Strategic Innovation Promotion Program（SIP）
“Technologies for Smart Bioindustry and Agriculture”
Research and Development Plan

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Director General for Science, Technology Innovation Policy

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Overview of the Research and Development Plan

1. Significance and Goals

(1) Significance

To expand our bioeconomy[1] and increase the competitiveness of bio-related industries in Japan, the "Technologies for Smart Bioindustry and Agriculture"(hereinafter referred to as "the SIP") will contribute to realizing the four social visions proposed as action plans in the "Biostrategies 2019 and 2020" policy package: ① a recycling-based society wherein all related industries are working together; ② a society wherein sustainable primary production is linked with diversifying needs; ③ a society wherein raw materials and materials are bioprocessed through sustainable manufacturing methods; and ④ a society wherein medical care and healthcare are connected to prolong the people's participation in society.

Specifically, for the sustainability of global environmental resources, using the theme of "food" sustainability, we will construct a platform to apply/utilize data and information on "food"-related research and development. These data and information are required to comprehensively achieve: ① sustainability in agriculture; ② sustainability of ingredients and foods; and ③ sustainability of "food"-related resources and environment. In addition, we will practically utilize and expand the respective research and development results that constitute the system of and promote the economy of "food"-circulation. Based on these approaches, we will construct a "smart food system" model to contribute to the sustainability of global environmental resources; additionally, we shall ensure that the developed system can autonomously keep expanding even after the SIP's completion.

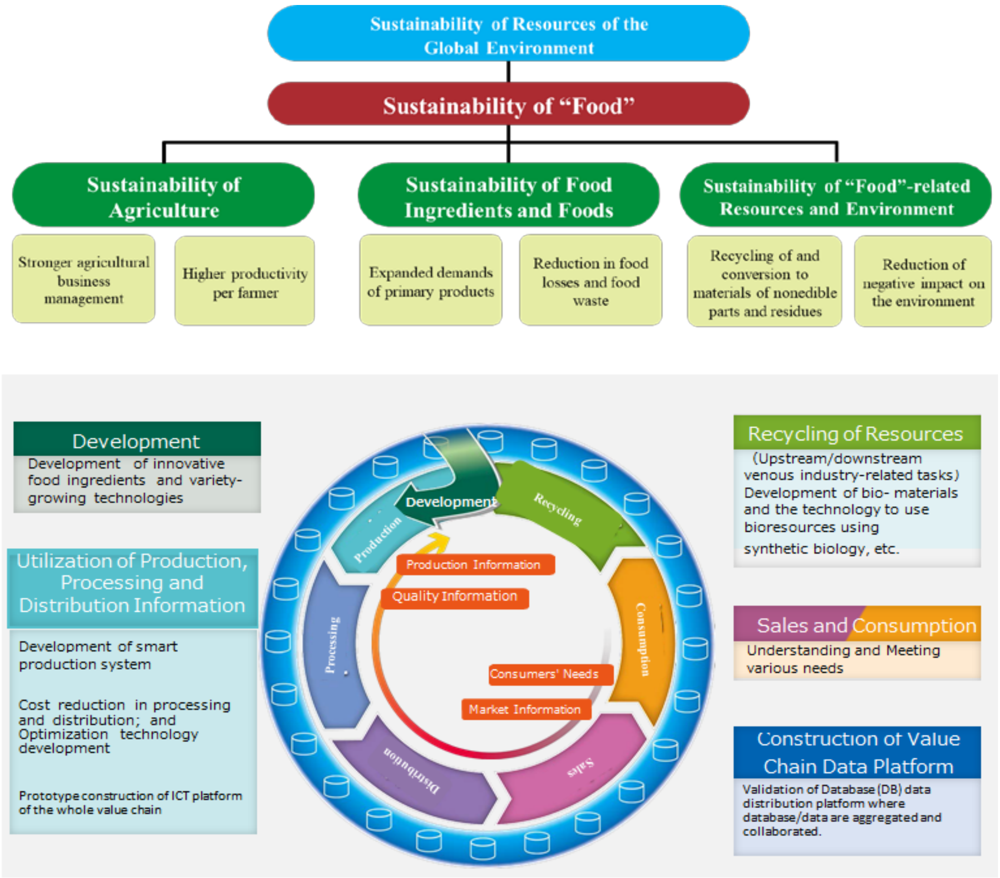

Fig. 1 Overview of "Core Technologies for Smart Bioindustry and Agriculture" in SIP

[1] Herein, "bioeconomy" refers to the group of markets and industries that use biotechnology and/or biomass. The Organisation for Economic Co-operation and Development (OECD) predicts that the bioeconomy of OECD countries will grow to $1.6T (GDP) by 2030, wherein the bioindustry would account for 39% and agriculture would account for 36% of the GDP (OECD Report "Bioeconomy to 2030")

(2) Output goals upon SIP completion

We will collect and utilize/apply the information obtained at each stage—“Development,” “Production,” “Process,” “Distribution,” and “Consumption”—and work on seeds–needs matchings. Through this approach, we will aim to achieve ① more efficient actual agricultural sites and more competent agricultural management; ② reduction in food loss and food waste; ③ development of high-added-value food ingredients and foods; and ④ optimization of the food chain, including development of the primary industry via export in terms of sustainability. Additionally, we will present a model case for the developed “smart food system,” which involves biodigital fusion to achieve “food” sustainability. The “smart food system” developed herein includes the recycling and circulation of the end forms in the food chain, i.e., food waste after consumption and unused portions of agricultural products. Furthermore, we will incorporate the platform for distributing “food”-related information together with the research results of the constituent themes in our society. The platform referred to herein is rarely found anywhere worldwide and it can contribute to the sustainability of the global environmental resources.

Using the abovementioned approaches, we will attempt to contribute to the maintenance and development of the food industry in Japan. For example, we will attempt to acquire new markets (over ¥240B) by expanding the bioeconomy of our country and developing smart agricultural technology and systems both inside and outside the country. We will also attempt to expand the export of primary products and processed foods, develop the technology for quality maintenance, and convert nonedible portions of food ingredients to resources.

(3) Outcome Goals (Social and economic ripple effects (e.g., large market-scales))

① Social ripple effects

Because of the COVID-19 chaos, going forward, we must consider coexisting with infectious disease(s). In the meantime, strengthening the agricultural platform to maintain the “food” environment in our country regardless of unsteady or stagnated flows of people and goods due to the disease(s) is critical.

Objectives of the SIP include improving the environment to utilize/apply data and information on primary products’ supply chains and developing the technologies for the respective tasks. In addition, through the SIP, we aim to reinforce the agricultural management platform and stabilize businesses, such as improvement in the productivity per farmer and actualization of market-interactive agricultural management. Simultaneously, we will attempt to build the abovementioned platform such that it supports people who are novices to agriculture and provides agricultural workers with or enables them to participate in both existing and new various services that support agricultural production technologies and management. By building such a platform, we expect to increase the number of agricultural workers and thereby maintain and improve the production of primary products.

In addition, we will improve the added values of agricultural products, develop environmentally sustainable agricultural technologies, and propose a circular economy model, in which nonedible parts of agricultural products and food residues are converted to resources. Through these approaches, we aim to contribute to realizing the Sustainable Development Goals (SDGs), such as the stable food supply to the world, a sustainable economy/society, and extended health and lives of the people (i.e., controlling increasing medical costs).

② Economic ripple effects such as market expansion

The present SIP is intended to function as the common platform to realize the “Society5.0” version in the agricultural and food fields, which constitutes about 10% of the GDP of our country. Through this SIP, we expect to (i) promote the digitalization of the overall agricultural sector including administrative procedures before other sectors achieve it; (ii) expand and activate the whole market of agriculture and food industry together with smart agriculture; and (iii) develop new services with unique concepts that cannot be found in the conventional agriculture and food industry, such as the first data-transaction markets and/or information banks in our country.

For overseas expansion, we believe we can make packages of the respective research results to expand to Monsoon Asia, a rice-producing region similar to Japan. Therefore, by developing technologies for the respective tasks involved in the smart food system, such as automation and intelligent technologies of agricultural works, we could contribute to achieving one of the Government’s goals, i.e., the acquisition of the smart agriculture market, which is worth over ¥100B.

In addition, one of the subjects in the empirical research of use cases is the expansion of agricultural export. With the export of Japanese food ingredients and overseas food processing for processed foods with Japanese quality, we can accelerate the overseas expansion of Japanese foods. Furthermore, by collecting overseas food/diet preference information, we can expect acceleration in the development of overseas-preferred seeds/seedlings and foods.

Many of the present technical goals of the country include high social and economic ripple effects. With these goals, we can expect to contribute to achieving the targeted numbers—30% reduction in working hours and 10% reduction in food loss—which are the Government's export goals for agricultural and marine products as well as food (increasing to ¥2T by 2025 and subsequently reaching ¥5T in 2030).

【Goals in Demonstration Cases (Prototype Validation)】

① Implementation of the whole smart food system

We will construct a model of the data and information distribution platform, wherein national research institutes, universities, and nongovernment bodies can easily collect, utilize, and apply food-related "data" and "information" for their own purposes; this model would promote the creation of new businesses that support such collection, utilization, and application of the food "data" and "information."

Specifically, by 2025, we will develop an environment in which primary bearers of agriculture can practice the "agriculture linked with the market by utilizing or applying data and information."

② Implementation based on each smart food system's component theme

- Reduction of working hours at the production site, using technologies to manage the work regardless of the decreased number of farmers and aging population: 30% reduction in the use case
- Reduction in food loss and food waste via precision shipping and supply–demand matching between the production sites and demands in the market: 10% reduction in the use case
- Shipping cost for agricultural and processed foods in the exports of particular produce: 10% reduction in the use case
- Use of nonedible parts for biomass: five or more cases in material development and the development of two or more types of containers/packaging materials
- Expansion of functional foods from agricultural products, which have evidence(s) that would help the development of the healthcare industry and the development of processed foods: five or more types of new material development and trial sales at 900 convenience stores

2. Research Projects

(1) Implementation of the whole smart food system

For bio-related databases (DBs) that have been accumulated on the basis of past biostrategies and are currently dispersed, we will proceed with API development for antecedent data collaboration and develop an application to comprehensively analyze the integrated DB group comprising a plurality of DBs, thereby developing the base environment that facilitates artificial intelligence (AI) analysis. Moreover, for developing new fields that will be our country's strength, we will effectively acquire data from the integrated DB group and develop the base environment to facilitate data processing for AI analysis, etc.

For the integrated DB group to establish the base environment, we will introduce an open–close system to stratify them to the data accessible to the general public and the data accessible to user forums. While accelerating the efforts for such bio-DB integration, we will promote the development and construction of biodigital fusion hubs by promoting their utilization and application.

While promoting the distribution and utilization or application of data and information, we will investigate the needs of the intended users and incorporate functions in plural frameworks that will "clear the house for information" on the basis of the considered purpose.

Furthermore, we will have the services and projects that have been already started in any areas or by private sectors participate in the developed system to enhance their services and projects. Through this attempt, we can explore and work on data collection and technical tasks that are necessary to further enrich our projects and expand the user base. Simultaneously, we will develop rules and work on the existing regulations to achieve collaboration between various related sectors and/or projects.

(2) Implementation using the individual smart food system structural theme

① Development of technology that contributes to agricultural sustainability

i. Development of breeding technology that enables the rapid and accurate production of necessary produce, such as varieties that can fulfill market needs and/or are tolerant against climate changes.

Currently in "breeding" technology, we depend on the tacit knowledge of breeders for making important choices at each stage of the breeding process. Therefore, we will make the breeding process sharable as explicit knowledge and ensure that it is data-analyzable to create models. Through this approach, we would achieve rapid and efficient breeding in a "data-driven" manner. Collaborating with breeding sites, we will run trials on and verify "data-driven breeding" and build a practical and versatile platform.

In addition, for genome editing, we will work on ① the development of a precise genome-editing technique and a genome-editing enzyme-introducing technique; ② the development of new genome-editing enzymes; and ③ technical assessments performed by developing genome-edited produce, in which multiple traits are improved. Through this approach, we can develop methods to enable the introduction of useful trait(s) in a short duration as planned and validate them with several types of produce.

ii. Construction of the system for engineering the agro-environment, which enables us to realize the sustainable recycling society and develop farming methods using plant-microbe symbiosis

We will conduct the "field agri-omics" analysis of data related to plant-microbe symbiosis and soil to comprehensively acquire information. Then, combining the information with integrated informatics analysis, we will significantly develop the soil diagnostic evaluation and develop a prototype of an agro-environmental engineering system, which will be a new axis of evaluation.

iii. Development of a data-driven smart production system to provide primary products while enhancing production efficiency by employing a small number of people to fulfill the demands

In this implementation, we will utilize the platform collaborated with agricultural and big data, in which breeding information and other data used in numerous farmlands are accumulated. With such utilization, we will develop production techniques that can realize adjustable shipping according to the demands. In addition, we will develop technologies and systems to reflect on the production management work based on soil and environmental prediction data. Considering expansion to hilly and mountainous areas and East Asia, we will develop the system to operate robotic-based agricultural machines for driving on farm roads; this will provide robustness and develop automated work machines that can be used for various items and in diverse terrains.

② Development of technology that contributes to the sustainability of food ingredients and foods.

i. Development of information distribution core technology that can realize data collaboration from production through distribution and consumption to support reduction in food loss and food waste and "market-in (market-oriented)" agriculture

We will build a new smart food chain that covers everything from production to processing, distribution, sale, consumption, and export. We will secure quality reliability by maintaining consistent traceability from the beginning to the end. In this attempt, we will prevent tampering to create new values. In addition, we will achieve stable supply through proper stock and shipping management at the production stage and optimized networking of production sites. We will also optimize distribution based on production information and stabilize the supply–demand balance. In this manner, we will reduce food loss. Further, we will facilitate the exports by providing feedback on consumer preference inside and outside the country to the production side.

Herein, for actualization of the technologies required to develop the distribution process of primary products (e.g., shortening of lead time till supply), we will collaborate with the SIP "Smart Distribution Service."

ii. Development of food ingredients and foods with health evidences that meet the market's needs and result in value improvement

We will develop the health index for health conditions and mildly poor physical and mental conditions and the "grading system for mildly poor physical and mental conditions." In addition, we will acquire scientific evidence(s) of health maintaining and improving effects of agricultural, forestry and fishery, and food products; additionally, the index will develop intestinal microbiome data. Utilizing these evidence data, we will develop a DB for integrating the health information of agricultural, forestry and fishery, and food products and provide the structure that can be utilized by companies in product development. In this manner, we will implement our research results in society.

③ Development of technologies that contribute to the sustainability of “food”-related resources and environment

i. Development of next-generation core technology for the chemical industry utilizing unused agricultural and forestry and fishery resources

We will develop a consistent process to isolate and collect numerous useful components and/or high-quality biomaterials having added values from components of unused resources (particularly nonedible parts) of agricultural and forestry and fishery industries. Alternatively, we will develop a consistent process to convert inexpensive sugars that can be obtained through the aforementioned technique for functional chemicals or to obtain high addedvalue based on a biofunctional design. Using this technology as a use case, we will first develop and implement a supply value chain in a specific area, and then propose a business model with the aim of implementing the developed supply value chain in multiple areas.

ⅱ Development of production technology for new biomaterials and high-performance products based on biofunctional-designUsing organisms such as microorganisms and insects, which have high-design functions, we will work on the development and implementation of high-performance materials, such as high-performance polymers and high-performance proteins. In this approach, specifically focusing on the microbial production of bio-polybenzimidazole (PBI) and polyhydric phenol, we will actualize more efficient microbial production of the raw material monomers, apply them in ultra-high heat-resistant coating materials and electrolytes for secondary batteries, and conduct validation tests. In this process, we will develop an accelerating method for molecular design, functional design, and the production of innovative biomaterials and high-performance products. Narrowing down the scope of application to specific targets, such as aromatic high-performance materials derived from microorganisms and biodegradable materials that contribute to resource recycling, we will achieve early realization of the proposed technology in the society.

iii. Advancement of supply-chain-related technologies that support the recycling of nonedible parts and empirical research

As described above, through the technology of using nonedible parts, inexpensive sugars can be produced. To produce and realize the practical use of biomaterials and high-performance products made from such inexpensive sugars, one of the key processes is wastewater treatment. For total cost reduction, we will work on membrane separation technology, through which we can expect advancement in efficiency improvement in the terms of wastewater treatment and quality of the treated water. In this approach, we will advance the operation, by developing the DB of analysis and state observation of microbial flora in activated sludge to develop a reasonable operation method.

3. Implementation System

Noriaki Kobayashi, Program Director (hereinafter referred to as PD) shall be in charge of planning and promoting the Research and Development Plan.

The PD shall serve as a chairperson, and the Cabinet Office shall serve as the Bureau. The Promotion Committee including related government agencies and experts shall make comprehensive coordination or arrangements.

Using grants provided to the Bio-oriented Technology Research Advancement Institution (BRAIN) (hereinafter referred to as the “Management Corporation”), the Management Corporation shall engage in research and management in collaboration with the New Energy and Industrial Technology Development Organization (NEDO).

4. Intellectual Property Management

The Intellectual Property Committee shall be organized in the Management Corporation and work on proper intellectual property management to secure the incentives of inventors and professionals who work on promotion at the work sites, industrialization, and the increase in people’s interests.

5. Evaluation

Prior to each year-end evaluation by the governing board, peer reviews by external experts and self-inspection by agents of the research and the PD shall be conducted to make the system autonomically improvable.

6. Exit Strategy (Strategy for Desired Outcomes)

① Manpower, material, and monetary contributionsfrom participating companies

Companies participating in each consortium shall provide manpower, technology, knowledge, and funds for research and development.

② Linkage with other related tasks

Research and development related to the “smart food system” shall be addressed by linking with SIP “Smart Distribution Service,” SIP “cyber space base technology using big data and AI,” and related tasks of Public/Private R&D Investment Strategic Expansion Program (PRISM).

③ Recipients of the obtained research results

The platform to utilize or apply data and information, which constitute the smart food system, is going to run itself as a public service by collaborating with the DB provided by the Database Center for Life Science (DBCLS), the National Bioscience Database Center (NBDC), and the Agriculture Data Collaboration Platforms (WAGRI), including the open data obtained from each task.

In addition, for those in which the research results of each constituting theme are incorporated in the market in the form of products and/or services, companies participating in the respective consortiums or business partners shall make them practicable. The platform-type research results that are widely used by the government and the private sector, such as the system that supports the food value chain, shall be made practicable by widely involving the companies participating in the respective consortiums and by incorporating new business ideas therein.

④ Technical transfer to private companies

For the research results to be practically used and/or implemented on products, we will be involved up to the stage of fabricating prototypes using SIP, and the recipient private companies shall work on rendering the prototypes in a practically usable form, including mass production. For the research results to be widely used by the government and private sectors, such as the system that supports the food value chain, SIP shall be involved up to the validation of the effectiveness in use case. Thereafter, they will be primarily operated, maintained, and managed by the companies participating in the consortium.

⑤ Training of human resources

For creating innovations through biodigital fusion, training human resources to have multidisciplinary skills and knowledge and to have a sense of business management is indispensable. In the research and development of each task, we will call young researchers for on-the-job training and collaborate with promotive plans for the recurrent education of manpower training for AI informatics, etc., to train human resources.

Research and development Plan

1. Significance and Goals

(1) Backgrounds/Situations inside and outside the country

With advancing technological innovation such as Internet of Things (IoT), AI, robotics, and genome editing technology, we can attempt to create new markets of bio-industries and improve productivity in agricultural and forestry and fishery industries together with the food industry, using various as well as a vast volume of big data. In this scenario, to expand our bioeconomy and increase the competitiveness of related industries of our country, we will establish the platform of innovation through biodigital fusion and attempt actualization of “food”-based health improvement in the society along with the promotion and creation of innovative biomaterials and product industries. In addition, for agriculture producing “food,” we will build the smart food chain to mutually utilize data from production to processing, distribution, sales, consumption, and export and to develop innovative smart agricultural technology and systems driven by various data. Using this approach, we will address the urgent task of realizing a sustainable growing society via craftsmanship that utilizes biofunctions; we will also realize and bioproductivity innovation and increase the competitiveness of agricultural, forestry and fishery, and food industries.

Considering domestic and overseas states, for bio-related fields, the Organization for Economic Co-operation and Development (OECD) predicts that the bio-economy of the OECD countries will expand to 1.6 trillion dollars by 2030, of which the industrial field will constitute 39% and the agricultural field will constitute 36%. The European Commission (EC) set their goals such as switching 30% of petroleum-derived products to biological substances by 2030. The United States of America (USA) also presented its vision of switching 36% of petroleum products to alternative products, producing biological products, and creating employment and potential market(s) by 2030. Our country formulated “Bio-strategy 2019” at the Council for Integrated Innovation Strategy. As the overall goal, we chose the realization of the world’s most advanced bioeconomic society by 2030and aim for the actualization of ① the bio-first concept; ② the development of biocommunities; and ③ biological data-driven processes.

Moreover, in the agricultural field, our country is facing issues such as decrease in and aging of the people engaging in agriculture-related work. Such insufficient work force in agriculture is negatively impacting the scaling-up of the production and the achievement of stable production. With advancement in the diversification of processors’ (product users’) needs and in the expectation or requirement of food, such as on-time availability, constant supply, and stable quality, there are challenges such as mismatching between supply and demand owing to poor collaboration from the production to the distribution of food and food waste and loss. For expanding the global food market, we have to meet market needs, mainly those of Asia; however, we are still in the middle of establishing a production–distribution–export system to meet market needs. In contrast, advanced countries, particularly USA and Europe, utilize the most advanced technologies such as IoT and sensor technology to develop precision farming[2] according to each country’s objectives and farming styles. With the acceleration in the development of the most advanced technology in precision farming, they are about to create a system for establishing a “information value chain” by automatically collecting various sensing data from production to consumption to accumulate big data.

Accordingly, to expand our country’s bioeconomy, improve productivity, increase the competitiveness of our agricultural, forestry and fishery, and food industries, and contribute to the realization of a sustainable recycling-baced society and achievement of the SDGs, we need to promote integrated project research at an increasing speed through collaboration between industry–academic–government sectors and government departments, ministries, and agencies to generate a tremendous synergy effect and build the platform for biotechnology and agricultural fields.

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[2] “Precision faming” is an agricultural management method. It is intended to comprehensively increase the amount of harvest, produce a higher quality of produce, and reduce the environmental impact via thorough observation and precise control of farmland and produce, which are complicated and varied.

(2) Significance and Political Importance

To expand our country's bioeconomy and increase the competitiveness of related companies, the SIP shall contribute to achieving the four social visions presented as action plans in the "Biostrategies 2019 and 2020" policy package: ① recycling-based society in which all industries can work together; ② a society with sustainable primary production to meet diversifying needs; ③ a society in which raw materials and materials are bio-engineered/bioprocessed using sustainable manufacturing method(s); ④ a society in which people can participate longer owing to the collaboration of medical care and healthcare.

Specifically, in terms of the sustainability of global environmental resources, considering the theme of food sustainability (sustainability of "food"), we will attempt to build a platform to utilize and apply data and information of "food"-related research and development, which will be required to comprehensively achieve ① sustainability in agriculture; ② sustainability in food ingredients and foods; and ③ sustainability in "food"-related resources and environment. In addition, we will practically use and expand individual research and development results that compose the system to promote the "food" circulation economy to autonomically expand the system even after completion of the SIP and construct a model case of the smart food system that can contribute to the sustainability of global environmental resources.

Further, as an individual theme constituting the system, we will work on data-driven breeding and the development of genome editing, which will become a worldwide trend in "food"-producing agriculture; the establishment of data-driven smart agriculture; the construction of the smart food chain; the realization of a "food"-based health-improving society; and research and development for practically using the technology to utilize bioresources, which would help in realizing a recycling-based society; and research and development for biomaterials and the practical use of high-performance foods. In addition, we will implement necessary system reforms and environmental development, as required.

Expanding the SIP result of the 1st term, "Agriculture Data Collaboration Platforms (WAGRI)" to the whole food value chain, we incorporate "production sites–market interaction" in a conventional model, which was mainly developed for "providers," who connect production, processing, and distribution. In addition, we will aim for the actualization of the "food"-based health-improving society and encourage and create innovative biomaterial product industries. For the objects, we will build a model case of the smart food system, in which processing post consumption and recycling will also be incorporated. In particular, mainly for agriculture, we will construct the smart food chain platform to mutually utilize data from production through processing, distribution, sales, consumption, and export; then, we will develop innovative smart agricultural technology and system, which are driven by various data; finally, we will develop technology to promote data-driven breeding. Through these endeavors, we will to realize a sustainable growing society, productivity revolution, and increased competitiveness of the agricultural, forestry and fishery, and food industries.

Decreasing birthrate and aging population are serious issues in our country compared with other countries. Therefore, in this regard, our urgent tasks comprise improving the people's quality of life (QOL) and controlling the increasing medical costs, including those for senior nursing care. In this research, we aim to contribute to reducing the risk of lifestyle-related diseases, facilitate the extension of healthy lives, and control increasing medical costs by encouraging and creating a food-based healthcare industry, which proposes and provides diet and meals (foods) suitable for an individual's health conditions and lifestyle.

Moreover, we will accumulate scientific evidence related to health maintenance and enhancement effects. Through this effort, we aim to improve the added values of Japanese foods and domestic agricultural, forestry and fishery, and food products, thereby contributing to the improvement of producers' income and expansion of exports.

With the SDGs and international agreements on countermeasures against global warming (Paris Agreement), the transition to the sustainable economy and society, in which we do not depend on petroleum-based products, is now an urgent task that must be globally addressed. In this research, we aim to achieve superior productivity in biofunction-based packaging and related materials over petroleum-based materials; the development of high-functioning products, which are difficult to synthesize, and thereby contribute to solving global issues. Specifically, in this research, we will work on production using nonedible parts generated in the food value chain, treat residues, and utilize unused resources from the agriculture and forestry and fishery industries.

In addition, we aim to contribute to the creation of new industry and employment in farming and mountainous areas by producing high-functioning products using local bioresources.

While the global food market is growing, our country's agricultural, forestry and fishery, and food industries are capable of producing various high-quality products. In addition, those industries are mostly expected to grow in the future. Despite of the decreasing labor force, we attempt to significantly save the required labor force and advance automation in respective works by sharing and utilizing data from production through processing, distribution, sales, and export and by implementing data-driven smart agriculture. Through this approach, we aim to achieve drastic improvements in the productivity of the agricultural and forestry and fishery industries, flexible (i.e., demand-based) production and distribution, and an increase in the competitiveness of the agricultural and forestry and fishery industries by enhancing the brand values of the domestic agricultural, forestry and fishery, and food products.

We will also develop environmentally less-impacting agricultural varieties, which are tolerant to climate change and expand the varieties both domestically and internationally. We will also work on reducing food loss in the whole food value chain through flexible production and distribution suitable for market needs. Through these approaches, we aim to contribute to the stable supply of foods in our country and worldwide.

(3) Goals and Targets

① Actualization of Society 5.0

- We will share and utilize data from production through processing, distribution, sale, and consumption beyond the framework of the industries. Through this approach, we will construct the smart food chain platform, which enables production and supply including the export of agricultural, forestry and fishery, and food products based on the market's needs. In addition, we will aim to realize data-driven smart agriculture.
- We will construct an architecture to help cross-field data collaboration through demonstration business projects using geographic data.
- We will realize "data-driven breeding," which enables the development of agricultural varieties in a short duration according to factors such as the market's needs and climate changes.
- We will link the function-designing technology/innovative production technology of innovative biomaterials and high-performance chemicals with industrial groups that constitute various value chains, and thereby build a new industry and realize the recycling-based society.
- We will create a market of not less than ¥240B by improving productivity and increasing the competitiveness of the agricultural, forestry and fishery, and food industries. For this purpose, we will develop and construct an assessment system and DB of food-based health improving effects, which enable food-based reduction in lifestyle-related diseases and the extension of healthy lives. We will also expand the bioeconomy (including food-related ones) and fortify the technical platform as well as expand the market of functional foods.

② Social goals

i. Overall implementation of the smart food system

As the social chaos related with COVID-19 spreads, we need to consider living with infectious diseases. Under such circumstances, to maintain the domestic "food" environment regardless of stagnation in the distributions of people and goods, strengthening the agricultural platform of Japan is critical.

This SIP is intended for maintaining and improving the production platform of primary products by increasing the number of agricultural workers. For this purpose, we will strengthen the platform for agricultural management and stabilize the businesses by developing the environment to utilize and apply data and information of the primary products' supply chain; developing task-specific technologies; improving the productivity per farmer; and strengthening the management platform of agriculture such as achieving market-interactive agricultural management. Simultaneously, we will build a platform to support new people who wish to participate in agriculture and allow farmers to participate in and receive existing and new various services that support them in agricultural production technology and management.

Moreover, we will set the goal as contributing to the achievement of the SDGs (stable food supply in the world, sustainable economy and society, and extension of healthy lives by controlling increasing medical costs). To achieve this goal, we present the circular economic model that improves the added values of the agricultural products, develops environmentally sustainable agricultural technology, and recycles nonedible parts of agricultural products and food residues.

ii. Implementation of each smart food system constituting theme

- We will contribute to the reduction of food loss through need-based food supply using the smart food chain platform.
- We will contribute to stable food supply worldwide by developing agricultural varieties with a low environmental impact that will be tolerable against climate changes.
- We will contribute to the realization of a carbon-recycling society through the production of high-added-value products using local bioresources.
- We will contribute to the reduction of people’s disease risks such as lifestyle-related diseases and extension of healthy lives by building and utilizing a new health system that can suggest the foods and a diet suitable for an individual’s health condition and lifestyle.

③ Goals in industrial aspect

- We will create new businesses that utilize and apply “food”-related development data and information and perform the data-driven technology development and integrate such technology in the society. Using this approach, we will contribute to the expansion of the bioeconomy market*, which is comparable with the expansion size of the world’s bioeconomy market (OECD predicted that the GDP of the OECD countries will grow to about 1.06 trillion dollars by 2030).
  (*The expansion will be valued at least ¥20T in 2030 based on the estimate using the percentage of GDP of Japan in the GDP of the current OECD countries.)
- We will contribute to the establishment of international hub(s) to attract human resources and global investments, which is one of the goals listed in the “Biostrategies 2019 and 2020” policy package, by developing the data and information platform.
- We will contribute to developing an environment by 2025, in which almost all farmers can exercise data-based agriculture.
- We will contribute to the acquisition of a ¥100B market by 2025 through the expansion of smart agricultural technology and system both inside and outside the country.
- We will contribute to achieving the goals for agricultural, forestry and fishery, and food products set by the government (¥2T by 2025 and ¥5T by 2030).
- We will encourage and create industrial groups by 2025 that will contribute to food-based health maintenance and improvement of the people using the integrated DB of health information related to agricultural, forestry and fishery, and food products. In addition, we will increase the number of function-claimed fresh produce items from the current five items to three times the number, i.e., 15 items (through this increase we can contribute to increasing the fresh produce market size from the current value of ¥8.9B to about ¥30B.
- We will contribute to establishing the industry-related market of ¥1T by 2030 through the development of innovative biomaterials and high-performance chemicals.

④ Goals in terms of technical aspects

(The deadline to achieve goals is by FY 2022 unless specifically indicated otherwise)

【Implementation of the whole smart food system】

I.) Construction of the bio-related value chain data platform for the “smart food system” to create value

i. Bio-DB collaboration and development of integrated use system (integrated DB group) for future analysis using AI.

ii. Promotion for the private sector to use biological information in the form of big data (Construction of a system to provide bio-related big data owned by national research institutes in easily usable

form for the private sector).

iii. Promotion to use the data obtained in each task of the SIP and the development of an environment to use the biodata for industrial purposes by developing the open–close system.

【Implementation of individual constituting themes of the smart food system】

I.) Development of the technology to contribute to agricultural sustainability: [Development], [Production]

i. Development of breeding technology to rapidly and accurately create necessary produce, such as agricultural varieties that meet the market needs and are resistant to climate change

- We will develop technology such as a breeding application programming interface (API) for promoting "data-driven breeding" through industry–academia–government collaboration.
- We will provide new values to consumers and processors (users of food processing) and develop at least eight agricultural varieties/breeding materials that will promote distribution reform and export expansion.

ii. Construction of the agro-environmental engineering system to realize a sustainable recycling-based society and development of farming methods using plant-microorganisms

- We will substantially develop soil diagnostic assessment and develop a prototype of an agro-environmental engineering system that will be a new assessment axis.
- Construction of a development platform for new agricultural materials and farming methods

iii. Development of data-driven smart production system to provide primary products while enhancing product efficiency by reducing the number of people needed for operations, based on the needs on the demand side.

- Develop the technology for sensing and automatically collecting information on cultivation management and the technology to create a big data platform by 2020
- Develop the technology to analyze big data and reflect the results in the production management work by 2021

II.) Development of the technology to contribute to the sustainability of food ingredients and foods: [Distribution], [Use of Information], [Sales and Consumption]

i. Development of technology for the information distribution platform, which enables data collaboration from production through distribution and consumption to support reduction of food loss and food waste and the market-oriented agriculture

- Create big data from various related data, from production through consumption and export, and construct an information and communications technology(ICT) platform to use the big data.
- Conduct verification tests on the constructed smart food chain platform including farmers and related companies for production, distribution, and consumption to verify the effectiveness (e.g., 10% reduction in food loss and 30% reduction in working hours), thus making a projection for implementation in society.

ii. Development of food ingredients and foods with health evidence, which meet market needs, for future value enhancement

- Define health condition indexes that reflect mild changes in physical conditions and develop a system for daily measurement of health conditions that can be easily implemented at low cost, and then verify their effectiveness
- Acquire scientific evidence regarding health-maintaining and enhancing effects of agricultural, forestry and fishery, and food products
- Develop intestinal microbiome data and verify the effectiveness of food ingredients to improve the intestinal environment
- Develop an integrated DB for health information on agricultural, forestry and fishery, and food products, including scientific evidence and data on food and health
- Implement as a model service the designing and proposal of an optimum diet suitable for an individual's health condition using the system and make a projection for implementation in society

III.) Development of technologies contributing to the sustainability of "food"-related resources/Environment [Resource Circulation]

i. Development of next-generation core technology for the chemical industry using unused resources in agriculture and forestry and fishery industries

- Develop next-generation core technologies for the chemical industry, using unused resources in agricultural and forestry and fishery industries (establishment of the technology to extract and produce a plurality of useful components in a series of processes from unused resources in local agricultural and forestry and fishery resources)

ii. Development of production technology for new biomaterials and high-performance products based on biofunctional-design

- Develop and practically use the production system of high-performance products and biomaterials, which is operable at lower cost than conventional ones and can reduce negative environmental impacts such as CO_2 emissions by 30% or more using biofunctions
- With these technological developments, develop at least five cases of innovative biomaterials and high-performance products and make a projection for their practical implementation

iii. Advancement and empirical research of the supply-chain-related technology, which supports the recycling of non-edible parts

- Develop reasonable operation methods for a membrane separation technique, wherein bioprocess wastewater can be treated more efficiently and the quality of the treated water can be enhanced.
- With effective use of algae and advanced separation techniques, develop technology to enable the utilization of nonedible parts as effective resources

⑤ Goals for the system

- Standardization and normalization of data for mutually utilizing/applying agricultural information in different systems and devices
- Promotion of the general public's understanding about the most advanced biotechnology, including genome editing
- Reflection of the assessment system of health-maintaining and enhancing effects of agricultural and forestry and fishery products as well that of the scientific evidence in the system for foods with health claims (examination of functionality assessment (health claims) and expansion of health claims that can be labeled on the foods according to characteristics of fresh produce)
- Develop normalization and international standardization of labeling health claims and component analysis methods in the field of food functionalities and standardization of measurement methods such as the one for intestinal microbiome
- Visualization of usefulness and environmental performance of products using biofunctions and bioresources (establishment of a labeling system)
- International standardization of standards and assessment methods for biomass plastics (reflecting Japanese development technology)

⑥ Global benchmarks

- The agricultural data collaboration platforms available overseas are mainly configured for large global companies to sell their products. In contrast, in Japan, numerous companies participate in and lead the public institutes. Based on this advantage, we will construct an open data platform spanning production through processing, distribution, sales, consumption, and export ahead of the world. Using this platform, we will contribute to the improvement in brand values of our country's agricultural, forestry and fishery, and food products as well as expand the smart agricultural technology and system overseas.
- Japan's breeding and cultivation technologies can achieve high-quality and high-added-value rice, vegetables, and fruits. In addition, our accumulation of vegetable genetic resources is at the top level globally. Based on these advantages, we will construct a promoting system through industry–

government–academia collaboration for “data-driven breeding,” in which digital technology will be incorporated. Then, we will develop superior agricultural varieties to those produced by other countries in a shorter period than that taken by conventional methods and thereby contribute to the improvement in the incomes of domestic producers.

- Taking advantage of our country’s world-class strengths, i.e., better health and long life of the population, we will enhance the added values of Japanese foods, domestic agricultural, forestry and fishery, and food products by acquiring scientific evidence of the health-improving effects of these foods and products. Based on the corresponding results, we will contribute to the improvement in the incomes of domestic producers and export expansion.
- One of Japan’s strengths is “product creation via craftsmanship” that uses biofunctions of microorganisms such as fermentation. In addition, we have developed competitive biomass technologies that have been demonstrated to be top-notch worldwide by the number of patent applications filed by Japanese companies. Based on these advantages, we will develop innovative materials and high-performance products using smart cells and thus acquire markets.

⑦ Collaboration with municipalities

- We will collaborate with Japanese Agricultural Cooperatives (JA) and municipalities, which work on data-based cultivation and quality management, for the development of a stable production technology to meet the processors’ and consumers’ needs in the development and verification of an efficient food distribution system utilizing artificial intelligence (AI).
- We will collaborate with municipalities and medical institutes, which work on health improvements of local residents, in human intervention studies for acquiring scientific evidence of health-maintaining and enhancing effects of agricultural, forestry and fishery, and food products.
- We will construct a collaboration system for commercialization with the participation of municipalities from the starting stage of the research and development in the development of the next-generation core technology for the chemical industry utilizing unused resources from agricultural and forestry and fishery industries.

2. Research and Development Projects

To expand our country's bioeconomy and achieve the SDGs, we will realize a "food"-based health-improving society; innovate agricultural, forestry and fishery, and food industries; and realize a sustainable growing society. For these approaches and goals, we will work on the following research and development projects.

（1）"Development of agricultural sustainability-contributing technologies: [Development], [Production]

[Development] Develop innovative food ingredients and quality development technology

[Production] Develop the smart production system

（2）Development of the technology for the sustainability of food ingredients and foods: [Distribution], [Utilization of Information], [Sales and Consumption]

[Distribution and Processing]   Achieve low cost and develop an optimization technology

[Utilization of Information] Construct a prototype of an information and communications technology (ICT) platform to build the smart food system

[Sales and Consumption]   Meet various needs

（3）Development of technologies contributing to the sustainability of "food"-related resources/environment: [Resource Circulation]

[Resource Circulation] Develop biomaterials and technology to use bioresources such as non-edible parts and residues

（4）Construction of the bio-related value chain data platform for the "smart food system" to create a value

[Construction of Value Chain Data Basis] Construct and validate the DB data distribution platform, in which DB data are aggregated and collaborated.

(1) Technology development for agricultural sustainability: [Development], [Production]

(1)-1 [Development] Development of innovative food ingredients and quality development technology

【Summary】

To strengthen Japan's development system for seeds and seedlings, we will develop technology to promote "data-driven breeding" to develop agricultural varieties using breeding big data and new breeding technologies. In addition, we will develop agricultural varieties that can create new values in consumption and distribution as well as major agricultural varieties that would contribute to achieving the SDGs.

【Necessary Expenses】

FY 2018	¥355M
FY 2019	¥272M
FY 2020	¥235M

i. **Development of breeding technology to rapidly and accurately generate necessary produce, such as agricultural varieties that meet the market's needs and are resistant to climate change.**

ii. **Construction of an agro-environmental engineering system that can realize a sustainable recycling-based society and development of farming methods using plant–microbe symbiosis**

(1)-1-1 Development of technology for promoting "data-driven breeding"

【Research Projects and Development】

With industry–academia–government cross-collaboration, we will promote "data-driven breeding" to develop agricultural varieties using breeding big data, data acquired from the "smart food chain platform," and data obtained from the new breeding technology (e.g., genomic selection and genome editing). For this purpose, we will develop technologies such as a breeding API. We will also develop agricultural varieties that were difficult to create in the past but have new values (e.g., agricultural varieties that can provide new values in a diet; agricultural varieties that can promote distribution reform, expansion of exports, and reduction of food loss; and agricultural varieties that are resistant to climate change, require less fertilizers and agricultural chemicals, and can stably yield profits). In addition, we will develop genome-edited agricultural produce created by simultaneous modification of plural characters, which has not been accomplished in the world thus far, and develop the genome editing technology, which enables precision rewriting of DNA.

Further, analyzing the data on plant–microbe symbiosis and soil with the agro-environmental engineering system, we will develop farming methods that utilize plant–microbe symbiosis, enabling reduction in the amounts of agricultural chemicals and chemical fertilizers to be used.

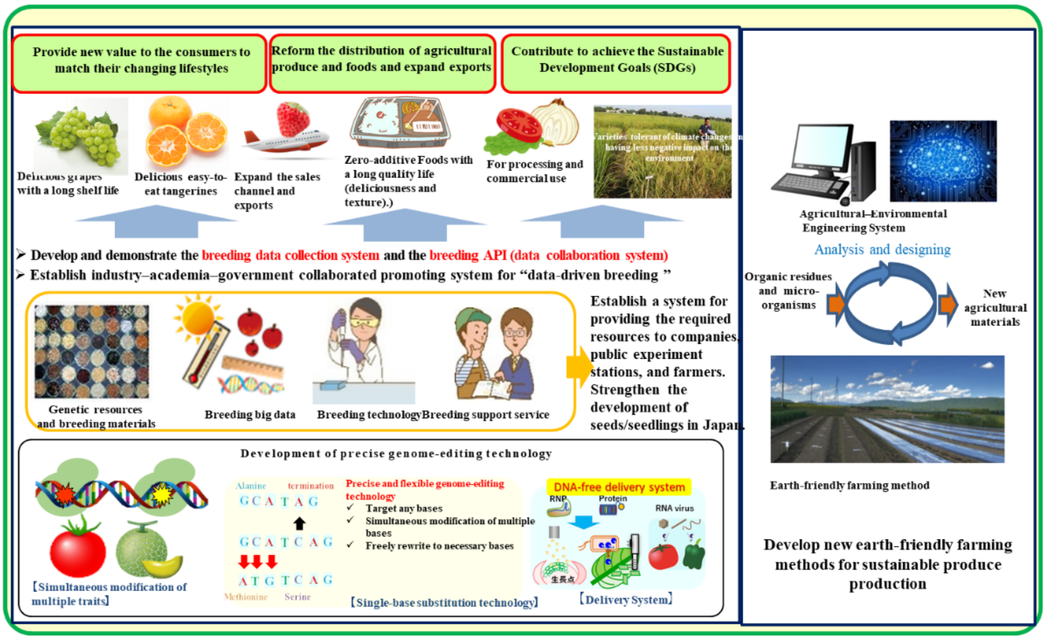


Fig. 2-1 Illustration of technology development for promoting “data-driven breeding”

【Participating Organizations】

① Development of technology for the platform that promotes “data-driven breeding” and development of agricultural varieties with new values using developed technology

Principal Investigator: Masao Ishimoto (National Agriculture and Food Research Organization)

National Agriculture and Food Research Organization; Nisshin Flour Milling Inc.; Nihon Shokuhin Kako Co. Ltd.; Kaneko Seeds Co. Ltd.; Watanabe Seed Co. Ltd.; ListenField Co.,Ltd..; Genomedia Inc.; Fukui Agricultural Experiment Station; Fukuoka Agriculture and Forestry Research Center; Tochigi Agricultural Experiment Station; Chiba Prefectural Agriculture and Forestry Research Center; Fruit Tree Research Institute; Kumamoto Prefectural Agricultural Research Center; Wakayama Fruit Tree Experiment Station; Aomori Prefectural Industrial Technology Research Center; Tottori Horticultural Experiment Station; Kazusa DNA Research Institute; Japan International Research Center for Agricultural Sciences Library; Kyoto Prefectural University; University of Tokyo; Meiji University

② Development of the core technology for precision genome editing that contributes to bioindustry and agriculture

Principal Investigator: Seiichi Toki (National Agriculture and Food Research Organization)

National Agriculture and Food Research Organization; University of Tokyo; University of Tsukuba; Nisshin Flour Milling Inc.; Nippon Norin Seed Co.; Kaneka Corporation; Sanatech Seed Co. Ltd.; Sumitomo Chemical Co. Ltd.; Sumika Agriotech Co. Ltd.

③ Development of “the agro-environmental engineering system” to realize a sustainable recycling-based society

Principal Investigator: Yasunori Ichihashi (Institute of Physical and Chemical Research (RIKEN))

Institute of Physical and Chemical Research (RIKEN); National Agriculture and Food Research Organization; Fukushima University; University of Tokyo; University of Tsukuba; Ehime University; Fukushima Agricultural Technology Center; Maekawa Research Institute Co. Ltd.; Ajinomoto Co. Inc.; Sermas Co. Ltd.; Chitose Laboratory Corp.; Euglena Co. Ltd.; Japan Bio Farm Inc.; Kao Corporation; Nagase Sanbio Co. Ltd.; Neopharma Japan Co. Ltd.; San-ei Sucrochemical Co. Ltd.; Daichi no Inochi Co. Ltd.; Ac-Planta Inc.; Kaneka Corporation; Qunie Corporation; DGC Technology Inc.

【Goals of the Year】

① Develop the core technology for promoting “data-driven breeding” and develop the agricultural varieties with new values using the developed technology

- Development of the core technology for promoting “data-driven breeding”
  For this goal, we will work on developing data analytic algorisms and a breeding application programming interface (API). We will complete a prototype of the application for utilizing the API and then experimentally use, evaluate, and validate it in the consortium(s). We will also provide a system for

corporate use, and conduct evaluation. We will construct a comprehensive system to connect with the breeding API, by achieving improved efficiency in acquiring the phenotype data and the data normalization and normalization of the process from identifying individuals in the selected group through genotyping.

- Development of agricultural varieties with new values using the core technology for promoting "data-driven breeding"
  For each agricultural produce, we will proceed with the acquisition of genomic data using next-generation sequencers and collection and evaluation of the phenotype data. Through this approach, we will build a prediction model, using which we will make selections and evaluate the selection results to achieve high precision. For the preceding breeding lines that are promising, we will start the evaluation of the usefulness of these lines as breeding materials.

② Develop the core technology for precision genome editing that contributes to bioindustry and agriculture

- Development of the precision genome-editing technology and the technology for delivering a genome-editing enzyme
  For this goal, we will establish the genome-editing technology for precision modification at one base-editing level. Simultaneously, for constructing an efficient targeted recombination system, we will develop a precise DNA modification technology using donor DNAs. In addition, we will work on precision control of gene expressions via genome editing in the cis elements. Further, we will develop the technology to deliver genome-edited enzymes using bacteria. We will obtain tobacco plants with base substitution delivered by viral vectors. In addition, we will develop the technology for delivering genome-editing enzymes through physical methods.

- Development of new genome-editing enzymes
  We will establish the CRISPR-Cas system with expanded target sequences. Based on the information obtained from crystal structures, we will create BICas9 mutants with different protospacer adjacent motif (PAM) specificities. Moreover, for the purpose of developing new DNA-cleaving enzymes, we will screen ribozymes that can sequence-specifically cleave DNA.

- Development of genome-edited produce with modified traits
  For the development and practical use of molecular breeding techniques for innovative bio-engineered potted flowers via genomic editing, we will verify the absence of foreign nucleic acid in genome-edited morning glory plants and file an application for approval to exhibit and cultivate the plant. Furthermore, we will create tomatoes and melons imparted with a plurality of useful traits.

③ Develop the agro-environmental engineering system to realize a sustainable recycling-based society

- System construction project. Based on the conditions determined in the previous year, we will comprehensively acquire the agro-environment data on plant–microorganisms–soil through "field agri-omics" for the materials and farming methods provided by companies and the National Agriculture and Food Research Organization (NARO). In addition, we will analyze the acquired data via integrated informatics analysis.

- Technology development project. Based on the results obtained in the previous year, we will provide the produce and soil samples developed using the new materials and farming methods for high-profit-making agricultural produce. The analytical team will analyze the data using the "field agri-omics" and acquire and analyze the plant–microbe–soil-related agro-environment data through integrated informatics analysis. Through these approaches, we will study their impacts in the field of farm technology candidates.

【Interim Goals】

① Develop the technology for the promoting platform of "data-driven breeding" and develop agricultural produce with new values using this technology

- Development of the core technology for promoting "data-driven breeding"
  We will complete a prototype of the application for using the API. Partner companies will conduct system evaluation. We will introduce the open–close system in the DB of publicly-established research institutes and of independent administrative corporations. We will develop or introduce analytic technology for genetic polymorphism, which can be used genome-wide and flexibly. In addition, we

will proceed with the establishment of efficient and proper platform technology for the above-stated purpose.

- Development of agricultural varieties with new values using the core technology for promoting "data-driven breeding"
  For the produce (citrus, apples, Japanese pears, grapes, onions, strawberries, and paddy rice), we will reveal the relation between the phenotype and genotype data on the targeted traits. Based on the results, we will build a prediction model and proceed with the breeding line selection.

② Develop the core technology for precision genome editing that contributes to bioindustry and agriculture

- Development of precision genome-editing technology and development of technology fordelivering genome-editing enzymes.
  For developing the genome-editing technology with one base-level precision, we will evaluate the genome-editing efficiencies of BICas9 and its mutants using plant cells. In addition, setting optimal conditions for targeted recombination, we will improve the efficiency of the targeted recombination. To precisely control gene expression via genome editing of cis elements, we will additionally target five genes and create the genome-edited population with deleted target areas in a total of 250 or more individuals. We will conduct evaluation in the model system of genome editing withbacteria. In addition, we will verify theabsence of foreign nucleic acid in tobacco that is genome-edited through a viral vector method. We will use a new gene/protein-delivery method based on the "in planta Particle Bombardment (iPB)" method, which is a physics-based method; we will prepare multiple genome-edited individuals and thereby proceed with the establishment of the methodology.

- Development of new genome-editing enzymes
  Based on the information obtained from crystal structures, we will prepare BICas9 mutants with different PAM specificities. Using these results, we will establish the CRISPR-Cas system with expanded target sequences and screen DNA-cleaving enzymes (ribozymes).

- Development of genome-edited produce with multiple modified traits
  For this purpose, we will conduct tests such as cultivation of genome-edited lines of morning glory. Simultaneously, we will identify the acetolactate synthase (ALS) genes of cyclamen via genomic analysis and develop a genome-editing method using them. For tomatoes and melons, we will prepare genome-edited individuals, which are imparted with the trait of high GABA accumulation and a parthenocarpic trait and/or the trait of a long shelf life (a long period before being perished/spoiled). We will evaluate the genotype of T0 generations and obtain null-segregants and homozygous mutant lines by accelerating the generations.

③ Develop the agro-environmental engineering system to realize a sustainable recycling-based society

- System construction project. We will finalize the concept as the innovation platform for agricultural technology. We will complete big data acquisition, which are required for a prototype of the agro-environmental engineering system. We will also complete the development and improvement of analytic technology. In addition, using funds from the companies that participate in the industrial strategy team, we will start inventing a business model using the system.

- Technology development project. We will verify whether the technologies of interest can be applicable in actual agricultural sites. We will attempt to provide the produce and soil samples prepared using the new materials and farming methods for high profit-making produce. We will comprehensively acquire and analyze the plant–microbe–soil-related agro-environment data to reveal the impacts in farm fields of the technology candidates. In addition, we will review the obtained results in light of market trends.

【Final Goals】

① Develop the core technology for promoting "data-driven breeding" and develop agricultural produce having new values using the technology

- Development of core technology for promoting "data-driven breeding"
  We will initiate the employment and serious operation of the data-driven breeding technique at actual breeding sites. We will work on familiarizing the comprehensive "data-driven breeding" platform, such as optimization of breeding strategy and support in decision making for the breeding process and establish a promoting system for data-driven breeding.

- Development of agricultural varieties with new values using the core technology for promoting "data-driven breeding"
  By implementing data-driven breeding, we will develop eight or more types of produce such as agricultural varieties and breeding materials of paddy rice, strawberries, and onions, which promote the distribution reform and export expansion of paddy rice that is resistant to climate change and has less negative impact on the environment.

② Development of the core technology for precision genome editing that contributes to bioindustry and agriculture

- Development of precision genome-editing technology and development of technology for delivering a genome-editing enzyme
  We will deliver a Cas9-base editor in plant cells as a Cas9-gRNA complex, and thereby develop the base substitution-delivery system that is free of foreign DNA and is efficient. We will demonstrate that we can rewrite the base sequence as planned in produce that are practically in use. In control of gene expression, we will demonstrate that we can modify phoenotype as planned. In developing the technology for delivering genome-editing enzymes, we will successfully perform the genome editing of endogenous genes of actual produce usingbacteria. We will also obtain tomato plants, into which base substitution is introduced through a viral vector. In addition, we will complete the technology for directly delivering a genome-editing enzyme based on new methodology.

- Development of new genome-editing enzymes
  We will widely examine the effectiveness of the BlCas9-base editor and expand the target sequences. In addition, we will theoretically design new DNA-cleaving ribozymes having high activity.

- Development of genome-edited produce with multiple modified traits
  We will conduct tests to evaluate the cultivation of the genome-edited lines of cyclamen. We will also conduct final evaluation of new varieties of morning glory and cyclamen. For preparation of tomatoes and melons imparted with multiple useful traits, we will cultivate commercial F1 hybrids in special netted-houses (i.e., netted houses designed for genetically modified plants) and evaluate the traits.

③ Development of the agro-environmental engineering system to realize a sustainable recycling-based society

- System construction project. We will complete a prototype of the agro-environmental engineering system. We will construct the system that stores all agro-environmental data obtained in this test research plan.

- Technology development project. Using the agro-environmental engineering system, we will develop new agricultural materials and farming methods based on our understanding of the agroecosystem. Simultaneously, we will complete a business model for using this system.

(1)-1-2 Promoting people's understanding of biotechnology and investigation and research of technological trends.

【Research Projects and Development】

To promote the use of biotechnology, we will conduct sociological investigation and research on the general public's understanding. Simultaneously, we will investigate technologies, intellectual properties, and regulations of the most advanced biotechnology and provide this information to industries.

This task is intended to construct advanced common research and developmentplatform mainly for the fields of agriculture and forestry and fishery, including applications in industrial, medical, and healthcare fields. For this purpose, we need to work together through cross-ministerial and agency collaboration and industry–academia–government collaboration.

We will also conduct investigation and research on communication methods to effectively realize the understanding and involvement of consumers and various stakeholders. Simultaneously, we will work for promoting people's understanding about biotechnology by providing information to the media. In addition, we will investigate and organize the trends of technologies, intellectual properties, and regulations related to the most advanced biotechnology, and build and run websites to provide information to the industries including start-up companies.

【Participating Organizations】

Principal Investigator: Manabu Takahara (National Agriculture and Food Research Organization)

National Agriculture and Food Research Organization; University of Tsukuba; Tokai National Higher Education and Research System; University of Tokyo; International Christian University; Hokkaido University; Centcrest IP Attorneys; Japan Association for Techno-innovation in Agriculture; Forestry and Fisheries; Nonprofit Organization Life & Bio Plaza 21; Leave a Nest Co. Ltd.

【Goals of the Year】

- We will continue to investigate, analyze, and release information about domestic and overseas trends of the most advanced research and development, regulations, strategies for implementation in society, and intellectual properties regarding advanced biotechnology
- We will improve the contents of the website “Bio-Station,” which we launched through this task to share information. Simultaneously, we will also start creating and publishing the content for children
- We will evaluate the effectiveness of the information that we provide to help consumers’ understanding through questionnaire surveys and will reflect their feedback in the information sharing method and contents
- We will analyze the web information using AI (e.g., text mining) to understand the characteristics of the general public’s awareness trends. In addition, we will study the method to provide the results as feedback to improve the information sharing methods and the content
- With the themes of genome-edited foods, bio-based chemical products, and functional foods, we will develop prototypes of teaching materials that can be easily used by teachers at schools. We will organize model classes using the developed teaching materials at least five times. Based on the results, we will improve the teaching materials
- We will plan and develop hands-on learning programs of genome editing. Carefully examining the status of the novel coronavirus pandemic, we will attempt to conduct at least one trial. In addition, we will prepare articles to post for teachers and students and then distribute or publish them

【Interim Goals】

- We will continuously conduct investigation and analysis of the latest information. Based on the results, we will improve the contents of the information website, and we will continue providing information regularly to the media, academia, and industries
- We will attempt to understand the trend of people’s awareness through questionnaire surveys and AI analysis. Simultaneously, we will examine methods to reflect the results in the methods and contents of the information to be provided
- With the themes of genome-edited foods, bio-derived chemical products, and functional foods, we will develop a prototype for teaching material to be used at schools. Further, we will start organizing model classes using the developed teaching materials and improving the teaching materials based on the results. In addition, we will develop and create hands-on learning programs and articles to post on the website

【Final Goals】

- We will build an information website to provide information on genome editing to the media, educational communities, industries, and administrative organizations and effectively provide information to and communicate with them. Simultaneously, we will develop a continuous operation system
- We will develop an educational program (comprising teaching materials) for utilizing/applying the bioeconomy mainly related to genome-edited foods, bio-derived chemical products, and functional foods. We will release the program to be widely recognized while actually using the programs at educational sites.

iii. Development of a data-driven smart production system to provide primary products while enhancing product efficiency by reducing the number of people needed for operations based on the needs on the demand side.

(1)-2 [Production] Development of the Smart Production System

We will integrally implement the development of the smart production system in combination with (2)-1 below.

【Summary】

We will construct the "data platform of the smart food chain." For this purpose, we will develop a data system to share the information from production through processing, distribution, sales, consumption, and export among industries regardless of the types of the industries. In addition, we will develop the technology that enables production and supply that accurately meet the needs.

In particular, we will work on the parts related to production through "(1)-2 [Production] Development of the Smart Production System" described above.

(2) Development of technology for the sustainability of food ingredients and foods: [Distribution], [Utilization of Information], [Sales and Consumption]

i. Development of the core technology for information distribution, which enables data collaboration from production through distribution and consumption in addition to supporting the reduction of food losses and food wastes and the market-in agriculture.

(2)-1 [Distribution and Processing] Cost reduction and development of the optimization technology; and

[Utilization of Information] Construction of a prototype of the information and communication technology (ICT) platform for subsequent construction of the smart food system

[Construction of the smart food chain, which enables optimization through data collaboration from production through distribution and consumption]

【Summary】

We will develop a data system to share the information across industries from production through processing, distribution, sales, consumption, and export. In addition, we will develop the technology that can produce and supply to properly meet the needs. Using these approaches, we will construct a data platform of the "smart food chain."

In this task, for production-related parts, we will work in (1)-2 [Production] Development of the smart production system. For the parts related to processing, distribution, sales, consumption, and export, we will work in (2)-１ [Distribution and Processing] Cost reduction and development of the optimization technology and [Utilization of Information] Construction of a prototype of the ICT platform for construction of the smart food system. In this task, as a whole, we will work on the "construction of the smart food chain" that enables optimization through data collaboration from production through distribution and consumption."

In particular, we will construct an information transmission system that bidirectionally connects information from production through consumption in the distribution process. Simultaneously, in addition to a production technology that can meet the demands, we will develop a production-demand matching technology for meeting demands both inside and outside the country. Moreover, we will develop a technology and a system to achieve data-driven smart production, such as feed-forward-style cultivation management based on factors such as the produce's growing information and soil data.

We shall work on this task integrally and compositely by handling big data and biotechnology such as highly-advanced ICT/AI technology, agricultural information, and biological information. Therefore, we need to address the task through the cross-ministerial and agency collaboration of industrial, agricultural, and biological research institutes, universities, and companies.

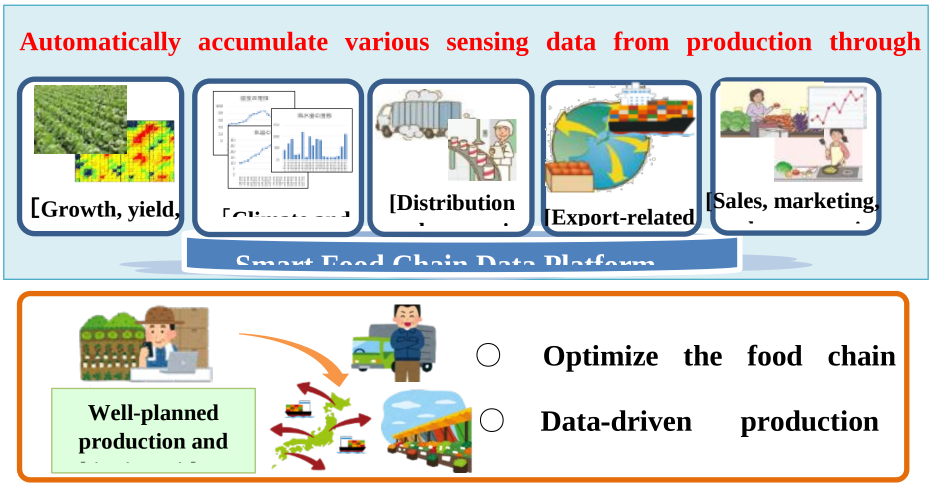


Fig. 2-2 Concept of the construction of a data platform for the smart food chain

【Necessary Expenses】

Year 2018	¥1,164M
Year 2018, corrected	¥200M
Year 2019	¥1,086M
Year 2020	¥759M

【Research Projects and Development】

In this project, we will construct a new smart food chain from production through processing, distribution, sales, consumption, and export. With this new smart food chain, we aim to share information such as needs inside and outside the country with the production side and to develop a production system that can satisfy these needs. Furthermore, in this smart food chain, we will secure reliability with traceability throughout the flow and adopt measures to prevent alterations/modifications of the products, thus creating new value. In addition, using this approach, we will work on establishing stable food supply with proper stock and shipping management, on optimized networking among places of production, and on stabilization of the demand–supply balance, thereby reducing food losses. Furthermore, providing feedback to production sites regarding the consumers' preferences inside and outside the country, we will facilitate exports. To successfully realize these objectives, we will work on the following technology developments.

[Production]

Utilizing big data in which the produce's growing information suitable for numerous farming fields is aggregated and the collaboration platform for agricultural data collaboration, we will develop a production technology that enables demand-based shipping while considering outdoor cultivation as a future target. In addition, for the purpose of developing intelligent machines, we will develop a technology and a system to reflect data such as soil data and environmental predictions to the product management work. Simultaneously, in view of expanding the technology and system to hilly and mountainous areas of our country and to East Asia, we will develop a more robust operating system for the robotic-based agricultural machines that can be driven on farm roads. Furthermore, we will develop automated work machines that are applicable to various items and in diverse terrains.

[Distribution and Processing], [Utilization of Information]

① For these aspects, we will develop an information-sharing system shares information regarding the respective stages of agricultural and forestry and fishery produce, i.e., information regarding production, processing, distribution, sales, and consumption. Using this system, we will expand the function of the agricultural data collaboration platform and aggregate information therein, thereby constructing big data that can optimize the products' distribution. Moreover, we will develop an AI-based production–demand matching technology. Particularly for this purpose, we will construct the architecture of the smart food chain and implement the demonstration projects of joint distribution (optimized consolidation in distribution) for future expansion of the export. Through this approach, we will construct an architecture based on the demonstration export project of each produce and other distribution data.

② In addition to the aforementioned element technologies to be achieved, we will develop the ICT platform that covers production through consumption, enabling produce supply while securing reliability in terms of need-based prices, quantities, quality, and timing. In the use case by trial operation, we will reduce food losses and stabilize the demand–supply balance. We will utilize the demonstration export project described above in ① as a use case.

Herein, for realizing the technologies required for improving the efficiency primary product distribution (e.g., shortening of lead time to supply), we will collaborate with the SIP "Smart Distribution Service."

【Participating Organizations】

Principal Investigator: Hisatomi Harada (National Agriculture and Food Research Organization)

National Agriculture and Food Research Organization; Keio Research Institute at SFC; Akita Prefectural University; Gifu University; Kindai University; Chiba University; Mie University; Yamagata University; Hokkaido University of Education; Kyoto University; University of Tokyo; Ritsumeikan University; Hokkaido University; National University Corporation Kitami Institute of Technology; Azabu University; Kagoshima University; Kyushu University; Tokyo University of Agriculture and Technology; University of Miyazaki; Nagoya University; Tohoku University; University of Tsukuba; NEC Corporation; NEC Solution Innovators Ltd.; Fujitsu Limited; Fujitsu Research Institute; Agri Open Innovation Practical and Applied Research Center; Kewpie Corporation; VisionTech Inc.; Academic Express Inc.; Hitachi Zosen Kabushiki Kaisha; Space-Agri Corporation; E-Support Link, Ltd.; Agri Communications Co. Ltd.; Kabushiki Gaisha Zukosha; Calbee Potato Inc.; Suzuki Motor Corporation; Shibuya Seiki Co. Ltd.; Toyo Noki K.K.; Iseki & Co. Ltd.; Yanmar Agri Co. Ltd.; Kubota Corporation; Mitsubishi Mahindra Agricultural Machinery Co. Ltd.; NTT Data Corporation; Panasonic Corporation; Takii & Co. Ltd.; Mitsubishi Chemical Corporation; Kikkkoman Corporation; Horiba., Ltd.; Yamato Holdings Co. Ltd.; ZENRIN-Datacom Co. Ltd.; NEXTY Electronics Corporation; Maruyama Mfg. Co. Inc.; Nishi-Nippon Railroad Co. Ltd.; Oishi Sangyo Co. Ltd.; Kyushu Agricultural Products Trading Co. Ltd.; JA Memuro; JA Shikaoi; Federation of Japan Agricultural Cooperatives in Tokachi; Keyware Solutions Inc.; Okinawa Cellular Telephone Company; Kanagawa Agricultural Technology Center; Kumamoto Prefectural Agricultural Research Center; Hokkaido Research Organization; National Institute of Advanced Industrial Science and Technology; Institute of Physical and Chemical Research (RIKEN); Distribution Economics Inst. of Japan (DEI); Fukuoka Agriculture and Forestry Research Center; Kagoshima Prefectural Osumi Food Technology Development Center; JA Chikuzen Asakura; JA Yashiro Area; JA Ibusuki

【Goals of the Year】

- We will develop the technology for normalization, standardization, and data-aggregation, which enables information sharing from production through consumption. We will run a test operation on the developed system in which the abovementioned technology is incorporated. Through this test, we will validate the constructed system, extract tasks that will be necessary for implementation in other applications, and accumulate the operation know-hows.

- We will apply a prototype of the ICT platform in use case demonstration. This ICT platform covers the whole smart food chain and helps in increasing the added value including export expansion. In addition, we will construct a joint distribution (optimized consolidation in distribution) system and demonstrate implementation in overseas export. We will construct an architecture and apply the prototype of the ICT platform as well as the joint distribution (optimized consolidation in distribution) in use case demonstration, aiming for improvements in distribution efficiency via consolidated shipping. Furthermore, we will verify system functions using actual data.
- We will develop a technology to automatically acquire information on cultivation management. We will also develop a technology for more robust vehicle-type robot-operated agricultural machines, which can perform remote monitoring and move among farm fields. We will construct an intelligent agricultural machine-operating system for hilly and mountainous areas and cultivation fields at test farmlands, where the system is controllable.

【Interim Goals】

- We will develop and conduct a test operation on the technology for data normalization, standardization, and aggregation to examine the validity of the constructed system, extract tasks required for rolling out the system's application, and accumulate the operation's know-hows of the operation.
- In the use case, we will apply the ICT platform's prototype that helps increase the added value including export expansion and confirms normal operation. Additionally, we will conduct demonstration projects for overseas export and build a suitable architecture. Furthermore, we will apply joint distribution (optimized consolidation in distribution) in the use case to achieve improved distribution efficiency via consolidated shipping.
- We will develop the technology to automatically acquire information on cultivation management. We will also develop robot-operated agricultural machines that can implement remote monitoring, move among farm fields, and can even properly work at places with adverse conditions. In addition, we will construct an operating system for intelligent agricultural machines for hilly, mountainous areas and cultivation fields at test farmlands where the system is controllable.
- To accelerate the construction of the smart food chain, we will strengthen the collaboration of related research themes for particular items. By the end of 2020, we will initiate a prototype of the smart food chain from production through distribution and sales on which we can conduct the test operation. Using this prototype, we will evaluate the developed system in terms of business management and investigate its effectiveness. Simultaneously, we will extract tasks that require improvement(s).

【Final Goals】

- By the end of 2022, we will develop demand-predicting technology, technology to process matching information, and technology for quality evaluation and quality maintenance. Based on these developments, we will construct the data platform of the smart food chain for mutually providing and sharing necessary information on time.
- By 2022, we will develop intelligent machines and a system to reflect the demand-based production and shipping management technology together with big data to the production management work and subsequently conduct on-site tests.
- By 2022, while utilizing essential technology such as the production-demand matching technology and demand-oriented production technology, we will demonstrate the developed system's effectiveness by conducting demonstration tests (10% reduction in food loss and 30% reduction in working hours at production site(s) in the use case at the time of test operation).

ii. Development of market-need-based food ingredients and foods with health evidence(s) for value enhancement

(2)-2 [Sales and Consumption] Efforts to meet various needs

"Contribution to longer healthy life by establishing the food-based health system"

【Summary】

In our country, the number of patients with health issues such as lifestyle-related diseases, dementia, and cancer are increasing with changing lifestyles. Therefore, in this regard, our social tasks include reducing the risk of lifestyle-related diseases, extending healthy life, and controlling the increasing national medical costs.

To achieve these social tasks and contribute to meeting the expanding agricultural produce demands, we will establish a new health system for extending our lives through "food," the source of our health. In particular, we will develop and construct a system for evaluating health-maintenance and enhancement effects of agricultural and forestry and fishery produce; such produce comprises various inconsistent components that are different from pharmaceuticals and supplements and only mildly influence the human body. In addition, we will collect and organize the microbiome data of Japanese people and conduct functional evaluations of foods that regulate the intestinal microbiome environment. Through these approaches, we will facilitate and create a healthcare industrial group that contributes to enhancing the people's health through "food" with a scientific basis. Furthermore, we will build a platform for the "food"-mediated self-medication system, which can suggest and provide personalized diets and meal regimens according to an individual's health conditions and lifestyle.

To this end, we will integrally work on system development for judging mild physical condition changes, study the influences of agricultural and forestry and fishery produce on health, and construct a health-related DB. Therefore, cross-ministry and -agency collaboration is indispensable, wherein industrial, agricultural, medical, and biological research institutions and universities must collaborate with related companies.

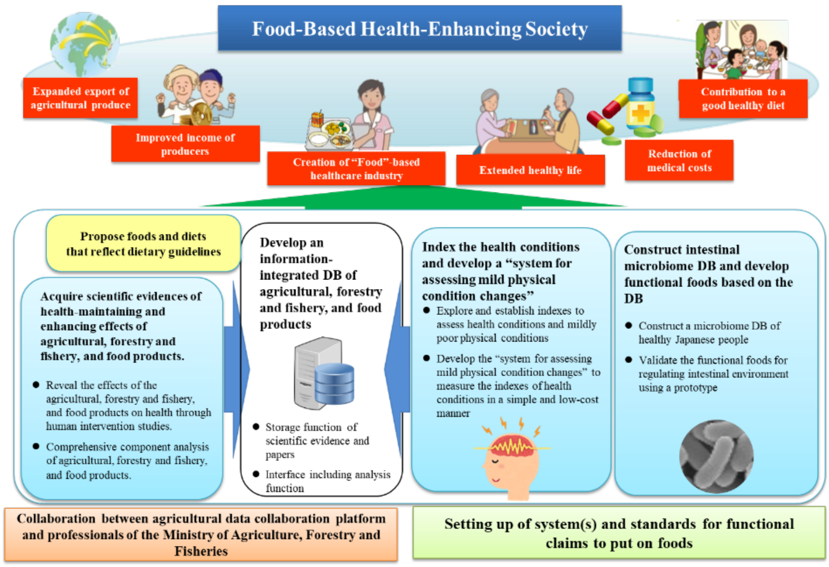


Fig. 2-3 Concept of meeting the people's various healthcare needs

【Necessary Expenses】

Year 2018	¥445M
Year 2019	¥341M
Year 2020	¥340M

【Research Projects and Development】

We will define health condition indexes that reflect physical conditions, including mild changes in physical conditions, and develop a "system for assessing mild physical changes." We will acquire scientific evidence regarding health-maintenance and enhancement effects of agricultural, forestry and fishery, and food products. We will organize intestinal microbiome data. Using these evidence data, we will develop the "integrated health information DB of agricultural, forestry and fishery, and food products to analyze health-maintaining and enhancing effects of agricultural, forestry and fishery, and food products". Specifically, the details of each project that we will work on are as follows.

① Development of physical condition indexes and the "system to assess mild physical condition changes"

We will explore and establish indexes to assess an individual's state of health and mild physical condition changes.

Simultaneously, we will develop a “system for assessing mild physical condition changes” for measuring the established indexes in a simple, cost-effective manner on a daily basis.

② Acquisition of scientific evidence regarding health-maintenance and enhancement effects of agricultural, forestry and fishery, and food products

Through human-intervention studies using the “system for assessing mild physical condition changes,” we will scientifically identify agricultural, forestry and fishery, and food products that improve mild physical condition changes in individuals. Furthermore, via comprehensive analysis, we will identify the components of these agricultural, forestry and fishery, and food products.

③ Collection of intestinal microbiome data and examination using a prototype of functional foods

We will collect and organize reference intestinal microbiome data of the Japanese people, including metagenome and metabolome information that are in high demanded in the food industry. We will also develop a sampling data analysis protocol associated with foods. Finally, we will examine the usefulness of the data using a prototype of functional foods.

【Participating Organizations】

Principal Investigator: Mari Yamada (Maeda) (National Agriculture and Food Research Organization)

National Agriculture and Food Research Organization; Hokkaido Information University; Kyoto University; University of Miyazaki; University of Nagasaki; Sapporo Medical University; Kyushu University; National Institutes of Biomedical Innovation; Health and Nutrition; Institute of Physical and Chemical Research (RIKEN); National Institute of Advanced Industrial Science and Technology; National Institute of Genetics (Research Organization of Information and Systems (ROIS), Inter-University Research Institute Corporation); Nagasaki Agricultural & Forestry Technical Development Center; Japan Microbiome Consortium (JMBC); PGV Company, Link & Communication Inc.; Japan Food Research Laboratories; Asahi Quality & Innovations, Ltd.; Ezaki Glico Company Ltd; Kagome Co. Ltd.; Kirin Holdings Company Ltd.; Gekkeikan Sake Company Ltd.; POKKA *SAPPORO* Food & Beverage Ltd.; Suntory Holdings Ltd.; Shimadzu Corporation; Taisho Pharmaceutical Co. Ltd.; Chitose Laboratory Corp.; Nisshin Seifun Group Inc., Japan Headquarters; Mitsubishi Chemical Corporation; Meiji Co. Ltd.; LAWSON Inc.

【Goals of the Year】

- We will prepare a device that can measure the quality of sleep and changes in the autonomic nerve system, which are going to be used as indexes to evaluate mildly poor physical conditions. In addition, for studying the relation between health and food, we will acquire data by conducting human and pilot studies. Based on the acquired measurement data, we will analyze the patterns of mildly poor physical condition changes in terms of an individual’s health and define evaluation indexes.

- We will continue human studies on the relation between food and health and acquire the data of 400 individuals biannually: in the summer and winter. Using the acquired data, we will analyze relations among genes through genome-wide association analysis (GWAS) and epigenome-wide association analysis (EWAS), habitual diets, daily living, vital signs, and blood components. Based on the results thus obtained, we will identify habitual diets that contribute to health-maintenance and enhancement. In addition, we will conduct pilot intervention studies for at least five items of agricultural, forestry and fishery, and food products and develop a protocol for this test.

- We will analyze the intestinal microbiome data of 400 Japanese people (long-read metagenomes of 50 individuals; shotgun metagenomes of 400 individuals; fecal and blood metabolomes of 90 individuals), thus revealing the microbiome profiles of the Japanese people.

【Interim Goals】

- Based on the progress of 2019, we will adjust for final goals toward the verification tests to be conducted in 2021 and 2022.

- We will acquire data from human tests and pilot studies for obtaining the measurements of the sleep quality and changes in the autonomic nerve system, which are going to be used as indexes for the evaluation of mildly poor physical conditions and for the relation between food and mildly poor health conditions. Using the acquired data, we will analyze the patterns of the changes between healthy conditions to mildly poor physical conditions and define the evaluation indexes.

- We will continue human studies regarding the food–health relation and identify the habitual diet that contributes to health-maintenance and enhancement. We will conduct pilot studies on at least five items of agricultural and forestry and fishery produce, then prepare a protocol of the test.

- We will analyze the intestinal microbiome data and acquire metabolome data. Based on this approach, we will reveal the profile of the Japanese people’s microbiomes.

【Final Goals】

- We will develop a “system for assessing mildly poor physical conditions.” Simultaneously, we will introduce this system in model areas in collaboration with local convenience and grocery stores to verify the food-based health-maintenance and enhancement effects.

- We will conduct intervention tests to verify the effect of improving mildly poor physical conditions of at least five types of “agricultural, forestry and fishery, and food products” and reveal their health- maintaining and enhancing effects.

- Using the reference DB developed in the previous year, we will analyze the samples of new foods and food ingredients for our intervention studies. Based on the results, we will verify and demonstrate the effectiveness of the scientific evaluation system for evaluating the improvement effects of intestinal flora according to foods and food ingredients. We will also conduct intervention studies for validating the intestinal microbiome-improving effects of at least two types of foods and food ingredients. As a final goal, we will reveal the health-maintaining and enhancing effects of at least five types of functional food prototypes.
- For implementation in the society, we will further explore practical use. We will aim to release the food–microbiome–health information-integrated DB; develop high-added-value functional foods that improve mildly poor physical conditions; sell personalized healthcare meals, i.e., ready-made meals and restaurant foods; provide health management services based on the indexes of changes between healthy and mildly poor physical conditions; and provide a new device using which people can easily evaluate their mildly poor physical conditions.

(3) Technology development for the sustainability of “food”-related resources and environment [Resource Circulation]

[Resource Circulation] Development of biomaterials and bioresource utilization technology

【Summary】

We will reduce our dependence on petroleum and realize a sustainable growing society. For this purpose, we will develop the technology to produce new biomaterials and high-performance products based on biofunctional designing. We will also work on developing the technology to remove a bottleneck in a supply chain such as the one for biomaterials.

This task includes creating new bio-related industries that span cross-industrial fields. Therefore, the collaboration between industrial, agricultural, medical, and biological research institutes and universities and companies through cross-ministerial and agency collaboration is necessary.

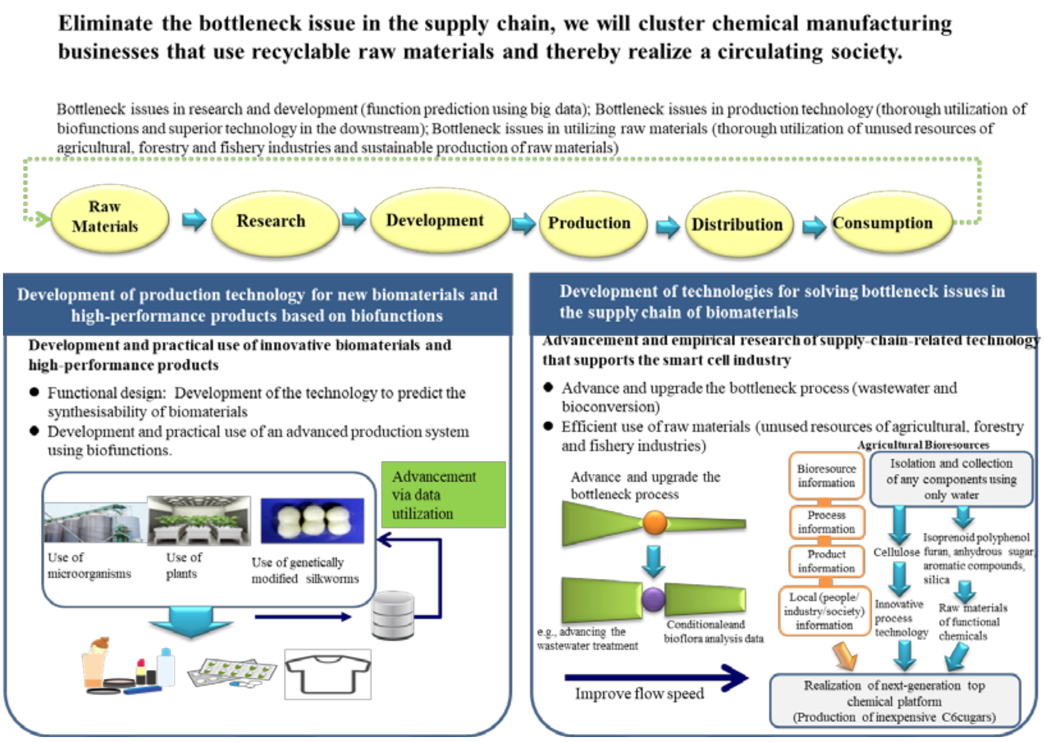


Fig. 2-4 Concept of a sustainable growing society based on “biofunction-based product creation via craftsmanship”

【Necessary Expenses】

Fiscal Year 2018	¥761M
Fiscal Yea r 2019	¥584M
Fiscal Year 2020	¥496M

i. Development of production technology for new biomaterials and high-performance products based on biofunctional-design

ii. Development of the next-generation chemical industry utilizing unused resources of agricultural and forestry and fishery industries.

iii. Studies on the advancement and empirical research of supply-chain-related technology that supports nonedible part recycling.

【Research Projects and Development】

We will develop the agri–bio–chemical production system based on nonedible part recycling; the technology to produce new biomaterials and high-performance products based on biofunctional designing; and the technology to solve a bottleneck in supply chain of biology-applied new high-performance products, biomaterials, and functional products.

① Development of an agri–bio smart chemical production system

A bottleneck issue is encountered in establishing a chemical industry utilizing unused resources of agricultural and forestry and fishery industries as raw materials because the system technology is yet to be fully established for supplying core compounds at reasonable prices. To solve this bottleneck, we will isolate and collect constituents of unused resources of agricultural and forestry and fishery industries as a plurality of useful components and high-quality biomaterials (e.g., C6 monosaccharides), which have high-added values, provide high yields, or can be converted to functional chemicals. Then, we will develop an integrated process to stably supply platform compounds at reasonable prices and develop the “Agri–Bio smart Chemical production system (ABCs)” to implement this integrated process in various areas. Through these approaches, we will build a business model assuming its application in multiple areas. In addition, we will develop a technology to utilize organic residues for the raw material production of the next-generation chemical industry.

② Development of functional-design and production technologies for innovative bio-materials and products

To secure food sustainability and realize a low CO_2 emission society, we will contribute to resource recycling by converting agricultural residues to monomers that can be used as raw materials for high-added-value polymers. For this purpose, we will develop new biopolymers in practically usable forms.

To efficiently design and produce high-performance polymers comprising monomers produced via biotechnology-based methods, we will develop the core technology for “biopolymer designing (BPD).” In addition, we will develop and validate platform element technology, using data-driven methods to achieve the efficient production of monomers utilizing microorganisms. In this manner, we will establish a production system that enables bioproduction independent of plant-derived sugars.

Furthermore, using high-performance bio-polybenzimidazole (PBI) and polyhydric phenol-based materials (PPM), we will produce platform aromatic biomass raw materials using functions of microorganisms. Moreover, using the abovementioned raw materials, we will develop high-performance and high-added-value products.

③ Development and practical utilization of the production technology of useful proteins and new high-performance materials using insects (silkworms)

Utilizing high-functional-design organisms such as microorganisms, animal and plant cells, and insects, we will develop a production technology for innovative biomaterials and high-performance products. Using the obtained data, we will further advance the competitive production system.

Using silkworms as a bioreactor, we will establish manufacturing technology for proteins and high-performance materials that can be used in medical, diagnostic, and electronic fields, at a practically viable level. We will proceed with practical utilization and implementation in the society through industrial–academia collaboration and cross-ministerial and agency collaboration. While creating pioneer cases, we will establish quality and manufacturing management technologies that comply with the appropriate regulations and are suitable for future standardization.

④ Development of bioprocess optimization technology to realize a smart biosociety

Various membrane separation technologies that can be expected to improve the efficiency of wastewater treatment and the quality of treated water in order to eliminate the bottleneck for optimizing the food value chain, which is important for the practical application of biomaterial production. Cost reduction will be achieved by improving the operation using sensors and developing a rational operation method by creating a database of bacterial flora analysis and state observation of activated sludge. In addition, a local bioeconomy simulation tool will be created.

【Participating Organizations of the Research Projects】

① Development of the ABCs

Principal Investigator: Junichiro Hayashi (Kyushu University)

Kyushu University; Kyoto University; Tohoku University; Nagaoka University of Technology; Kagoshima University; Akita Prefectural University; National Agriculture and Food Research Organization; National Institute of Advanced Industrial Science and Technology; Akita Research Institute of Food and Brewing; Mizuho Information & Research Institute, Inc.; Japan Bioindustry Association; DKS Co. Ltd.; Kao Corporation; Toray Industries, Inc.; Shinko Sugar Co. Ltd.; Fuji Oil Holdings, Inc.; Akita Prefectural Livestock Experiment Station

②

Development of functional-design and production technologies for innovative bio-materials and products Principal Investigator: Takahito Nakajima,

Institute of Physical and Chemical Research (RIKEN); National Institute of Advanced Industrial Science and Technology; Research Institute of Innovative Technology for the Earth; University of Tokyo; Kyushu University; National Institutes of Biomedical Innovation, Health and Nutrition; National Institute of Health and Nutrition; Tohoku University; SyntheticGestalt Ltd.; National Institute for Materials Science; University of Tsukuba; Japan Advanced Institute of Science and Technology; Niigata University

③ Development and practical utilization of manufacturing technology for useful proteins and new high-performance materials using insects (e.g., silkworms)

Principal Investigator: Hideki Sezutsu (National Agriculture and Food Research Organization)

National Agriculture and Food Research Organization; Immuno-Biological Laboratories Co. Ltd.; Kumamoto University; Kyorin Co. Ltd.; Nippon Bio-Test Laboratories, Inc.; AI Silk Corporation; Kyushu University; University of the Ryukyus; Kagoshima University; Nippon Zenyaku Kogyo Co. Ltd.; Atsumaru Holdings Co. Ltd.; Nippon Institute for Biological Science; Tokyo City University

④ Development of optimization technology for bioprocesses to realize a smart biosociety

Principal Investigator: Tomohiro Tamura (National Institute of Advanced Industrial Science and Technology)

National Institute of Advanced Industrial Science and Technology; Institute of Physical and Chemical Research (RIKEN); Saga University, Saga City; Mitsubishi Chemical Corporation; Ajinomoto Co. Inc.; Chitose Laboratory Corp.

【Goals of the Year】

① Development of the ABCs

- We will demonstrate the performance of the following research and development projects by performing bench continuous tests: research and development of technology for converting agri–bio resources to low-cost raw materials; research and development of the evaluation and optimization systems for supply chain; research and development of the manufacturing of intermediate products; research and development of the manufacturing of agri-pulp-derived products; and research and development of the manufacturing of agri-pulp or C6 sugar-derived products.

Development of functional-design and production technologies for innovative bio-materials and products

- We will produce PBI-related monomers or their precursors using microorganisms to evaluate their functions (1g/1L). Then, we will establish a method of purifying candidate compounds from fermented liquid (90% or high purity). In addition, we will reveal the electrochemistry of PBI-based ionic gel electrolytes in a battery and identify the conditions for minimizing the interfacial resistance of the battery cell. Simultaneously, we will scale-up the synthesis and prepare a PBI/PA membrane that exhibits optimal electric characteristics including those at high-temperature conditions.
- We will study PPM production gene and increase the productivity by five times. We will reveal the basic physical characteristics of the target PPM compounds, e.g., purity and other general properties. In addition, we will establish a method of collecting protocatechuic acid (PCA) from fermented liquid (90% or higher purity). Simultaneously, we will improve the microbial production efficiency of caffeic acid and establish a method for synthesizing a lithium (Li)-borate-based solid polymer electrolyte from caffeic acid.
- We will construct the first version of BPD technology and the corresponding tool in addition to suggesting candidates for a new high-performance polymer. Using the developed tool, we will fabricate a new high-performance polymer that will be a candidate in three target regions. Furthermore, we will proceed with investigating the decomposition mechanism of marine biodegradability.
- For obtaining at least two types of target monomers to manufacture a biopolymer, we will develop high-performance enzyme(s) required in core enzyme reactions for biopolymer synthesis. We will also demonstrate the capability of efficient biomonomer production. Moreover, utilizing high-performance enzymes for efficient biomonomer production, we will design the required metabolic path as well as biomonomer-producing bacteria.

② Development and practical use of manufacturing technology for useful proteins and new high-performance materials using insects (silkworms)

- Using proteins made from silkworms, we will prepare candidate products for AGEs study kits and clarify the disease of interest in this project. In addition, we will start manufacturing antibodies for the nonclinical and clinical studies.
- We will create and evaluate a prototype of a disease-control filter device and an easy diagnostic kit for ulcer disease of common carp, using antibody-infused silk. We will also create a wearable prototype in which a device for electromyography (EMG) using conductive silk is mounted, known as wearable EMG silk.
- We will develop and conduct evaluation tests on diagnostic drugs for canine babesiosis, diagnostic drugs and vaccines for bovine leukemia, and two types of other vaccines. We will develop prototypes of 15 types of protein products for reagent use and release them (as a part of interleukins) in the market.
- We will select evaluation methods to measure various potential impact levels according to CO_2 emissions. For an advanced production system, we will develop a DB and a catalogue of gene expressions along with application to gene network model(s).

③ Development of bioprocess optimization technology to achieve a smart biosociety

- For about 50 samples of industrial wastewater and activated sludge obtained from the bioprocess(es) and model reactor(s), we will collect and analyze data via bacterial flora analysis using 16S rRNA genes, shotgun metagenome analysis, and metabolome analysis. Based on the data thus obtained, we will identify at least two candidate indexes for the predictive diagnosis of wastewater treatment. In addition, we will conduct laboratory-scale treatment experiments on various types of wastewater such as those conducted in biofermentation and land-based aqua-culturing processes; in this manner, we will promote platform element technology. Furthermore, we will develop tools for material and energy cycles in model areas, study environmental impact effects, and construct model scenarios.

Involved in the development of advanced membrane clogging suppression technology, we will elucidate the factors that affect the membrane clogging of the membrane separation reactor from experiments by changing the components of wastewater (for example, proteins / polysaccharides) and the physical properties (crystal / amorphous) of the membrane. In addition, time-series data of potential fluctuations in the model membrane separation reactor will be acquired and the membrane separation performance will be evaluated. In addition to improving the membrane performance of two or more types of separation membranes, we will evaluate the membrane separation performance of a three-component simulated fermentation broth containing water for four or more types of separation membranes and proceed with data collection.

- We will culture microalgae at 100-L scale using industrial wastewater from bioprocesses in outdoor PVC vinyl greenhouse, wherein a large-scale culturing facility is assumed to be installed. In this project, we will achieve at least an 80% removal rate of nutritive salts (essential inorganic and organic salts for organisms).

【Interim Goals】

① Development of the ABCs

- For supplying agri–bio resources in addition to conversion and function-imparting to chemical products, we will propose a technical package for the collection, storage, and quality optimization ,simultaneously, we will demonstrate the production technology for intermediate raw materials through bench tests and consistent process mock tests. In particular, for the "stable supply of C6 sugars at a strategic low price," we will clarify the technological and economic reasonability.For developing the supply value chain, we will establish the evaluation technology for agri–bio chemical systems and the optimization technology for the supply value chain, and the develop them to be in usable forms for users.

② Development of functional-design and production technologies for innovative bio-materials and products

- Using microorganisms, we will efficiently produce PBI-related monomers or their precursors at the function-evaluable level. Simultaneously, we will prepare PBI/PA membranes, which exhibit optimal electrical characteristics including high-temperature characteristics in PBI-based ion gel electrolyte batteries.

- We will increase the productivity of PPM-producing bacteria by five times. We will unravel the basic physical properties of the target PPM compounds, including their purities and other general properties. We will establish a method of collecting (PCA). Simultaneously, we will improve the efficiency of caffeic acid's microbial production system. Based on these approaches, we will establish a method to synthesize a Li-borate-based solid polymer electrolyte from caffeic acid.

- We will construct the first version of BPD technology and the corresponding tool as well as propose candidates for new high-performance polymers. Using the developed technology and tool, we will fabricate new high-performance polymers. In addition, we will investigate the decomposition mechanism of marine biodegradability.

- We will demonstrate the feasibility of efficient biomonomer production. For this purpose, we will utilize high-performance enzymes and design biomonomer-producingbacteria.

③ Development and practical use of the manufacturing technology for useful proteins and new high-performance technology using insects (e.g., silkworms)

- We will develop candidate products of AGE study kits and clarify the diseases to conduct tests. In addition, we will start the production of antibodies for conducting the non-clinical study.

- We will develop and evaluate a prototype of a disease-control filter device and an easy diagnostic kit for ulcer disease of common carp using antibody-infused silk. We will create silk having (disease-) specific affinity and develop a prototype of a simple diagnostic kit. Moreover, we will develop a prototype of clothing in which a device for electromyography (EMG) using conductive silk is incorporated, completing it as a wearable EMG silk product prototype.

- We will develop diagnostic drugs for various animal diseases and vaccines and subject them to evaluation tests. We will develop prototypes of 15 types of protein products for reagent use and release them (as a part of interleukins) in the market.

- We will select evaluation methods to measure various potential impact levels based on CO_2 emissions. For an advanced production system, we will develop a DB and a catalogue of gene expressions and applications to gene network model(s).

④ Development of the bioprocess optimization technology to achieve a smart biosociety

- We will promote the membrane separation reactor's advancement, which is anticipated to work as a system that can save space and perform high-load operation. We will conduct laboratory-scale treatment experiments for various types of wastewater discharged from biofermentation and land-based aqua-culturing processes., thus promoting platform element technology.

- Collaborating with Nagaoka City and Nagaoka University of Technology, we will initiate empirical experiments via pilot-scale experiments for organic food loss wastewater.

- We will construct a system that is robust against various types of wastewater. For this purpose, we will continue developing predictive and diagnostic systems for actual-scale waste-water treatment processes implemented by companies in addition to developing an appropriate sensing system.

【Final Goals】

① Development of ABCs

- We will demonstrate the technology to provide agri–bio resources at ¥20/dry-kg and the manufacturing technology for at least 10 types of chemicals (excluding C6 sugars) from the agri–bio resources. We will further demonstrate the technology for stably supplying C6 sugars at ¥30/kg based on the total added values of the chemicals. Through these approaches, we will determine the specifications of involved processes and systems at their actual implementation scales. We will further develop the proposing system through technical assessments, user tests, and process designing such that it can be implemented in the Yokote area in Akita prefecture. Simultaneously, we will show that the proposed system can be implemented in other areas.

② Development of functional-design and production technologies for innovative bio materials and products.

- We will perform microbial production of PBI raw materials at pilot scale (a few ten-gram scale). We will develop a prototype of a Li-ion conductor as a solid electrolyte and wire coating, evaluate test data of the prototype of a highly heat-resistant insulator, and acquire normalization data. In the PBI electrolyte–caffeic acid binder system, we will optimize conditions and achieve 1,200mAh/g^{-1} discharge capacity in a battery cell after 500 discharge cycles. In addition, we will fabricate a highly heat-resistant insulator that exhibits 100 MV/m of withheld voltage at 300 °C.

- We will perform microbial production of PPM raw materials at a pilot scale (a few ten-gram scale). We will obtain PCA/PPM with a purity and general properties that would not hinder their conversion to a material and develop a bio-PPM prototype. We will demonstrate that one type of polyhydric phenol can be used as a "functionally-designed epoch-making biomaterial," the practical use of which can be estimated.

- In the each of the three targeted fields—highly temperature-resistant and highly rigid polymers, rubber elastomers, and biodegradable polymers—we will propose at least one type of high-performance polymer as a candidate. In these fields, we will suggest at least six types of new polymers, and subsequently investigate their potentials. We will complete a prototype of the technology-integrated tool of biomaterial designing and production and investigate its effectiveness. Additionally, we will develop a rapid evaluation method for marine biodegradability and reveal the developed method's correlation with the existing evaluation method(s).

- We will construct at least two types of high-monomer-producing strains and utilize their advantages. For at least two types of monomers to be used in the production of the targeted high-performance polymers, we will introduce microorganisms to evaluate the productivity of the biomonomers, and thereby achieve the efficient production of the biomonomers. Using a small-sized electrochemical reactor to demonstrate the productivity of the biomonomers, we will demonstrate that the modified electro-synthesized microorganisms can synthesize the biomonomers.

③ Development and practical use of the manufacturing technology for useful proteins and high-performance materials using insects (e.g., silkworms)

- We will fabricate and demonstrate the AGE test kits. We will evaluate at least two types of silkworms with modified gene and genome sequences that are expected to improve productivity and quality. We will begin manufacturing antibodies for clinical studies and initiate clinical studies (P1). We will create a diagnostic drug product for canine babesiosis and release it in the market.

- We will evaluate the performance of a simple diagnostic kit's prototype related to animal diseases using the antibody-infused silk and accordingly improvise the final product. We will finalize the production method of diagnostic drugs and vaccines for animal diseases. Using conductive silk, we will complete and release in the market a wearable, sensing-device-loaded product for vital data measurements.

- We will analyze the contribution of this product in terms of the reduction in environmental negative impact and demonstrate that our developed technology can achieve at least 30% reduction. In addition, we will verify improvements in the production quantity by releasing the DB and modifying the gene network.

④ Development of the bioprocess optimization technology to achieve a smart biosociety

- We will monitor the predictive and diagnostic index candidates at facilities for treating bioprocess-derived industrial wastewater. Through this monitoring, we will identify the predictive and diagnostic indexes at actual wastewater treatment facilities and in model membrane separation reactors. Using the identified indexes, we will control the treatment operation. Using these approaches, we aim increase the amount of treated wastewater by 10%–20% or generate 10%–20% improvement in treatment efficiency.

- Based on the results of the investigation of domestic and international bioeconomy trends, we will develop a bioeconomy simulation tool that is applicable in the scenarios in Asia as well as certain areas in Japan. Using this tool, we will study and evaluate the utilization scenario that is specific to regional characteristics, the contribution levels to the bioeconomy, and environmental impact levels.

- We will develop an advanced membrane clog-controlling technology and improve membrane clogging in the membrane separation reactor to about 30%. Furthermore, using an electrocatalytic material, we will generate about 30% improvement in membrane clogging by perturbing the electrochemical oxygen level. For at least five types of separation membranes, we will evaluate membrane separation in a mock solution of at least four components, which simulates actual fermented liquid, and then proceed with data collection.

- Utilizing actual algae biomass cultured using wastewater from a bioprocess, we will determine optimal conditions for supercritical CO_2 extraction of useful chemical substances. For large-scale culturing while assuming the quantity of actual wastewater form bioprocess industries, we will design the optimal processing device. We will initiate research in collaboration with companies for the utilization of algae cultured using wastewater from bioprocess industries.

(4) Construction of a bio-related value chain data platform for the “smart food system” to create value

［Construction of Value Chain Data Platform］ Construction and validation of the DB data distribution platform, in which DB data are aggregated and collaborated

【Summary】

We will work on the technological development to provide “information” and “products” that serve as the foundations for innovative creation by harmonizing biotechnologies and digital technologies; further, implement the research studies and provision of information to promote the use of biotechnologies. These foundations will be used in the other programs of the related projects.

Regarding the “information,” to promote the public use of the biology-related data owned by national institutes, we will develop and construct the API to share biological data. It should be developed considering the results of research investigations of the industrial needs.

Regarding the “bioresources”, we will develop a common infrastructural technology that allows the mass culturing and screening of high-functional bacteria for constructing a high-throughput bacteria cultturing and screening platform.

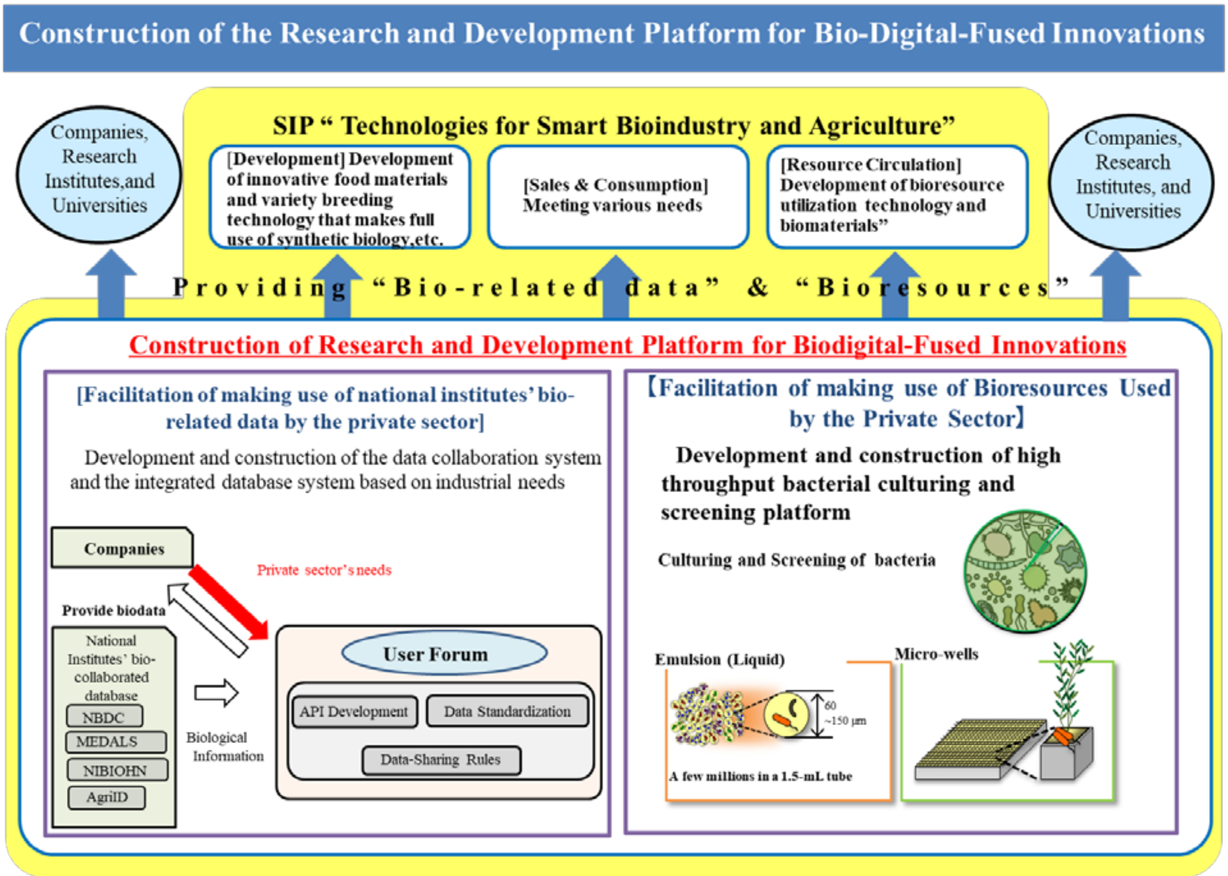


Fig. 2-5 Concept of the construction of a research and development platform for biodigital fusion innovations

Overall image of the biodata collaboration and tasks that we would address.

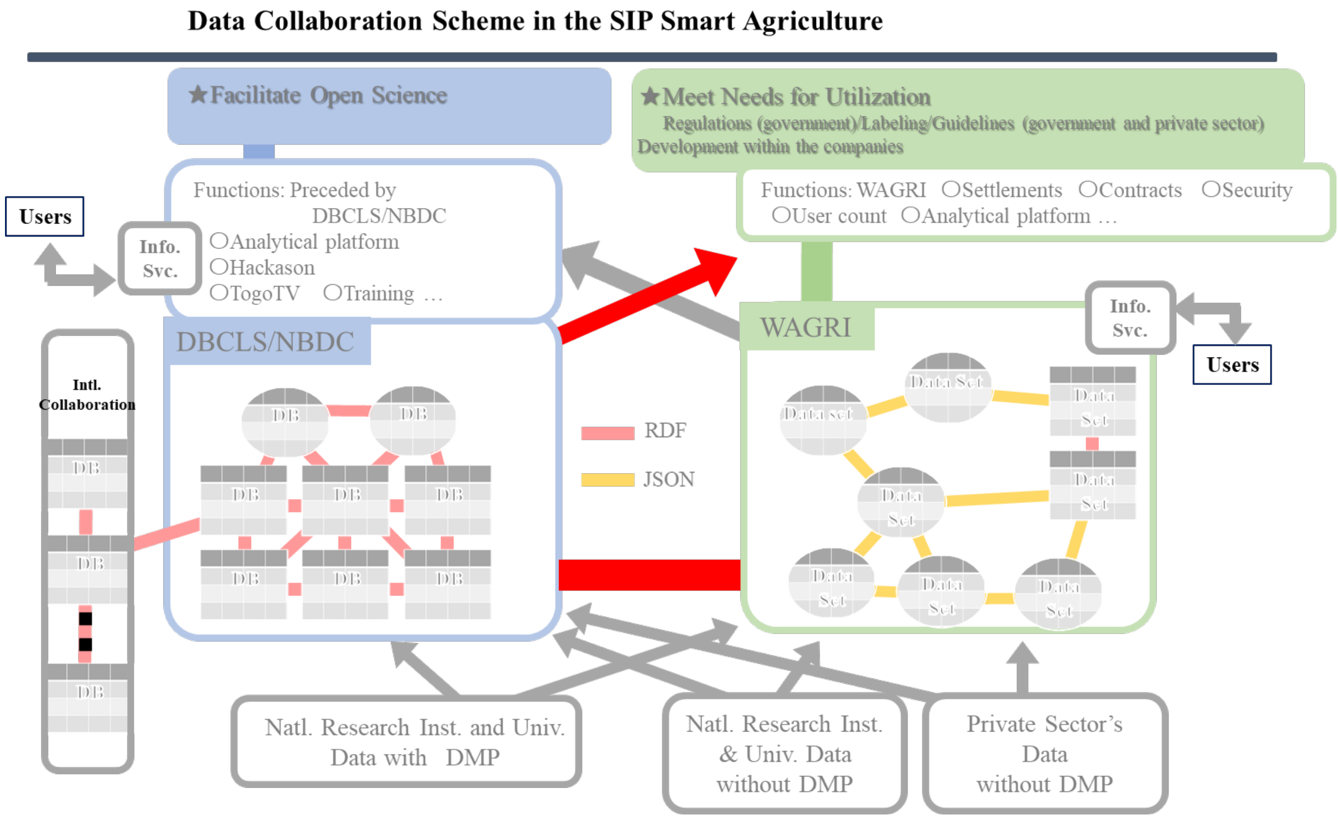


Fig. 2-6 **Schematic illustration showing the relation with WAGRI and data utilization.**

【Necessary Expenses】

Fiscal year 2018	¥185M
Fiscal year 2019	¥142M
Fiscal year 2020	¥121M

【Research Projects and Development】

We will investigate industrial requirements related to biological information. For the existing bio-related DB and the bio-related DB constructed in the present SIP task(s), we will proceed with API development for data collaboration. In addition, we will develop an application for integral analysis using AI. We will construct the system to use the bio-DB collaboratively and integrally, equipped with AI-analyzing function (integrated DB group). With the establishment of a security platform for block chain technology and development of the structure for data distribution, we will encourage the sharing of former competitive domain data from bio-companies, thereby further accelerating innovation. To explore new field(s) that will be our country's strength, we will develop the platform environment to effectively acquire data from the integrated DB group and easily use it for AI analysis. In addition, introducing the open–close system, we will classify the data into data open to general public and data open to user forum(s). We will accelerate our work on integration of the bio-DB. Simultaneously, we will promote works for the development and construction of the biodigital collaboration hub(s) through facilitation of their utilization and application.

Furthermore, we will develop small-sized high-speed microbial isolation, culturing, and screening technologies. By establishing a culturing method using microchannels and microsubstrates, it becomes possible to realize a work that conventionally required 1000 agar culture plates with an miniaturized device. We will construct a platform that can perform large-scale culturing and screening of high-performance bacteria, intestinal bacteria, and bacteria that promote plant growth. Using this platform, we will discover new functional bacteria and develop a large-scale biological resource collection. Among the acquired bacteria , for the useful ones, we will collect data regarding their gene and functional information. Simultaneously, we will store the data in the integrated DB, which we proceed with in parallel, to facilitate their utilization and application.

【Participating Organizations】

Principal Researcher: Yuji Kohara (Research Organization of Information and Systems)

Research Organization of Information and Systems; National Agriculture and Food Research Organization; National Institutes of Biomedical Innovation; Health and Nutrition; National Institute of Technology and Evaluation; Institute of Physical and Chemical Research (RIKEN); Kazusa DNA Research Institute; Hitachi Ltd.; Nagaoka University of Technology; University of Tokyo; University of Yamanashi; Niigata University of Pharmacy and Applied Life Sciences; National Institute of Technology, Tsuruoka College; Research Organization for Nano & Life Innovation, Waseda University; National Institute of Advanced Industrial

Science and Technology; Kyushu University; On-chip Biotechnologies Co. Ltd.; Nikon Instech Co. Ltd.; National Institute of Technology, Nagaoka College

【Goals of the Year】

- We will continue converting data obtained from collaborating agencies into resource description framewaork(RDF)data. Simultaneously, we will release the API for cross-database search. Based on a prototype of the open–close system, we will start developing the system to collaboratively and integrally utilize the bio-DB, which is equipped with AI-analyzing functions (integrated DB group). We will perform test operations on the prototype of the open–close system and identify improvement scope. We will also proceed with biodata standardization of other tasks and start storing the biodata in the open–close system. We will continue developing a prototype of the security platform and provisionally operate the data obtained in other tasks as sample(s). Simultaneously, we will ask the participating companies of the respective tasks for test use to obtain feedback. We will continue organizing meetings related to company needs regarding the utilization of bio-related data and former competitive domain data.
- We will establish a technology to efficiently search the biological resources of Japan. For acquiring domesic biological resources and developing data of biological information obtained from the biological resources, we will accelerate the demonstration of large-scale culturing and screening via the high-speed isolation and culturing platform developed by the second year. Specifically, in the development of the microbial culturing and screening platform using water-in-oil droplets (WODL), we will construct a single droplet isolation system. Furthermore, we will create product(s) of the developed large WODL making chips. We will also construct an assay system for screening bacteria that live symbiotically with plants. In addition, we will conduct microbial screening for isolating actinomycetes from the rhizosphere of terrestrial plants and for wastewater treatment. For the acquired microbial group(s), we will obtain data by 16S/18S amplicon analysis, which would subsequently be stored provided the integrated DB.

【Interim Goals】

- We will continue collecting RDF data and will release an API for cross-DB searches. We will initiate the development of a system for collaborated and integrated utilization of the bio-DB, which is equipped with an AI-analyzing function. We will also advance the biodata standardization and start storing them in the system. We will continue developing a prototype of the security platform. We will tentatively operate the platform by using the data acquired from the respective tasks as samples.
- We will accelerate the demonstration of large-scale culturing and screening using the high-speed isolation and culturing platform of bacteria, developed by the second year. In WODL development, we will construct a single-droplet isolation system. Furthermore, we will develop products of the large WODL making chips that we developed. We will also construct an assay system for screening the microbial group that lives symbiotically with terrestrial plants. Furthermore, we will conduct microbial screening for isolating actinomycetes from the rhizosphere of terrestrial plants and for wastewater treatment. For the acquired microbial group(s), we will obtain by 16S/18S amplicon analysis, which would be sored in the integrated DB.

【Final Goals】

- We will officially release the integrated DB group(s) that we have developed. Simultaneously, we will continuously obtain feedback and improve the system. We will continue the standardization of biodata obtained from other tasks and storing them in the open–close system. We will begin the operation of the security platform including the former competitive domain data as well as the open–close system. We will continue our efforts for obtaining the former competitive domain data that we could distribute in the future. We will integrate the existing DBs in Japan such that they would be usable in society and industries, and subsequently construct biodigital distribution hub(s). We will also study the system’s structure to attain autonomic system operation.
- We will complete developing the technology platform for company need-oriented biological resources, which is easily used and is useful for general purposes. We will develop the biological resources and biological gene resources. Simultaneously, we will strengthen the structure for practical use of the developed platform and utilization of biodata and biological resources by the private sector. For this purpose, we will complete developing the technology for high-speed microbial isolation, culturing, and screening based on the WODL; then, we will construct the utilization system. In the case of element technologies, we will proceed with quickly initiating their practical use after completion of the project for those that can be easily put in practical use, such as a microdevice that is suitable for WODL observation, replica production and storage, reagent kit(s) for detecting microbial growth droplets using a florescent probe. While collaborating with other tasks, we will make progress in acquiring the intestinal microbial group and microbial groups that live symbiotically with plants; next, we will proceed with providing them to the integrated DB. Taking advantage of our capability of acquiring the bacteriathemselves, we will also focus on the acquisition of real data, which can be obtained from actual culturing, in addition to the genome information. Based on this acquisition, we will contribute to the enhancement of international competitiveness of Japan in bioresource data.

3. Implementation System

(1) Activity of Bio-oriented Technology Research Advancement Institution, National Agriculture and Food Research Organization (BRAIN/NARO)

With the grant provided to the BRAIN/NARO (hereinafter referred to as “the management corporation”), we will work on the project in the system shown in Fig. 3-1.

Based on the decisions made by the PD and the Promotion Committee, the management corporation shall recruit the primary participants for the respective research, organize selection and evaluation committee(s), and conclude agreements. In addition, the management corporation shall manage funds, manage progress in the respective research work (including IP management), operate plan study meetings and peer review meetings, as well as work on public relations of tasks and research results. In addition, the management corporation shall provide necessary support to administrative works related to the self-examination by the main participant(s) of the research and administrative works related to third party evaluation, which is required for self-examination by the PD based on directions from the PD and the Cabinet Office secretariat.

(2) Selection of Principal Researchers

Based on the project, the management corporation shall publicly recruit candidates for the primary participant(s) of the research. Based on the examination results of the selection and evaluation committee comprising the PD, Sub-PD, and external specialists, the management corporation shall select the primary participants of the research. The management corporation will be in charge of administrative work in the examination.

Here, the examination criteria and committee members shall be determined in consultation with the PD and the Cabinet Office.

Any committee members having interests in the primary participants of the research, who make proposals to be examined, shall be excluded from the examination of the proposals.

(3) Optimization of the Research System

① Establishment of the Promotion Committee

To make the adjustments required to implement the task, we establish a Promotion Committee. In this Promotion Committee, the PD shall serve as the chairperson and the Cabinet Office shall serve as its secretariat. In addition, the Acting PD, Sub-PD, Strategy Coordinators (hereinafter referred to as “Strategy C”), related ministries, the management corporation, and specialists shall participate in the Promotion Committee.

② Collaboration with New Energy and Industrial Technology Development Organization

For proceeding the work described above in (1), the management corporation shall collaborate with New Energy and Industrial Technology Development Organization (hereinafter referred to as “NEDO”) and make efforts to generate a synergetic effect.

③ Research System

(i) Research promotion by a consortium unit.

This task is based on forming a consortium by each recruiting unit to conduct research. Each of the consortiums described herein comprises universities, national research and development agencies, and companies aiming at the practical use of research results.

A Principal Researcher of each of the consortiums will closely collaborate with other members under guidance and advice from the PD and the Sub-PD and proceed with the research to generate synergetic effects.

(ii) Collaboration between consortiums

The PD or the Sub-PD shall understand the progress status of research works in the respective research consortiums,and provide guidance and advice to the respective principal researchers for the matters that require collaborations among the consortiums. Simultaneously, the PD or the Sub-PD shall call for those involved as necessary along with study measures for effective collaboration.

(4) Cross-Ministerial and Agency Collaboration

We will create innovations to expand the bioeconomy in Japan, improve productivity in the agricultural, forestry and fishery, and food industries, and strengthen Japan’s competitiveness. For this purpose, we need to gather and fuse advanced technologies as well as basic and platform technologies of various fields, such as biotechnology, IoT, robot, data science, and AI, which the respective ministries are involved in. Simultaneously, we need to systematically implement the projects of the respective research and development tasks in layers.

In addition, we need to develop the environment to facilitate the use of research and development results by the private sector, such as construction of the data collaboration system and integrated DB, and need to collaborate with ministries responsible for the related regulations and systems.

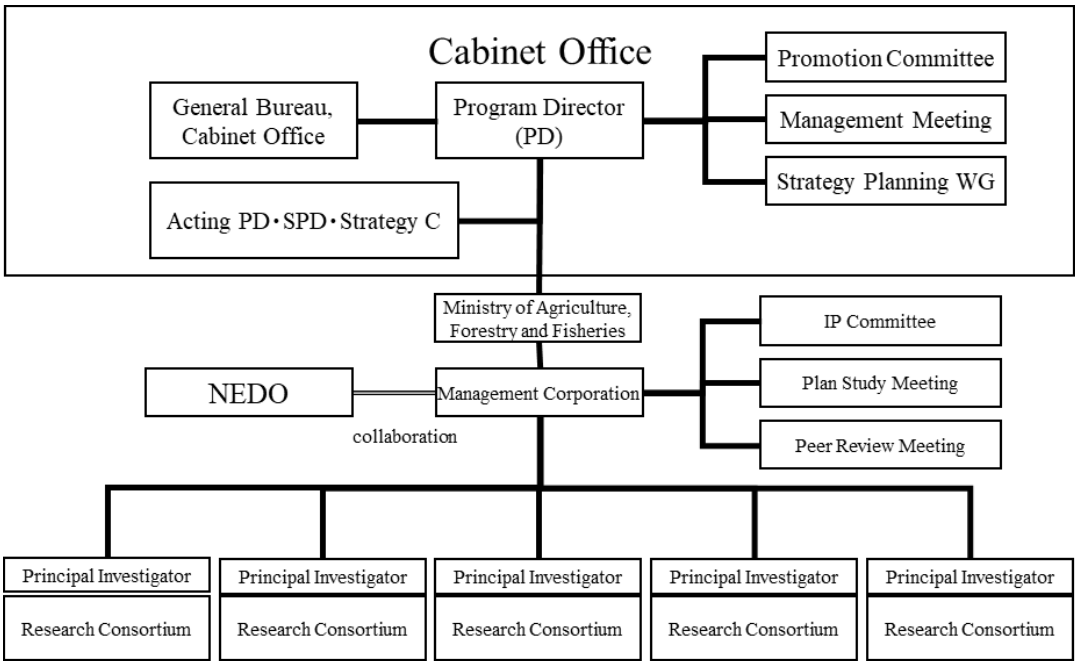
For this reason, the PD will take initiative and the related ministries will closely collaborate each other to work on those

R&Ds, development of the environment, and renovation of the regulations and systems.

(5) Contributions from the Industrial Communities

The companies that participate in the respective consortiums shall contribute to the research and development by providing resources, such as human resources, technologies, knowledge, and funds. The (expected) investment ratio from the participating companies and business partners for the overall research and development expenses shall be based on the Strategic Innovation Guidelines.

Fig. 3-1 Implementation System



Organization	Members
Promotion Committee	PD (chairperson); Acting PD; Sub-PD; Strategy Coordinator (Strategy C) Cabinet Secretariat Information & Communication Technology Strategic Office; Cabinet Office National Space Policy Secretariat; National Tax Agency; Ministry of Education, Culture, Sports, Science and Technology; Ministry of Agriculture, Forestry and Fisheries; Ministry of Economy, Trade and Industry; Ministry of Land, Infrastructure, Transport and Tourism; Ministry of Environment; Cabinet Office (Secretariat); Management companies, etc.
Management Meeting	PD (chairperson); Acting PD; Sub-PD; Strategy C, etc.
StrategyPlanning Working Group (WG)	PD (chairperson); Acting PD; Strategy C, etc.
Peer Review Meeting	Peer Review Evaluation Committee (including the chairperson); PD; Acting PD; Sub-PD; Strategy C; Research representatives, etc.
Plan Study Meeting	PD (chairperson); Acting PD; Sub-PD; Strategy C; External specialists.

Title	Full Name	Affiliate
PD	Noriaki Kobayashi	Kirin Holdings Company, Ltd.
Acting PD	Noboru Noguchi	Graduate School of Agriculture, Hokkaido University
Sub-Program Director（Sub-PD）	Yoichi Kamagata	National Institute of Advanced Industrial Science and Technology
	Toshihiko Komari	Japan Tobacco Inc.
	Wataru Mizunashi	New Energy and Industrial Technology Development Organization (NEDO)
Strategy Coordinators (Strategy C)	Koichi Kadowaki	National Agriculture and Food Research Organization
	Takayoshi Kawakami	Industrial Growth Platform Inc. (IGPI)
	Masahiko Shoji	Musashi University
	Atsuhiro Hagiwara	Object of Null Inc.
	Yasufumi Miwa	Japan Research Institute, Ltd

4. Intellectual Properties (IPs)

(1) Intellectual Property Committee

- We establish the Intellectual Property Committee under the management corporation. Based on the policy, the committee of intellectual properties (IPs) can be established in the affiliate institution (contractor) of the principal researcher.
- The Intellectual Property Committee shall be in charge of making decisions on plans related to filing applications and maintenance of the paper publications and patents of research and development results of the institute (hereinafter referred to as "IPs") and will make adjustments. regarding licenses of the IPs as necessary.
- As a general rule, the Intellectual Property Committee shall comprise a PD or an acting PD, major concerned parties, and experts.
- Details of the operating method of the Intellectual Property Committee shall be defined by the institutes to establish the Intellectual Property Committee.
- We will dispatch an advisor who is familiar with IPs, international standardization, data protection, and data distribution.

(2) Agreements on IP Rights

- The management corporation shall determine details by advance agreement(s) with contractor(s), regarding how to handle confidentialities, background IPs, and foreground IPs. Here, background IPs refer to IPs acquired by the principal researcher and/or its affiliate institute before participation in the program and IPs acquired without SIP management expenses. The foreground IPs herein refer to the IPs accrued by the SIP project expenses in the program.

(3) Licensing the Background IP Rights

- Licensing of the background IP rights of the participants in other program(s) shall be based on the conditions set forth by the holder of the IP right (or "based on the agreement between the program participants") and such IP right holders can grant the license.
- In case there is a concern in the IP right holder's response to the conditions that negatively affect the promotion of the SIP (including practical use and commercialization of the results as well as research and development), such an issue shall be coordinated by the Intellectual Property Committee to obtain reasonable solution(s).

(4) Management of Foreground IP Rights

- As a general rule, Article 19 paragraph 1 of the Industrial Technology Enhancement Act shall be applied to the foreground IPs, and the IP rights shall belong to the affiliated institution (contractor) of the principal researcher, who is the inventor.
- Patent rights accrued through joint research between contractor members or between the contractor and cooperating agencies can be shared between the involved parties based on the joint application agreement between the parties of the joint research. The share of each party shall be determined via consultation between the involved parties according to the accrued level of the contribution to the patent right.
- In case the IP right holder is not motivated to commercialization, the Intellectual Property Committee shall recommend the IP to be held by a person who actively commercializes and the setting of license to be held by a person who actively aims for commercialization.
- For a person who opts out during the participation period, the management corporation can have such a person assign and set the license of all or a part of the results he/she obtained by the SIP project fund during the participation period, provided that, if the person participated in a plurality of years, the results herein refer to any results since he/she participated.
- As a general rule, the expenses to file application(s) and maintain IPs shall be borne by the intellectual right holder(s). If an application is filed jointly, the share ratio and expense allocation shall be determined via consultation between the parties.

(5) Licensing Foreground IP Rights

- Licensing of the foreground IP rights to other program participant(s) shall be allowed by the IP right holder(s) according to the conditions set by the IP right holder (or "according to the agreement among the program participants").
- Licensing of the foreground IP rights to a third party may be allowed by the IP right holder according to the conditions set by the IP right holder within the scope that such a third party shall not have more advantageous conditions than those of the program participants.
- In case the response of the IP right holder to those conditions negatively affects the promotion of SIP (including practical use and commercialization of the results as well as research and development), the Intellectual Property Committee shall make suitable coordination and seek for a reasonable solution.

(6) Consents on transfer of Foreground IP Rights and Setting and Transfer of Exclusive Licenses

- Based on Article 19 paragraph 1-4 of the Industrial Technology Enhancement Act, transfer of the foreground IP rights and establishment and/or transfer of exclusive license requires approval of the management corporation, excluding the case of transfer due to company merger or split, transfer of IP rights, establishment/transfer of exclusive license to subsidiary and/or parent company, or the like (hereinafter, referred to as "case of transfer of IP right(s) accompanied by company merger and/or other similar reason).
- In case of transfer of IP right(s) accompanied by company merger and/or other similar reasons, based on the agreement with the management corporation, the IP right holder shall need approval by the management corporation.
- Even after the transfer of IP right(s) accompanied by company merger or other similar reasons, the management corporation shall still be able to hold the license with a sublicense. If the IP right holder cannot accept the condition(s), such transfer shall not be approved.

(7) Management of IP Rights at the Time of Completion

- At the completion of research and development, the Intellectual Property Committee shall discuss what to do with IP rights that nobody desires to hold (abandon or succeed by the management corporation, or the like).

(8) Participations of Foreign Institutes (Companies, Universities, and Researchers of Foreign Countries)

- When participation of foreign institutes is necessary in view of promoting the task, such participation shall be allowed.
- As a general rule, in terms of proper execution management, they must have a liaison office or an agent, which/who can perform administrative works related to the contracting work of the research and development in Japan.
- In case of foreign institutes, the IP right(s) shall be shared between the management corporation and the foreign institute(s).

5. Evaluations

(1) Evaluating Body

Using a report of self-examination results obtained by the PD and the management corporation as a reference, the Governing Board shall invite external experts and conduct the evaluation. At this time, the Governing Board can organize the evaluation by field or by task.

(2) Evaluation Timings

- Evaluations shall include advance evaluation, year-end annual evaluation, and final evaluation.
- After completion, once a certain period of time (3 years in general) has passed, follow-up evaluation may be conducted as necessary.
- In addition to the above, evaluation can be conducted as necessary, such as in the middle of the year.

(3) Evaluation Items and Standards

Based on the "General guidelines for evaluating national research and development" (Decision by the Prime Minister on December 21, 2016)," the evaluation items and standards are set as follows in terms of necessity, efficiency, and effectiveness. The evaluation shall not be conducted focusing on only the level of accomplishment of goal(s); rather, it should be conducted to analyze the causes/reasons and to propose measures for improvements.

① Consistency with significance and object(s) of the SIP system(s).
② Rationality of the goal(s), particularly outcome goal(s), and of achievement levels in the project timeline toward achieving the goal(s).
③ Appropriateness of management, especially in view of how the effects of the cross-ministerial and agency collaboration are exhibited.
④ Strategic approaches and achievement level toward practical use and commercialization
⑤ Expected or ripple effects at the time of final evaluation. Presence of the follow-up method after completion that is properly and clearly set.
⑥ The items listed below.

1) Consistency with Society 5.0
2) Focus level toward the field that requires productivity revolution.
3) Contribution level to the social revolution.
4) Level of contribution to solving social tasks and Japanese economic/industrial competitiveness.
5) Clarity of the exit strategy toward commercialization, practical use, and implementation in the society. (Clear vision for commercialization after 5 years)
6) Presence/Absence of the exit strategy in the systemic aspect, e.g., IP strategy, international standardization, and regulatory reform.
7) Engagement level in cross-field task(s), which essentially require cross-ministerial and agency collaboration.
8) Strategic approaches in research and development considering from basic research through commercialization and practical use.
9) Setting of the "cooperating area(s)" and presence/absence of distinction from the "competing area(s)." (i.e., whether it has an open–close strategy)
10) Level of construction of the industrial–academia–government collaborating system, and built-in level of a structure and matching funds to connect research and development results to practical use and commercialization by participating companies

⑦ Status of achieving technology readiness levels (TRLs) through research theme(s) of the respective tasks

(4) How to Reflect the Evaluation Results

- Advance evaluation shall be conducted for the plan(s) of the subsequent years and the evaluation results shall be reflected in the plans of the subsequent years.
- In the year-end evaluation of each year, we will narrow down or add task(s) and research theme(s) as necessary.
- The year-end evaluation shall be conducted for the performance up to the year and plans of the following year and later, and the evaluation results shall be reflected in the plans of the subsequent years.
- The final evaluation shall be conducted for the results up to the final year and the evaluation results shall be reflected in follow-ups after completion.
- The follow-up evaluation shall be conducted for progress in practical use and commercialization of the results of the respective tasks and include the proposal of measures for improvement.

(5) Publication of the Evaluation Results

- As a general rule, the evaluation results shall be released.
- The Governing Board that conducts the evaluations also handles research and development information that is not open to public. Therefore, its evaluation results shall not be released.

(6) Self-Examination

① Self-examination by a principal researcher

A PD shall select a principal researcher who conducts self-examination (as a general rule, primary researchers/research institutes of the respective research items shall be selected for this position). The selected principal researcher shall follow the Evaluation Items and Standards in 5.(3) and shall conduct inspection on both the performance after the previous evaluation and future plan. The principal researcher shall put together analysis results of the causes/reasons of the performance and measures for improvement, as well as judgment on the achievement level of the goal(s).

② Technical evaluation in expert's view（peer review）

The self-examination shall be conducted by the management corporation using technical evaluation through an expert's view (peer review). The results of this self-examination shall be reported to the Governing Board.

③ Self-Examination by PD

Using the self-examination results by the principal researcher and peer review results by external experts as reference, and following the evaluation items and standards in 5.(3) listed above, the PD shall inspect the PD him/herself, the management corporation, and the respective principal researchers in terms of their performance and future plans. In addition, to grade the achievement level of the goal(s), the PD shall put together his/her analysis on the causes/reasons of the achievement levels and measures for improvement. With these results, continuation of the research such as the respective research subjects and provide necessary advices to the principal researchers. Using this approach, the system can be made autonomically improvable.

Based on the results, the PD shall prepare reference materials for the Governing Board with support from the management corporation.

④ Self-Examination by the management corporation

The self-examination by the management corporation shall be conducted to evaluate whether the administrative procedures have been properly implemented for budget implementation.

6. Exit Strategy

(1) Promoting exit-oriented research

As a whole, we will keep the following items in our mind:

- Based on the introduction of matching-fund method after the interim evaluation in 2020, we will clearly indicate the items to be invested into from the private sector to the respective research consortiums and promote their increase.
- We will conduct global benchmark investigation in future. Based on the results, we will regukarky update the research.

① Contribution of manpower, materials, and funds from participating companies

The companies participating in the respective consortiums shall provide manpower, technology, knowledge, and funds to contribute to the research and development. The investment ratio (expected) from the participating companies and business partners for the overall research and development expenses shall be based on the Strategic Innovation Guidelines.

② Collaboration with other related tasks

For the "productivity revolution and higher profit of the agricultural, forestry and fishery, and food industries using the smart food system that utilizes various data," we will collaborate with tasks related to the SIP "smart distribution service," the SIP "cyber space platform technology using big data and AI," and PRISM to generate synergetic effects.

③ Transfer destination (recipient) of the research results

To release products and/or services in the market as an exit of the research results, the research results shall be practically used by a company participating in the respective consortiums, or by a company/companies to which the IP right(s) of the research results are assigned/transferred to from the IP right holder(s), such as national research and development institutes and universities.

For the platform-type research results that are to be widely used by the government and the private sector, such as the smart food system,, we will practically implement the results by widely calling for new business ideas and for companies participating in the respective consortiums.

④ Technology transfer to the private sector

For results that are to be practically implemented or developed into actual products, the SIP shall create a prototype. Then, the recipient company, or the like will be in charge of the practical use including mass production.

For the research results to be widely used by the government and the private sector, the SIP shall validate the effectiveness of the results in a use case. Thereafter, the operation, maintenance, and management shall be primarily performed by the companies participating in the consortium.

⑤ Manpower training

For creating innovations via biodigital fusion, training human resources to have cross-field skills and knowledge and to further have a sense of business management is indispensable.

In the research and development of this task, we will gather young researchers to provide on-the-job training. Simultaneously, we will collaborate with a promoting plan for recurrent education of AI/informatics manpower training to train manpower.

(2) Strategies to be Widely Recognized

As a whole, we will keep the following points in our mind.

- According to the progress status of the task, we will release information domestically and internationally, and expand and enrich international collaboration by organizing international meetings.

① [Development] Development of innovative food ingredients and quality development technology

We will prepare an environment for the major seeds and seedling companies and municipalities of Japan to practice and use "data-driven breeding," thereby achieving the breeding of varieties matching the domestic and/or international market and the needs of processors that are also consumers sooner. Based on this approach, we will aim at strengthening our country's system in terms of developing seeds and seedlings. In addition, we will lower the technical hurdles to encourage participation in the development of the seeds and seedlings by other types of industries.

We will also tackle other hurdles such as regulations and people's understanding and build actual cases of production and commercial sale of genome-edited agricultural produce. This will further promote the people engaging in the agricultural, forestry and fishery, and food industries to produce, utilize, and sell genome-edited agricultural produce.

② [Production] Development of the Smart Production System; ［Distribution and Processing］ Cost reduction and development of the optimization technology; and ［Utilization of Information］ Construction of a prototype of the ICT platform for establishing the smart food system

The completed technology shall be successively transformed into saleable products and commercialized by the participating company/companies, or by a company/companies to which the license is assigned from the research institute(s) having the IP right(s). In addition, for the smart food system, even after task completion, we will work on the expansion of the participating institutes and improvement of functions.

③ ［Construction of Value Chain Data Platform］ Construction and validation of the DB data distribution platform, in which DB data are aggregated and collaborated.

For the development and operation of the bio-related big data, we will construct the collaboration system for DB-related institutes, such as the Japan Science and Technology Agency (JST) and the National Bioscience Database Center (NBDC). We will develop the system to comprehensively use the omics data linked with biofunctions such as metabolic capability, as one big data. We will organize the systems, such as open or closed data and give incentives for providing closed data. In addition, we will encourage participation from industries. Through these approaches, we will advance the industrial use of biological information.

④ [Sales and Consumption] Efforts to meet various needs

While promoting the research, we will also expand the network for the industry–academia–government collaboration. Even after task completion, we will continuously construct and develop the system to accumulate and use the scientific evidence.

Utilizing the “integrated information DB of the agricultural, forestry and fishery, and food products,” the research institutes, universities, and companies can fulfill the quality and content of their research reviews of health-improving effects of agricultural, forestry and fishery, and food products, and can conduct secondary data analysis. Based on this, we will encourage agricultural corporations, food companies, companies providing readymade meals, restaurant foods, and school meals to file applications for foods with function claims of agricultural, forestry and fishery, and food products to release them in the market. Furthermore, formulating new diet guidelines and a guide for maintaining and enhancing health, we will promote the provision and utilization of the agricultural, forestry and fishery, and food products that are expected to provide health-maintaining and enhancing effects based on scientific evidence.

In addition, we will introduce a new service to selected municipalities in advance. In this new service, using the developed health-check technology such as the one used to determine mild physical condition changes, an individual’s health condition is checked; accordingly, foods and a diet plan will be proposed based on the individual’s health condition. We will release the results in collaboration with the media and then expand the service nationwide.

For the “integrated information DB of agricultural, forestry and fishery, and food products,” the national research and development institute(s) will continue to take initiatives even after task completion, and construct the system to develop and operate in collaboration with the private sector and related research institutes. Moreover, for the intestinal microbiome data, the private sector and related research institutes will collaborate and construct the system to develop and operate an industrially usable database.

⑤ [Resource Circulation] Development of biomaterials and bioresource utilization technology

In the development and practical use of the production system of high-performance products and biomaterials that use biofunctions, we will implement them at a pilot-scale level and demonstrate their usefulness. We will also encourage the building of full-scaled plant(s) based on investments by companies and advancing commercialization.

For the development of the next-generation core technology in the chemical industry utilizing unused resources of the agricultural and forestry and fishery industries, we will construct a collaboration system for commercialization, with the participation of related companies, related organizations of agricultural and forestry and fishery industries, and municipal governments from the beginning of the research and development. Simultaneously, we will prepare an environment for commercialization by studying the collection system and the commercialization model of unused resources of agricultural and forestry and fishery industries while considering the cost and supply stability.

7. Other Important Matters

(1) Overall Strategic Flow

2020 is the interim evaluation year. We will implement the stage-gate process during peer review and narrow down the research themes and contents that are suitable for optimization and advancement of the entire smart food system and are feasible to implement in actual society. In addition, we will make further progress with the following points.

- Thorough implementation of task management via stage-gate and exit strategy based on the implementation and narrowing down as well as promotion of important points of the research and development themes in view of overseas trends.
- Clarification of the implementation goals in actual society for each task and acceleration of our attempts/efforts for the goals.

(2) Flexible Plan Modifications

We will flexibly review the plan in view of accelerating and maximizing the results.

(3) Laws and Ordinances

This subject shall be implemented based on the following legislation:

Act for Establishment of the Cabinet Office
（Act. No. 89 of 1999）Article 4, Paragraph 3, Item 7-3)
Basic Policy of Funds for the Creation and Promotion of Science, Technology and Innovation
（Council for Science, Technology, and Innovation on May 23, 2014）
Cross-ministerial Strategic Innovation Promotion Program (SIP), The 2nd Term (Amended budget measures of 2017) Implementation Policy
(Council for Science, Technology and Innovation, March 29, 2018)
Cross-ministerial Strategic Innovation Promotion Program (SIP) (Amended budget measures of 2018) Implementation Policy
(Council for Science, Technology and Innovation Governing Board, February 28, 2019)
2019 Cross-ministerial Strategic Innovation Promotion Program (SIP) Implementation Policy
(Council for Science, Technology and Innovation Governing Board, June 27, 2019)
Cross-ministerial Strategic Innovation Promotion Program Guidelines

(Council for Science, Technology and Innovation Governing Board, June 27, 2019)

(4) Program Director and Person-in-Charge (Service Periods)

① Program Director

Noriaki Kobayashi (April 2018–)

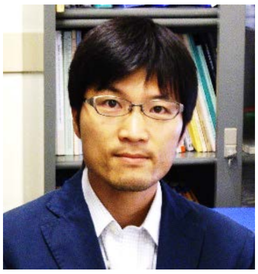
② Directors (Officers, Counselors)

Kiyoshi Nakajima
(April 2018–December 2018)

Sachiko Mori
(January 2019–)

③ Persons-in Charge

Takeshi Ishii
(April 2018–
April 2020)



Akifumi Ogino
(April 2018–
April 2019)

Hisataka Numa
(April 2019–
December 2019)

Akira Fukushima
(January 2020–
March 2020)

Yuto Arata
(April 2020–)

Tadaharu Hibi
(April 2020–)

Appendix

Financial Plan and Estimates

Year 2018 Total ¥3,200M

（Itemized Expenses）

1. Research expenses (including general management costs and indirect costs) ¥2,910M

（Expenses by research and development subjects）

(A) Establishment of new food-based health system for longer healthy life ¥445M

(B) Productivity revolution and strengthening of competitiveness of the agricultural, forestry and fishery, and food industries by utilizing various data ¥1,489M

(C) Realization of a sustainable growing society by "product creation using biofunctions" ¥761M

(D) Construction of a research and development platform to create biodigital fused innovations ¥215M

2. Business project promoting expenses (e.g., labor costs, evaluation fees, and meeting expenses) ¥90M
3. Expenses required for enhancing the business projects (*Expenses increased at the time of set allocation, which is expected to be adjusted in the following year) ¥200M

TOTAL ¥3,200M

Year 2018 supplementary budget by the measures Total ¥200M

（Itemized Expenses）

1. Research expenses (including general management costs and indirect costs) ¥194M

（Expenses by research and development subjects）

(2) [Production] Development of the Smart Production System;［Distribution and Processing］Cost reduction, development of optimization technology; and［Utilization of Information］Construction of a prototype of the ICT platform for construction of the smart food system ¥194M

2. Business project promoting expenses (e.g., labor costs, evaluation costs, and meeting expenses) ¥6M

TOTAL ¥200M

Year 2019 Total ¥2,500M (including the adjustment of item 3 of 2018)

（Itemized Expenses）

1. Research expenses (including general management costs and indirect costs) ¥2,425M

（Expenses by research and development subjects）

(1)［Development］Development of innovative food ingredients and variety growing technology using synthetic biology. ¥272M

(2) [Production] Development of the smart production system;［Distribution and Processing］Cost reduction and development of optimization technology; and［Utilization of Information］Construction of a prototype of the ICT platform for construction of the smart food system ¥1,086M

(3)［Construction of Value Chain Data Basis］Validation of the database (DB) data distribution platform, in which DB data are aggregated and collaborated ¥142M

(4) [Sales and Consumption] Efforts to meet various needs ¥341M

(5) [Resource Circulation] Development of biomaterials and bioresource utilization technology ¥584M

2. Business project promoting expenses (e.g., labor costs, evaluation costs, and meeting expenses) ¥75M

TOTAL ¥2,500M

Year 2020 Total ¥2,375M

（Itemized Expenses）

1. Research expenses (including general management costs and indirect costs) ¥2,233M

（Expenses by research and development subjects）

(1) [Development] Development of innovative food ingredients and quality development technology	¥235M
(2) [Production] Development of the smart production system; ［Distribution and Processing］ Cost reduction and development of optimization technology; and ［Utilization of Information］ Construction of a prototype of the ICT platform for construction of the smart food system	¥759M
(3) [Sales and Consumption] Efforts to meet various needs	¥340M
(4) [Resource Circulation] Development of biomaterials and bioresource utilization technology	¥496M
(5) ［Construction of Value Chain Data Basis］ Construction and validation of the DB data distribution platform, in which DB data are aggregated and collaborated	¥121M
2. Strategic acceleration research expense (reserved at the beginning of the year)	¥281M
3. Business project promoting expenses (e.g., labor costs, evaluation costs, and meeting expenses)	¥143M
TOTAL	¥2,375M

Project Timeline