TECHNOLOGIES TO WATCH IN 2024 (4)

INGREDIENT INFORMATICS: THE FUTURE OF FOOD DEVELOPMENT
— R&D INNOVATIONS CO-CREATED BY AI —

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ABOUT INGREDIENT INFORMATICS

(1) AI-based food development

Ingredient informatics is a technology that uses AI to optimize various research and development processes for food products. By utilizing machine learning and analyzing the correlation between food ingredient functionality data, physical property data, final product quality data, and consumer purchase data, ingredient informatics can easily predict and propose the ideal combinations of ingredients to shape the food products and dishes that consumers seek. Specifically, the technology can be used to devise new concepts based on the latest consumer trends, improve quality (taste, texture, nutritional value, health functions, etc.), and refine existing products with alternative ingredients (reduction of fat, salt, sugar content, etc.). It can also be applied to the process to search for food ingredients with specific functions. Proprietary algorithms are built and services are provided based on an integrated dataset of external public data (ingredient databases, academic papers, recipes, social networking sites, etc.) or internal data held by companies (consumer purchase data, sensory evaluation data, Omics analysis data).[1]

(2) Background to the need for this technology

In recent years, the value of food products consumers seek has expanded beyond simple nutrition and flavor to include health functions, sustainability and naturalness, and consideration for animal welfare. In addition, consumer trends have been changing faster and faster recently, and companies in the industry are under pressure to respond. However, conventional product development is conducted in a personal and inefficient manner, relying on the intuition and experience of skilled developers, or a large staff. That is the reason why it is difficult to respond quickly and accurately to consumer trends. Furthermore, consumers are extremely sensitive to food prices, and it is not easy to pass on the burden of labor, R&D, and raw material costs. Against this backdrop, there is new demand for the construction of product development processes that produce maximum output while reducing necessary expenses. In this regard, ingredient informatics is attracting attention for its enabling capabilities, along with the recent rapid development of AI.

(3) Investment and technological development trends

According to Lux Research data, investment in this area has increased over the last five years, with annual investment reaching $170 million in 2022 (Figure 1, left).[2] The majority of this is venture capital investment in startups, and the actual amount is expected to be even higher when including joint ventures by multiple firms and investment in R&D within companies. The number of submitted research papers has also remained high in

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[1] Lux Research - Ingredient Informatics (11.09.2023 separately provided data)
[2] Ingredient Informatics :: Lux Research (luxresearchinc.com)

recent years (Figure 1, right), indicating that technological development in this field is becoming more active.

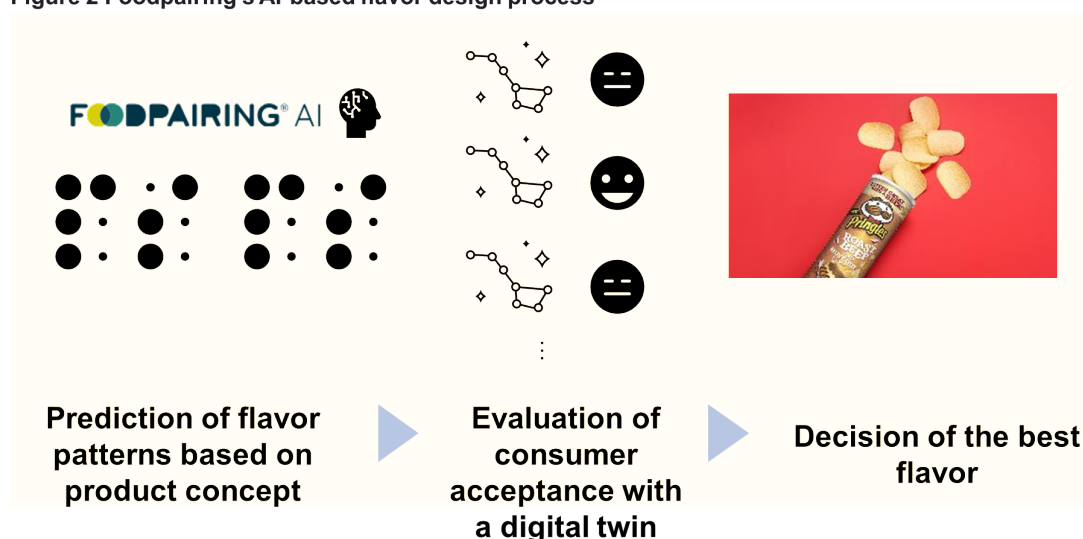## Figure 1 Investment and number of papers submitted in the field of ingredient
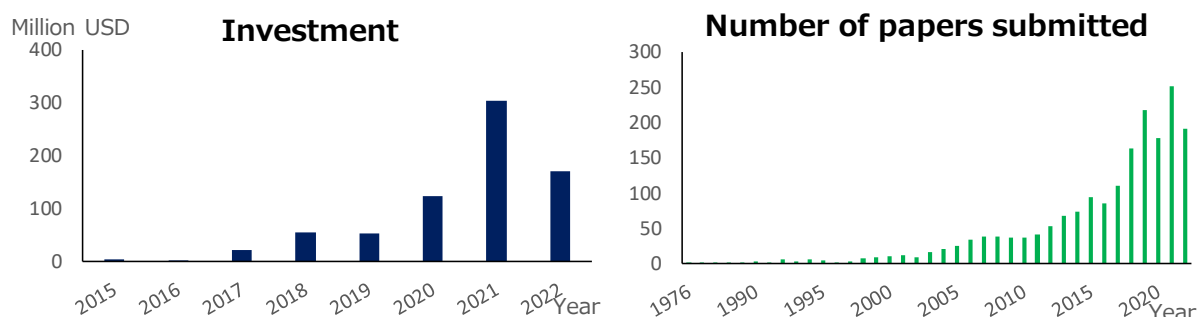
Source: Prepared by Mitsui & Co. Global Strategic Studies Institute based on Lux Research Inc. and PubMed data

PROMISING FIELDS OF APPLICATION

(1) Flavor design that realizes flavors preferred by consumers

The taste of the processed foods and beverages that we habitually eat is designed by combining multiple flavors. Traditionally, developers called "flavorists" use their senses to select ten to a hundred flavors from among thousands and formulate them to shape the taste of the target product.[3] Foodpairing (Belgium) has developed an algorithm based on flavor data and consumers' sensory evaluation of products. The company has rolled out a service to predict and propose the ideal combination of flavors and aroma components for the product concept that the client wants to realize. The millions of predicted patterns are then tested on a digital twin of the target consumer to determine the most favored patterns (Figure 2). This service makes it possible for developers with little experience or know-how to easily develop products that meet consumer needs, thereby reducing the time it takes to train employees to become experienced flavorists,[4] and lowering product costs (Foodpairing claims

Figure 2 Foodpairing's AI-based flavor design process

Prediction of flavor patterns based on product concept ▶ **Evaluation of consumer acceptance with a digital twin** ▶ **Decision of the best flavor**

Source: Prepared by Mitsui & Co. Global Strategic Studies Institute
(Logo and photo: https://www.foodpairing.com/industry/case/pringles/ (accessed November 13, 2023))

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[3] "Chemistry of Fragrance," *Chemistry and Education* [in Japanese] Vol. 51, No. 2 (2003)
[4] Development of New Food Flavors and Fragrances Through Integration of Analytical, Synthesis and Flavoring Technologies [in Japanese] (T. HASEGAWA CO., LTD.)

to be able to reduce product costs by up to 20% and time to market by 28%). Using this service, Kellogg's (US) has developed and launched a roast beef and mustard-flavored potato chip targeting beer lovers.[5]

(2) Development of dishes reflecting the latest consumer trends in real time

Food manufacturers and foodservice companies have to spend a great deal of time and money on in-house research, sales data analysis, and food and beverage consultants in order to understand consumer trends. However, with consumer trends changing at a tremendously rapid pace, it is extremely difficult to provide the food products and dishes that are demanded by consumers in a timely and accurate manner with limited resources. Tastewise (Israel) provides a service that suggests recipes, marketing strategies, and the like by predicting which foods and dishes are currently in demand by consumers. This is achieved by collecting publicly available data on dishes, ingredients, and consumer preferences and trends from multiple sources, including restaurant websites, social networking sites, food delivery platforms, and recipe sites (Figure 3).[6, 7] This service reduces development time and costs, while enabling timely product development that is in line with consumer feedback. Several major companies such as Nestle (Switzerland) and PepsiCo (US) have already introduced Tastewise's services into their product development process.

Figure 3 Tastewise's AI-based trend forecasting and food/dish proposals

Source: Prepared by Mitsui & Co. Global Strategic Studies Institute
(Logo and site images: https://tastewise.io/home and https://tastewise.io/pro/USA/insights/dashboard/top-trends (accessed November 13, 2023))

(3) Imitation of realistic tastes for plant-based substitute foods

The plant-based alternative food market is expanding as the number of vegans and flexitarians increases. However, many challenges exist as it is difficult to completely imitate conventional animal products using only plant-based ingredients, especially in terms of texture, nutritional value, and cost. Climax Foods (US) has developed a platform that uses AI machine learning to predict the food functions of edible plants based on protein structure data contained in 300,000 species. This platform enables the identification of plant-based, high-performance proteins that give an amino acid balance and sensory characteristics to plant-based foods that are equal to or better than those of animal products. Currently, Climax Foods has entered into a partnership

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[5] Foodpairing :: Company Profile :: Lux Research (luxresearchinc.com)
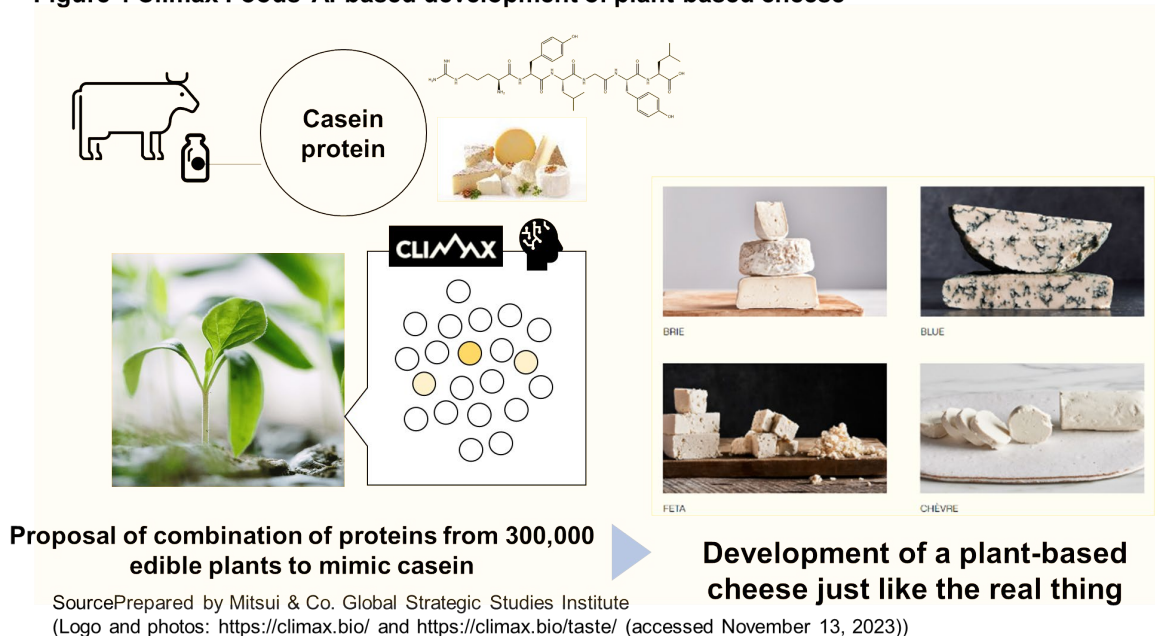[6] "Market Intelligence Platform Tastewise Uses AI to Turn Diverse Data into Real-Time Insights" [in Japanese] (AT PARTNERS)
[7] Tastewise General One Pager

with Bel (France), a major dairy products company, to search for a plant-based protein that mimics the function of casein, which has been considered difficult to mimic, and develop vegan cheese containing this protein (Figure 4).[8]

Figure 4 Climax Foods' AI-based development of plant-based cheese

Proposal of combination of proteins from 300,000 edible plants to mimic casein

Development of a plant-based cheese just like the real thing

SourcePrepared by Mitsui & Co. Global Strategic Studies Institute
(Logo and photos: https://climax.bio/ and https://climax.bio/taste/ (accessed November 13, 2023))

(4) Efficient and comprehensive screening for functional food ingredients

In exploratory research for functional food ingredients, a long period of time ranging from several to ten years is spent in determining and evaluating experimental conditions to evaluate specific functions, identifying active ingredients in plant extracts, experiments on animals, safety tests, etc. However, the chance that the efficacy is finally demonstrated in humans and the product goes to market is extremely low. Brightseed (US) has developed a platform that predicts and suggests ingredients with 15 kinds of health function (metabolic improvement,

Figure 5 Brightseed's AI-based search process for functional ingredients
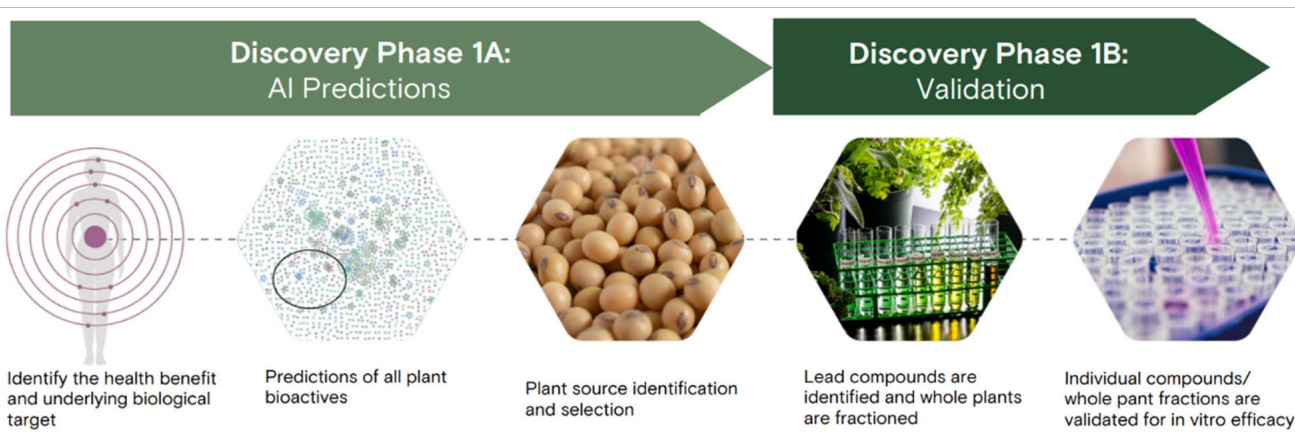
Source: Pharmavite case study (Brightseed)
https://downloads.ctfassets.net/oz7i9nkwgj2z/4e0q5r6cVX56z4dXGqk2tt/a99cf39f529146fdf07115409917090d/Pharmative_Case_Study_2023_-_Nature_Made.pdf (accessed 13 November 2023)

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[8] Climax Foods :: Company Snapshot :: Lux Research (luxresearchinc.com)

immune enhancement, cognitive function enhancement, etc.) based on structural data of about two million ingredients derived from edible plants (Figure 5). Using this platform, the company aims to easily find more economical and effective functional ingredients (the company claims to be able to increase the speed of research and development by ten times, and time to market by 50%).[9] Pharmavite (US), known for its Nature Made supplement brand, aims to launch plant-derived products that can improve sleep and reduce stress through a partnership with Brightseed, which has successfully selected more than ten candidate ingredients for each.[10]

(5) Search for growth media and growth factors that contribute to commercial production of cultivated meat

One of the biggest challenges to the commercialization of cultivated meat is the high cost of production, and the majority of the cost is supposedly attributable to the growth medium and growth factors used to culture, grow, and differentiate cells. In particular, expensive bovine serum has been conventionally used as a growth factor, which means that there is a need to develop plant-based and inexpensive alternatives. Multus Biotechnology (UK) develops and supplies customized serum-free media and plant-based growth factors to cultivated meat development companies by utilizing AI in the composition of growth media that differ for each cell strain and the process of searching and identifying growth factors. The company aims to contribute to the commercialization of cultivated meat by providing low-cost, high-performance growth media and growth factors using its proprietary platform.[11]

FUTURE PROSPECTS

In the food industry, the further spread and evolution of ingredient informatics is expected in the next five to ten years through the use of the above services, company acquisitions, and collaborations. Specifically, the timely prediction of the precise combination of ingredients that meets consumer needs and preferences will become possible, enabling the rapid development of food products that are in demand by consumers at that time. Ingredient informatics will also enable the development of supplements with more economical and ground-breaking functions. It furthermore has the potential to bring innovative approaches to the challenges faced by the plant-based food, cultivated meat, and other new food industries.

On the other hand, while AI is excellent at making forecasts based on past data, it currently faces difficulties in detecting things yet to exist, innovations created by the fusion of different fields, and latent consumer needs. We look forward to a future in which food R&D personnel effectively utilize the margin created by collaboration with AI to focus on cross-disciplinary communication and innovative research activities, resulting in the birth of new, groundbreaking products.

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[9] Brightseed :: Company Profile :: Lux Research (luxresearchinc.com)
[10] Pharmavite Case Study (Brightseed)
[11] Multus Media :: Company Snapshot :: Lux Research (luxresearchinc.com)

TECHNOLOGIES TO WATCH IN 2024 — INTELLECTUAL PROPERTY REPORT —

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This paper examines, analyzes, and reports on international trends in patent applications related to ingredient informatics, which were featured in Technologies to Watch in 2024. This investigation and analysis were conducted using PatSnap Analytics, a global patent search and analysis tool, and PatSnap Discovery, a search tool for various kinds of technical information, provided by PatSnap. All data was obtained on December 1, 2023.

INGREDIENT INFORMATICS

Figure : Trend in the Number of Patent Applications Related to Ingredient Informatics
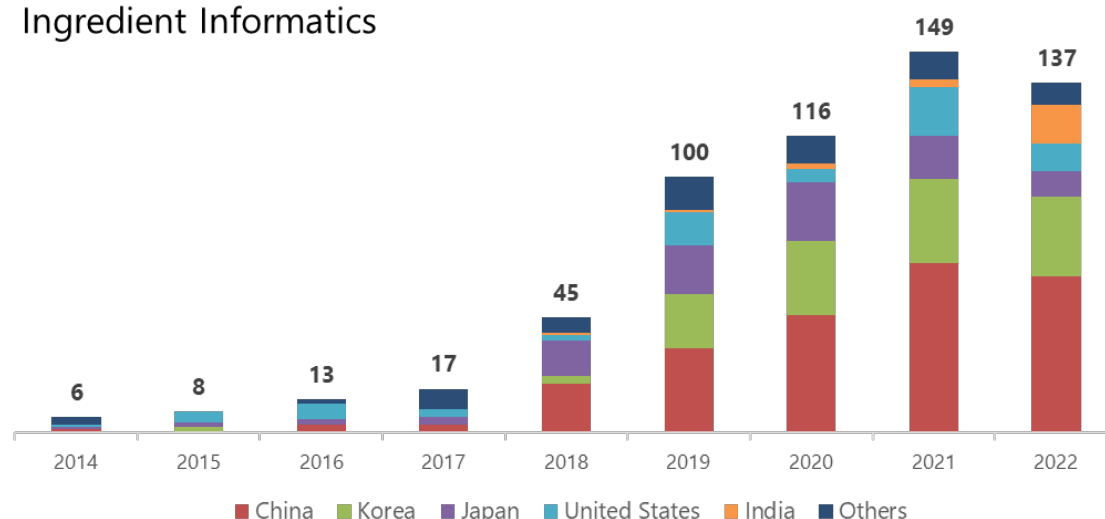
Source: Prepared by Mitsui & Co. Global Strategic Studies Institute based on PatSnap Analytics data

ANNUAL TRENDS IN PATENT APPLICATIONS

There has been a remarkable growth in the number of patent applications related to ingredient informatics since 2017, with a compound annual growth rate (CAGR) of 52%. Note that although the graph shows a decrease in the number of patent applications in 2022, it is necessary to take into account the time lag between when a patent application is filed and when it is published. Based on data, the final number of patent applications in 2022 is projected to be approximately 226.

The CAGR for each country is 83% for China, 79% for Korea, 97% for India, 27% for Japan, and 30% for the US. In particular, China, Korea, and India have shown very high growth rates, reflecting the rapid development in this sector. On the other hand, while slower than these countries, Japan and the US still show high growth rates of about 30% for these emerging technologies and fast-growing markets.

TECHNICAL FOCUS

The data on patent applications for 2014 and beyond were analyzed for technical focus.

The analysis of patent applications related to ingredient informatics can be divided into four major categories.

1. Food development and manufacturing methods: Inventions related to the development of new food products or the improvement of manufacturing processes for existing products. Include new ingredient combinations, innovations in manufacturing technologies, and sustainable production methods.

2. Food safety and quality control: Inventions related to techniques and systems to ensure food safety and control quality. Include systems to detect food freshness and technologies to identify falsification and contamination.

3. Technology and data utilization: Inventions that increase efficiency and improve the consumer experience in the food industry using IoT devices, big data analytics, AI algorithms, etc. Include inventory management, demand forecasting, analysis of consumer behavior. etc.

4. Market trend and consumer behavior analysis: Inventions that analyze market trends and consumer behavior for use in product strategy and marketing. Include systems for predicting consumer preferences and purchasing trends, and data analysis tools for market research.

REPRESENTATIVE PATENT APPLICANTS

1. Shiru (US): Development of proteins suitable for food production at high throughput.

2. CirclesX (US): Recommendation of foods optimized for individual nutritional needs through analysis of biomarker data.

3. Anhui Academy of Agricultural Sciences (China): Analysis of wheat varieties based on reinforcement learning to select wheat with appropriate gluten content.