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Loss reduction and technological innovation in food processing

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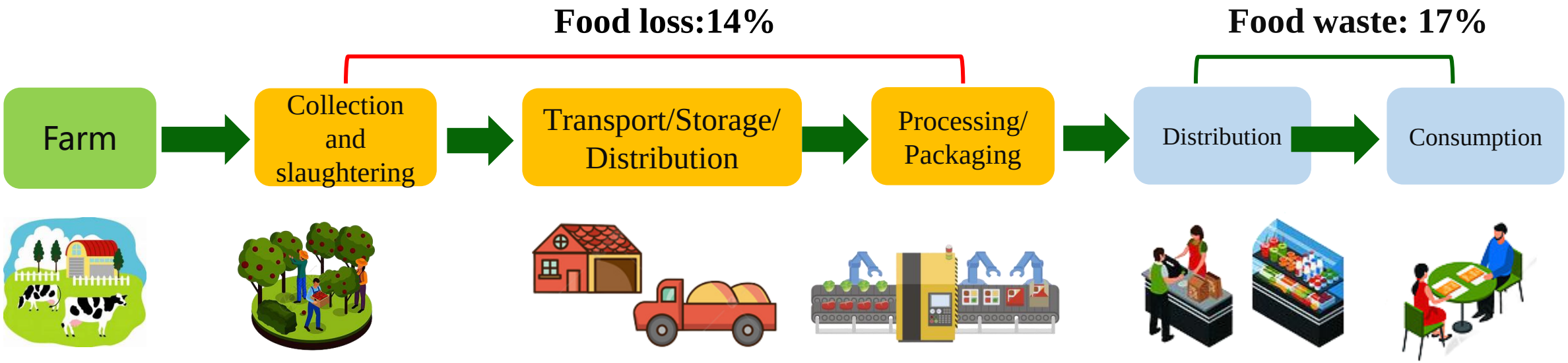
Food loss and waste

Food loss and waste take place at all stages of the supply chain:

- About 1/3 of the food supply is lost each year in the supply chain
- About 14% of food is lost in storage, transportation, processing and packaging every year, amounting to 767 million tons
- 17% of total food is wasted, reaching 931 million tons, of which 61% is consumed by households, 26% by catering, and 13% by retail

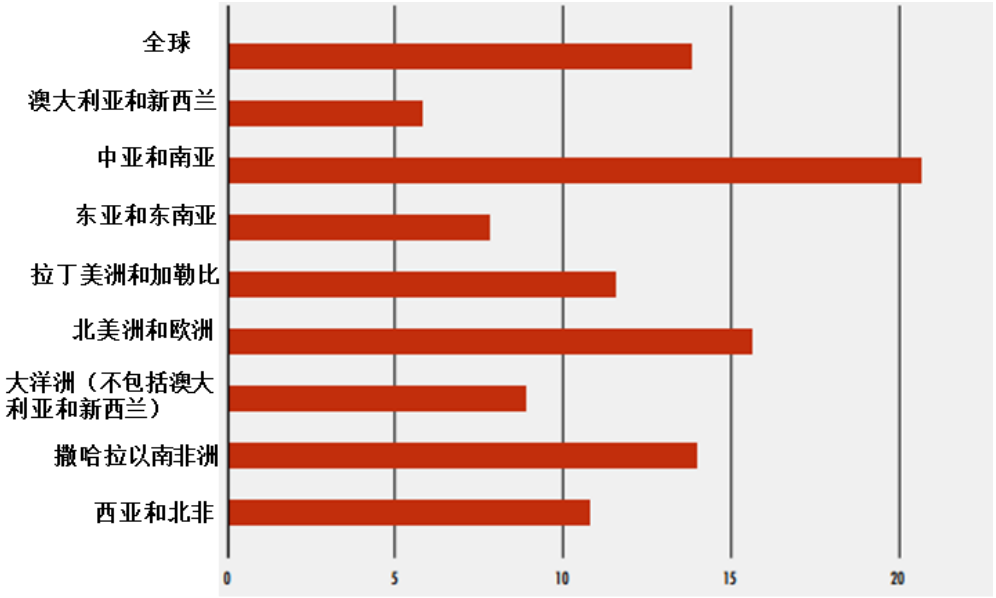


FAO. Moving Forward on Food Loss and Waste Production, 2019; UNEP. Food Waste Index Report 2021

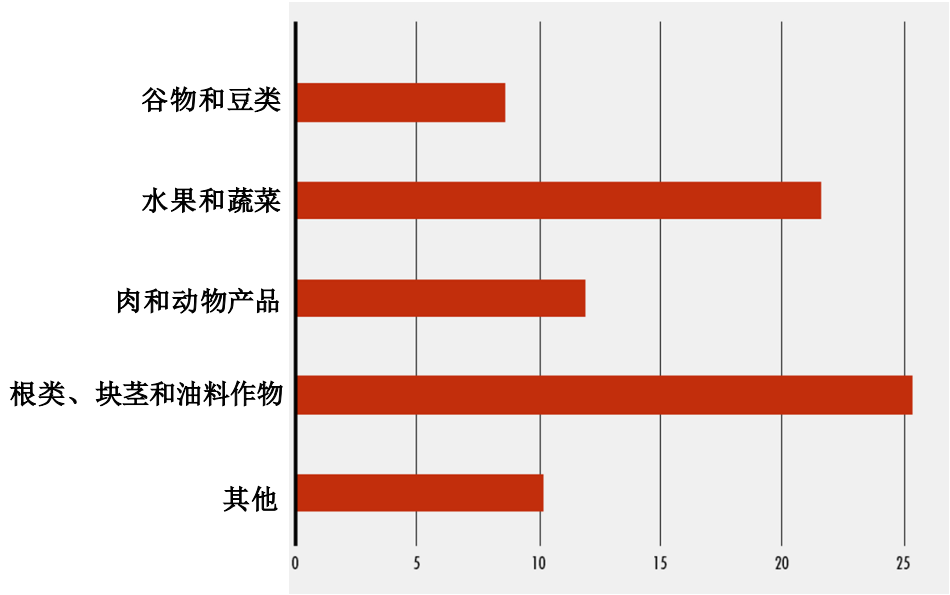
Food loss and waste

Food loss (dominant): food loss in collection, storage and transportation, etc., food quantity reduction

- **Central and South Asia have the highest food loss rates, followed by North America and Europe, all of which were higher than the global average**
- **Fruits and vegetables, roots and tubers and oil crops have high losses, all exceeding 20%**



Percentage of food lost globally and by region



Percentage of global food loss by type

FAO. Moving Forward on Food Loss and Waste Production, 2019

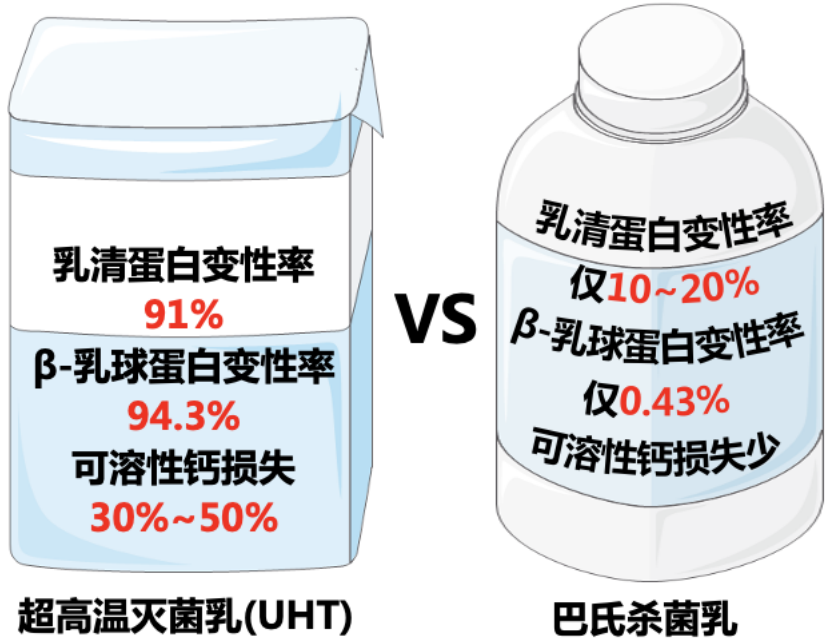
Food loss and waste

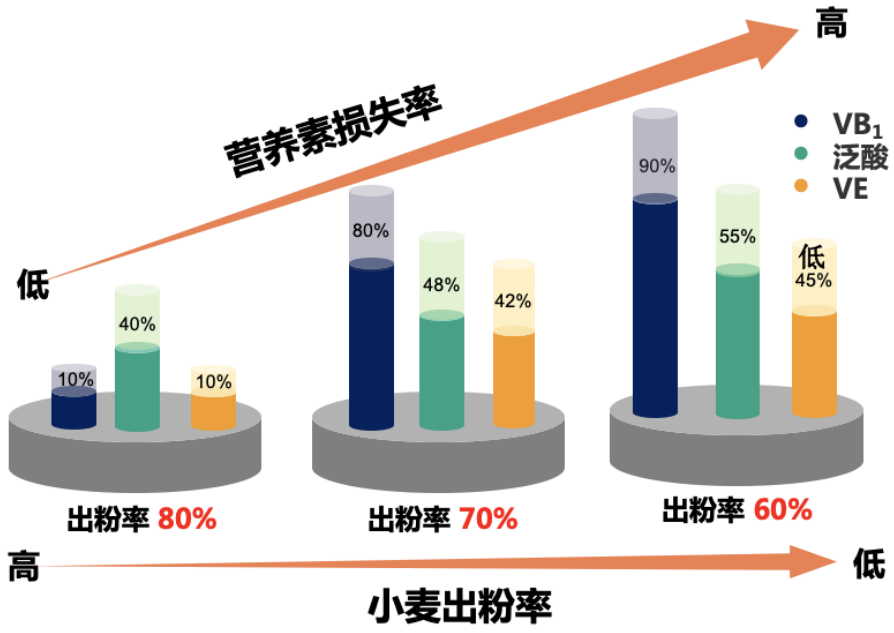
Food loss (recessive): Nutrient loss due to overprocessing

Excessive processing leads to serious loss of nutrients:

- ✓ **Oversterilization**
- ✓ **Over power-making**
- ✓ **Over polished**
- ✓ **Over refined**
- ✓ **……**

For example, ultra-high temperature sterilization (UHT) leads to the denaturation of more than 90% of whey protein and active β-Lactoglobulin, and the loss of 30%-50% of soluble calcium; excessive processing of wheat flour causes the flour extraction rate of wheat to drop from 80% to 60%, the loss rate of vitamin B1 and vitamin E increased from 10% to 90% and 45% respectively





Wang Jiaqi, 2011; Yang Huaigu et al., 2016; Wang Xiao

Food loss and waste

Food waste (dominant): Food waste on the table, etc.

- In 2015, Cheng Shengkui's research team from the Geographical Sciences and Natural Resources Research (IGSNRR), Chinese Academy of Sciences (CAS), conducted a survey of 195 restaurants in Beijing, Shanghai, Chengdu and Lhasa and the result showed that the per capita food waste in the four cities is about 93 grams per person per meal, and the waste rate is 11.7%.
- Preliminary estimates show that in 2015, the total waste of catering food in Chinese cities was about 17-18 million tons, equivalent to the annual food of 30-50 million people

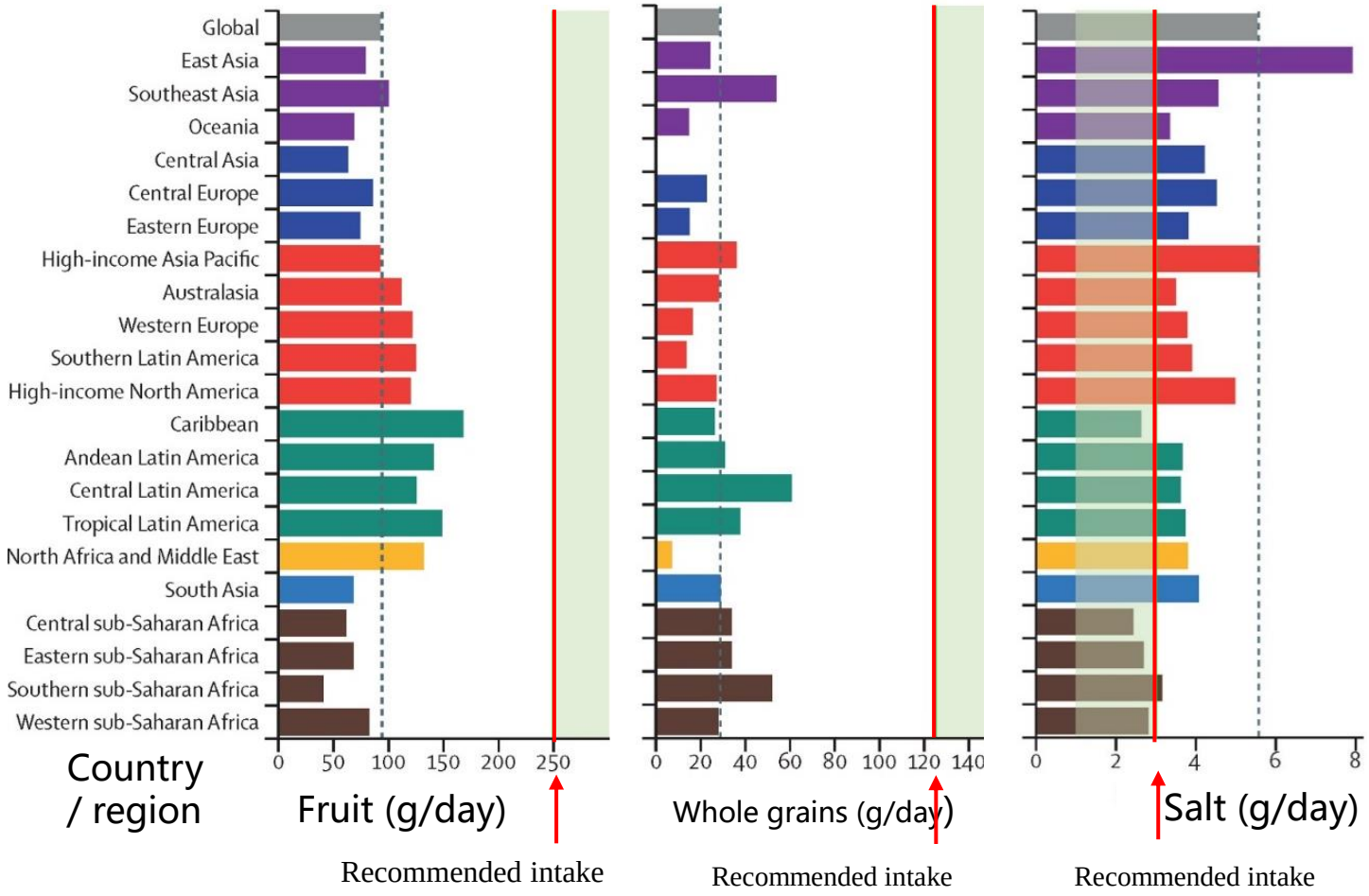
2018 Report on China Urban Catering Industry Food Waste

Food loss and waste

Food waste (recessive): nutrient waste due to excess and unbalanced energy intake

Imbalanced nutrition: Insufficient intake of whole grains, vegetables, and fruits, while salt intake is much higher than the recommended intake

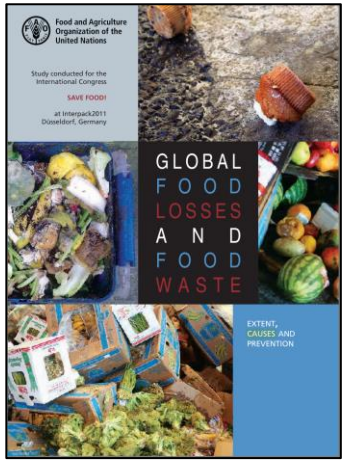
Excess energy intake: excessive intake of empty calorie foods (sugar, oil, etc.), meat protein and over-processed foods

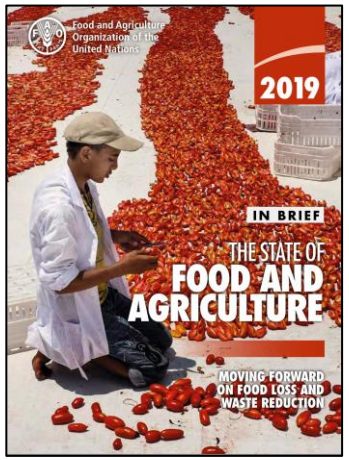


Ashkan Afshin et al.The Lancet, 2019; Anne Mullen. Nature Food, 2020

Adverse impact of food loss and waste

- **Economic loss:** about **$750 billion** a year
- **Waste of resources:** waste **24%** of the world's freshwater resources, **23%** of agricultural land area
- **Environmental cost:** food loss and waste produces about **8%** of the total CO2 produced by human activities every year
- **Food shortage:** there are still **768 million** hungry people in the world in 2020, and about **3 million** children under the age of 5 die each year due to undernourishment/nutritional deficiency
- **Health issues:** about **38.9 million** children under the age of 5 were overweight globally in 2020, and dietary risks accounted for **22%** of all adult deaths in 2017





Kummu, M., et al. Lost Food, Wasted Resources, 2012; FAO. Global Food loss and food waste, 2011; UNEP. Food Waste Index Report 2021； Ashkan Afshin et al. Lancet 2019; WHO

Global consensus on food loss reduction

- **Transforming our World: The 2030 Agenda for Sustainable Development proposes 17 sustainable development goals, of which Article 12 "Responsible Consumption and Production" sets food loss goals**

SDG 12.3: By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses

Global consensus on food loss reduction

In September 2021, the Chinese government initiated and held the first International Conference on Food Loss and Waste. Representatives from more than 50 countries attended and released the Jinan Initiative and reached ten consensus on loss reduction:

Consensus 4: Tap the potential of intangible fertile land and reduce post-harvest losses

In terms of technology research and development, standardization, investment guidance, etc., advance the organic integration and effective connection of warehousing, transportation, processing and other links, reduce grain loss during the whole post-harvest process, build "invisible fertile land", and realize "landless production increase".

Policy initiatives for food loss reduction in China

China's policy measures to reduce food loss and waste

Policy name	Main contents	Release date	Subjects
Outline of Medium and Long-term Plan for National Food Security (2008-2020)	Key objectives and countermeasures to strengthen food storage, processing and retailing systems	2008.11.13	State Council
National Plan for Newly Increased Grain Production Capacity of 100 Billion Catties (2009–2020)	Strategies and targets to reduce agricultural losses (1-2% reduction in pests by 2020) and postharvest losses	2009.11.03	National Development and Reform Commission (NDRC)
Grain Storage Management Measures	Detailed measures and reporting requirements for grain storage	2009.12.29	NDRC
National Grain-saving Animal Husbandry Development Plan (2011-2020)	Short-, medium- and long-term goals for non-agricultural feed production	2011.12.21	MOC
China's Program for Food and Nutrition Development (2014-2020)	Focus on creating a good social atmosphere of practicing strict economy and opposing waste	2014.01.18	Office of the State Council
Opinions on Frugal Spending and Opposing Food Waste》	Clarify the supervision and inspection responsibilities of finance and other departments against food waste	2014.03.18	CCP General Office General Office of the State Council
Guiding Opinions on Promoting Green Consumption	Carry out anti-food waste actions, strive to clean plate, strengthen management in all links, and reduce food loss and waste	2016.03.01	NDRC and ten departments
Dietary Guidelines for Chinese Residents (2016)	Eliminate waste to foster a new food trend; cherish food, prepare meals according to needs, and advocate sharing meals without waste; cook reasonably	2016.05.13	National Health and Family Planning Commission (NHFPC)
Anti-Food Waste Laws	Formulate legislation against food waste	2021.04.29	National People's Congress

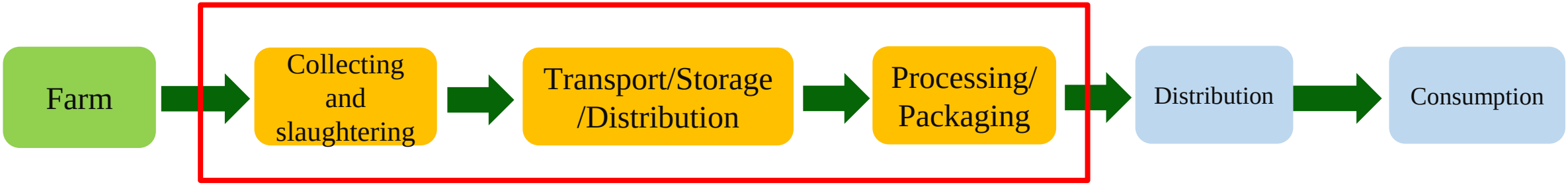
Policy initiatives for food loss reduction in China

China's strategic projects to reduce food loss and waste

National projects	Project name	Time
National 863 Program	Research and development of key technologies for biotransformation and refining of low-value protein resources	2011-2015
National 863 Program	Research and creation of core technology for green and intelligent agricultural product supply chain	2012-2015
National Science and Technology Support Program	Research and demonstration of key technologies for energy-saving and efficiency-enhancing green grain storage	2011-2015
National Science and Technology Support Program	Bulk grain green processing and products	2012-2015
National Science and Technology Support Program	Research and application of logistics agricultural product quality maintenance and quality safety control technology	2013-2015
National Key Research and Development Program	Green ecological low-carbon intelligent storage technology demonstration project of modern granary	2016-2020
National Key Research and Development Program	Research, development and demonstration of appropriate grain and oil processing and comprehensive utilization of complete sets of technologies and intelligent equipment	2016-2020
National Key Research and Development Program	R&D and demonstration of key technical equipment for processing large-scale rice nutritional products	2016-2020
National Key Research and Development Program	Development of key technologies for grain purchase and storage, quality assurance, consumption reduction and grain situation monitoring	2016-2020

Loss reduction and technological innovation in food process

Loss reduction measures around the link of food processing



Before processing
Processing
After processing

1. Establish a commercialized place of origin and a cold chain logistics system for fresh agricultural products
2. Improve the timely drying of grain and oil and green grain storage technology
3. Adopt reasonable processing methods
4. Develop new processing technologies for agricultural products
5. Innovate smart packaging technology

Loss reduction and technological innovation in food processing

1. Establish a commercialized place of origin of fresh agricultural products and a cold chain logistics system

(1)Commercialization of origin

- Develop harvesting standards according to local conditions to reduce harvesting losses
- Conduct grading and primary commercialization at the place of origin after harvesting to accurately match subsequent processing
- Conduct timely pre-cooling at the place of origin to prevent the loss of perishable agricultural products

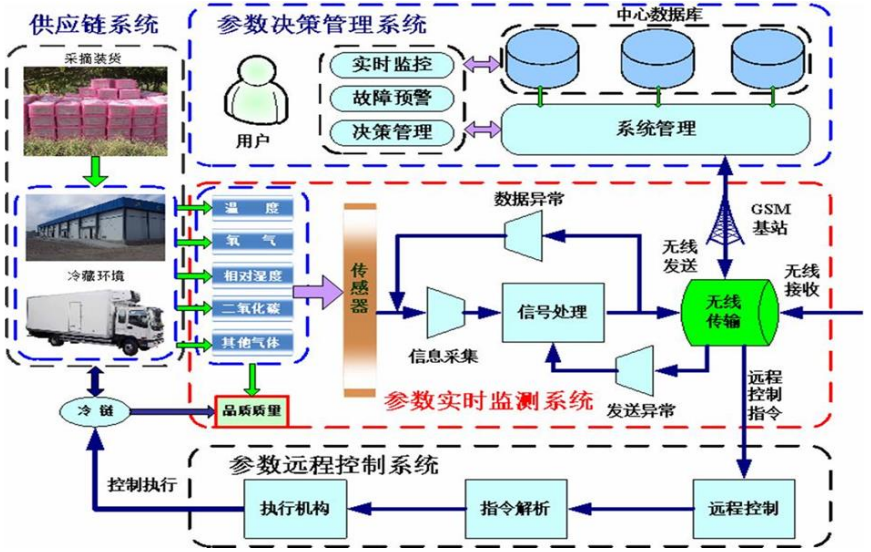
Precise harvesting and grading

Origin pre-cooling

Loss reduction and technological innovation in food processing

(2) Establish an efficient, complete and intelligent cold chain logistics system

- **Develop cold storage, mobile warehousing, low-temperature sorting and other facilities and equipment and dynamic fresh-keeping technology, improve the connection of multi-channel cold chain logistics, realize efficient combined transportation in water, land and air multi-temperature areas, and improve the "first mile" and "last mile" of cold chain facilities in production areas to solve the problem of broken chain**
- **Utilize IoT technologies such as RFID and near-field communication, and information technologies such as 5G+, big data, and blockchain are used to monitor information such as the transportation location, surrounding environment, and composition changes of fresh and live agricultural products in the cold chain, and conduct route optimization, shelf life prediction and energy consumption optimization, which can improve cold chain security and decision-making accuracy, and build an intelligent cold chain logistics system**



Loss reduction and technological innovation in food processing

2. Improve the timely drying of grain and oil and green grain storage technology

(1) Timely drying of grain and oil is an important measure to maintain the quality of grain and oil and reduce losses. The application of new technology equipment such as multi-stage temperature-variable drying and forward-countercurrent drying can reduce grain loss by 2 percentage points. Gradually advance the application of new energy-saving and environmentally friendly drying systems that use biomass and heat pumps as heat sources.

Downstream and countercurrent and multi-stage variable temperature drying

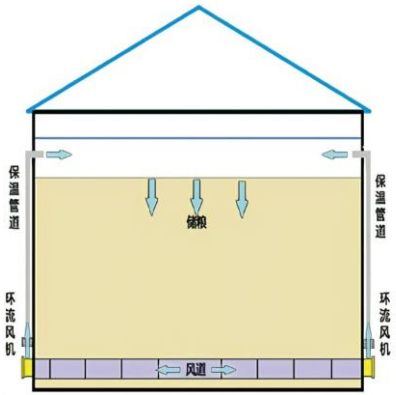
Biomass heat pump drying

Loss reduction and technological innovation in food processing

2. Improve the timely drying of grain and oil and green grain storage technology

(2) Develop green grain storage technologies such as nitrogen-modified atmosphere storage and internal circulation temperature-controlled grain storage to effectively reduce grain losses caused by insects and pests

PSA Nitrogen Modified atmosphere storage



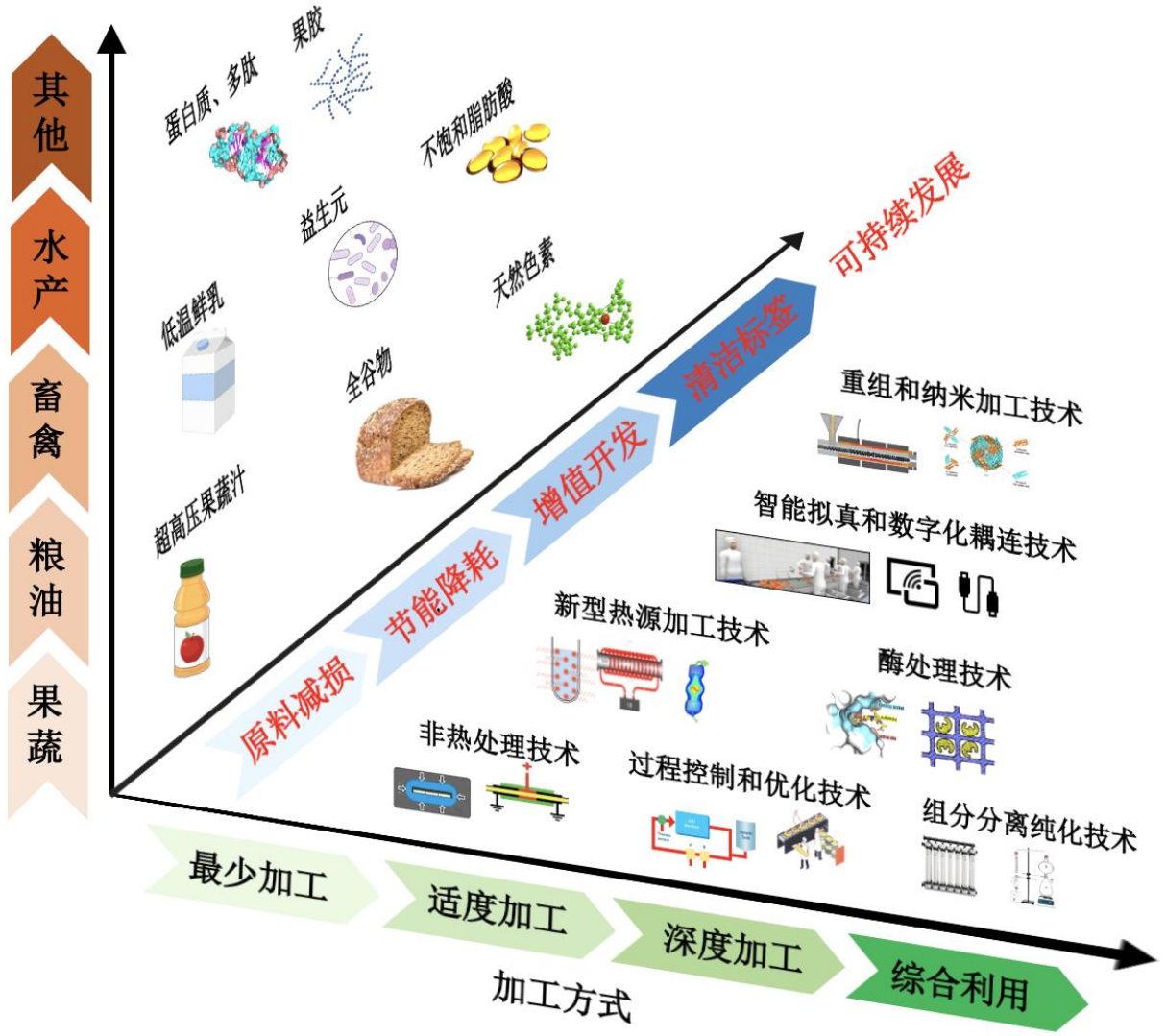
Inner circulation temperature control grain storage

Loss reduction and technological innovation in food processing

3. According to agricultural product processing characteristics and market demand, adopt reasonable processing methods:

- **Minimal processing:** to keep the original quality to the greatest extent
- **Moderate processing:** to avoid quality loss caused by excessive processing
- **Deep processing:** to accelerate the conversion of raw materials with high added value
- **Comprehensive utilization:** to maximize the utilization of by-products

Reduce the loss of agricultural products and realize the efficient use of resources



Loss reduction and technological innovation in food processing

(1) Minimal processing - maintain the original quality to the greatest extent

- **Taking NFC fruit and vegetable juice processing as an example, the minimum processing method based on ultra high-pressure technology can effectively retain nutrients such as vitamin C, anthocyanins, and superoxide dismutase SOD, as well as reduce the loss of raw material nutrient**

- **Fresh-cut fruits and vegetables can achieve low cost, low loss, freshness, convenience and safety through the minimum processing method of "cleaning-cutting-packaging" combined with advanced fresh-keeping technology**
- **Taking dairy processing as an example, use 1.4 micron pore size low-temperature ceramic membrane filtration technology to replace traditional ultra-high temperature processing sterilization. There is almost no loss of acidic protein and β-lactoglobulin in fresh milk, folic acid loss is within 10%, and the flavor is better**

Loss reduction and technological innovation in food processing

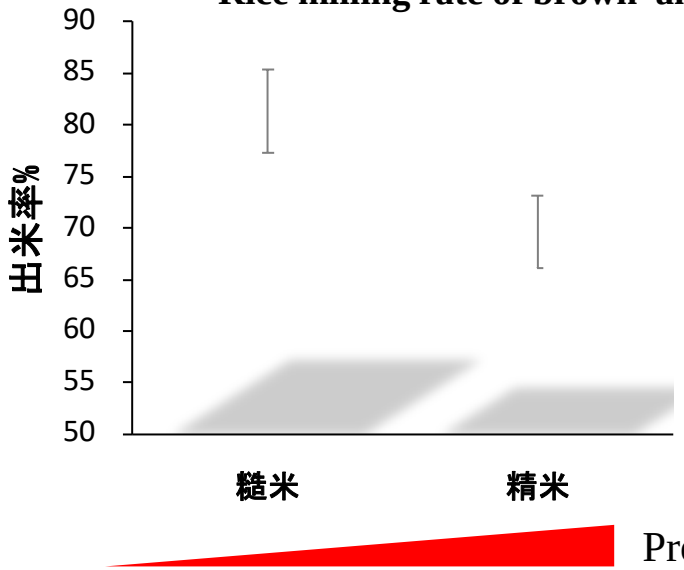
(2) Moderate processing - avoid quality loss caused by excessive processing

- **Strictly limit excessive processing, improve conversion utilization, and reduce raw material loss**

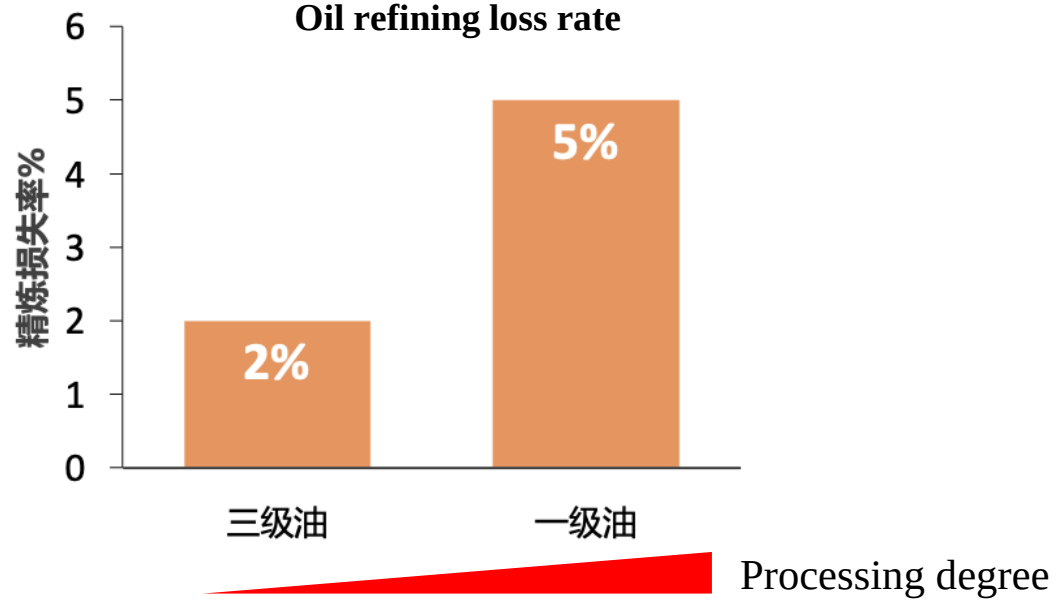
Taking rice as an example, rice milling rates of primary rice processed into brown rice can reach 81% (the loss rate is less than 20%), and the yield rate of processed rice into polished rice is only 70%. Milling brown rice into polished rice will lose 85% of fat, 15% of protein, 75% of phosphorus, 90% of calcium and 70% of B vitamins

Taking vegetable oil as an example, as the degree of refinement increases, the loss rate increases from 2% (third-grade oil) to 5% (first-grade oil), and a large amount of phytosterols, vitamin E, etc. are lost

Rice milling rate of brown and polished rice



Oil refining loss rate



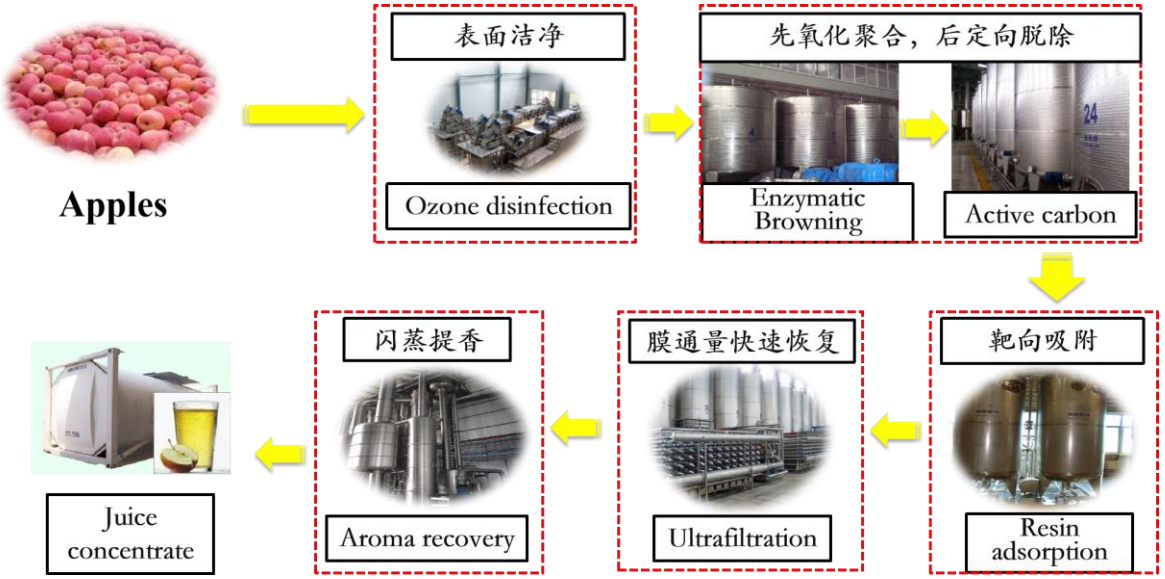
Vetha Varshini, P.,et al. Brown rice—Hidden nutrients. 2013； 吕荣文等,稻谷出糙率和出米率关系探讨. 2022；王瑞元等,食用油精准适度加工理论的发端、实践进程和发展局势, 2019

Loss reduction and technological innovation in food processing

(3) Deep processing - accelerate the conversion of raw materials with high added value

- **Conduct deep processing of agricultural products, extend the processing chain, promote the conversion of raw materials to high value-added, and improve economic benefits**

Taking apples as an example, apples can be processed into high-quality concentrated apple juice through surface cleaning, targeted adsorption, ultrafiltration, flash evaporation and other processes



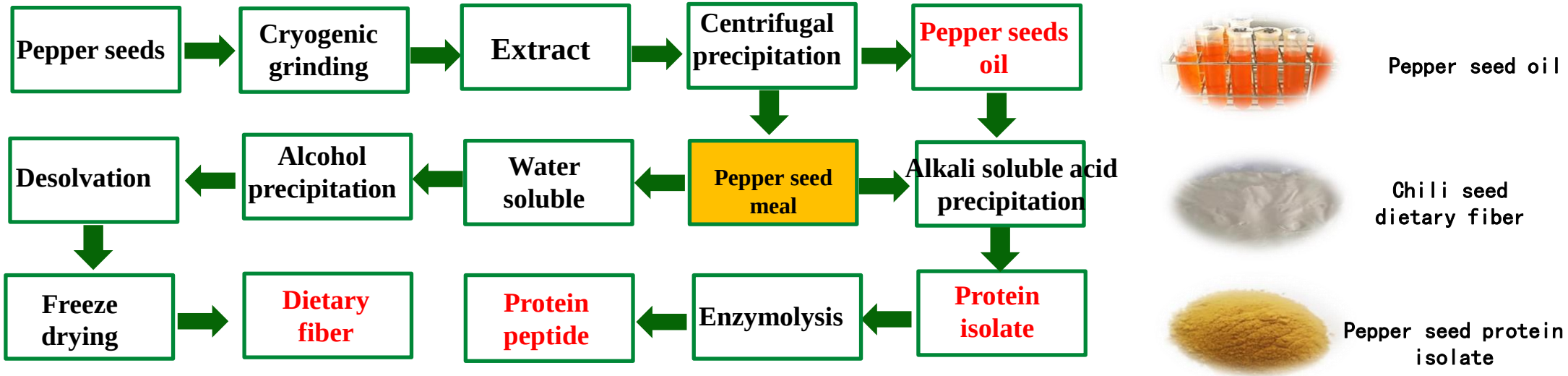
Taking jujube as an example, various products such as concentrated pulp, jujube powder, nutritional chewable tablets, polysaccharides, and pigments can be obtained through deep processing

Loss reduction and technological innovation in food processing

(4) Comprehensive utilization-maximize the utilization of by-products

China produces 20 million tons of rice bran, 10 million tons of corncobs, 7 million tons of bagasse, 5 million tons of pomace, 26 million tons of livestock and poultry bones, and 6 million tons of blood, which need to be developed and utilized to improve utilization and added value

- Taking pepper as an example, the output of pepper in China is 64 million tons, ranking first in the world. Pepper seeds are the main processing by-products, which can produce about 25 million tons every year, and are in urgent need of comprehensive utilization. Pepper seeds can be developed into products such as dietary fiber, oil, and alternative protein, thus the value of the products can be greatly increased



Comprehensive utilization of pepper seeds

Loss reduction and technological innovation in food processing

4. Develop new processing technologies for agricultural products

- ✓ **Low-carbon drying:** microwave drying, vacuum pulse drying, high-voltage electrostatic field drying, superheated steam drying
- ✓ **Efficient freezing:** CO2 freezing, immersion freezing, air shock quick freezing
- ✓ **Non-thermal sterilization:** ultra-high pressure, high-voltage pulsed electric field, membrane separation, plasma
- ✓ **Green extraction:** supercritical/subcritical fluid extraction, ultrasonic extraction, ionic liquid, enzyme-assisted extraction
- ✓ **Biotransformation:** multi-enzyme coupling, cell synthesis, controlled degradation, targeted modification
- ✓ **Component recombination:** ultrafine pulverization, high moisture extrusion, nano-encapsulation, molecular self-assembly, additive manufacturing

Ultra-high pressure non-thermal sterilization technology (HPP)

Ultra-high pressure technology is to put the food sealed in the elastic container in the pressure system of water or other liquid as the pressure transmission medium. After the pressure treatment of more than 100 MPa, it can achieve the purpose of sterilization and inactivation of enzymes to improve the quality of food at room temperature.

- ✓ **Low sterilization temperature**
- ✓ **Keep the original quality**
- ✓ **Free of additive**
- ✓ **Little environmental pollution**
- ✓ **Low processing energy consumption**

HPP technology can be directly applied to food sterilization for fruit and vegetable juices, fresh-cut vegetables, seasonings, prepared vegetables, and dairy products. For example, the total phenolic, Vc content and antioxidant capacity of HPP fruit and vegetable juice were increased by 21.8%, 53.6% and 22.6% respectively compared with high temperature short-time treatment (HTST)

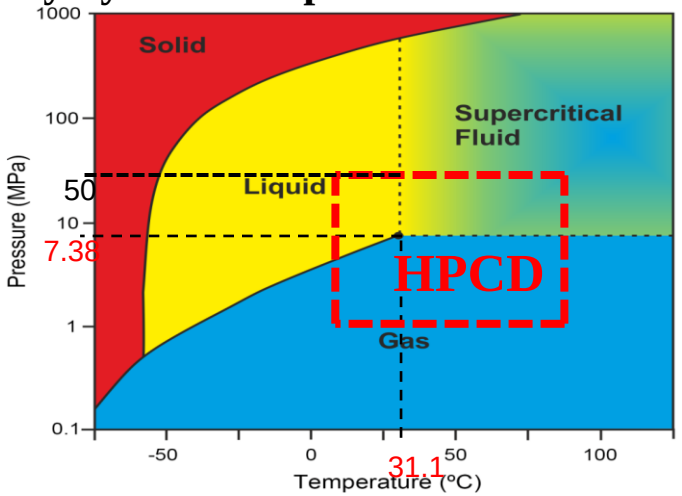
Zhao et al., 2016; Zhao et al., 2018; Ma et al., 2019; Liu et al, 2022; Yang et al, 2022

High-pressure carbon dioxide (HPCD) green extraction technology

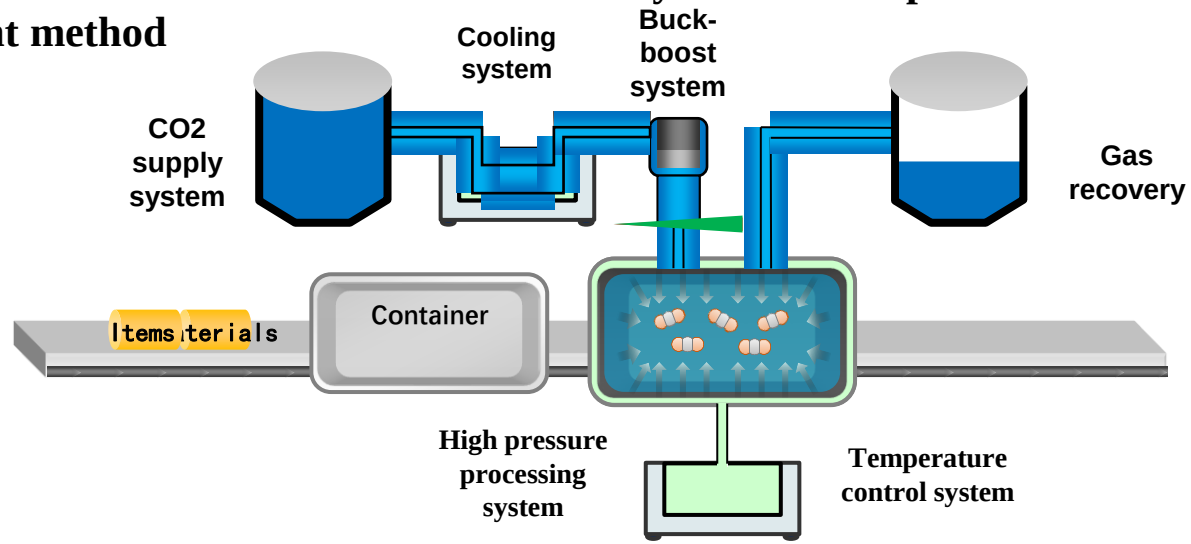
Under a certain pressure (<50 MPa) and lower temperature (<60°C), the effects of carbon dioxide CO2 dissolution, permeation, acidification, explosion and other effects are comprehensively used to achieve efficient extraction of components

- ✓ **No chemicals required**
- ✓ **Short extraction time**
- ✓ **High extraction rate**
- ✓ **High retention rate of active ingredients**

HPCD technology can be used for the extraction of natural pigments, flavonoids, plant essential oils and other components. For example, HPCD extracts blueberry anthocyanins, which shortens the extraction time by 50% and improves the efficiency by 50% compared with the traditional solvent method



CO2 pressure-temperature phase diagram



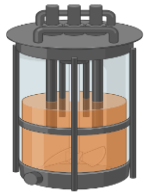
High pressure CO2 equipment diagram

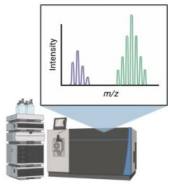
Enzyme catalyst technology

Through high-activity and high-specificity industrial biological enzymes, the by-products of agricultural products are converted into components such as high-value-added active peptides and prebiotics, and the comprehensive utilization rate of by-products is improved.

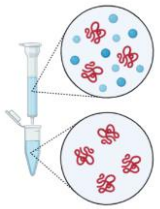
- ✓ **Mild transformation conditions**
- ✓ **High catalytic efficiency**
- ✓ **High substrate specificity**
- ✓ **High product activity**

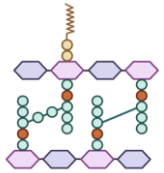
Fish skin, soybean meal and other by-products

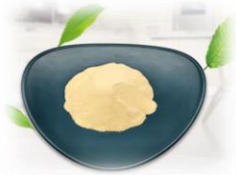




Protein raw material → **Preprocessing** → **Enzymolysis** → **Isolation and purification** → **Activity identification** → **Target peptide** → **Composition identification** → **Active peptide products**







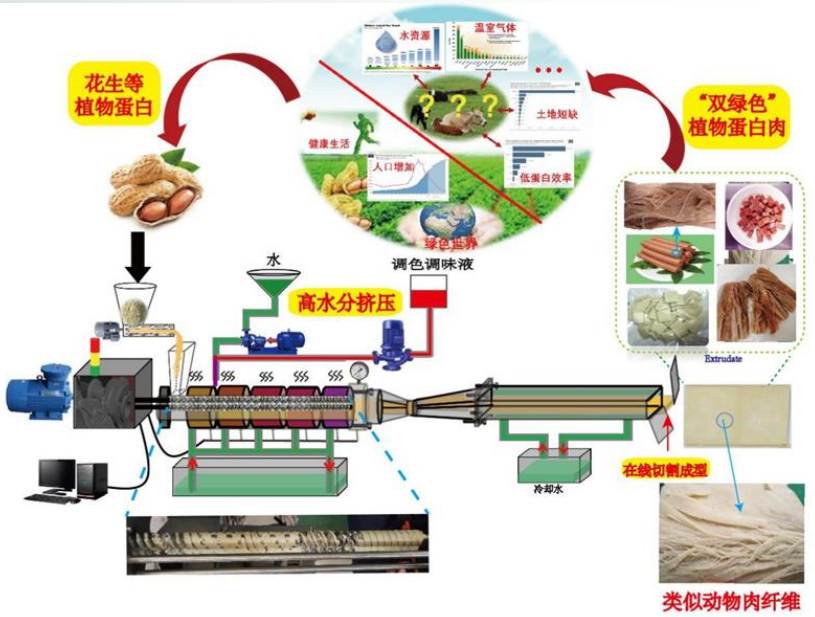
Enzyme-catalyzed technology to prepare biologically active peptide process

Component recombination technology

Plant-based protein meat manufacturing technology based on texture recombination

Under high temperature, high shear and hydration, plant protein forms a fibrous structure that is highly similar to animal meat through molecular rearrangement

- ✓ **Low raw material cost**
- ✓ **Strong product plasticity and high added value**
- ✓ **Without animal hormones**
- ✓ **Sustainable development**

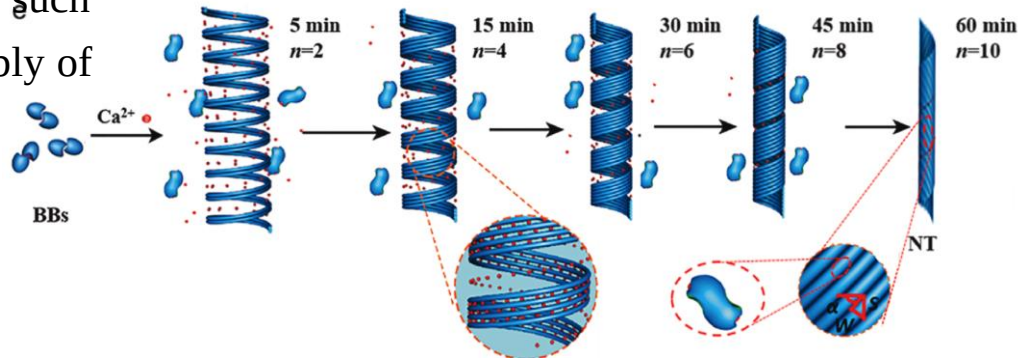


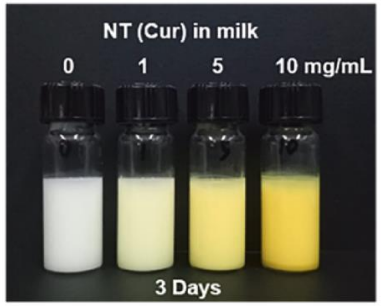
Production of vegetable protein by using high moisture extrusion technology

Nutrient stabilization technology based on nano-encapsulation

Encapsulate natural active compounds with structures such as nanoparticles and nanotubes formed by self-assembly of natural polymers

- ✓ **Improve stability**
- ✓ **Enhance bioavailability**
- ✓ **Targeted delivery**





α-Lactalbumin self-assembled nanotubes for encapsulation of curcumin

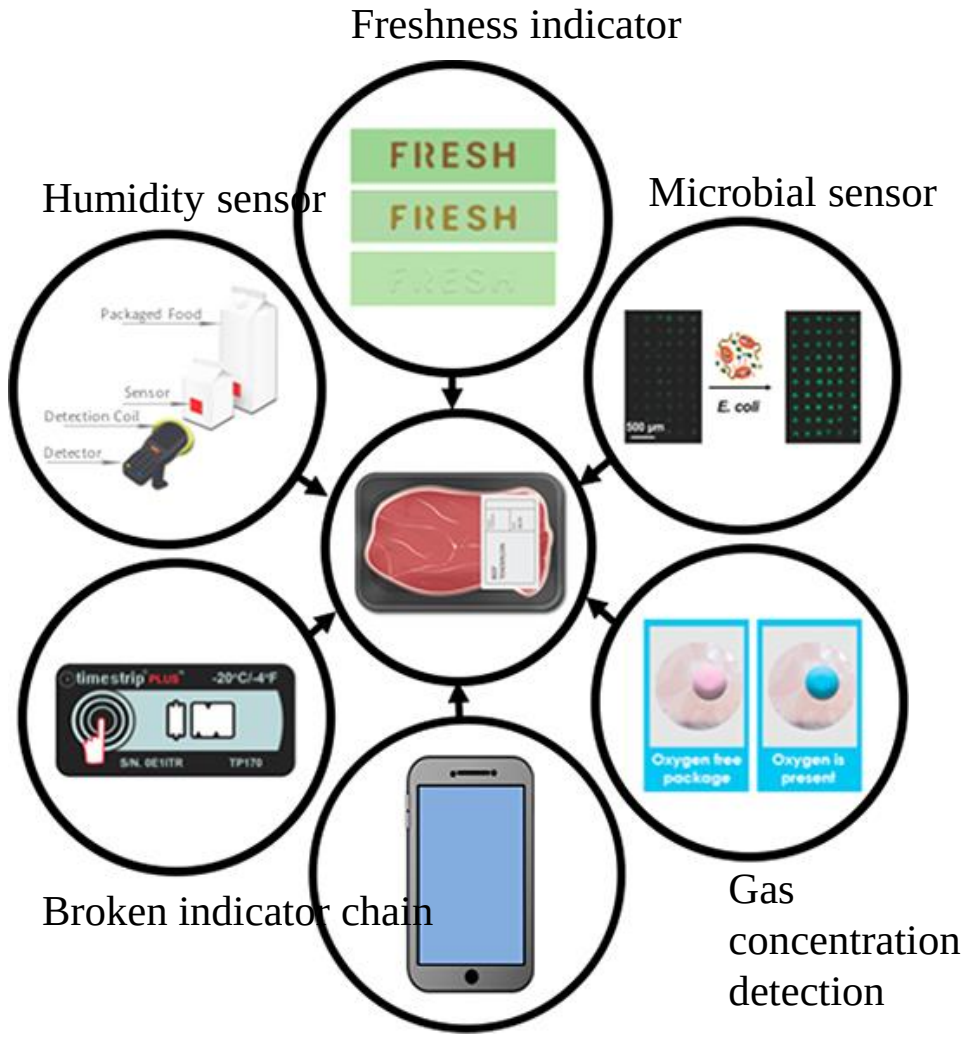
Zhang et al, Biomaterials, 2022

Loss reduction and technological innovation in food processing

5. Develop smart packaging technology

(1) Intelligent detection and sensing prediction

Real-time monitoring of environmental temperature and humidity, gas concentration, microorganisms, etc. through smart sensors can accurately predict and indicate the freshness of agricultural products, transportation chain breaks, etc., and integrate packaging into the intelligent logistics system through intelligent interconnection



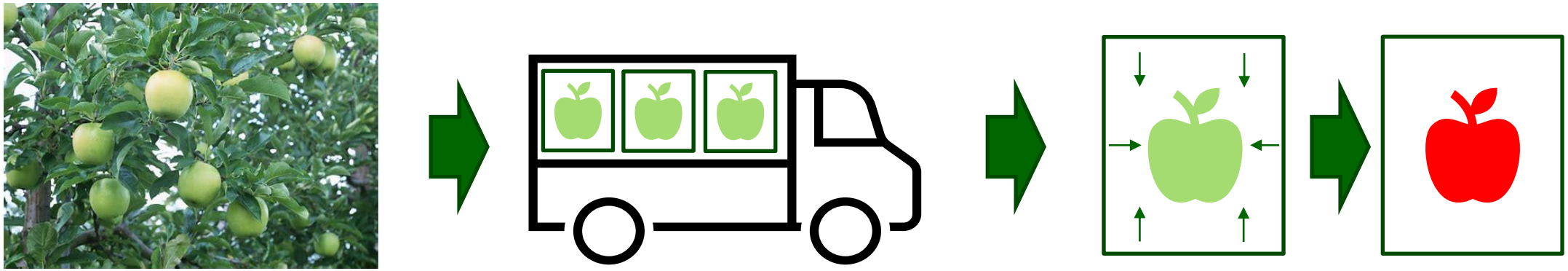
Yousefi, H, et al. "Intelligent food packaging: A review of smart sensing technologies for monitoring food quality." *ACS sensors* 4.4 (2019): 808-821.

Loss reduction and technological innovation in food processing

(2)Shift from passive detection to personalized active control

On the basis of sensing and monitoring the post-harvest status of agricultural products, intelligent adjustments are made "actively" to agricultural products of different states or degrees of maturity

- For example, for harvested fruits with low maturity, smart packaging can quickly accelerate ripening through precise control of gas composition, so that consumers can enjoy fresh fruits at a specific moment; at the same time, the harvesting time of fruits and vegetables is relaxed, and the post-harvest storage and transportation capacity is improved, greatly reducing storage and transportation losses



Yousefi, H, et al. "Intelligent food packaging: A review of smart sensing technologies for monitoring food quality." *ACS sensors* 4.4 (2019): 808-821.

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Thank you!