Core Technological Competence and Knowledge Accumulation in the Functional Food Industry: An Empirical Study of Japanese Food Firms

Paveena Lalitnorasate, Kumiko Miyazaki
Graduate School of Innovation Management, Tokyo Institute of Technology, Japan

Abstract--**Technological competence, an important factor for competitive advantage in several industries, was seldom studied in the food industry. While being called low-tech and largely dependent on markets and suppliers, the food industry has continuously adapted and innovated products responding to changing market and technological opportunities. The flourishing functional food industry in Japan (FOSHU), regardless of existing complex systematic regulation, is one of a proof that food firms have capabilities to perceive the market opportunity and technological changes, seek for knowledge and learn to efficiently integrate acquired knowledge in their core competences.**

The study on technological profiles and patent analysis allows understanding in firms' technological strategies such as positioning and dynamics of technological competences. The findings on six Japanese food firms that have FOSHU product activities have confirmed the role of core technological competence as a foundation of new creations under uncertainties, and imply the strategic importance of organizational flexibility in knowledge accumulation and learning process that facilitate firms in creating competitive advantage and responding to the new opportunities.

I. INTRODUCTION

Food industry, along with the tide of changes in global demands and technology, has evolved and developed unceasingly to supply the world's nutrition and respond to consumers' needs. Together with their accumulating experience, food industry employed knowledge from both new discoveries and other industries to create new values. While price-performance alone is not adequate to win over the fierce competition, innovation and value-creation have become the factor that differentiate the leaders. Food innovations have gone beyond the conventional practices that usually revolve around how to satisfy consumer's appetite, increase the shelf-life, and lower the cost to novel products of more fashionable and customized food.

As the trend of health food has been emerging, the new opportunity in food industry is open up. This recent trend that has gained high interest including 'functional food' which is defined by The Functional Food Center (FFC) as "Natural or processed foods that contains known or unknown biologically-active compounds; which, in defined quantitative and qualitative amounts, provide a clinically proven and documented health benefit for the prevention, management, or treatment of chronic disease". Despite the attractive market value and advance in development, the steps of functional food from idea creation to commercialization is not simple. Efficacy, safety concerns and consumer acceptance are inevitably problematic [12]. It requires additional knowledge of medical, novel production techniques and clinical trial to deliver the qualified products and pass the stringent regulatory standard. With regard to the extra distinct stages it has added, the creation of functional food is far beyond the conventional practices in food industry. The general process of product development that they usually follow may not be sufficient to fully answer the requirements [3].

New opportunities that food firms are unfamiliar with could adversely become threats if they only stick to their traditional competitive strategy and fail to realize the true potential of science-based innovations. In contrast with the managerial problems in food firms, functional food provides competitive advantages to new science-based entrants and pharmaceutical companies that are more capable with this kind of research and regulation [30]. However, as evidenced by the Japanese functional food industry, there are food firms that are able to incorporate external knowledge with their competences to efficiently participate in this new value-added products sector.

Considering the extent of technologies that food industry has been involved, it may not be plausible for food firms to utilize and integrate these knowledge without proper resources and competences. The study by Tunzelmann [10] has indicated that food firms especially in Japan have dealt with wide area of non-food technologies ranging from mechanical, chemical, pharmaceutical and biotechnology. As firms accumulate knowledge and built up technological competence in several areas to achieve productive resources, it possesses an ability to interact with the rapid changing technologies and emerging opportunities. Knowledge and experience in a broad area, even is an important element to competitiveness, is not what firms can fully dedicate their resources to since it comes with cost and time. The unknown future profits may make them reluctant to spend their valuable financial and human resources out of the boundary that they are familiar with. So, how do food firms catch up with emerging technologies and innovate? The case study in European food manufacturers by Traill and Meulenberg suggested that food firms have dominant product, process and market orientation that determines company culture and the types of innovation [27]. In line with the notion of 'core competence' by Prahald and Hamel, new innovations or the end products could be branched off from the dominant or core products that are sustained by firm's core competence [21]. Firms' core technological competence could be a key factor in connecting firms to emerging opportunities, and via learning and experimentation; firms are able to direct their development path efficiently.

Due to its low overall R&D intensity, food industry is used to be regarded as low-tech that mostly rely on technologies

supplied by other industries [18]. On the one hand, its role of R&D and technological competence is rarely studied as a crucial source of competitive advantages, but on the other hand, this statement seems to be inappropriate as the recent food industry draw upon range of advanced technologies and they need to have absorptive capacities to make productive use of these upstream developments [29].

This study aims to emphasize the role of core competences and learning process in a low to medium technological oriented sector like food industry in the environment of new technological opportunity by investigating Japanese food firms that successfully cope with new market opportunity of functional food. We propose that the ability to innovate with their limited resources come from a combination of internal core technological competence that gives them suitable development path and their flexible learning behavior that soften the probable organizational rigidity.

Section II illustrates the overall picture of functional food industry in Japan. The theoretical concept of core competence and its relationship with the process of knowledge accumulation is explained in section III. The scope of data and patenting statistics as a methodology is given in section IV. The core technological competence and its contribution to the knowledge accumulation in functional food sector is clarified and discussed in section V.

II. FUNCTIONAL FOOD INDUSTRY IN JAPAN

The concept of functional food has begun in Japan in 1980s among Japanese scientific academia, where functional food was defined as food with tertiary or physiologically active functions, such as the regulation of a physical condition or the prevention of certain kinds of disease [1], [17]. The first legal approval system for commercialization of functional food has been established by the Ministry of Health and Welfare in 1991. In this system, Functional Food is categorized as "Food for Specified Health Uses―特定保健用食品", or FOSHU (トクホ) in short. Each FOSHU product has to pass the assessment of FOSHU individually. FOSHU system requires all food that label with health claims meet the FOSHU conditions, which include: (1) scientific evidence of the effectiveness of the functional component on human body, (2) absence of any safety issues, as assessed from historical consumption pattern data, (3) use of nutritionally appropriate ingredients, (4) guarantee of compatibility with product specification by the time of consumption, and (5) established quality control methods, such as specifications of products and ingredients, processes, and method of analysis [14]. The data from the Consumer Affair Agency, Government of Japan revealed that there were totally 1063 approved FOSHU products from October 1997 to June 2013, with a market value around 5175 hundred million yen in 2011 approximated by a market survey from Japan Health and Nutrition Food Association. The top companies with highest number of approved products are from the leading Japanese food companies.

The development and commercialization of functional food is more complex, expensive and riskier than that of traditional food product. While the marketing and management challenges are the common challenges for food firms, special requirements from regulators and technological challenges become another barrier that prevent many food firms from participating in the functional food industry [24]. Technical challenges exist in the complex process of the functional food production such as specific technologies for preventing the deterioration of physiologically active compound. Additionally, to comply with the governmental regulations, production of functional food requires additional steps such as confirmation of bioactive ingredients activity and guarantee of safety in human which could be challenging for food firms that have no experience in a clinical trial processes.

Metabolic syndrome related functional foods

Metabolic syndrome is a disorder of energy utilization and storage, indicated by a group of heart attack risk factors including high blood pressure, high blood sugar, unhealthy cholesterol level and abdominal fat. According to the data from International Diabetes Federation (IDF), it is estimated that 20-25 percent of the world's adult population have metabolic syndrome. Since the cause of metabolic syndrome is directly related to diet lifestyle, it gradually becomes a major interest among the functional food categories. The market value of functional food products targeting on the prevention or reduction of metabolic syndrome risk factors is relatively large, accounted to one-third of FOSHU market based on market survey from JHNFA in 2011. The examples functional food that help fight against metabolic syndrome include several compounds found in natural food, for instance; omega 3, digestive enzyme inhibitors, polyphenols in tea, cocoa and coffee, fruits containing anthocyanins, antioxidants; dietary fibers; phenolics and plant sterol found in grains and legumes [16]. The common FOSHU products in this category are tea and coffee beverages, and cooking oils.

III. CORE TECHNOLOGICAL COMPETENCES AND THE ACCUMULATION OF KNOWLEDGE

The introduction of new opportunities and technologies often presents new challenges to managerial practices in the organizations. Firms need to rethink how to adapt and renew their strategic planning accordingly with their limited resources. To gain the sustainable competitive advantage, firms' competence that allow them to control over and integrate their valuable strategic resources with new resources flexibly become indispensable.

Firm's core competence is regarded as fundamental business which can be enhanced by combination with the appropriate complementary assets [25]. It is rare, less imitable by competitors and difficult to be substituted [2]. Goddard [9] has explained functions of core competences as: differentiating the company from competitors, creating values

to customers, acting as a platform for growth and providing strategic focus and direction. Unlike organizational resources, core competences are strategically dynamic and flexible, and are an integral part of organizational learning and competence building process [11]. To sustain the competitive advantage and enable itself in the emerging market, firm should identify, build up, and exploit its core competences that embed in the organization [21]. While core competences guide managerial decision, they are built up from continuous improvement and enhancement in a long period of knowledge accumulation. Core competences are not restricted in a strategic business unit but relate to several aspects in the organization including financial, marketing, production, and technological. The importance of core technological competences were discussed as a source of competitive advantage that could fill the performance and opportunity gaps if firms learn to harmonize and enhance them properly [22] [15].

The role of technological accumulation, searching and learning has been emphasized in the process firms build up their competences. Firms input resources such as physical and intellectual assets to form capabilities. Unique key capabilities that provide potential access to variety of markets and significantly contribute to the end products become core competences [11], [21]. The study by Miyazaki in Japanese and European firms in optoelectronic field indicated that trajectories of competence building is path-dependent as firms have to acquire knowledge and deepen their knowledge in the early phase, and later the activities could be more focused after a long period trial-error and experimentation [15]. The prior accumulated knowledge was also mentioned by Cohen and Levinthal as an important factor that gives firms 'absorptive capacity', or the ability to recognize the value of new, external information and apply it to the commercial ends [5].

Core competences and knowledge accumulation relates in a way that: firms build up their core competences from what they have learned and experienced, and those built-up core competences give firms direction to further development. In the environment of new technological opportunities, firms have to understand the linkage between the technologies they are opting and their own core competences in order to increase the chance of success [26]. Since the sources of technological opportunities, apart from the industry's own technological advances, could arise from advance in scientific understanding, technological advances originating in other industries and in other private and governmental institutions [13], recognition of core competences will give an ability to draw a clearer development path and build up appropriate competence to achieve the competitive advantages.

While most studies on core technological competence and organizational learning center on the high-tech industries, there was no clear evidence about their role in low to medium tech sector such as the food industry. The emergent functional food paradigm presented new opportunities to food industry. Under such competitive environment, firms seek to innovate and differentiate themselves efficiently. The ability to respond to this opportunity efficiently rely on firms' core technological competences and long-path of continuous learning. In the creation of functional food product, which is more complex than the usual products in food firm, existing core technological competence will play a key role as a growth platform guiding the direction of functional food development and be a foundation for trial-and-error during the knowledge accumulation process. The gap between existing competence and the emerging opportunity is gradually filled with firms' learning and experience. Cumulative knowledge is in turn integrated and complement with firms' resources to form new competences.

IV. DATA AND METHODOLOGY

A. Patent statistics as a proxy of innovative activities

Patent information was discussed by Ernst in its strategic value in assessing a firm's technological competence and impact on the future competitiveness [8]. Patent statistics is a potential proxy measure of firms' patterns of innovative activities such as output of product invention and impact. Even though patent count has some well-known limitations, it has advantages in its descriptive details and availability which enable time series analysis and the breadth and depth in a firm's technological field [6], [20]. This study adopts the method to create technological profiles from patent statistics proposed by Patel and Pavitt [19].

Functional food industry has exhibited a high degree of technological complexity and blurring boundary of scientific discipline [7] which cannot be simply defined via conventional patent classification. To select functional food related patents, a keyword search strategy in title, abstract and claims was carried out. This method was described as the best method to retrieve patents from an interdisciplinary domain [31]. The preliminary patent search was done by using keywords "functional food" and "health food" in order to retrieve high precision functional food related patents. The corresponding patents were examined and the likely to be appropriate functional food and metabolic syndrome related keyword list was created. Additional keywords were obtained after consulting a functional food expert to get 'metabolic-syndrome' and 'functional food' related keywords. Finally, product-specific patents that have relation to the selected commercialized product were indicated via specific keywords from the main component or active ingredients found in products which are compiled by the Consumer Affairs Agency, of the Japanese government. Retrieved patents were then classified into 35 technological areas based on the WIPO technology-IPC concordance (2013) for further analysis.

B. Samples

Major Japanese food companies that have functional food products in the metabolic syndrome category were selected, only the ones that have a high number of patent applications were further investigated. In this work, we include six

companies that have both similar and different businesses, which are Ajinomoto, Suntory, Yakult, Kewpie, Nisshin Oillio and Itoen.

Ajinomoto is a food and chemical corporation which has food products and amino acids as a core field of operation. Its first and main product is 'Umami' seasoning made from glutamic acid. Other business groups include bioscience products & fine chemicals, and pharmaceuticals, which are all originally branched from the applications of amino acids. Ajinomoto has put high importance on R&D activity and intellectual property. Its R&D department includes the Institute of Innovation, the Institute of Food Sciences and Technologies, the Research Institute for Bioscience Products & Fine Chemicals.

Suntory Holdings Limited is a brewing and distilling company group. Its core business is the production and distribution of alcoholic beverages. Its business has expanded to foods and non-alcoholic beverages, and other segment including health supplements, skin-care cosmetics, restaurants, processed foods and other services. Its R&D started from the use of microorganisms and enzymes and its distillation technology. Suntory emphasizes various aspects of health and biotechnology as major research.

Yakult Honsha Co, Ltd. has started its business with fermented milk containing cultivated Lactobasillus casei strain Shirota, which has health benefits on the intestinal tract. Its microbiology research has been expanded to other dairy products and the company has diversified its business into cosmetics and pharmaceuticals. Its Central Institute of Microbiological Research is responsible for the development of basic research, food material, pharmaceuticals, cosmetics and various analysis.

Kewpie is the first Japan's jarred mayonnaise producer. Its current food business includes prepared and processed foods such as jam and sauce. Kewpie also claims to be an egg expert and has several businesses related to egg material, which is the main ingredient in mayonnaise. Another business segment is health function products including healthcare business e.g. baby food, nursing care food and medical foods, and fine chemicals e.g. medical and cosmetic material. Kewpie has R&D activities mainly on the application of eggs and on the improvement of food tastes, nutrition and quality. Other R&D themes include health function in food and food container.

The Nisshin Oillio Group provides food products mainly related to oils and fats such as edible oils, margarines, shortenings, processed fats. It also has health food business e.g. food for elderly, nursing care, supplements and healthy dressings. Other business segments include Fine chemicals (raw materials for cosmetic, chemical and food ingredients) and Soy foods. Its R&D activities include basic research and new product innovations especially on oils.

Itoen, ltd is a leader in green tea business. Its main products are green tea and healthy beverages such as tea, fruit and vegetable juice, coffee and lactic drink. Other products include nutritional supplements and functional beverages. Its R&D is mostly related to green tea production and the application of tea extract.

All firms in this study have high commitment of the R&D activities and all of them is more or less active in 'health' business, or pharmaceuticals. It can be noticed that all of them has R&D themes that related to their core businesses which could be a factor to their core competences. A brief detail on the ratio of business segment, year of establishment and R&D expenditure is shown in Table 1.

C. Sources of Patent Data

As to illustrate the innovative activities of functional food industry in the Japanese food industry, patent applications from Japanese Patent Office (JPO) from 1988-2011 is obtained via the service of JP-Net. The English version of Japanese patent could also be downloaded via JP-Net e[1]. Translated title and abstracts can be found free of charge in Patent and Utility Model Gazette database provided by IPDL-Industrial Property Digital Library[2]. The total number of patents from these six firms is 8,252 and 953 of them are identified to have contents related to metabolic syndrome (Figure 1).

A. Identifying Core Technological Competences

Even though core technological competences of the firms contribute to the main business activities such as shown in Table 1, they cannot be simply identified from the business profiles. Core technological competences for functional food here are defined via metabolic syndrome functional food related R&D activities, represented by patenting data.

Profile of technological competencies developed by Patel and Pavitt was adopted in this study to explain the core technological competences. Technological profiles are classified into four groups: core, background, marginal and niche based on patent share and RTA. Patent share is defined as the share of a firm's total patenting and RTA is Revealed Technology Advantage which is defined by the share of the firm in total patenting divided by the firm's aggregate share in all the fields. Core and niche competence are technological fields that are comparatively stronger than the others. The difference is that the core competence indicates main competence of the firm, and thus located in the region of high patent share and high RTA, while niche competence is located in the region of low patent share but high RTA. Background competence is where a firm allocates large amount of share in its resources, but considering the size of field, a firm gains no higher advantage than the others. Marginal competence is where a firm neither allocates large share of resources nor gains more advantages than others [19]. The technological profiles of overall patenting activities of all six firms in two periods, 1988-1995 and 2004-2011 are

[1] JP-Net e provides English translation in the part of bibliographic and abstracts data, and other information.

[2] Industrial Property Digital Library (http://www.ipdl.inpit.go.jp/homepg_e.ipdl)

TABLE 1 CORPORATE BUSINESS AND R&D EXPENDITURE

Company (established year; number of employee)	Core business (% of total sales)	Other businesses (% of sales)	Capital/ R&D Expenditure*
Ajinomoto (1917; 27,518)	Food and Beverage – Seasonings, Processed foods (50.1), Bioscience Products and Fine chemicals – amino acids, specialty chemicals (17.4)	Pharmaceuticals (6.1), Others (21.3)	79.9 34.8
Suntory (1899; 28,767)	Food and Beverage (53), Alcoholic Beverage (30)	Others (17)	70.0 17.0
Yakult (1930; 2,987)	Dairy Products - Fermented milk (40.4), Pharmaceuticals (22.5), Beverages (21.2)	Cosmetics (3.7), Others (8.8)	31.1 12.4
Kewpie (1919; 12,425)	Condiment and processed foods (35.7), Egg products (17.6), Salads and prepared foods (17.6)	Health function products (3.8)	24.1 3.42
Nisshin Oillio (1907; 2,867)	Oils and meals - Edible oils (64.2), Processed oils & fat – margarine, shortenings (27.5)	Fine Chemicals (3.4), Healthy foods (2.3), Others (2.6)	16.3 2.00
Itoen (1966; 5,307)	Japanese tea (46.3), Fruit and vegetable juice (16.8), Other tea and coffee (16.7)	Tea leaves (8.8), Others (2.0)	19.9 1.69

*The figures are estimated for 2012 in billion yen unit.

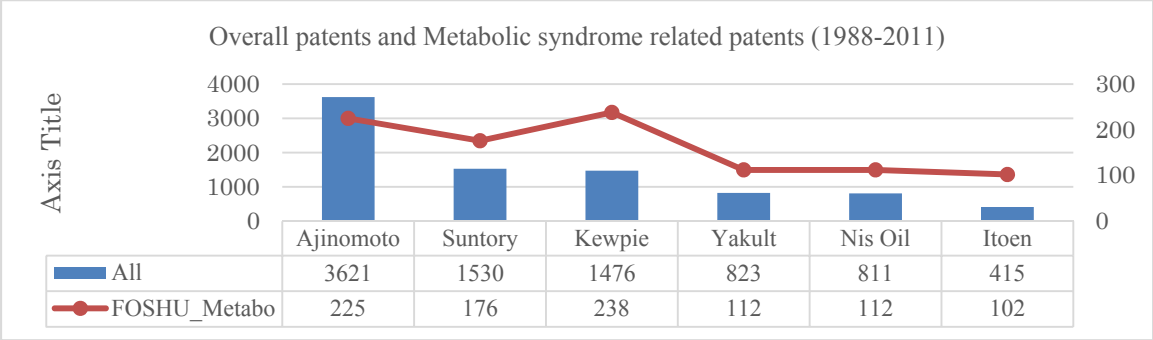

Figure 1 Overall patents and Metabolic syndrome related patents from 1988-2011

presented in Table 2. The period of 1996-2003 is intentionally omitted here since we would like to emphasize the change in technological strategies over a long period. The early period represented the technological development at the beginning of functional food paradigm, while the later period represented the recent R&D activity after firms have gained more experience. The technologically focused areas and level of diversification of each firm, even in the same industry, are not necessarily identical. While food chemistry and pharmaceuticals appear to be the main research interest of all firms in this sample as the levels of competences lie in either core or background quadrants, some areas such as biotechnology and organic fine chemistry gain high interest only in some firms. IT method appears to be a new area of R&D, and food chemistry is shown to be core competence in 4 out of 6 firms in 2004-2011.

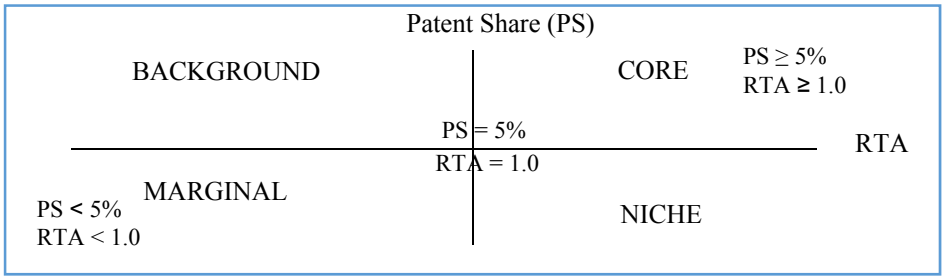

Figure 2 Technology Profile (based on Patel & Pavitt, 1997)

TABLE 2 TECHNOLOGICAL PROFILES OF THE OVERALL PATENTS

Company – (Period)	Ajinomoto		Suntory		Yakult		Kewpie		Nis. Oil.		Itoen	
Technological Field	(I)	(III)	(I)	(III)	(I)	(III)	(I)	(III)	(I)	(III)	(I)	(III)
Food Chemistry	C	B	B	C	B	B	C	C	C	C	B	C
Pharmaceuticals	B	C	C	C	C	C	B	B	B	B	C	C
Biotechnology	C	C	C	C	C	C	B	M	B	B	B	M
Organic fine chemistry	B	C	C	C	C	C	M	M	C	B	C	B
Handling	M	B	C	C	C	B	C	C		M		M
Basic materials chemistry	C	C	B	M	M	M	M	M	C	C	C	M
Macromolecular chemistry	C	C	M	M	M	M	M	M	M	N	M	M
Measurement	M	N	C	C	C	C	M	M	M	M		M
Chemical engineering	N	M	M	N	M	N	M	M	N	M	M	N
Other special machines	N	C	M	M	M	M	C	M	M	M	M	N
Textile and papermachines	N	M	N	M	M	N	M	M	M			C
Surface technology,coating	N	N	N	M	M		M	M			M	M
Medical Technology	M	C	M	M	M	M	C	M		M	M	M
Audio-visual technology	N	C	M	M				M	N	M		
Environmental technology	M	M	N	N	N	N	M	M	M	N		N
Furniture|games	M	M	M	N	N		N	M	M	M		M
Optics	N	N							M			
Computer technology	M	N	N	M		N		M				
Other consumer goods	N	M	M	N								N
Electrical Engineering, Energy	N	M		N	M			M		N		
Materials, Metallurgy	N	M	N	M	M			M		N		N
Machine tools	M	M	N	N	N	N		M	N			N
Thermal processes and apparatus	N		M	N				M	N			
Control	M	M	N	N	N	N		N				N
Civil engineering	N	M	N	N	N			M				N
Mechanical elements	M		N	N	N			N				
Semiconductors	N	N	N									
IT methods for management		N		M		N		N				N
Telecommunications		N	N									
Engines, pumps, turbines			N	N			N	M				
Transport	M		N	N				N				
Micro-structure, nano-technology		N										

Firms' technological profiles in two periods, 1988-1995 and 2004-2011 are denoted by (I) and (III) respectively. The symbols indicating technological competences are as follow:

Background: B Core: C Marginal: M Niche: N

B. Technological Competences Profile and Core Competences in Metabolic Syndrome related Patent Applications

The change in core technological competences for metabolic syndrome functional food development in each firm in the early period I (1988-1995) and the more recent period III (2004-2011) are shown in Table 3. The firms' technological strategies in coping with the new opportunity at the very beginning period of functional food development and after firms have gained experience and passed the process of knowledge accumulation can be observed. For more comprehensive understanding on how core technological competences are utilized in the development of new product, both overall technological profiles and the specific R&D theme should be interpreted concurrently. Here, it is noticeable that the overall technological profile is much more diversified than what firms use in developing specific R&D theme of products. Some competences that were shown as core competences of the firm considering overall activity may not be utilized or emphasized in the metabolic syndrome functional food development due to firm's multi-technology characteristic. Technological competence profile of one firm

was expected to be similar in both periods if that firm developed new products based on existing technological competence.

In the early period (1988-1995), the presence of metabolic syndrome functional food core technological competences were noticeably similar among firms that were involved in similar technological areas in their core products. For example, biotechnology, or more specific fermentation technique, is highly important for the core products of Ajinomoto (amino acid), Suntory (alcohol) and Yakult (fermented milk) as shown in Table 2. Even though not all the core technological competences that appear in the firm's overall technological profiles were translated into functional food related activities, most of the core technological competences that were used in functional food activities were distinct and similar to firms' core competences. For instance, food chemistry, organic fine chemistry and basic material chemistry but not biotechnology was found to be core R&D activities in Nisshin Oillio.

In the later period (2004-2011), most core technological competences were preserved in most firms in the sample, due to strategic continuity. Some of core technological competences may have fallen into the background areas. This indicates that firms still kept similar R&D direction, but may have lost their technological leading position due to high investment of other firms. Nevertheless, the direction of R&D activities was not a static strategy. There were changes and the coverage of research activities in most firms was expanded in the later period. Some technological areas also appear as metabolic syndrome functional food core technological competences even though they were not highly emphasized in the early period. Many of niche and marginal competences were also developed.

Among firms, smaller firms with lower R&D expenditure seem to focus on only technological fields that they are good at or 'core' for functional food production. For example, Itoen had allocated its resource to only specific areas while Nisshin Oillio is the only firm in the group that emphasized on utilizing basic material chemistry from the beginning. Note that basic material chemistry was shown to be the second highest patented field for Nisshin Oillio. On the other hand, larger firms that usually have several business groups are rather multi-technology, engaging in a wide range of technological activities. Further investigation in the content of patent revealed that those firms have employed some niche competences on the inventions used in functional food R&D. Examples are the use of IT in managing nutritional and dietary system, and a combination of measurement, biotechnology and organic chemistry in the creation of devices for determining the amount of biological compound and detecting bacteria.

It is quite apparent that functional food development among firms involves common technological fields apart from food chemistry. This result agrees with Bröring and colleagues viewpoint on the convergence of pharmaceutical and food in the functional food industry [4], as all firms have pharmaceuticals either as background or core competence in the functional food development. Since the classification of technological theme is quite broad considering that samples are from the same industry, metabolic syndrome related patenting activities at IPC- 6 digits level of firms were analyzed. The results from Pearson bivariate correlation (Table 4) indicates high similarity in metabolic syndrome functional food patenting activities among firms even at a finer level of technological classification. Nevertheless, some pairs of firms that have relatively distinct business activities and core products have demonstrated low relevance in technological interests such as in Itoen and Kewpie.

TABLE 3 TECHNOLOGICAL PROFILES OF METABOLIC SYNDROME RELATED PATENTS

Company – (Period)	**Ajinomoto**		**Suntory**		**Yakult**		**Kewpie**		**Nis. Oil.**		**Itoen**	
Technological Field	**(I)**	**(III)**	**(I)**	**(III)**	**(I)**	**(III)**	**(I)**	**(III)**	**(I)**	**(III)**	**(I)**	**(III)**
Food Chemistry	C	B	C	C	B	B	C	C	C	B	B	C
Pharmaceuticals	B	C	C	C	C	C	B	B	B	B	C	C
Organic fine chemistry	B	C	C	C	C	M		M	C	B	B	C
Biotechnology	C	B	C	C	C	C		M	B	M		B
Basic materials chemistry	M	N	M	C		C		M	C	C		
Macromolecular chemistry	N				N			N				N
Chemical engineering	N	N						N	C			
Textile and paper machines	C	N										
Measurement		M		N		N		M				
Surface technology, coating	B	C						N				
Medical Technology		N		N		N						
Other special machines		N		N								
Environmental technology				N		N						
Handling								N				
IT methods for management		N										

Firms' technological profiles in two periods, 1988-1995 and 2004-2011 are denoted by (I) and (III) respectively. The symbols indicating technological competences are as follow:

Background:	B	Core:	C
Marginal:	M	Niche:	N

TABLE 4 PEARSON BIVARIATE CORRELATIONS BETWEEN COMPANIES' METABOLIC SYNDROME PATENT SHARE BASED ON INTERNATIONAL PATENT CLASSIFICATION AT GROUP-LEVEL (6-DIGITS)

	Ajinomoto	Kewpie	Suntory	Yakult	Nis Oil
Kewpie	.832				
Suntory	.907	.749			
Yakult	.745	.735	.882		
Nis Oil	.792	.827	.764	.719	
Itoen	.842	.692	.928	.843	.838

All correlation is significant at the 0.01 level (2-tailed).

C. Knowledge Accumulation and Learning

From the technological profiles (Table 3), it is noticeable that a number of technological areas that were not in the firms' interests in the earlier period and especially 'niche' competences have increased in the later period for almost all firms such as in Ajinomoto, Suntory, Yakult and Kewpie. This illustrates the process of learning and experiencing that have been occurring as the scope of knowledge accumulation expands. Some of these emerging fields also appeared as core competences of the firms considering the whole patenting activities, for instance 'measurement' is core for Suntory and Yakult. It could be explained that as firms develop their new products based on knowledge they have in the past, core competences takeover an important role such as deciding the form of products and the production method.

To examine the scope of knowledge accumulation in the development of end product and the influence of core competence in the learning process, technological competences underlying the selected FOSHU products were investigated.

From six firms, two product categories that have metabolic syndrome health function, tea polyphenol in tea and plant sterol in edible oil products were chosen. Tea polyphenol FOSHU products include tea catechin from Itoen, Guava tea from Yakult and Oolong tea from Suntory. Plant sterol FOSHU products include mayonnaise from Ajinomoto, cooking oil from Nisshin Oillio and mayonnaise from Kewpie. These selected FOSHU themes are considered to be core products for Itoen, Nisshin Oillio and Kewpie. Theme code and the contents written in each patent application were checked and summarized in Table 6 and Table 5.

In general, food firms that have a great number of overall patents also own a number of metabolic syndrome functional food related patents. Nevertheless, this trend is not identified considering specific patenting theme. The disaggregated patents reveal how prominent the selected theme to the company such as the patenting ratio could be high and the extent could be broad if that area is firm's interest.

In tea-polyphenol category, the content of patent applications of three firms all include nutritive quality improvement and therapeutic properties of tea polyphenol. Itoen has highest number of patents with widest range of patenting activities covered from the production of tea catechin, medicinal application and other applications. Since Itoen has tea beverage as its core business, the large number of patents and its wide coverage in contents is not surprising. The number of patents in Suntory and Yakult have no significant difference. However, while the content in Suntory's patents are mostly about medicinal properties of polyphenol, Yakult were more interested in using tea polyphenol in improving its fermentation technique which is Yakult's core competence. Note that both Suntory and Yakult have health care business division and both of them have relatively the strongest pharmaceutical competences among six firms.

In plant sterol category, every firm filed patent applications on the preparation of product containing plant sterol for medicinal property. The differences are shown in the extent of applications. Ajinomoto, with the lowest number of patents, focused only the method of preparation, while Nisshin Oillio elaborated the medicinal properties of plant sterol and various types of oil. Kewpie has the highest number of patents and applies plant sterol on broadest range of food products. Apart from medicinal properties of edible oil, Kewpie has applied plant sterol on other food products for various purposes such as improving the quality of products and smoothening the preparation process.

In both product themes, it is evidenced that firms utilize new knowledge most on what they are good at. If acquired knowledge has high relation to core competences, the scope of learning was broadening as to protect and efficiently appropriate their core competence. Also, the process of learning seems to be rather flexible as firms also attempted to integrate or to apply new knowledge on their core products. Flexibility such as the ability to redeploy resources to develop new capabilities was also pointed out to be an important feature of core competence [23], [25].

Considering the time firms firstly pass FOSHU approval and their patent filing on the selected products, it took time before R&D could be marketed. Surprisingly, Itoen which is the firm that has tea as a core product and has studied ea polyphenol earlier than others took longest time to have its first FOSHU tea approval. Here, it could be pointed out that even though firms are strong in a product that has high relevance to new opportunity, their existing core competences in the designated product do not necessarily make them faster than others since the development of functional food is more complex than the ordinary products and other barriers still exist. Competences in other area could not be viewed as a holistic function of core competences. The complexity of new products requires additional knowledge, delaying the time to commercialization.

TABLE 5 TECHNOLOGICAL SCOPE ON SELECTED THEMES

Company		Technological scope
Itoen	1.	Separation technique (tea extraction)
	2.	Preservation technique
	3.	Medicinal application of catechin and tea polyphenol
	4.	Composition for pharmaceutical usage
	5.	Tea extract in food/drink with pharmacological functions.
	6.	Other application of tea catechin (animal feeds)
Yakult Honsha	1.	Preservation technique (preventing precipitation, deterioration)
	2.	Bioconversion technique (flavoring, fermentation)
	3.	Medicinal application
	4.	Other application of Guava
Suntory	1.	Composition comprised of tea polyphenol for medicinal purpose
	2.	Medicinal application
	3.	Other applications of Oolong tea
Ajinomoto	1.	Production method
Nisshin Oillio	1.	Production method and preservation technique
	2.	Composition containing plant sterol
	3.	Medicinal application
	4.	Plant sterol preparation
Kewpie	1.	Production method
	2.	Application of plant sterol on various food products (quality improvement, processing enhancement)
	3.	Composition containing plant sterol

TABLE 6 SELECTED SUB-PRODUCT THEMES FOR METABOLIC SYNDROME

Company	Additional Keyword in patents selection	Number of patents found	First patent filed	First product approval
Itoen Ltd	A. Tea and claimed polyphenol substances	27	1994	2006
Yakult Honsha		11	1995	2000
Suntory		15	2003	2009
Ajinomoto	B. Plant Sterol, Phytosterol	3	1999	2001
Nisshin Oillio		9	1999	2003
Kewpie		32	2002	2005

V. CONCLUSIONS AND IMPLICATIONS

A. Summary and Implication

This paper explored the role of core technological competence on how it assists firms in the low to medium technology sector responding to new opportunities by using a comparative study of six food firms that are active in the Japanese functional food industry (FOSHU). Core technological competences have been shown to facilitate firms on responding to new opportunities by providing a knowledge building foundation for further exploration and experimentation. It took valuable resources, time and experience to develop new products that require capabilities unknown to prior activities. Therefore, firms need to set a goal and the development path correspondingly. Uncertain results may push them to search for the strategic direction that they are most familiar with, in the reach of their core competences.

Revealed Technological Advantage and technology profiles indicated four types of technological competences of the firms and those related to metabolic syndrome patenting activities. The technological profiles revealed that there is high association between existing core technological competences and the direction of R&D especially at the early phase. Distinction in metabolic syndrome technological profile was reflected by firms with different core businesses whereas similarity was found in firms that rely on similar technologies on their core businesses. As the relationship between product-technology is not a one-to-one function, there is no strict pathway of the development even in the similar end product, and one technological knowledge doesn't necessarily lead to similar results. It is more likely that competence, rather than resource, is the main factor driving the decision on front end innovation. After firms have decided on the new product development path, they may discover more suitable path by trial-and-error. Learning process occurred together with broadening technological scope, and the direction of knowledge accumulation was not constant but dynamically shaped by experience.

Coping with the emerging opportunity exerted by functional food industry, food firms may have localized search for the most reachable solution, for example firstly relying on their existing core competences. As shown in the technological competence profiles (Table 2, Table 3), metabolic syndrome functional food related activities at the beginning are mostly related to the technological fields firms usually utilize in their core products i.e. biotechnology in the case of Yakult, Suntory and Ajinomoto. While larger firms may have built up competences in a wider range afterwards, smaller firms with limited resources may prefer to focus on their core domain.

While resources are limited, the strategic flexibility of resources management can lead to new product strategy [23]. From these empirical results, the extent of learning was shown to go beyond the purpose of certain product development and firms attempted to apply new knowledge on their core

business. Flexibility allows firms to utilize acquired knowledge efficiently and implement it on other resources to form new kind of competences.

B. Limitations and Future work

Technological profile was adapted from the work of Patel and Pavitt that studied competences of several firms in several industries, while this paper worked with only a few firms in food industry. The size and homogeneity of data made the core competences between firms identical regardless of detailed differences. So this method may not clearly identify core competences considering the 'uniqueness' feature. We attempted to reduce this gap by increasing the threshold for core competence and make a qualitative analysis rather than focusing on a quantitative analysis. A finer result could be obtained if the IPC-technological concordance is customized to match the technological themes in the food industry.

Core technological competences could be important, but not the sole factor on the success of product development. The concept of knowledge accumulation is also broader than R&D activities. Other important factors affecting the success and rate of commercialization including organizational flexibility and sourcing strategy should be explored further.

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