

氏 名	中 野 光 敏
学位 (専攻分野の名称)	博 士 (生物産業学)
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論 文 審 査 委 員	主査 教 授・農 学 博 士 佐 藤 広 頭 教 授・博士 (農芸化学) 渡 部 俊 弘 教 授・博士 (生物産業学) 相 根 義 昌 教 授・農 学 博 士 高 野 克 己 博士 (農業経済学) 後 藤 一 寿*

論文内容の要旨

Recently, because of the development of information technology, various data related to dairy life and business, consisting of online search records or measurement data using sensors, have been accumulated in some available databases. Judgments and decision-making utilizing these data are carried out in many fields, such as medical care, education, and sports. In the field of business, a "data-driven approach" is garnering attention to solve problems in product development and marketing by analyzing the complex diversified consumer demands, based on a wide variety of data. However, at the site of sixth sector industrialization with the goal of regional activation, "product-driven performance" exists, which depends only on the products that can be manufactured by the business operator because company size and products that can be produced are limited. These problems may be mismatched with customers' demands and prevent product differentiation. In this thesis, the author discussed the fish sauce industry as an example of such a case.

Fish sauce is usually obtained by mixing fish materials with salt, which is subsequently fermented in a natural environment. Recent investigation indicates that interest in fish sauce produced in Japan has gradually declined among the Japanese people. Despite the waning consumer demand, however, the production of fish sauce has gained attention, and many local fish sauce products are being produced to revitalize local communities that have the advantage of an abundant supply of inedible fish material at low-market value that can be used in production. This situation indicates a large gap between consumer demand and supply.

In this study, the author introduced the "data-driven approach" to fish sauce market analysis, and discussed market potential for fish sauce in Japan. First, data related to fish sauce consumption were collected from web sites, including Google searches and Cookpad, to analyze consumer behavior. Next, the author analyzed the "smell," "taste," and "color" of 46 types of commercial fish sauces

*食品産業技術総合研究機構 上級研究員

manufactured in Asian countries by electronic panel (e-panel) analyses containing electronic tongue (e-tongue), nose (e-nose), and eye (e-eye) sensory assessments. Along with the e-panel analysis, the chemical properties of these fish sauces were analyzed to characterize the fish sauce in each country. However, from the results of mining online activity data, it became clear that the demand for Japanese fish sauce as a seasoning for *nabe* cuisine was increasing only in winter. Furthermore, it was suggested that the popularity of *shirako* seafood is rising as an ingredient of *nabe* cuisine. Based on these results, the author made a prototype fish sauce containing *shirako* and analyzed its smell, taste, and color by e-panel analysis.

1. Analysis of consumption trends of fish sauce by online data analysis

Internet search engines and online recipe repositories have become increasingly popular resources among households for recipes and meal planning. Meanwhile, the distinct flavor of fish sauce makes it a popular condiment in Southeast Asian countries. In Japan, although fish sauce is used as a condiment for traditional cuisine, it is not very popular for general household use. To understand the consumption behavior for fish sauce in Japanese households, we analyzed search trends for the words *nampla* (Thai fish sauce), *nuoc-mam* (Vietnamese fish sauce), and *shottsuru* (Japanese fish sauce) on the Google search engine and the Japanese online recipe site Cookpad. The results clearly indicated the rising popularity of *nampla* owing to the rapid spread of Thai cuisine, and increasing traditional annual consumption of Japanese fish sauce. These results provided insights into household demand for fish sauce.

2. Characterization of taste of Asian fish sauces by electronic tongue

Tastes of commercially available fish sauces from Japan, Thailand, Vietnam, the Philippines, and China were characterized by an e-tongue analysis. The results showed that Japanese fish sauce tended to have a strong sour and metallic taste and weak *umami* and sweetness compared with fish sauce from other countries. The values of sensor signal intensities were used in cluster analysis. As a result, Japanese and non-Japanese fish sauces were categorized into different clusters, indicating the distinct taste characteristics of these fish sauces. Meanwhile, it was revealed that Japanese fish sauces manufactured by traditional manufacturing methods were categorized into the same cluster as non-Japanese fish sauces. Thus, traditional Japanese products possessed similar taste characteristics as non-Japanese fish sauces.

3. Characterization of smell of Asian fish sauces by electronic nose

Olfaction characteristics of commercially available fish sauces were analyzed by an e-nose

analysis. Of 18 sensors, 13 sensors showed stronger signal intensities for Japanese fish sauces, whereas five sensors exhibited stronger intensities for the non-Japanese products. All the sensor data were used in a cluster analysis. The cluster analysis clearly distinguished the Japanese and non-Japanese products, although the Japanese ones with a traditional manufacturing method belonged to the same cluster as non-Japanese products. Broadly, the cluster indicated that the Japanese fish sauce had similar olfactory characteristics as soy sauce and Japanese fish sauce products tended to have suppressed the smell unique to fish sauce.

4. Characterization of color of Asian fish sauces by electronic eye

Colors of commercially available fish sauces in Asian countries were characterized by e-eye analysis. The colors of the fish sauces were characterized as yellowish to brownish. All the Thai fish sauces had yellowish colors; fish sauces from other countries, including Japan, had a wide variety of colors, ranging from yellowish to brownish. All the sensor data were used in a cluster analysis. Cluster analysis indicated that the color of the product was not influenced by the country, rather, by the raw material.

5. Characterization of chemical properties of Asian fish sauces

Chemical properties of commercially available fish sauces in Asian countries were analyzed based on the dried solid content, salinity, pH, acidity, and nitrogen content. As a result, the fish sauce from Thailand tended to have a higher dried-solid content, indicating the possibility that a relatively large amount of taste components was contained in the products. On the other hand, there were many low-salt-concentration products in Japanese fish sauces, and this was related to the tendency for the preference for products with reduced salt. In Vietnamese fish sauce, the total protein amount tended to be large, which could be caused by differences in production methods.

6. Introduction of a data-driven approach for salmon fish sauce production

The goal of this study was to give new value to salmon fish sauce based on data-mining for the internet activity of consumers and electronic sensor analyses of the products. Mining Google search activity indicated that Japanese consumers associated fish sauce produced in Japan with a limited type of dishes, namely *nabe* cuisine. It also suggested an increasing popularity of *shirako* as an ingredient in *nabe* cuisine. Based on these findings, we attempted to produce salmon fish sauce by supplementing the fermentation materials with *shirako*, as well as by using salmon of low-market value. The products were evaluated with a combination of electronic nose, tongue, and eye analyses. The results indicated that the fish sauce products made from low-market quality salmon compared

favorably with those made with high-quality salmon, and supplementing the fermentation materials with *shirako* did not significantly affect the flavor, taste, or appearance of the products. Consequently, supplementation of *shirako* in the fish sauce products would allow for improvement of the brand image to raise the commercial value, without decreasing the taste, smell, or color quality of the products.

In this study, the authors clearly showed trends of producers and consumers in the fish sauce industry by introducing a data-driven approach to market analysis of fish sauce, which had not been analyzed academically until now. Olfactory characteristic analysis indicated that the original Japanese fish sauce had a relatively similar flavor to that of Thai fish sauce; however, in recent years, many Japanese manufacturers are using a strategy that suppresses the smell peculiar to fish sauce. This is thought to be based on the view that the unique flavor of fish sauce is avoided for home use. However, it has revealed that the rapid spread of Thai cuisine since 2011 accelerated the popularization of Thai fish sauce into Japanese families. This was an important finding for developing a new strategy for the fish sauce market, such as developing Thai-style dishes utilizing Japanese fish sauce. Consequently, the data-driven approach used in this study can be widely applied to the development and marketing of products using other foods and agricultural crops.

審査報告概要

本論文は、食品産業分野に「データドリブンアプローチ」を導入することを提案し、検証したものである。本研究では、ケーススタディーとして魚醤に着目し、インターネット検索データやオンラインレシピデータを活用した「消費者動向解析」と、味・香り・色彩センサー解析と成分分析による「科学的解析」を組み合わせることで、魚醤がどのように利用されているのかを明らかにした。すなわち、日本では、タイ産魚醤ナンプラーの利用が増加していること、日本産魚醤は冬季の利用が増加していることを明らかにした。また、日本産魚醤でもナンプラーと同様の風味を持つものがあることを明らかにし、日本産魚醤の新たな市場開拓の可能性を示した。さらに、「消費者動向解析」と「科学的解析」を併用することで、付加価値を効果的に向上させた魚醤を試作した。本研究で用いたデータドリブンアプローチは、魚醤だけではなく、他の食品産業に広く応用が可能であり、今後、これらの手法の活用が期待される。よって、本研究は生物産業学において有用な知見であり、審査員一同は博士（生物産業学）の学位を授与する価値があると判断した。