grains of rice over a target distance and the force required to withdraw from the grains. Second, evaluating the appearance of rice by viewing is also considered one of the crucial sensory evaluation processes. Traditionally, in Japan, the appearance of rice is evaluated based on the plumpness of rice grains and the appearance of small holes called "*KANI-ANA*" (fig. 2), which means crab holes in Japanese, on the surface of the cooked rice. These are steam holes formed by the convection of water due to a high cooking temperature. The appearance of steam holes on the surface of cooked rice indicates perfectly cooked rice. Generally, the water inside the rice cooker reduces at a temperature exceeding 60°C, which results in rice that has a sticky texture. In addition to counting the "*KANI-*



Figure 2. *KANI-ANA*: It means crab hole in Japanese, and it is an indicator of flavorful rice. These holes appear on the surface of cooked rice. Adapted from a photo taken at the time of interview on January 19, 2017.

ANAs,” the cooked rice is evaluated for its appearance, mellowness, whiteness, shape, and clarity.

Third, sensory tests are conducted to evaluate the flavor of rice qualitatively, in terms of its sweetness, and aroma. Development staffs with a specialization in rice tasting perform these tests. Since the development of its first rice-cooker, the company had trained its staff and designers to evaluate the sensory properties of rice from the customer’s point of view. The staff plays an essential role in the development process. Beside them, at the final stage of product development, 20 prototype products are used in the homes of staff, who had not participated in the development, and are tested from viewpoints of flavor and usability.

This company believes that food texture and sweetness can be evaluated quantitatively. Along with the texture, indexes-hardness and stickiness-sensory tests were conducted to define the flavor profile of cooked rice. Based on these indexes, the company integrated its product developed in 2012 with a function that can provide texture options-hardness (“soft to hard” (five levels)) and stickiness (“dry to sticky” (three levels)). This function aimed to give the customer an option to choose from 15 kinds of cooking patterns-five hardness levels × three stickiness levels.

After completing the basic design of the rice cooker, the developers composed a software to determine the sequential order of varying temperatures for cooking different quantities and breeds of rice. According to the progress in software development, both performance tests and tasting tests are iteratively implemented until final specifications are developed.

3.4 Sensory evaluators

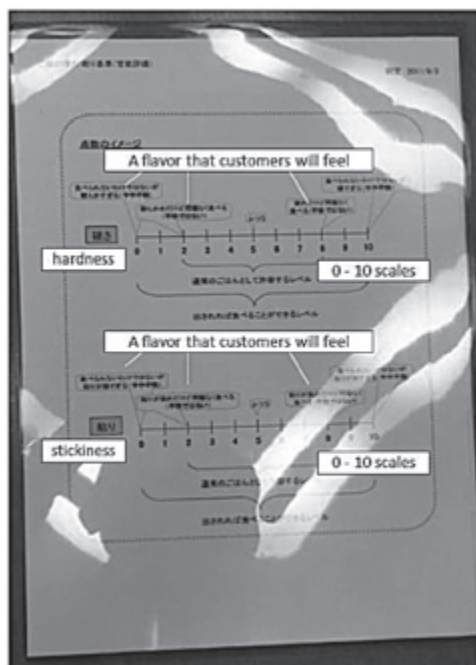
The company rarely invites individuals without sensory evaluation skills to participate in the sensory evaluation process during product development. Since each person has a different sensitivity to flavor, varied preferences, and lesser ability to express different sensory characteristics, it becomes difficult to determine trends the emerge from the tasting test results. The sensory evaluators of the company are familiar with product development histories and market circumstances and routinely evaluate a trial product. Based on their development experience or the sales volume of products developed by them, they identify trends in the evaluation results, and have the ability to translate their evaluation on the subtle flavor of cooked rice into technical parameters, such as approximate percentage of moisture content in rice, electricity consumption, or heating time, among others. Considering these qualities of sensory evaluators, it is difficult for individuals without the requisite skills to replace sensory evaluators.

This firm recommends the sensory evaluators to get certifications like “rice sommelier” from the Corporation of Rice-cooking of Japan or “rice meister” from the Japan Rice Retail Unions. The company’s evaluation team comprises five women with diverse career

backgrounds. It is not necessary for the evaluators to have a fixed background or knowledge base. The team members are not tested for their tasting abilities, before being assigned to this department.

The routines tests performed by the evaluators include sensory tests at every development phase; these tests are part of the evaluation stage of a function-prototype or a mass production-prototype. In a single cooking sequence, they evaluate the flavor of rice cooked in these prototypes 10 to 20 times and sometimes test rice samples totaling to 10 kg in a day. Before performing these tests, they verify their sense of flavor almost every day. As part of this verification process, all the evaluators taste from the same cooked rice sample and every member rates the texture of these rice samples in terms of its hardness or stickiness on a scale of 0-10 in a sheet. The members usually reach consensus on the ratings (fig. 3). Members who newly join this department memorize the sensory scale and different flavor profiles for two years because the flavor of rice changes under varying cooking conditions. Therefore, they memorize the different flavors of rice cooked under varying situations. It takes approximately 10 years for an evaluator to gain a solid understanding of

① Reference sheet



② Evaluation sheet

Date	日付				
Product Model	機種				
Cooking course	メニュー				
Amount of rice	炊飯量				
Breed of rice	米種				
Evaluation items	項目	硬さ	粘り	硬さ	粘り
Evaluator names	A()				
	B				
	C				
	D				
	E				
Impression	コメント				

Figure 3. Sheets for evaluation: Evaluating cooked rice sample according to the parameters in the ① sheet, rating the parameters in ② sheet on a scale of 0-10.

Adapted from a photo taken at the time of interview on January 19, 2017.

the flavor of cooked rice.

Besides some indexes like food textures that are expressed numerically, there are indexes on appearance, flavor, and aroma that are evaluated qualitatively through sensory tests during the product development. Therefore, sensory evaluators with a solid understanding of the flavor profiles of rice evaluate flavor and set up functionalities for the rice cooker.

3.5 Replicating *Kamado* by discovering new textural relationship

In 2015, the design and development team discovered new flavor features based on the relationship between water content and hardness of cooked rice; the team discovered this relationship during its examination of rice cooking on *Kamado*. This relationship between hardness and water content contributed toward enhancing the flavor of cooked rice when compared to the relationship between stickiness and hardness. Although an increase in water content for cooking rice in a rice cooker leads to softer grains that can disintegrate easily, the heating power of *Kamado* solves the tradeoff between high water content and hardness in cooked rice and results in plump and flavorful rice.

The key to achieving this texture lies in the heating power. This team successfully improved the heating power of its rice cooker by refining the heating system at the base of the cooker and by using carbon materials to make the rice pot and sealing it hermetically. However, intense heat frequently induced overflows from the inner pot. To prevent these overflows and enhance flavor, they investigated the *Kamado* rice cooking technique in Japanese food restaurants and private houses and found that the winged-shaped *Kamado* pot cools the hot bubbles on top of boiling rice by providing enough space for the water not to overflow from the sides of the *Kamado* pot. The wing of *Kamado* informs us of the top line of water. They understood the importance of the *Kamado* shape, especially in relation to the height required for cooling, and redesigned the next rice cooker.

4. Discussion

It is difficult to define the flavor of cooked rice because of its subtle flavor, which is influenced by varied consumer preferences. Although the objective of developing a rice cooker is to enhance the flavor of cooked rice, it is not easy to define this flavor quantitatively or qualitatively. The understanding of the flavor of cooked rice exists as a sensory experience that is shared by the evaluators and designers and forms the basis of their relationship. In this chapter, I show how this relationship drives the development process and improves the product quality in a sustainable manner.

4.1 Developing shared flavor through collaboration

Evaluators judge flavor from the consumer's perspective to ensure that the product

generates high demand in the market. The evaluators in the company should not judge flavor based on their individual preference but from the perspective of the possible market needs; however, it is also important to consider varied consumer preferences while planning the design of the cooker. For example, if the product is designed to target the youth market, then it would be important to modify the flavor of the rice cooked in the product in a manner that it appeals to a wider audience in the youth market. This example suggests that evaluators cannot base their judgement on their personal preference.

Flavor is an intangible sensory property; however, the flavor that the rice cooked in the rice cooker generates is collaboratively defined by evaluators and designers. Product development entails a bundle of decision making activities (Krishnan & Ulrich, 2001). Concerning the development of rice cooker, the decision-making must focus on the flavor of rice cooked in the product. And, the decision-making must be a collaborative activity involving a dialogue between the evaluators and designers. Designers can transfer their perception of flavor, which they think might promote sales, though the trial product to the evaluators, and thereby establish a platform for communication.

In this collaboration between the designers and evaluators, designers drive the technological initiatives in the development process, and evaluators support development by providing inputs from the customer's perspective. In other words, the designers are more seeds oriented as they focus on their company's technology, whereas evaluators are needs oriented as they focus on the market. In the development process, first, the designers transfer their sensory perception to a prototype product. Second, an evaluator attempts to assess the prototype. Third, based on the evaluation, designers adjust the flavor that the prototype produces. Since these three phases are iterative in nature, as indicated in previous studies (Thomke 2003, Wheelwright & Clark 1992), the evaluators and designers agree on at least two flavor perceptions. Consequently, they develop a shared perception of flavor that they perceive as logical.

Depending on the evaluation, designers transfer the outcomes of evaluation either to the physical surface or carry out operative changes, such as heating-time extension or replacement of different material components in the trial product. However, it is important that evaluators possess the communicative ability to inform designers about the evaluation accurately, and designers must also possess the technical knowledge or experience to incorporate evaluation into the trial functions precisely. Without the ability, knowledge, and experience, the process of providing and implementing feedback does not work effectively.

Furthermore, both designers and evaluators share know-how about the development process as well as the flavor, and this shared knowledge establishes platform for fluent two-way communication. This is similar to tacit knowledge (Nonaka & Takeuchi 1995), and is difficult to share quantitatively or verbally; it is also similar to personal skills that are

difficult to transfer or share, unlike explicit knowledge.

It can be said that this process of integrating the perception of evaluators with the designer represents the integration of technology with market needs. In a redundant system, including the trial-and-error approach, a trial manufacture can become more efficient when evaluators communicate their feedback accurately and designers incorporate the feedback effectively. And collaborating towards developing a shared sensory perception also contributes toward the success of the manufacturing approach.

4.2 Correction of flavor criterion

Flavor perception is not constant, and is influenced by changing trends, cultures, or societal mindsets. For example, a decline in the sales of a certain product can be attributed to a conflict between the existing flavor of the product and consumers' flavor preferences or needs. In other words, to capture overall market preferences consistently, it would be important to upgrade or alter the temporary flavor perception developed during the development process as per the market needs. However, changing market trends can be understood by evaluating market reactions toward the products on sale. Developers and evaluators have a shared perception, based on the flavor that the trial product produces during the development. By defining the flavor criteria developed during this trial and the actual sales volume of the final product, developers and evaluators will be able to maintain the flavor criteria through the iterative life cycle. Know-how, such as "If this is the flavor, then the reaction in the market will be this," can be obtained and accumulated empirically through this trial-and-error approach toward development.

As this company pointed out, it takes more than 10 years to develop a solid flavor perception, and hence continuous participation in product development is critical for avoiding divergence from this perception in the market. The criterion of flavor formed or accumulated among these designers and evaluators is the organizational capability that their relationship generates. Therefore, a long-term complementary relationship is necessary to cultivate or maintain the capability. The accumulation of know-how, comprising non-transferable and intangible personal skills, makes it difficult for competitors to imitate the development process.

This development can also be referred to as experience oriented development. Since the flavor perception of cooked rice is formed inductively, based on market experience, and is integrated with the product to serve as one of its functions, this flavor perception would have unique characteristics. This may lead to the development of a standard flavor profile for the product generations within the company; additionally, this flavor may become the signature flavor of the company.

4.3 Preference variety

Concerning varied preferences, when ordinary individuals check the flavor of cooked rice generated during trial production, based on their own preferences, the flavor does not always match with the overall preferences of the market. This company rarely invites individuals without sensory evaluation experience to take a part in product development. This is because evaluations fail to represent customer needs as they are based on different perceptions. Often, these individuals lack the expressive ability to communicate their perceptions. Since both the cooking environment and rice growing conditions influence the flavor of rice, it is difficult to control the flavor of rice cooked in this rice cooker. After the product is purchased by consumers, the flavor of rice cooked in the product may deviate from the flavor planned during the development process, owing to the varying flavor of rice. This variation in flavor of rice cannot be controlled by the developers even if they follow strict specifications during the development. However, it will be important for the developers to manage this variation to satisfy the huge demand for the product in the market. Therefore, this company has integrated its rice cooker with additional functionalities to enable the consumers to choose from a wide variety of flavor options. In reality, cooking sequences that classify consumer preferences into indexes are set as functional options and integrated with the product. Instead of developing a single function to satisfy all the benefits, it is appropriate to allow the customers to select the functions that satisfy their preferences.

4.4 Pursuit of the traditional *Kamado* method

Japanese firms are proficient in integrated development processes; namely, these firms can sustainably improve product quality and enhance product functionalities, and in some cases, exceed quality expectations. However, currently, most products are being designed using the modular architecture approach, and can be completed by assembling parts. Under these circumstances, pursuing a cost-effective and efficient assembly system is crucial. The overseas companies that do not have the accumulated advantages or experiences like Japanese companies, might find the current scenario advantageous, wherein Japanese companies are forced to adopt a stringent management approach (Fujimoto 2017). Focusing on these fields requiring such sensory properties, Japanese companies make the most of their ability. It is difficult for new competitors to gain competitive advantages like Japanese companies in these fields requiring such sensory properties.

This study emphasizes on the need for the integrated development of rice-cookers to balance the complex and subtle flavors of cooked rice. This flavor is representative of the rice cooked on “*Kamado*.” In Japanese cooking, *Kamado* symbolizes flavor; even the usage of images of *Kamado* on products is considered to have a positive impact on products.

Besides that, this study shows how the company used its past learnings on *Kamado* rice cooking techniques and set *Kamado* as a benchmark for upgrading its rice cooker.

There are several companies that manufacture, sell rice cookers and occupy a large market share in Japan, such as Panasonic, Tiger, Zojirushi, and Toshiba, in addition to the Mitsubishi Electric Home Appliance; many of them started developing products more than approximately 10 years ago. Both designers and evaluators are involved in these product developments. In the category of home appliances, a few companies lost their market share owing to the changing rules of market competition. However, concerning products that provide sensory benefits, such as these rice cookers, integrated development processes are still effective and can contribute toward the success of the company.

5. Conclusion

The judgment on flavor is based on sensory abilities. It is necessary to evaluate the non-quantifiable benefits of the rice cooker using these sensory abilities. This study reveals that functional options are provided to consumers to cater to their varying preferences. These functional options evaluate the quality of the rice cooker to meet various market needs. It is possible to adopt the redundancy system, also referred to as trial-and-error development approach, to facilitate the identification of subtle needs and benefits. It is critical for developers and evaluators to engage in a dialogue and have a common sensibility and vocabulary as a medium to facilitate effective exchange of perception and feedback. In this study, the development experience that cultivates this sensibility and vocabulary is pointed out. Accumulation of development experience also makes it possible to identify consumer expectations and achieve development goals. These criteria for evaluation formed based on different market experiences of each company are expected to influence the flavor profile developed by each company.

Previous studies on product development present many various definitions about success and factors that contribute toward successful product development, such as industry structure, competitive situation. Therefore, to construct the theory of success for each circumstance, it is considered that explicit theory limitation is also necessary. In this context, the concept discussed in this study may limit the generalization to other products. However, this study depicts the importance of establishing a dialogue for the development of mutual perception and shared knowledge. Additionally, this study underscores elements that contribute toward the sustainability of the product development process.

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