

Sustainable Solutions for Personal Food Production through Disruptive Technologies

“Development of Innovative Food Solution for Simultaneous Food Loss Reduction and QoL Improvement”

BRAIN - Moonshot Agriculture, Forestry and Fisheries Research and Development Project

NAKAJIMA Mitsutoshi

**Project Manager, University of Tsukuba
Chair, IUFoST - Japan**

We choose to go to the Moon.

John F. Kennedy

The Moonshot Research and Development Program sets ambitious goals to attract people, and promotes challenging R&D projects with the aim of resolving difficult societal issues while bringing together the wisdom of researchers from all over the world.

Moonshot for Human Well-being

Moonshot Research and Development Program

Bureau of Science, Technology and Innovation, Cabinet Office, Government of Japan



7 MS goals to be achieved

Goal #1: Realization of a society in which human beings can be free from limitations of body, brain, space, and time by 2050.

Goal #2: Realization of ultra-early disease prediction and intervention by 2050.

Goal #3: Realization of AI robots that autonomously learn, adapt to their environment, evolve in intelligence and act alongside human beings, by 2050.

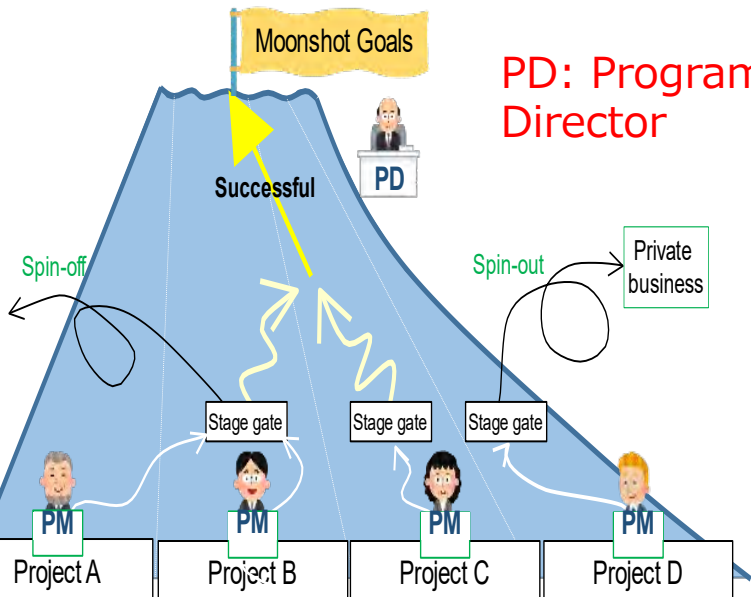
Goal #4: Realization of sustainable resource circulation to recover the global environment by 2050.

Creation of the industry that enables sustainable global
Goal #5: food supply by exploiting unused biological resources by 2050.

Goal #6: Realization of a fault-tolerant universal quantum computer that will revolutionize economy, industry, and security by 2050.

Goal #7: Realization of sustainable care systems to overcome major diseases by 2040, for enjoying one's life with relief and release from health concerns until 100 years old"

PD: Program Director



PM: Project Manager

Outline

To develop radical solutions for difficult societal challenge, the Government of Japan set inspiring and ambitious goals for challenging R&D.

Goals

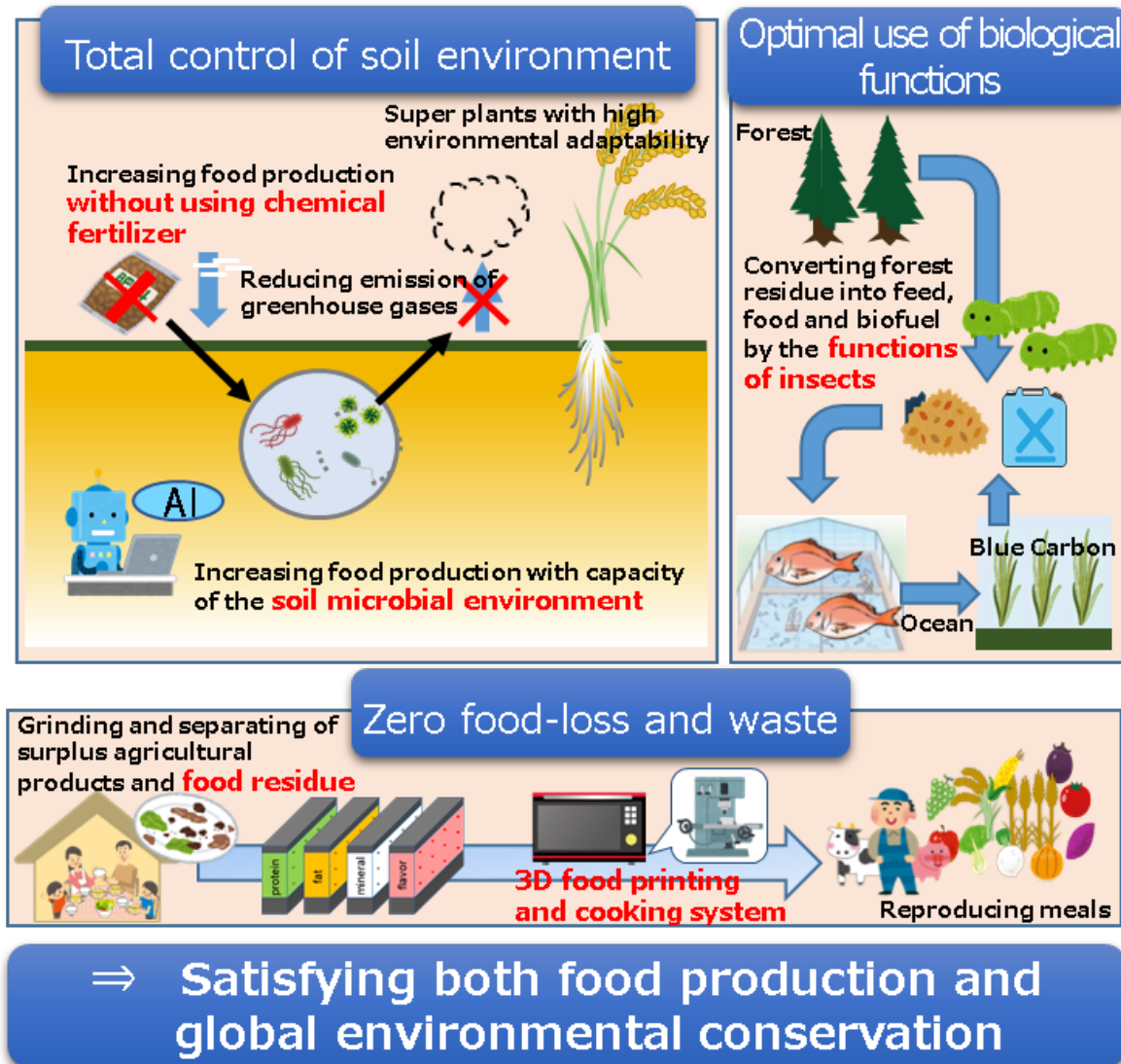
To realize “Human Well-being”, 7 Moonshot (MS) goals were decided in the area of society, environment, and economics.

Goal #5 BRAIN Moonshot Agriculture, Forestry and Fisheries Research and Development Project

Creation of the industry that enables sustainable global food supply by exploiting unused biological resources by 2050.

<Target of Moonshot Goal>

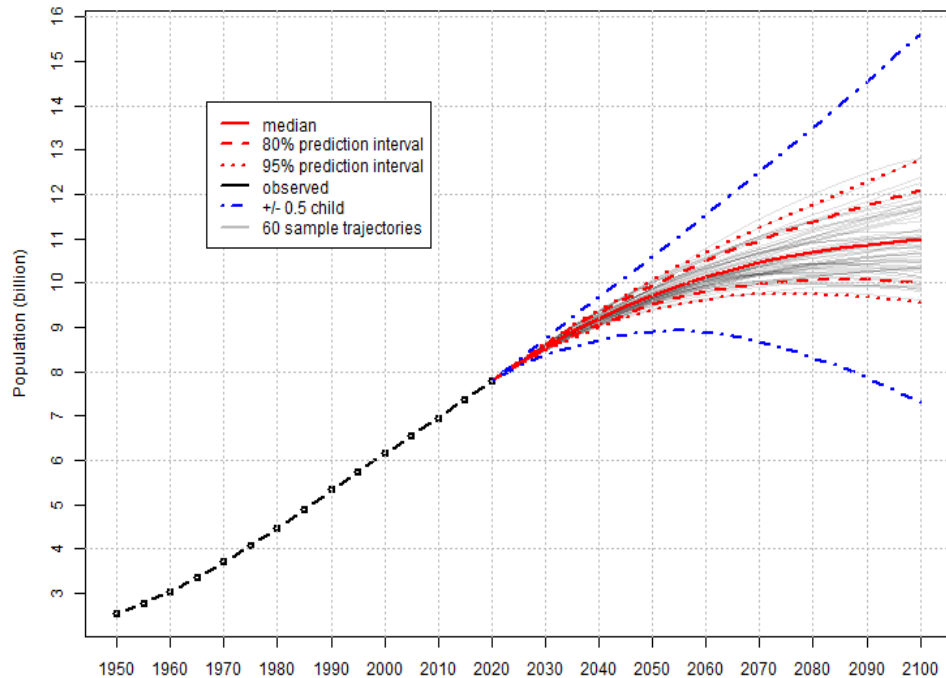
- Technical development of the circular food production systems by biological measures, e.g. utilizing microbes and insects, by 2050.
- **Development of technical solutions for eliminating food loss and waste and achieving both healthy life and sustainable food consumption by 2050.**
- Evaluation of the technical achievements and discussion on the ethical, legal and social implications (ELSI) matters will be done by 2030, for global spread of the technology by 2050.



Sustainable food supply without food-loss and environmental loading

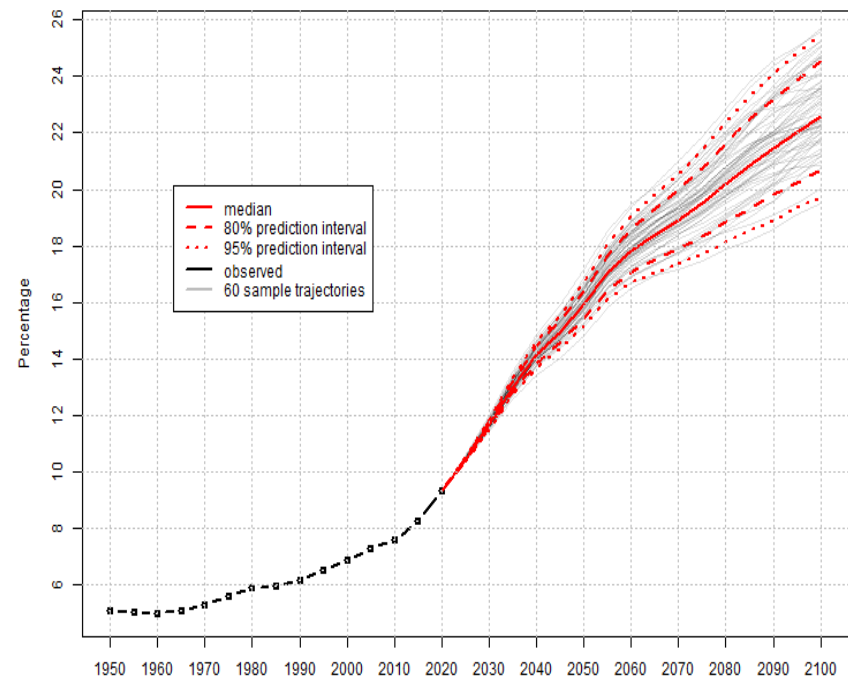
World Total Population and Percentage of Population Aged 65 Years or Over

World: Total Population



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United Nations, DESA, Population Division. *World Population Prospects 2019*. <http://population.un.org/wpp/>

World: Percentage of population aged 65 years or over



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United Nations, DESA, Population Division. *World Population Prospects 2019*. <http://population.un.org/wpp/>

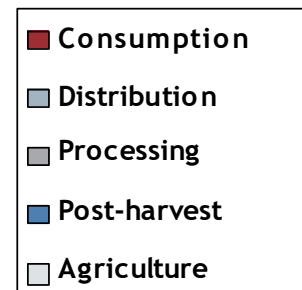
<https://population.un.org/wpp/Graphs/Probabilistic/POP/TOT/900>

World population and the Elderly population

	2015	2050
Total population	7350 M	9190 M
Developed countries	1260 M	1240 M
Developing countries	6090 M	7950 M
Developed (≥ 65)	220 M(17.6%)	330 M(26.1%)
Developing (≥ 65)	390 M(6.4%)	1170 M(14.7%)
Japan	130 M	100 M
Japan (≥ 65)	34 M(26.6%)	38 M (38.0%)

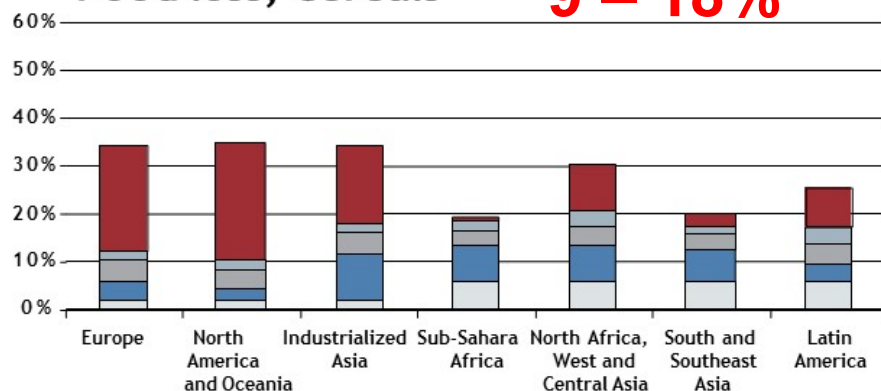
Of the growing 1800 M people, 900 M are the elderly in developing countries. Expectations are high for Japan, as the leading country in the aging society.

Food Loss, FAO 2011



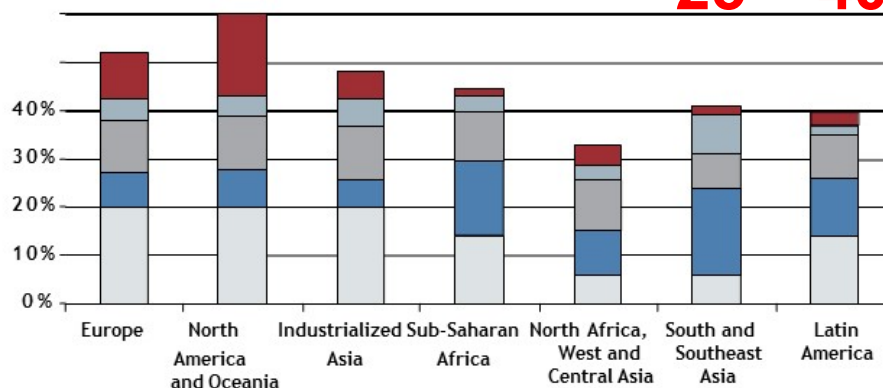
Food loss, Cereals

9 – 18%



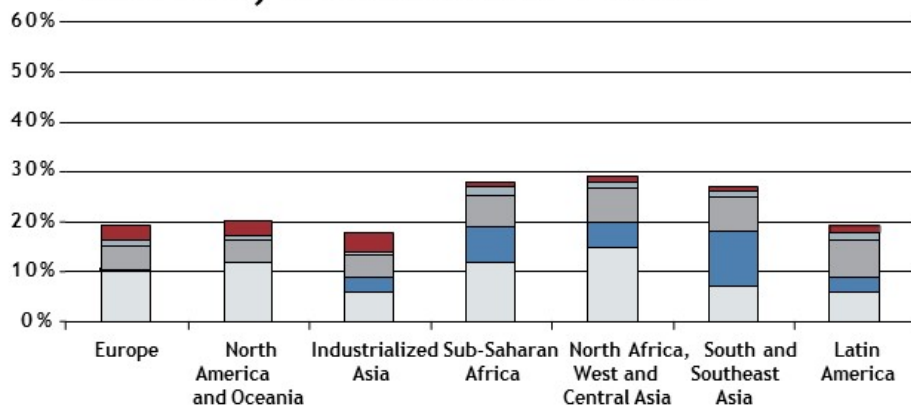
Food loss - Roots and Tubers

25 – 40%



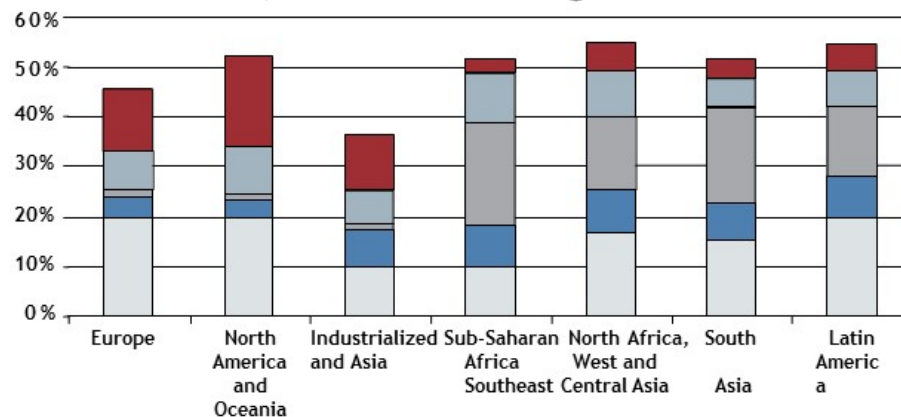
Food loss, Oilseeds and Pulses

15 – 27%

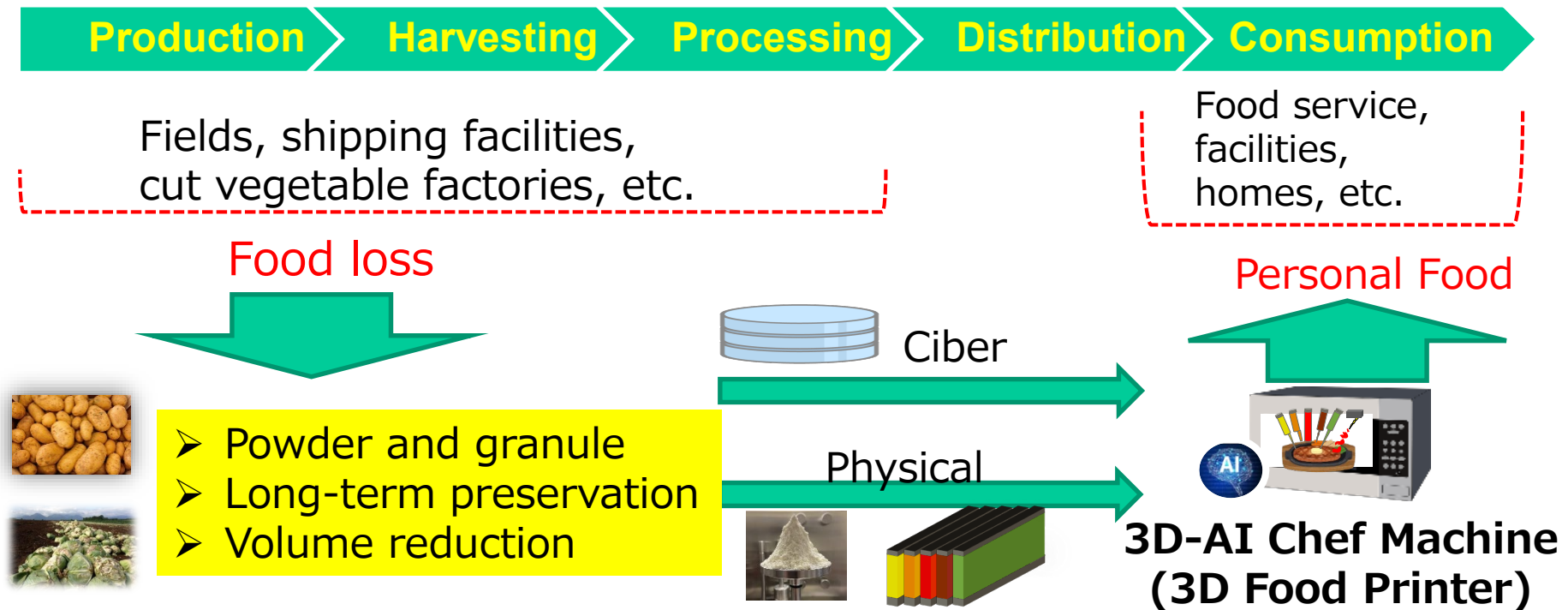


Food loss, Fruits and vegetables

20 – 42%



Long-term storage in upstream of the chain to reduce loss in downstream.



Personal foods from food loss materials.

QoL for the elderly, the growing population of lifestyle-related diseases, and nutritional imbalance.

Personal foods that meet individual tastes and health conditions, such as tasty foods for the elderly preventing lifestyle-related diseases, and longer healthy life expectancy.

Measures have been taken to reduce food loss and create a healthy society, but...

Problems of food loss control at the production stage

Freeze-dried foods: limited use, low consumption

Canned and retort-packed foods: lose their original texture and aroma

Frozen foods: The longer the shelf life, the higher the energy cost.

Dried foods: High variability in quality

Measures to improve quality of life (QoL)

Developed countries: Healthy food and supplements do not taste good. Excessive or insufficient nutrition (lifestyle-related diseases, etc.).

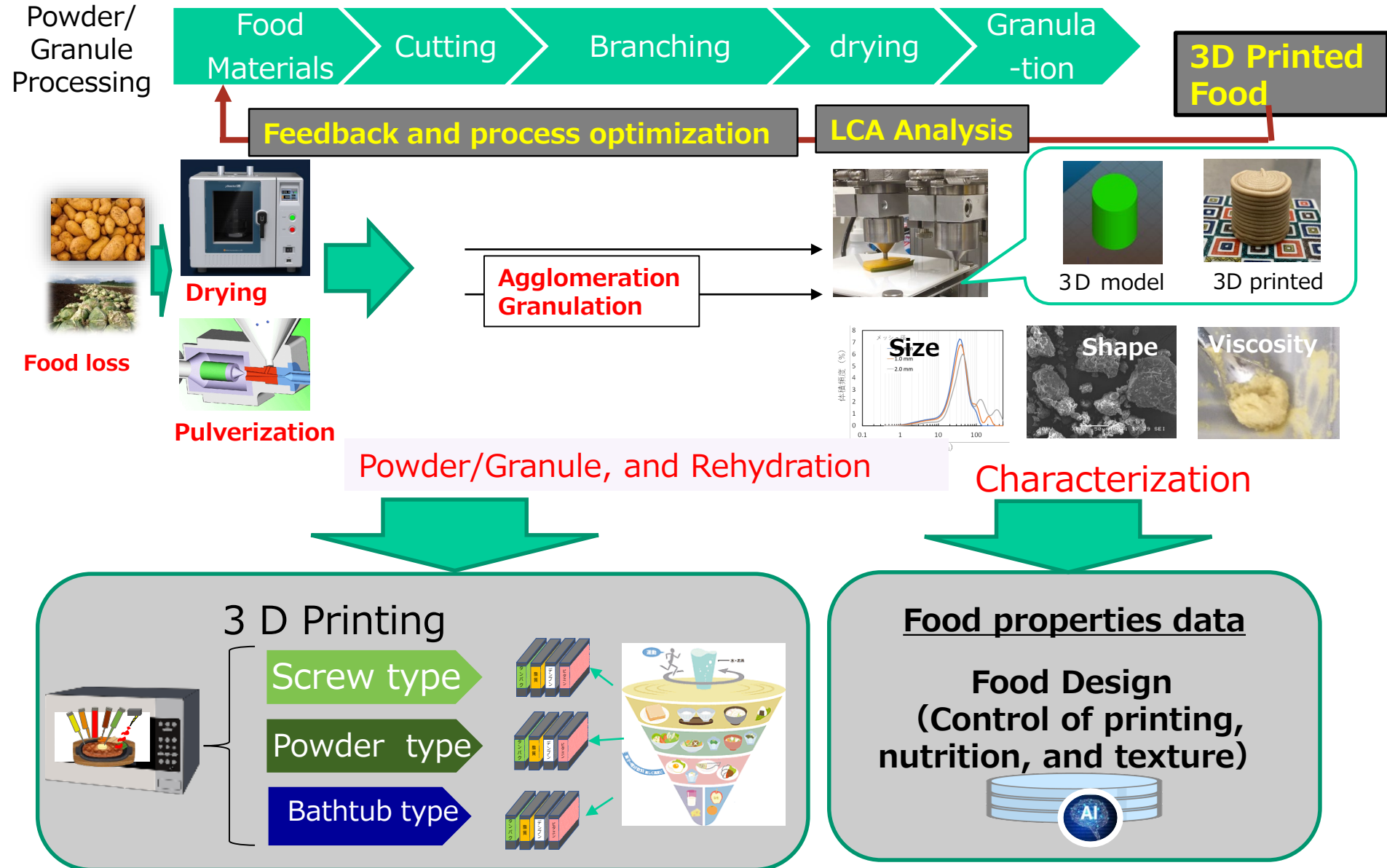
Developing countries: Poor food distribution, mainly cereals, difficulty of balanced diet



➤ Research on AI Chef Machine using 3D food printer to solve these problems

- From food loss to powders, granules, and pastes for keeping quality and long-term preservation.
- On-demand manufacturing using digital design to create complex food structures that are not possible with conventional methods.
- AI-based 3D food printing system (3D-AI Chef Machine) to provide personal food. Reduces food loss, and enables the use of new ingredients such as insects

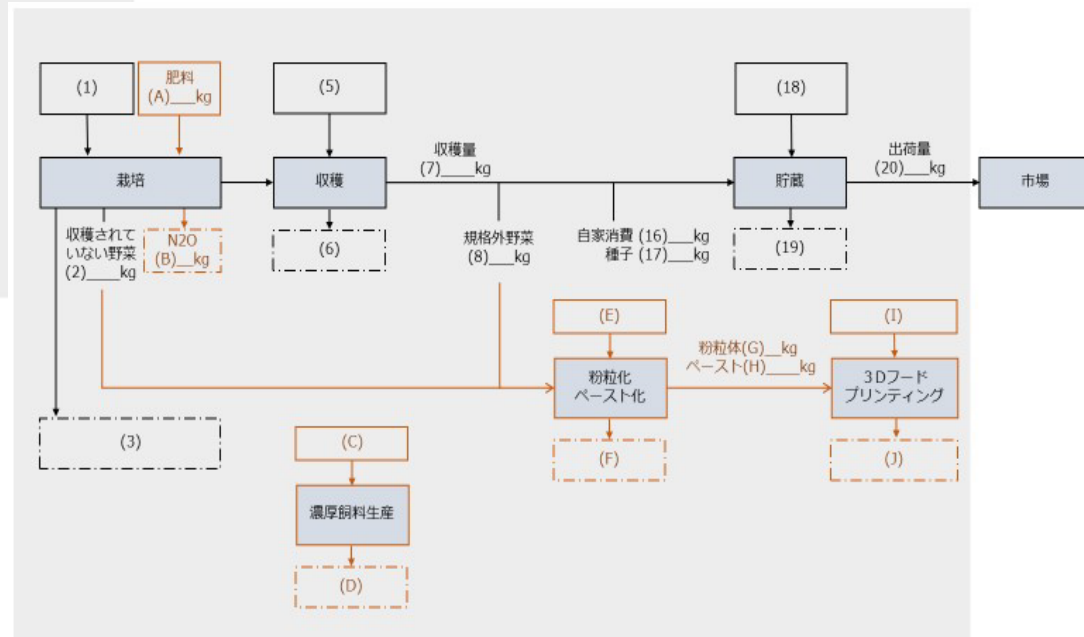
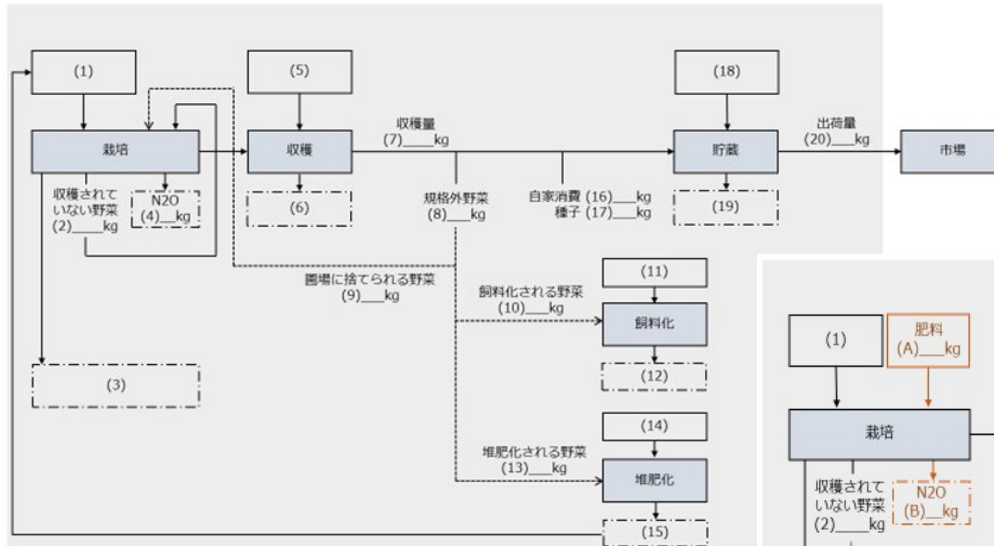
Development of Powder/Granule for 3D Food Printing



Life Cycle Assessment (LCA) Analysis of 3D Food Printing including Food Loss Recovery

Prof. Noguchi, University of Tsukuba

Before : Present flow from cultivation to market



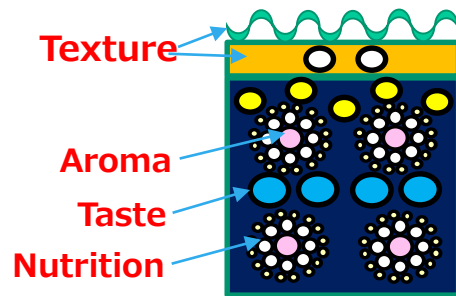
After : Future flow involving 3D Food Printing

Improving Food Taste with Flavor and Texture Evaluation Technology

PI : Dr. Kobori, NARO

- ✓ Timing of "taste, texture, and aroma" is key to produce delicious printed foods, based on dynamic evaluation.
- ✓ Integrated database of "taste, texture, and aroma," including dynamic data, for printed foods.

Digitalization of relation of deliciousness and structure



New 3D Printed Food

Patterns that feeling more fragrant later, etc

➡ Feedback to 3D Printing

Patterning of Taste/Deliciousness



Measuring and reproducing response during eating freshly made food

Mastication Measurement



Model Tongue

Chewing Robot

Reproducing oral cavity
Reproducing texture by multi-point measurement technology

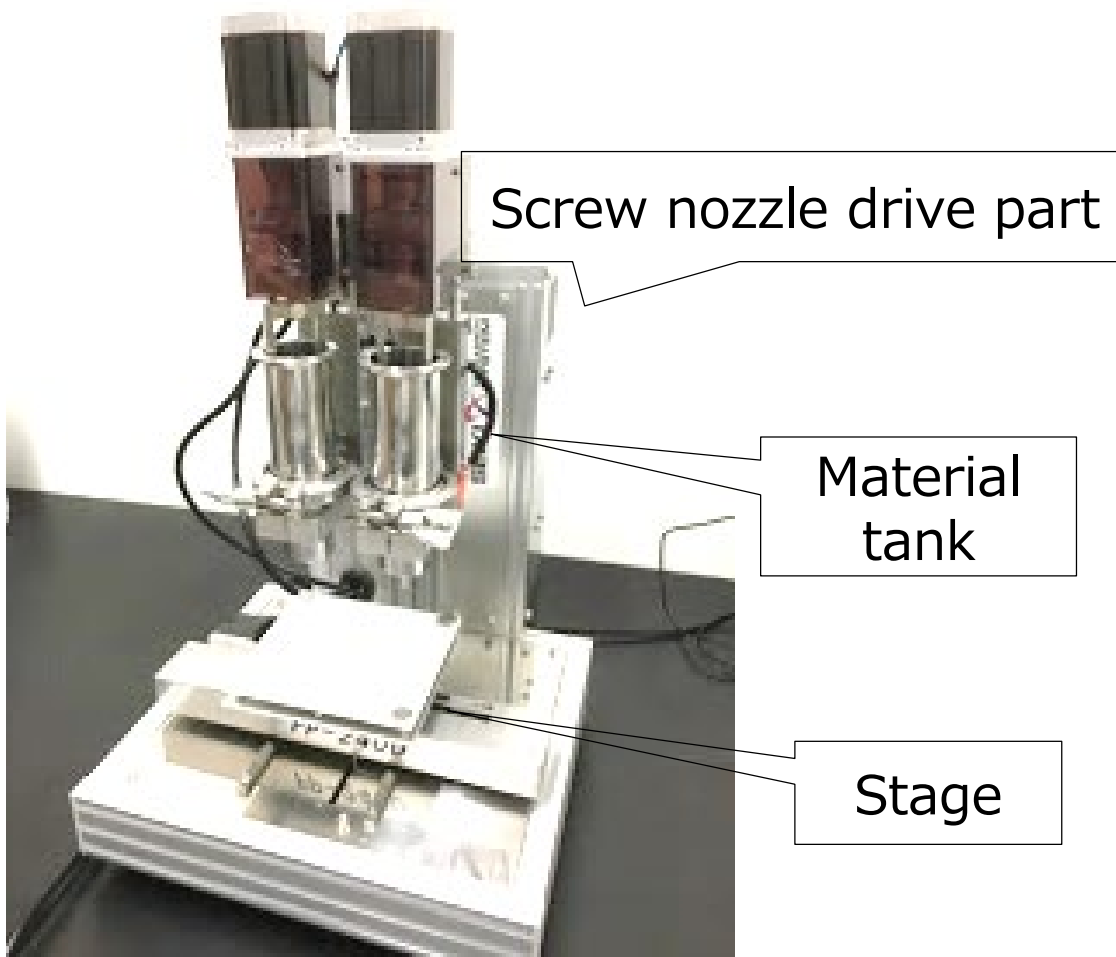
Brain activity, Pulse wave
Blood glucose, etc.

Discover characteristic patterns during a meal,
Understand timing of taste, texture, and aroma.

Dynamic Evaluation

Integrated Database of Food Deliciousness

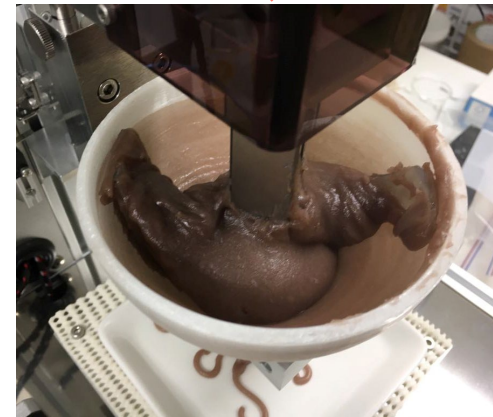
Screw-type Food 3D Printer FP-2400 (Yamagata University & SEIKI Co., Ltd.)



Screw-type
Food 3D Printer FP-2400



Pasty materials

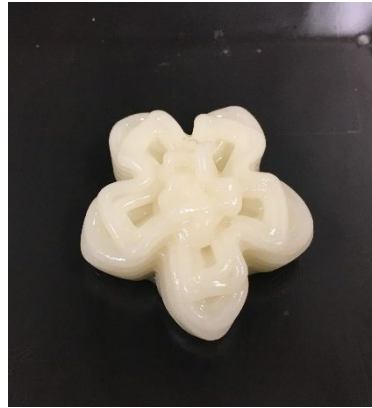


Inside of the material tank is a screw-type mechanism, so output control is easy.

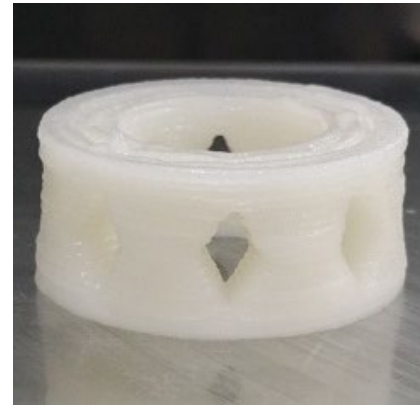
Formulation with 3D Food Printer FP-2400



Bean
paste gel



Gelsing agents for
nursing care foods



Rice flour gel



Mochi Texture Gel



Immediately
after output



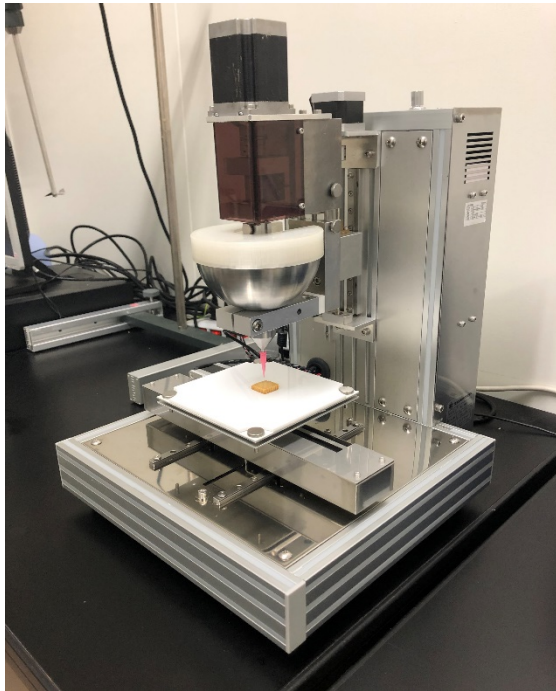
Cookies



After baking

3D Food Printing for Future Food Innovation

Food 3D printers are expected to be available to manufacture food tailored to individuals, i.e. personal food.



Support for nursing care meals and baby

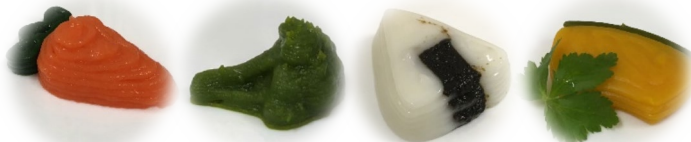


Designer Foods



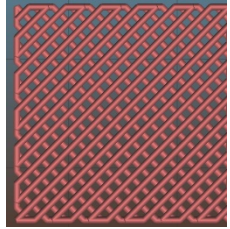
Nutrition tailored to the individual

Development of new texture

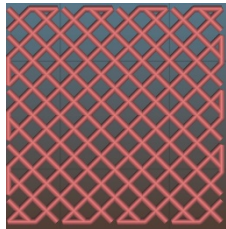


Post-Modeling Dimensions of 3D Printed Cookies

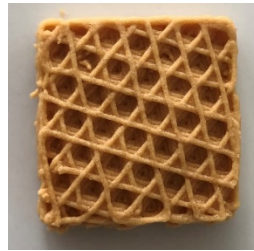
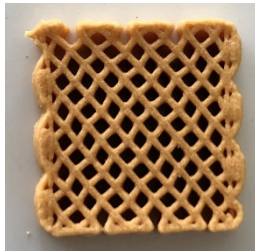
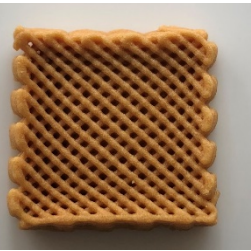
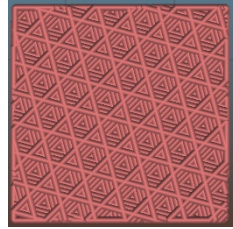
Rectilinear



Grid



Cubic



- ✓ Succeeded in cookie making with low error
- ✓ Cubic height is higher.
→ accuracy changes, depending on model structure.
- ✓ The weight can be changed by adjusting Infill %.

Dimensions and weight of cookies after baking

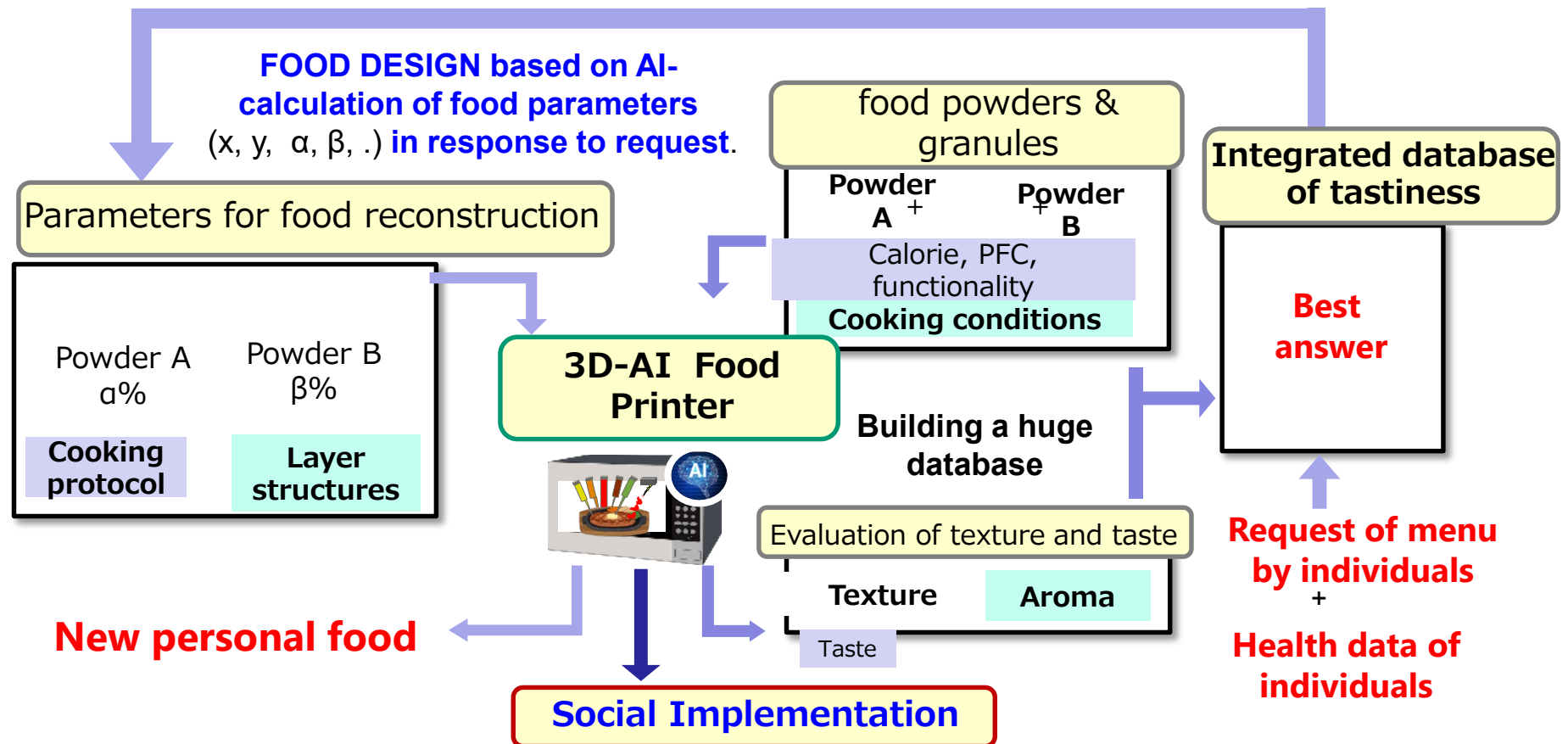
(mean \pm standard deviation, n=3)

structure name	Infill %	x (mm)	y (mm)	z (mm)	Weight (g)
Rectilinear	45	20.45 \pm 0.13	19.55 \pm 0.32	4.87 \pm 0.19	1.2 \pm 0.06
Grid	60	20.60 \pm 0.28	20.32 \pm 0.47	4.98 \pm 0.03	1.1 \pm 0.06
Cubic	60	20.87 \pm 0.15	21.11 \pm 0.41	6.25 \pm 0.09	1.3 \pm 0.06
3D data	-	20	20	5	-

Coefficient variation, lower than 5%

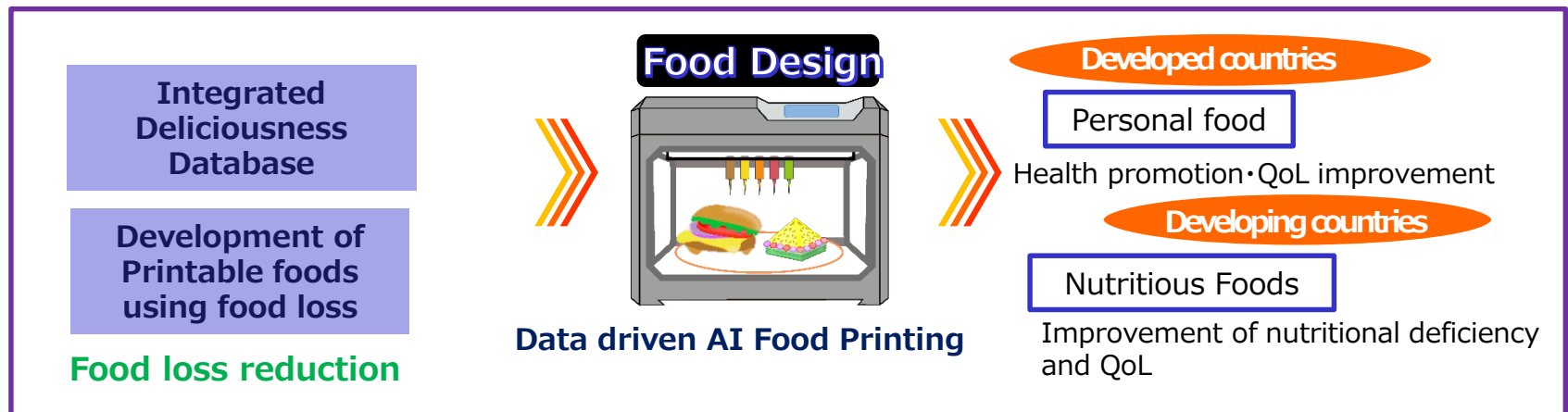
3D-AI Food Printing System with Integrated Database of Tastiness/Deliciousness

- ✓ Evaluating the elements of texture, taste, functionality, and nutrition created from the combination of ingredients for building an integrated database of tastiness/deliciousness.
- ✓ Calculating food parameters by AI and driving 3D-AI food printing to produce printed food.



3D AI Printing System for Personal Food Production

A new platform by 3D-AI Printing System will develop solutions to reduce food loss by turning unused food materials into long-life pulverized food materials for delicious consumption. Creation of the 3D-AI food printing industry will be realized as a new food supply industry that provides personal foods that take into account individual preferences and health conditions.





Thank you for your kind attention.

**I sincerely appreciate Prof. Kazuhiro Chiba,
Program Director, President of Tokyo University of
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**Dr. Kazuo Kyuma,
President of National Agriculture and Food Research
Organization (NARO),
and**

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Institution (BRAIN), NARO for supporting the Project.**