Digitalization and Innovation of Food Supply Chain in APEC Region

APEC POLICY PARTNERSHIP ON FOOD SECURITY

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Digitalization and Innovation of Food Supply Chain in APEC Region

SURVEY REPORT

APEC Policy Partnership on Food Security

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Produced by
Mr LI Tengfei, Ms. CHEN Wenya, Ms WANG Xiaocong, Ms. SUN Hui, and Mr GUO Weiqun
Academy of National Food and Strategic Reserves Administration
11 Baiwanzhuang Street, Xicheng District, Beijing, China
Email: cwy@ags.ac.cn

With support of:
Ms ZHANG Yi
National Food and Strategic Reserves Administration
Email: zhangyi6267@126.com

For
Asia-Pacific Economic Cooperation Secretariat
35 Heng Mui Keng Terrace
Singapore 119616
Tel: (65) 68919 600
Fax: (65) 68919 690
Email: info@apec.org
Website: www.apec.org

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1. Introduction

Climate change, resource constraints, and other uncertainties have increased the instability and risks of the global food supply chain. Digitalization and innovation have the potential to transform the food system and enhance sustainable food security.

To implement the *APEC Putrajaya Vision 2040*, the *APEC Food Security Roadmap Towards 2030*, it is necessary to strengthen exchanges and cooperation among stakeholders on digitalization and innovation across the food supply chain, focusing in particular on food production, processing, and distribution.

This project collected and shared best practices of public and private sectors on digitalization and innovation of APEC food supply chains. It promoted policy exchange and intends to be interconnected, innovative, and inclusive in strengthening MSMEs and small-scale producers. The outcome expects to contribute to carrying out the *Implementation Plan of the APEC Food Security Roadmap Towards 2030*.

1.1 About the Project

This project is aligned with two economic drivers of the *APEC Putrajaya Vision 2040*, 'Innovation and Digitalization' and 'Strong, Balanced, Secure, Sustainable and Inclusive Growth', as well as the *Aotearoa Plan of Action*. The project contributes to the implementation of the *APEC Food Security Roadmap Towards 2030*, and the *Bangkok Goals on Bio-Circular-Green (BCG) Economy*, by collecting and disseminating relevant technologies, information and best practice on digitalization and innovation in the food supply chain focusing in particular on food production, processing and distribution.

The project is focusing on 5 targets of the *Implementation Plan of the Food Security Roadmap Towards 2030*, including: **8(d)** Economies to make available and deliver training sessions and/or workshops to improve food system related digital literacy and capability for underserved communities, leveraging existing programmes where possible; **8(f)** Promote public-private investment to facilitate the use of innovative technologies for the whole food value chain, including those which improve efficiency and sustainability, and increase investment in micro, small and medium size enterprises (MSMEs), including start-ups, and small scale producers in the agri-food and fisheries sectors; **8(g)** Modernize food storage facilities and logistics capacity, through increased exchange and cooperation among government agencies, businesses and institutes focusing on post-harvest management and technologies; **17(c)** Share best practices on encouraging responsible investment into environmentally friendly, nature positive and sustainable food production, processing and distribution; and **17(d)** Acknowledging that economies use a range of different policy approaches in the food sector, we agree to identify and promote approaches that would support good environmental outcomes while also avoiding and/or minimising market distortion, including by drawing on work from relevant international organizations.

1.2 About the Survey

The survey is part of the project and covers the whole food supply chain, including storage, transportation, processing, food quality testing and so on. The questionnaire on technologies and policies of digitalization and innovation were designed according to the different stages of food supply chain, particularly on food production, processing and distribution. Questions were also included on aspects of particular focus for/importance to women and how technologies in the food industry eliminate inequality and vulnerabilities for women. The questionnaire was distributed to different subjects, including governments, academic organizations, MSMEs and small-scale producers from all APEC economies. The survey questionnaires were arranged according to four main sections, namely:

- The **application** of digitalization and innovation in the food supply chain;
- The **impact** of digitization and innovation on the food supply chain;
- The **challenges** of promoting digitization and innovation, mainly analyzing the difficulties that exist in the application and promotion process;
- The **suggestions** for promoting digital innovation in the food supply chain.

2. Survey and Analysis on the Application of Digitalization and Innovation

2.1 Collection of Questionnaires

In order to understand how well digital and innovative technologies are applied in the food supply chain, the "Survey on Digitalization and Innovation of Food Supply Chain in APEC Region" was conducted between October 2023 and October 2024 among the stakeholders in the food supply chain. The stakeholders surveyed included government agencies, quality watchdogs, research institutes and food-related enterprises, among others. They were practitioners in various parts of the food supply chain, including food production, trade, storage, processing, transportation, distribution and R&D. The survey featured single-choice, multiple-choice and fill-in-the-blank questions. The questionnaires were made into an Excel sheet, a mini program and a webpage, and were distributed in hard copy, by scanning a QR code or via group sending by the APEC Secretariat to the respondents.

A total of 360 questionnaires were collected, of which 332 were collected in 2023, with respondents from Australia; Chile; China; Hong Kong, China; Japan; the Philippines; Russia and the United States; and 28 were collected in 2024, with respondents from Australia, China, Japan and Thailand.

2.2 Analysis on the Application of Digitalization and Innovation

Digital technologies used in the food supply chain mainly included sensors, big data, cloud computing, artificial intelligence (AI) and blockchain (Figure 2-1). Specifically, 60.83% of the respondents adopted sensors, 46.11% big data, 22.22% cloud computing, 12.22% blockchain, and 11.67% AI.

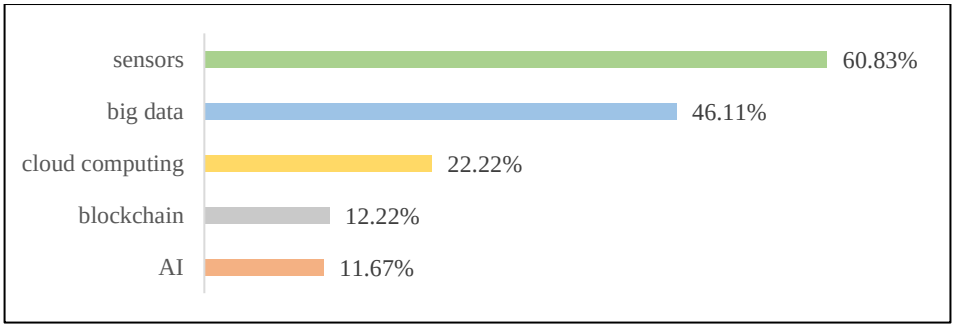

Figure 2-1 Digital technologies used in the food supply chain

Digital and innovative technologies used in the process of food production mainly included sowing, soil tillage, field management, plant protection, and information service technologies (Figure 2-2). Specifically, 31.11% of the respondents adopted information services, 20.00% field management, 19.17% sowing, 14.17% plant protection, and 12.22% soil tillage.

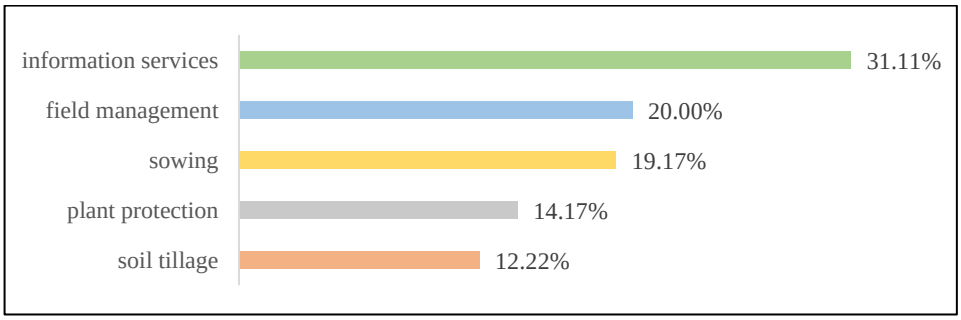

Figure 2-2 Digital and innovative technologies mainly used during food production

Digital and innovative technologies used in the process of food processing mainly included near infrared (NIR), online intelligent monitoring, and 5G+drone data acquisition technologies (Figure 2-3). Specifically, 38.89% of the respondents adopted online intelligent monitoring, 26.67% NIR technology, and 5.28% 5G+drone data acquisition.

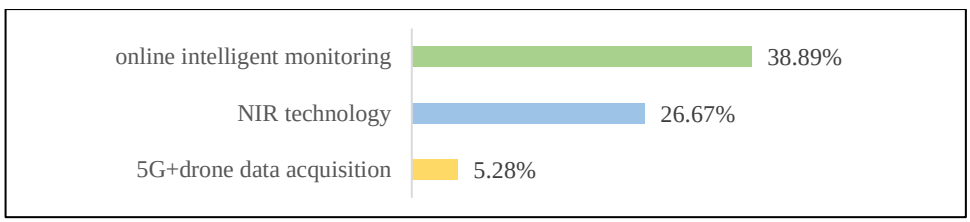

Figure 2-3 Digital and innovative technologies mainly used during food processing

Digital and innovative technologies used in the process of food storage mainly included intelligent grain storage management application platforms, grain storage management systems, multi-sensor dynamic grain condition monitoring, in- storage circular fumigation, temperature equalization systems, online pest and gas detection systems, quantity detectors and grain condition analysis software, on-in-one card management systems for logistics, drones and robots on duty in storage (Figure 2-4). Specifically, 63.89% of the respondents adopted grain storage management systems, 54.44% intelligent grain storage management application platforms, 50.83% multi-sensor dynamic grain condition monitoring, 48.06% in- storage circular fumigation, 26.94% quantity detectors and grain condition analysis software, 26.11% on-in-one card management systems for logistics, 25.83% temperature equalization systems, 13.33% online pest and gas detection systems, and 2.50% drones and robots on duty in storage.

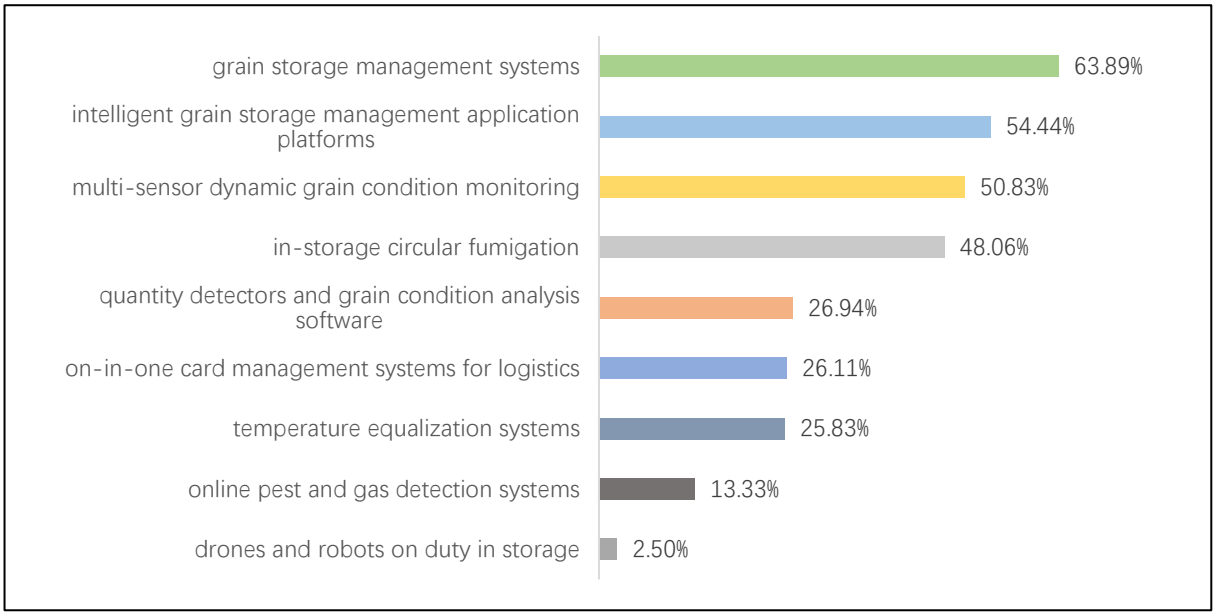

Figure 2-4 Digital and innovative technologies mainly used during food storage

Digital and innovative technologies used in the process of food transportation mainly included satellite positioning and communication transmission, data acquisition, early warning, smart park, and automatic quality inspection technologies (Figure 2-5). Specifically, 25.28% of the respondents adopted data acquisition, 17.22% satellite positioning and communication transmission, 8.61% automatic quality inspection, 7.50% early warning, and 6.39% smart parks.

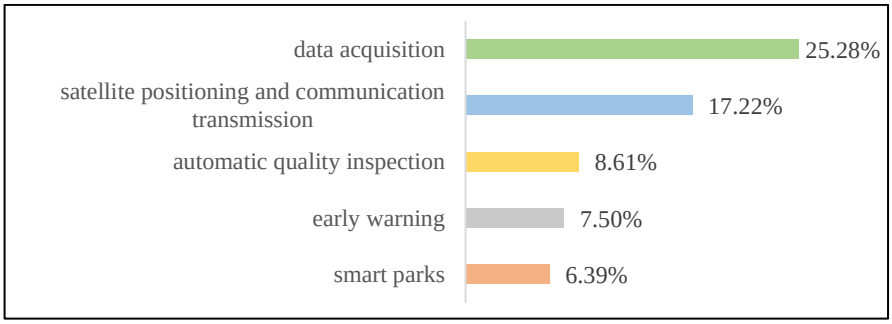

Table 2-5 Digital and innovative technologies mainly used during food transportation

Digital and innovative technologies used in the process of food quality inspection mainly included fully automatic inspection, QR code recognition, online printing, biosensing, molecular imprinting, and microfluidics technologies (Figure 2-6). Specifically, 33.61% of the respondents adopted fully automatic inspection, 26.39% QR code recognition, 18.89% online printing, 7.78% biosensing, 3.06% microfluidics, and 2.50% molecular imprinting.

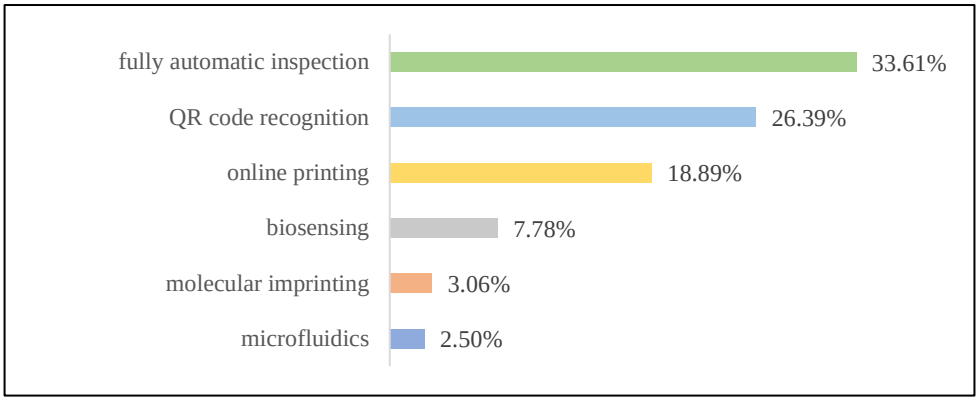

Figure 2-6 Digital and innovative technologies mainly used during food quality inspection

Digital and innovative technologies used in the process of food hygiene and safety inspection mainly included NIR, online intelligent monitoring, and 5G+drone data acquisition technologies (Figure 2-7). Specifically, 30.83% of the respondents adopted online intelligent monitoring, 26.67% NIR technology, and 3.89% 5G+drone data acquisition.

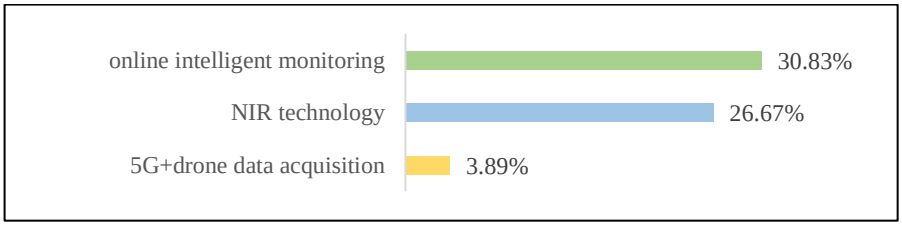

Figure 2-7 Digital and innovative technologies mainly used during food hygiene and safety inspection

Digital and innovative technologies used for food loss reduction mainly included insulation, humidity control, and grain condition monitoring technologies as well as information platforms (Figure 2-8). Specifically, 65.83% of the respondents adopted grain condition monitoring, 46.67% insulation, 35.00% information platforms, and 26.94% humidity control.

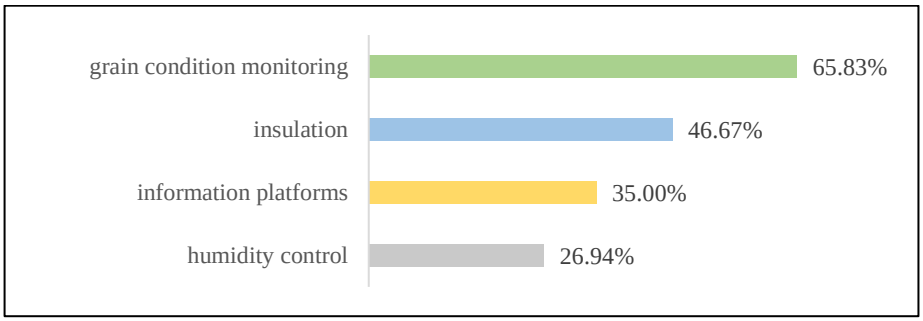

Figure 2-8 Digital and innovative technologies mainly used for grain conservation and food loss reduction

3. The Impact of Digitalization and Innovation on the Safe and Sustainable Development of the Food Supply Chain

3.1 Digital and Innovative Technologies as a Booster

Digitalization and innovation play an effective role in boosting the safe and sustainable development of the food supply chain. 88.89% of the respondents believed that digitalization could effectively promote the safe and sustainable development of the food supply chain, and the figure was 86.39% for innovation.

3.2 Management Efficiency of Digital and Innovative Technologies

The survey shows that 84.44% of the respondents considered digital and innovative technologies as having raised the management efficiency of their economies/enterprises, 70.00% suggested that these technologies had increased economic benefits, and 45.56% noted that they had improved social benefits (Figure 3-1).

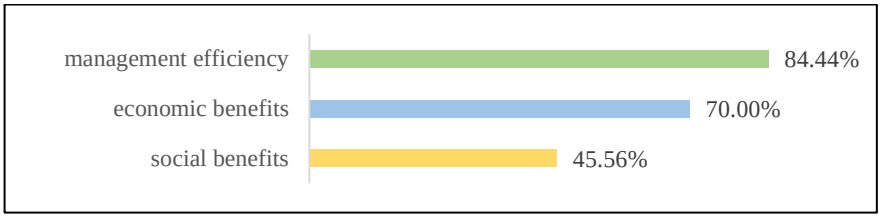

Figure 3-1 Management efficiency of digital and innovative technologies

Firstly, digital and innovative technologies help raise the level of management. According to the survey, these technologies were thought by 80.00% of the respondents to help achieve standardized management,

by 78.06% to help improve management efficiency, and by 42.22% to help innovate the public management mode (Figure 3-2).

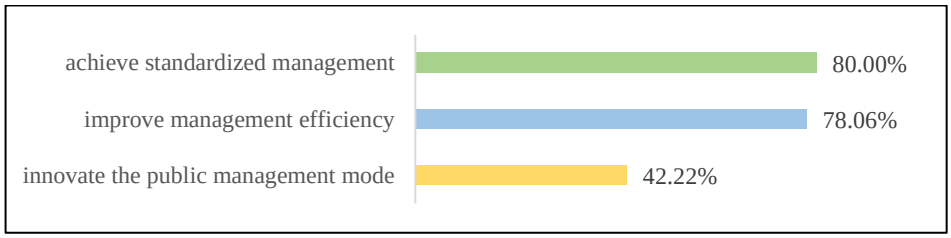

Figure 3-2 The impact of digitalization and innovation on management

Secondly, digital and innovative technologies help increase economic benefits. According to the survey, 77.50% of the respondents reported lower quality management costs, 58.06% reported higher corporate profits, and 42.22% reported better results in brand building (Figure 3-3).

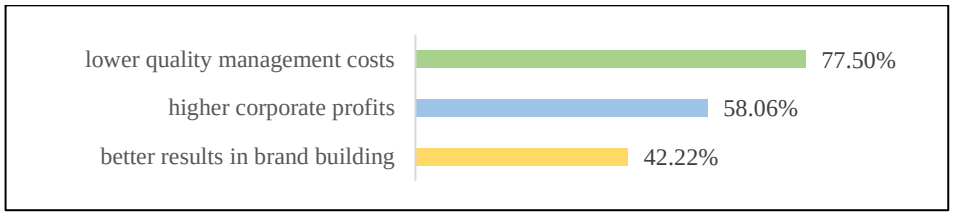

Figure 3-3 The impact of digitalization and innovation on economic benefits

Thirdly, digital and innovative technologies help improve social benefits. The survey indicates that 80.56% of the respondents believed that digital technologies delivered high-quality products and services, 54.17% argued that these technologies provided a demonstration effect, and 36.39% perceived the technologies to have brought about a fundamental change in the mode of economic growth (Figure 3-4).

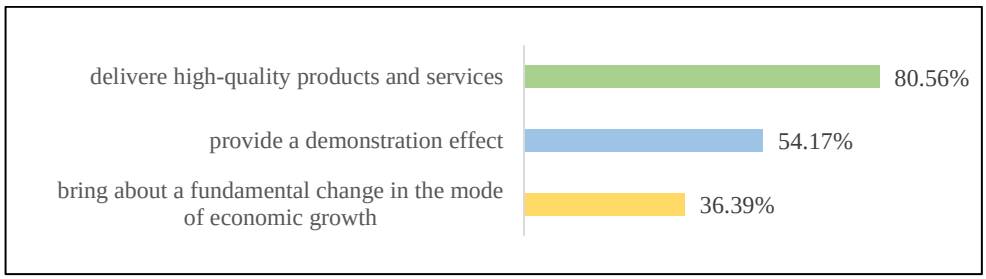

Figure 3-4 The impact of digitalization and innovation on social benefits

3.3 Digital and Innovative Technologies as a Contributor to Gender Equality

Digitalization and innovation help reduce the impact of gender gaps in the food industry. The development of digital technology has spawned more mental jobs, and physical and physiological

differences no longer constitute obstacles for women to participate in work. Mechanization, automation, man-machine collaboration make women get more job opportunities. Besides, remote working and online training can enhance work flexibility, improve working conditions and provide more opportunities for women to work and study. Digital and innovative technologies were recognized by 75.00% of the respondents to have the potential for eliminating women's vulnerability and inequality in the food industry. Of these respondents, 69.44%, 52.78%, 50.00% and 50.00% deemed narrowed gender gap in physical strength, enhanced job stability, increased flexibility in working hours, and improved working environment, respectively, as the key factor.

Of the respondents, the proportion of male is 73.89%, the proportion of female is 25.56%, and 0.56% of them prefer not to say the gender. It is worth noting that there was a slight difference between men and women in what they were concerned about digitalization and innovation in eliminating gender inequality. Men were more concerned about the improvement brought by digital and innovative technologies in the gender gap in physical strength, while women considered narrowed gender gap in physical strength, enhanced job stability and increased flexibility in working hours to be equally important.

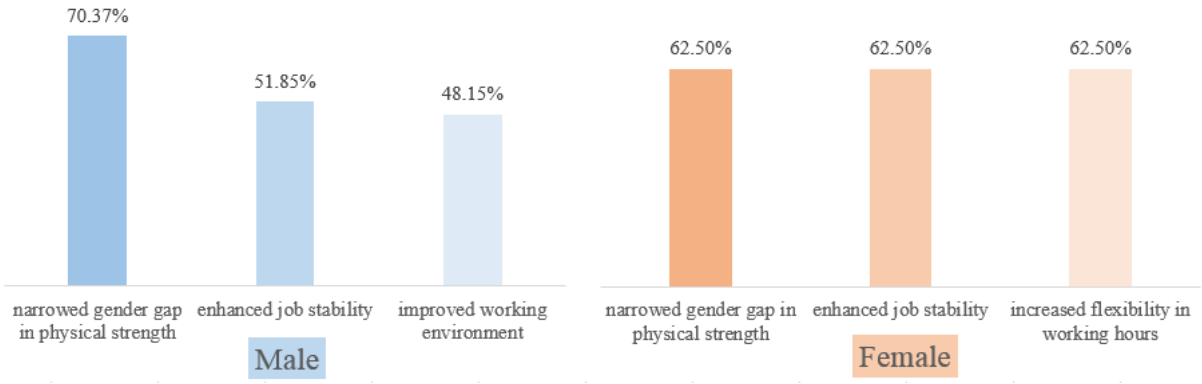

Figure 3-5 The impact of digitalization and innovation on social benefits

3.4 Different Perspectives on Digital and Innovative Technologies between Government and Enterprise

Overall, there is little difference on the response between the government and the enterprise on the application of digital technology. The two groups have similar views on the main types of digital technology applied in the food supply chain, and both groups believe the digital technology could enhance the efficiency of management, and improve the quality and safety of food. As to the digital and innovative technologies applied in the different stage of chain, such as food production, storage, transportation of the chain, the data shows that the proportion of digital technology applications as perceived by the government is higher than the actual adoption rate by enterprises. That is because the

government is able to deploy more resources and has the best grasp of various technologies which may be only applied in few enterprises. The result also implies that the government has significant potential to pitch different digital and innovative technologies.

However, there is still slight difference between the government and the enterprise in the following two aspects. Firstly, regarding the application of digital technology in the processing stage, 27.59% of the surveyed enterprises have adopted the near-infrared technology, while only 13.33% of the surveyed governments believed that the near-infrared technology has been applied in the processing stage, which indicates that the near-infrared technology is much more popular than the government think. Secondly, regarding the challenges faced by the application of digital technology, lack of professional information technology personnel is the factor that both groups chose the most, but there are also 50.00% of governments deemed that the main factor is the lack of scientific institutional norms while 28.84% of enterprises chose this option. That's because it is easier for an enterprise to develop its own management norms than the government since the government, as policy-maker, should be more considerate, rigorous and standardized, and usually takes long time to make norms.

4. Challenges to Promote the Application of Digital and Innovative Technologies

4.1 Key Factors Influencing Food Security

Factors influencing food security in the food supply chain vary depending on the specific components of the chain. Below is an analysis of the key factors in the processes of food production, procurement, storage, transportation, processing and distribution.

In the process of food production, 67.78% of the respondents believed that weather and climate were the main factors influencing food security, 55.83% voted unreasonable use of pesticide and fertilizer, while 53.61% suggested soil and water (Figure 4-1).

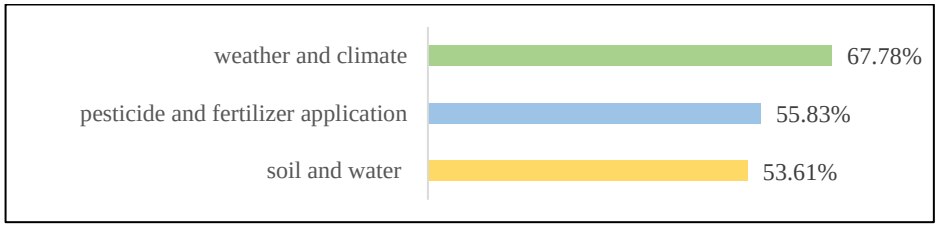

Figure 4-1 Key factors influencing food security during food production

In the process of food procurement, 60.83% of the respondents believed that lax control was the key factor influencing food security, 43.06% voted improper handling before storage, while 36.11% suggested unreasonable indicators for storage inspection (Figure 4-2).

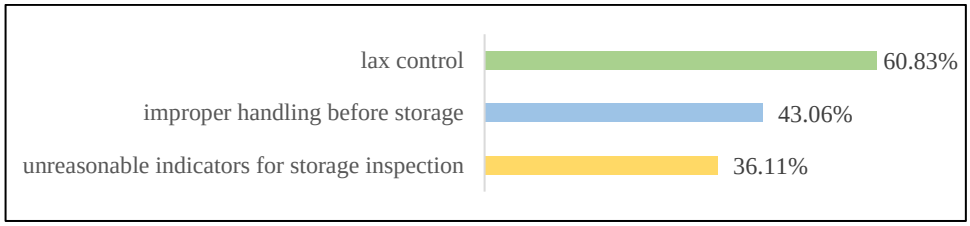

Figure 4-2 Key factors influencing food security during food procurement

In the process of food storage, 62.22% of the respondents believed that pests and mold were key factors influencing food security, 51.39% considered inaccurate temperature control as the key factor, 43.61% voted inaccurate humidity control, and 38.06% indicated poor storage management (Figure 4-3).

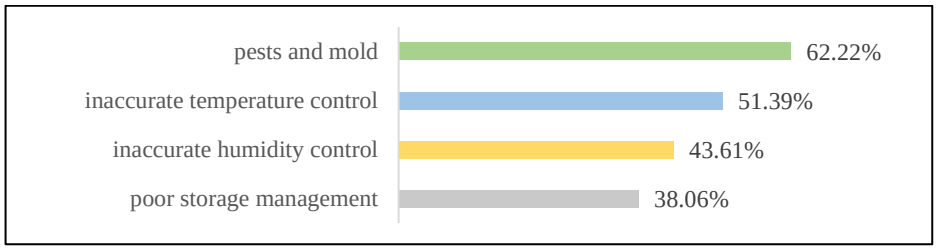

Figure 4-3 Key factors influencing food security during food storage

In the process of food transportation, 46.39% of the respondents believed that uncontrollable temperature during transportation was the key factor influencing food security, 43.33% considered improperly controlled humidity during transportation, while 35.83% voted improper packaging (Figure 4-4).

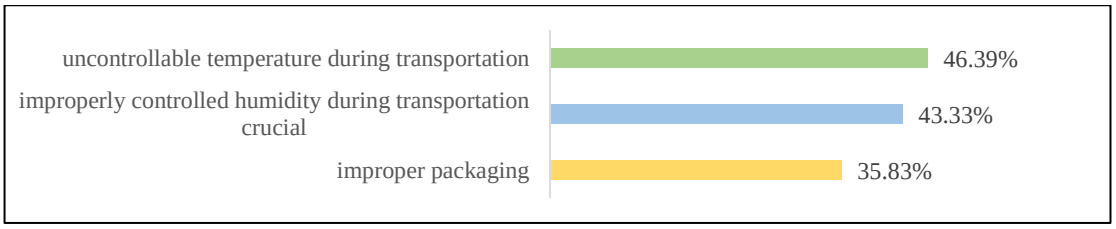

Figure 4-4 Key factors influencing food security during food transportation

In the process of food processing, 48.33% of the respondents believed that nutrient loss was the key factor influencing food security, 43.62% voted carcinogens and other harmful chemicals resulting from too high temperatures during food processing, while 19.17% attributed it to other chemical solvent residues (Figure 4-5).

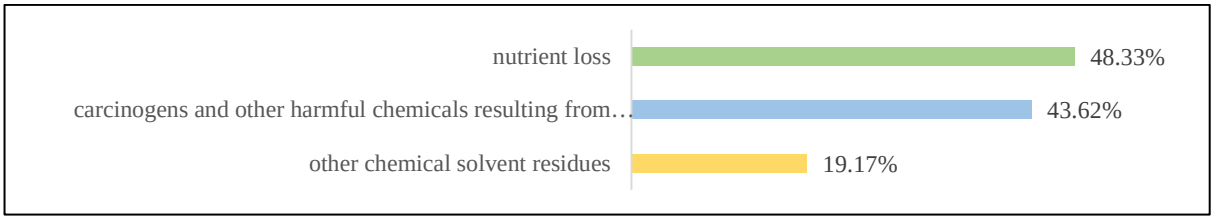

Figure 4-5 Key factors influencing food security during food processing

In the process of food distribution, 51.67% of the respondents believed that improper storage during food distribution was the key factor influencing food security, 44.72% ascribed it to too high ambient temperatures, 43.61% deemed broken packages as the dominant factor, while 33.06% voted excessive ambient humidity (Figure 4-6).

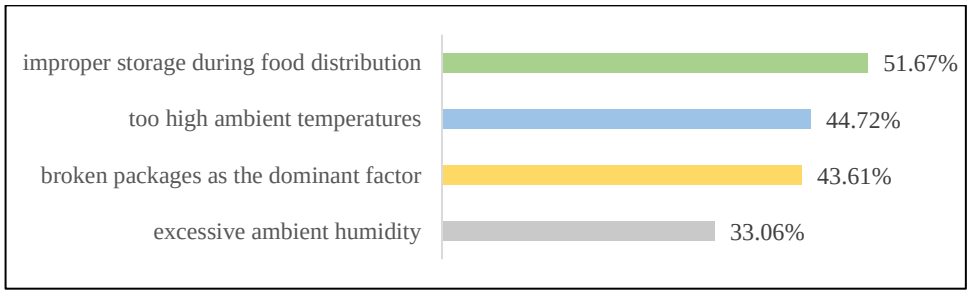

Figure 4-6 Key factors influencing food security during food distribution

4.2 Challenges in the Application and Promotion of Digital and Innovative Technologies

Real-time monitoring and data acquisition of humidity, temperature and other environmental parameters in the processes of food production, storage, processing and transportation through digital and innovative technologies such as sensors, Internet of Things (IoT), and big data have improved the efficiency of quality management and enhanced food security by identifying and solving potential problems in a timely manner. Therefore, it is necessary to strengthen the promotion and application of these technologies. However, there are certain difficulties and challenges in terms of policy, technology and funding, restricting the promotion and application of digital and innovative technologies in the food supply chain.

4.2.1 Difficulties and Challenges in Service

To intensify the application and promotion of digital and innovative technologies, economies have formulated relevant policies in terms of infrastructure development, standard setting, financial support, tax incentives, talent cultivation, industry-academia-research synergy, and technology promotion. However, the food supply chain is still faced with the following challenges in the process of digital transformation.

Firstly, insufficient investment. Most of the respondents were confronted with a lack of funding, affecting the application of digital and innovative technologies. 78.61% of the respondents anticipated financial policy, and 25.00% hoped for tax policy support.

Secondly, unsound industry standards. 30.56% of the respondents believed that there were no scientific standards or norms on digital agriculture and food safety, such as food quality related data classification and code of digital platform, and 28.06% noted a lack of unified standards. Standard setting has become one of the important constraints. The digital standards for production, storage, transportation, processing, and consumption in the supply chain are not sufficiently connected. There is a phenomenon of information isolated island between different enterprises/stages in the supply chain, which hinders the integration and sharing of data, and is not conducive to promoting the application of digital technology.

Thirdly, talent shortages. 72.50% of the respondents suggested a shortage of talents specializing in digital and innovative technologies, a phenomenon common in economies such as Chile and China. 66.67% of the respondents indicated a lack of professional information technology personnel, such as the respondents from Russia and China, and 46.94% hoped that policies would be introduced to strengthen talent cultivation.

Fourthly, insufficient industry-academia-research synergy. 19.44% of the respondents hoped to get policy support for industry-academia-research synergy. Enterprises, universities, research institutes and end-users have not yet established a network of partnerships or interactions, resulting in low efficiency of synergistic innovation.

Fifthly, ineffective technology promotion. There are few demonstrations or pilot projects for digital and innovative technologies, leading to limited channels for enterprises to learn about related products. R&D institutes have an insufficient understanding of the importance and means of promoting digital and innovative technologies, and technology application enterprises have difficulties and deviations in acquiring information on relevant technologies.

4.2.2 Difficulties and Challenges in Technology

Firstly, lack of support for core technologies. The food industry is currently characterized by weak basic capabilities of digital and innovative technology R&D, low degrees of technological development in terms of underlying operating systems and industrial software, and few technological solutions for digital transformation of enterprises. Moreover, the flourishing digital economy has triggered a digital transformation boom, and many enterprises have introduced digital technologies on a large scale, including new technologies such as AI, cloud computing, and big data. Nevertheless, single technologies cannot meet the realistic needs of food enterprises, while R&D of integrated technologies remains limited, making it impossible to fundamentally achieve digital transformation.

Secondly, insufficient data mining. Data mining involves massive data processing, algorithm design and model training, and requires huge computing capabilities and complicated technological support. Despite the increasingly widespread application of digital technologies in agriculture and the food industry, data mining technologies and tools have limitations that prevent them from enabling real-time monitoring, accurate forecasting or data analysis.

Thirdly, insufficient data integration and poor data connectivity in the food industry has led to serious data silos and made it hard to form an effective data sharing and collaborative analysis mechanism, resulting in the failure to effectively and fully integrate data in different stages of the food supply chain. 68.89% of the respondents believed that digital and innovative technologies and the different stages of the industry chain had been partially integrated, while 18.33% held that the two failed to be integrated. When it comes to the reasons for such failure, 36.39% of the respondents believed that inter-sector data could not be integrated, especially peripheral data closely related to food, such as meteorological, traffic, and financial data.

Fourthly, lack of individualized technological solutions. Small and medium-sized enterprises (SMEs) are technologically weak, and have difficulty in satisfying the needs for developing, deploying, operating and maintaining enterprise digital platforms. In addition, the current applications of digitalization and innovation in the market mostly provide general solutions, which cannot meet the individualized and integrated needs of SMEs.

4.2.3 Difficulties and Challenges in Funding

The application and promotion of digital and innovative technologies require substantial investment. The food industry is not a highly profitable one and is dominated by SMEs. The application of digital and innovative technologies may bring certain economic pressure to food-related enterprises, which need to find suitable financing channels and technology partners.

Firstly, high costs restrict the willingness to apply digital and innovative technologies. 72.50% of the respondents believed that the application of digital and innovative technologies required significant funding. The transition toward digital and innovative technologies is a systematic project involving organizational structure, business processes, operation and management. Given limited financial resources and high survival pressure, most SMEs are often deterred from these expensive, time-consuming and slow-acting technologies. Respondents from economies such as Russia, Chile, Australia and China also said that high investment was a major obstacle to the application of digital and innovative technologies.

Secondly, the application of digital and innovative technologies lacks a mature profit model. This was observed by 40.00% of the respondents. New profit models, such as cross-field integration, product

customization and digital marketing, have not yet been established in the food supply chain. As such, factors such as insignificant short-term economic benefits and long payback periods have reduced the willingness of SMEs to invest in these technologies.

5. Conclusion and Recommendations

5.1 Conclusion

Most economies have policy frameworks concerning digitalization and innovation in food supply chain, but the implementation is an issue for many economies. APEC economies have different policy needs: infrastructure construction, building the innovation platform, carry out pilot demonstration projects, implement development plans, formulate industrial standards, provide financing, loan support, tax incentives, talent cultivation, carry out technical publicity and so on.

5.2 Recommendations

By conducting the survey and holding the related seminar on member economies' best practices and applications of digitalization and innovation in food supply chain, we collected and shared some best practices of public and private sectors, focused in particular on food production, processing and distribution, promoted policy exchange and intended to be interconnected, innovative and inclusive in strengthening MSMEs and small-scale producers. Based on the practices and recommendations put forward by economies, we have some key recommendations as follows:

- Improve digital infrastructure, increase government investment in digital infrastructure, and promote the accelerated application of new-generation information technologies and new digital infrastructure represented by near-infrared technology, 5G, big data, cloud computing and AI, including by stepping up development of 5G base stations. On the one hand, digital infrastructure should satisfy the current economic development needs of economies; on the other hand, appropriately future-oriented digital infrastructure should be deployed to meet the actual requirements of future development of the digital economy.

- Governments should increase financial, tax and other support for digital technologies, encourage enterprises to strengthen R&D of digital technologies, and introduce tax incentives for digital technology R&D. Given the reality that MSMEs are weak in digitalization, economies may also consider the establishment of a fund that supports MSMEs in digital technology R&D and investment to actively guide MSMEs to carry out digital transformation and upgrading and popularize the application scenarios of the existing digital infrastructure that can support MSMEs. Encourage enterprises to participate

in the formulation of digital policies and standards, and accelerate the digital transformation of the industrial chain.

•Intensify research and promotion on digital technologies, and develop more low-cost and individualized technologies to meet the development needs of different economies and different entities in the supply chain.

•Strengthen the integration between digital technologies and other technologies, encourage the in-depth integration of new-generation digital technologies into the food supply chain, and explore new technologies, new forms of business, and new models for the digitalization of the food supply chain. Promote the use of precision agriculture technologies based on big data, and blockchain based agricultural product quality traceability systems, to improve farm management efficiency and product quality and safety levels. By drawing upon mature digital technology application scenarios in other industries, promote the in-depth integration of digital technologies into the food industry, improve the resilience of food supply chain and the management efficiency of the chain, and enhance the ability to resist natural and market risks.

•Leverage existing platforms like APIP, or set up a case studies section on APEC's official website to share the typical digitalization cases, and hold seminars on the digitalization of the food supply chain to enhance the exchange of information and sharing of experience among economies.

•Intensify digital technology training and talent cultivation, develop courses or training programs that meet the needs of economies with the help of universities and research institutes, and cultivate more digital technology talents for different aspects such as management and application. Develop new ways of training, and provide online and offline training courses to cultivate more human resources for digitalization.

•Promote the establishment of more demonstration and pilot projects for the application of digital technologies, and foster a group of mature and replicable digital food demonstration enterprises or models to drive other entities to embrace digital transformation and upgrading of the food industry.

•Explore the establishment of research centers for food loss reduction technologies, encourage governments, MSMEs, research institutes and other groups in the food supply chain to join in, facilitate the application and promotion of digital technologies in loss reduction throughout the food supply chain, promote the connectivity of relevant standards among economies, and ensure an efficient and smooth flow of information.

•Actively leverage the organizational and coordinating role of international organizations, increase efforts to train and enhance women's digital skills, and provide guidance and support to build capacity for young women. It is suggested that the economy strengthen its regulation on avoiding employment discrimination and gender discrimination in algorithms. Actively develop digital products for women, promoting women to enjoy the benefits of the digital economy, and enhancing their ability to participate in the development of the digital economy.