“Strategy for smart agricultural system in fruit tree research: breeding new varieties and sustainable/stable production with labor-saving technology”

Review Report

General Comments of the Evaluation Committee

The average level of the projects is high, covering a wide range of important crops in the Japanese fruit industry. Some recommendations and suggestions are listed below;

1) The project goals need to be clarified. What are the characteristics of the Japanese fruits? Where are the robust specialties of the Japanese fruits? How can synergy be achieved among projects? Understanding these issues can define the effect, duration, and effort required for the study. Some projects have many competing studies worldwide and do not need to be duplicated. It is essential to conduct internal brainstorming and develop strategies.
2) Project leaders need to clarify their long-term vision, goals, and success criteria at the completion of the project, as well as a roadmap to reach these goals.
3) It is important to have close collaboration between researchers and stakeholders, such as growers, marketers, and consumers, to ensure more meaningful outcomes consistent with the real needs of industry. Economic analysis is required for some project investment.
4) Both domestic and overseas relationships will be needed. It is vital to identify the national and the international organizations to work together to achieve the goals.
5) Industry-academia-government collaboration projects should make the relationships more tangible among these parties and the role of NARO.
6) Researchers should use digital information for the Society 5.0 to achieve a better society owing to the aging of the society and global warming and to further develop the agricultural and food industry.

NARO Response to the Comments of the Evaluation Committee

We express our gratitude for the many valuable comments. Below we describe the correspondence in each of the paragraphs.

1) The greatest advantage of Japanese fruits lies in their high quality. Not only is there superior quality of varieties, but the sophistication of their cultivation techniques is also extremely high. However, the shortage of successors to continue the management of domestic fruit orchards is severe and urgent action is needed. As such, an effective measure will be to promote the development of varieties having labor-saving characteristics and their labor-

saving cultivation techniques while still maintaining their superior quality. Overseas, fruit tree machinery such as fruit-harvesting robots is under development. However, such large machinery is not compatible with some Japanese orchards of differing scales. Thus, we consider they need to be modified to work in small orchards in our country.

2) We are drawn up a mid- to long-term road map for each project and advancing our associated research efforts for making continuing progress with clear objectives.
3) To date, we have been focusing on cooperative initiatives with individual growers and grower associations. However, in the future, we would like to pursue research initiatives in close cooperation with marketers and consumers as well. In that case, we would like to conduct economic analyses and draft a research plan such that the maximum results can be achieved with limited research resources.
4) We have been conducting research projects in close cooperation with prefectural research institute and universities. We are engaged in the long-term dispatch of researchers and joint research projects with overseas institutions, and at present, such cooperation is only at the project manager level. In the future, we would like to consider opportunities for strategic cooperation in each joint-research project.
5) We would like to continue industry-academia-government collaborative projects.
6) We would like to utilize digital information in cooperation with the newly established Research Center for Agricultural Information Technology, NARO.

Section 1: Smart breeding of fruit trees using genomic information

Project 1-1 Breeding of high-value-added citrus varieties using genomic information

Rating and Comments of the Evaluation Committee

Owing to the declining production and consumption of citrus fruits in Japan, it is very important for the future of the citrus industry to cultivate high value-added varieties using genomic information. This project addresses issues, such as expansion of the genetic base and shortening of the selection period and is suitable for both academic research and citrus breeding programs. However, it is essential to note the following points.

1) The number of single-nucleotide polymorphism (SNPs) in the genome-wide association analysis (GWAS) and the number of individuals in the population is too small. Information on the linkage disequilibrium should also be considered.
2) It is important to improve the efficiency of genomic selection (GS). Cost effectiveness compared to the traditional phenotypic breeding should also be considered.
3) Although an accelerated generation technology is very interesting, we should consider

whether the final product will be recognized as a non-GMO and if this approach may also be applied to numerous other traits.

4) It is important to conduct breeding programs that meets the needs of consumers, such as the seedless and the easy-to-peel varieties. Furthermore, owing to a large demand for varieties used for processing, it will be optimal to be able to propose growers not only the varieties for table use but also the varieties for processing.
5) Sustainable and stable production requires the development of varieties resistant to the tristeza virus and the citrus greening disease that affects oranges and lemons.
6) Close cooperation with local stakeholders (prefectures and growers), economists, and wholesale traders is essential when selecting and disseminating new varieties. It is also important that genomic scientists and breeders work together to directly link the results of genomic research to breeding. Collaboration with foreign researchers is important to improve the GS method.

The rating is: **A – good quality and minor revision needed.**

NARO Response to the Comments of the Evaluation Committee

1) It has been pointed out that the number of single nucleotide polymorphisms (SNPs) and the number of test specimens are important for improving the detection sensitivity and accuracy of genome-wide association studies (GWAS). In order to achieve this improvement, we are working to increase the quantity of data by increasing the number of SNPs and adding new varieties and selections. To increase the quantity of data, polymorphism information for approximately 70, 000 SNPs was obtained through Genotyping by Random Amplicon Sequencing-Direct (GRAS-Di) analysis using a high-speed sequencer. To add new varieties and selections, evaluation of the traits of the breeding population including genetic resources was continued; data accumulation is also planned. Information concerning linkage disequilibrium has been considered since the beginning of the GWAS analysis and will continue to be evaluated in the future in order to advance the active use of GWAS as an advanced technology for citrus breeding.
2) To improve the accuracy of genomic selection (GS), it is effective to increase the number of SNPs and individuals as stated above in 1), but factors such as the number of families, method of target trait evaluation, and the number of repetitions also affects predictive accuracy. Of these factors, the number of families are being augmented in an effort to increase the number of individuals, and imaging analysis is being conducted to improve the accuracy and efficiency of selection through more objective and high-accuracy trait evaluation. Meanwhile, in citrus breeding, it is necessary to consider more than 20 traits, and breeding costs will increase significantly if GS is performed with respect to each trait. As a

workaround for this issue, efforts are ongoing to achieve cost reduction through a 2-stage selection that combines marker-assisted selection (MAS) and GS developed using conventional quantitative trait locus (QTL) analysis and GWAS as seen above in 1). Genotyping costs decrease each year, and we aim to establish a more cost-effective selection system while comparing the costs of conventional phenotypic selection techniques.

3) In the event that a foreign gene is ultimately removed from the genome, the technology for fast track breeding system developed with citrus species is the same as the technology used for genome editing which limits modification of a trait to a specific sequence. The Japanese Ministry of Health, Labor and Welfare (MHLW) has announced that a safety review is not required prior to the distribution of genome-edited foods after October 1, 2019, and a notification system has been announced. The Japanese Ministry of Agriculture, Forestry, and Fisheries (MAFF) also organize genome-edited crops and organisms created by new breeding techniques other than genome-editing in the same way wherever possible. For this reason, the Citrus Tristeza Virus (CTV)-resistant null segregates obtained during the development process are expected to be approved for cultivation and distribution through necessary procedures as no foreign genes remain. This method can be applied to citrus species that can be crossed with early-flowering citrus if the trait to be introduced is controlled by a single gene and a selection marker has been developed.

4) For more than 20 years, seedlessness and ease of peeling have been included among breeding goals, and DNA marker development is ongoing. In addition, fruit tree management systems for processing are currently difficult to establish due to high labor costs and the comparatively small operating area for production structures in Japan. Therefore, it is necessary to consider how to further develop the corresponding technologies. However, we also recognize that it is necessary to develop varieties that can allow for reduced production costs even for varieties for fresh market, as well as develop efforts to improve traits related to lower production costs, such as annual bearing and high yield.

5) We are promoting the use of selections to which genes corresponding to CTV resistance originating from *Poncirus trifoliata* have been introduced. In addition, a metric for evaluating CTV resistance was established to aid selection in the national trial. Meanwhile, breeding for citrus greening disease resistance have not been started and are recognized as a future issue. At present, rapid response measures are difficult to implement due to the need for quarantine facilities in Japan (for example, we believe it is more efficient to select varieties/lines in which onset has already occurred that have been cultivated by the National Agriculture and Food Research Organization (NARO) overseas in cooperation with foreign research institutes.)

6) We work closely with prefectural researchers, for example, through the Fruit Tree Research

Meeting held annually to discuss common issues and conduct joint research activities. In addition, the marketing of varieties with new traits is important, and we are conducting joint research projects involving economists. Regarding cooperation with growers, we are accepting visitors, allowing to sample and providing information related to cultural characteristics of our new varieties. In NARO's breeding scheme, before registering apple varieties, we have been conducted seminars and tasting events to confirm that new traits and/or quality of the variety are acceptable by the participants. Collaborative activities between genomic researchers and breeding researchers are discussed starting from the planning stages, and joint studies to achieve identified objectives are underway. Regarding the development of genomic analysis tools, we are promoting international cooperation in the creation of a citrus genome research base, through activities such as participating in the International Citrus Genome Consortium. To further strengthen international cooperation, we are developing a mikan genome database that will enable viewing of the DNA markers and genome information of the unshu mikan (*Citrus unshiu*), and we hope that it will serve as a starting point for international joint research. To develop technologies for controlling invasive pests associated with the advancement of global warming, we have invited overseas researchers under the OECD program and dispatched researchers under the NARO long-term overseas research program. We also have plans to further develop our genome editing technology through international collaboration.

Project 1-2 Current apple breeding and genomic research in NARO, Japan

Rating and Comments of the Evaluation Committee

The apple industry is the second largest fruit tree industry in Japan and has a high exportation value; however, the aging and the declining population of apple growers are problematic. A goal of this project is to develop technologies to expand the scale of production and marketable varieties that enable adaptations to global climate change and the consumer demands. Although the program integrated well both academic research and their use in breeding programs, it is essential to note the following points.

1) In genetic studies, we recommend expansion of the genetic diversity of the population and increasing the number of SNPs. Target traits for marker development should be aligned with actual breeding goals (e.g., less effort on improving the fruit quality). Markers, such as Kasp, which are cheaper than simple sequence repeats (SSR), should be used for marker-assisted breeding. Quantitative trait loci (QTLs) developed for rooting capability of rootstocks and for watercore management should be tested in other populations.

2) Breeding should be scaled up to increase the efficiency of obtaining individuals with the target traits. Research on phenology should be conducted from a long-term perspective, as a breeding goal for the adaptation to the climate change, rather than focusing on coloring alone. Research should also focus on apple scab resistance. There is a genetic link between the columnar tree shape and biennial bearing and poorer quality. Is columnar tree a good model for apple production? Perhaps the trait for skin color should be aimed not only by crossbreeding but also explore the effect of mutation and genetic modification?
3) It is vital to investigate whether genome editing is acceptable to the Japanese consumers before heavily investing in this technology.
4) Partnerships with producers, traders, and consumers should be strengthened, and consumer surveys should be conducted for new traits, such as the red-flesh apples, before proceeding with commercialization.
5) It is inefficient to have several independent breeding programs of apple in Japan; therefore, the programs should be integrated to establish a national breeding consortium. Collaboration should be strengthened in genomic research and breeding with overseas research institutes.

The rating is: **A – good quality and minor revision needed.**

NARO Response to the Comments of the Evaluation Committee

1) As mentioned previously, it is important in genetic research to expand the genetic diversity of the population and increase the number of SNPs. NARO plans to continue to utilize its genetic resources of *Malus*. It is important to match target traits for marker development with breeding goals in order to improve the efficiency of variety development. We are planning to work on marker development focusing on traits that aims at improved fruit quality. Although simple sequence repeat (SSR) markers are useful in both genetic analyses and in the selection of seedlings genetic analysis methods such as arrays and next-generation sequencing (NGS) that can handle a large number of markers have been widely applied in recent years. It is necessary to reconsider the seedling selection method using efficient marker detection system. In this connection, we consider Kompetitive Allele-specific PCR (KASP) marker is useful, and we are going to try to develop the marker in 2020. Validation of the developed QTL using other populations is ongoing. GWAS is mainly used for traits related to dessert apple, while verification is conducted in several populations of subsequent generations for rootstock traits.
2) In order to increase breeding scale, it is necessary to further invest funds and human resources and to expand breeding fields. Therefore, we improve the efficiency of breeding through activities such as marker development and application, while considering cost-effectiveness. In regard to breeding for the adaptation to the climate change, tolerances to environmental stress such as frost resistance, cold resistance, heat resistance, and flowering uniformity are

considered as a long-term research issue to be pursued in the future. Breeding for resistance to apple scab is one of the main goals. We believe that a cultivation model using columnar trees which enable apple growers to save labor for pruning and harvesting can be a valuable model in the land-intensive Japanese apple cultivation system. Although columnar tree habit is linked to the biennial bearing and fruits with lower soluble solids concentrations, it has been shown that linkage with undesirable traits can be overcome by promoting backcrossing with varieties and selections with good fruit quality. Regarding skin color, cross breeding and the expansion of genetic diversity by gene editing are studied.

3) Whether products modified by genome editing will be accepted by Japanese consumers is currently under assessment through projects such as SIP, and the development of the relevant technologies is also proceeding in parallel. Regarding the genome editing of apples by NARO, efforts to advance the development of editing technologies capable of ultimately removing foreign genes from the genome are in progress. MHLW has announced that a distribution system for genome-edited foods will not require a safety review while a notification system will be required. MAFF will also organize genome-edited crops based on the same concept.
4) It is indeed important as pointed out to understand the needs of growers, market, and consumers and to develop varieties satisfying those needs. In NARO's breeding scheme, before registering apple varieties, we have been conducted seminars and tasting events to confirm that new traits and/or quality of the variety are acceptable by the participants. Before registration, we had understood that the red-flesh apples have potential value for both dessert and processed use.
5) It is true that there are several apple breeding programs in Japan, and that there are some common breeding objectives between these programs. However, apple breeding by prefectural organizations is aiming at the development and extension of original varieties in their own prefectures. At present, it is difficult to integrate a national breeding consortium led by NARO, thus we are working on sharing information as much as possible through activities such as providing information on early selection markers and research results on apple breeding. NARO is also actively exchanging information related to breeding research such as DNA markers with overseas research institutions, and we would like to strengthen such collaboration in the future.

Project 1-3 Breeding of high-value-added temperate fruits varieties using genomic information

Rating and Comments of the Evaluation Committee

Deciduous fruit breeding focuses on breeding and has not produced results that have as much academic significance as that for citrus fruits and apples. Excellent varieties have been produced,

including ‘Shine Muscat’, the Japanese pear cultivar ‘Kanta’, and the Japanese chestnut ‘Porotan’; however, it is essential to note the following points.

1) The overview of the pear's marker-assisted selection (MAS) process, costs, and utilization rate was very helpful. Prediction of the return on investment for MAS is very important and requires a clear focus on the most important characteristics and those with high-quality QTLs. Additionally, when selecting DNA markers for pears and chestnuts, it will be sensible to increase the number of seedlings selected. This will provide more individuals after marker selection, leading to the selection of other agriculturally useful traits.
2) Five different varieties of pears targeting different traits were created; however, will it be better to create one variety that combines these characteristics? Alternatively, will it be better to compare each of the characteristics of these varieties and propose the best varieties for each region?
3) What is the extent of cooperation with other domestic programs on pear breeding? NARO should create opportunities for the coordination or the integration of the national program. Competition (potential markets) with other crop species should also be considered.
4) What kind of coordination exists between the breeding program and the stakeholders, such as growers and traders? It may be a good idea to set up an advisory board of industry stakeholders, including growers.
5) What is the extent of cooperation with the international programs? Are minor fruits considered, especially persimmons and the stone fruit?

The rating is: **B – fair quality and moderate revision needed.**

NARO Response to the Comments of the Evaluation Committee

1) As discussed previously, we recognize that securing seeds and seedlings is one of the most important issues in the selection of DNA markers. Considering the breeding scale based on factors such as current field area and the number of personnel, the current selection parameters are believed to be virtually suitable and it is impossible to significantly increase them. By contrast, depending on the mating combination, the number of seedlings may greatly decrease with respect to the seeds acquired owing to poor growth after sowing. In such cases, it is more important to advance measures to improve the total seedling yield efficiently rather than to increase the total number of seedlings.
2) Currently, only varieties having a small number of useful traits are bred. As mentioned previously, NARO is focusing its efforts on breeding programs in which useful traits are accumulated as much as possible. Regarding the regional adaptability of new selections, cultivation tests are being conducted at the national test and the regional adaptabilities are

largely clarified at the time the varieties are introduced.

3) There are more than 10 prefectural research institutions in Japan that have pear breeding program but their breeding programs are often premised on extension of original varieties in their own prefectures, and it is currently difficult to integrate or adjust these programs. At present, NARO cooperates by actively responding to requests for information on breeding methods and DNA markers. As for competition with other crops, NARO plans to seek to open potential markets by extending the maturity period, extending the supply period by improving storability, adding new traits, and improving fruit quality.
4) Regarding cooperation with growers, NARO has accepted visitors, and tasting of our new varieties and information on cultivation characteristics are provided. In NARO's breeding scheme, before registering apple varieties, we have been conducted seminars and tasting events to confirm that new traits and/or quality of the variety are acceptable by the participants.
5) There are currently no international programs specifically related to pears and chestnuts. Persimmon cultivation is increasing in Europe, and NARO is conducting joint research on the breeding of sweet persimmons with the Valencian Institute of Agricultural Research (IVIA) in Spain. In addition, NARO has exchanged genetic resources and genome information with two universities in China as part of the international development of advanced fruit tree crops. Meanwhile, no specific collaboration is currently ongoing with respect to peach breeding. Cooperation with overseas organizations is key, and NARO would like to exchange information with foreign researchers at international conferences.

Section 2: Development of sustainable/stable production with labor-saving technology
Project 2-1 Towards the development and implementation of smart production system of fruit

Rating and Comments of the Evaluation Committee

Fruit tree production is labor intensive and difficult to mechanize compared to that of other agricultural products. Although it is clear that the aging of producers and the lack of successors to take over production requires new labor-saving technologies while maintaining the quality, it is vital to carefully consider the focus of NARO's mission. It is commendable that this project adopts both a short-term and a long-term approach. In this project, short-term solutions unaffected by scale, such as arm-lifting tools and specialized scissors, have been successful; however, it is essential to note the following points.

1) It is important to formulate a NARO strategy, with private companies around the world investing considerable amounts of money in precision agriculture, mechanization. and sensing. It is vital that stakeholders from both agriculture and engineering participate in planning,

implementation, and evaluation of the project. It is also necessary to include economists and sociologists to evaluate economic and social costs.

2) The Marudori system has already been put into practice in Japan and around the world, but is research ongoing or are efforts now focused on the widespread uptake of this system? It would have been better if the Marudori system had automated controls.
3) Stakeholder surveys and detailed benchmarking are required before starting a new development. For example, although it is good to work towards adapting the shape of apple trees to suit the machinery, there are concerns regarding a decline in the quality of the fruit. Quality is particularly important in Japan, so preliminary surveys of the end-users are essential.
4) Many orchards in Japan are situated in mountainous areas, so will autonomous mobile robots and harvesting robots be feasible in these locations? Also, many are small-scale family businesses, thus, can machines be introduced in these orchards?

The rating is: **B – fair quality and moderate revision needed.**

NARO Response to the Comments of the Evaluation Committee

1) While the staff of the Institute of Fruit Tree and Tea Science at NARO have knowledge and skills related to fruit tree production, little research has been conducted on mechanization technologies. For this reason, a technical system will be developed in cooperation with universities, private companies, and other departments within NARO with regard to advanced mechanization and sensor technologies. In addition, various research projects will be continued while being evaluated by academic committees specializing in agriculture and engineering sciences. The opinions of panels including representatives from government and growers will also be received. At the same time, projects are being promoted jointly with experts in the social sciences who will assess economic and social costs.
2) The basic technology of the “Marudori” method has already been established, and the development of peripheral technologies (water source securing and utilization technologies, etc.) is currently ongoing such that operation according to the climate realities of different regions is possible. Monitoring systems for weather, soil moisture environment, and other factors have been implemented, and research toward automatic control systems using these as parameters is currently ongoing. In addition, since this system carries a large burden in the form of installation costs, it will be able to promote the spread of this system at the time of its introduction while also providing on-demand support to local areas and making use of public subsidies, in collaboration with prefectural research institute, local government and MAFF.
3) At the start of the research project, we gathered information on the needs of stakeholders through administrative channels. Research projects to adapt the tree shape to agricultural machines are also being promoted with the goal of maintaining fruit quality and yield at typical

levels.

4) Development is ongoing for a self-propelled vehicle and a harvesting robot using the vehicle intended for use in orchards located on large-scale plantations (more than 2 ha) with flat to gentle slopes, which are expected to increase in the future. Meanwhile, the same technology cannot be used in small orchards located on sloping terrain, and as such different research strategies are being devised to adapt the orchard circumstances. NARO is also advancing the development of machinery suitable for even small-scale family-owned growers while studying ways to make such tools available for shared use.

Project 2-2 Developing technologies for sustainable fruit production in Japan

Rating and Comments of the Evaluation Committee

Global climate change is increasing the number of incompatible growing areas and the risk of pests. It is necessary to have accurate predictions of future climate change and to develop technologies to reduce the adverse effects of this change. This project is implementing research and development for short-, medium-, and long-term strategies to ensure the future competitiveness of Japanese orchards, and is a good model for other projects to follow. The project has also established cooperation with overseas organizations, published international papers, and produced results for the practical implementation of pest management models in cooperation with prefectures. The w-tenteki program and hot-water treatment applications can now be used for organic agriculture, but it is essential to note the following points.

1) It is necessary to carefully consider the accuracy and validity of the data used for modeling.
2) Hot-water treatment for the white root rot can be difficult in terms of capital investment; thus, it may be better to use it in combination with biological control.

The rating is: **B – fair quality and moderate revision needed.**

NARO Response to the Comments of the Evaluation Committee

1) NARO will continue to collect long-term data and build models for adaptability of fruit trees to climate change. Data collection and analysis will be carried out in cooperation with prefectural research institutes, taking into account external opinions on the accuracy and validity of the data.
2) Hot water treatment uses commercially available equipment as much as possible and is devised so that it can be inexpensive, but it requires an initial investment (approximately 1.6 million yen). Therefore, it is assumed that the device is not purchased individually but shared in the production area. NARO is developing complementary technologies that combine biological

control, such as technologies that quickly recover soil microflora after hot water treatment.

Section 3: Development of technology for Smart Food Value Chain and expanding consumption
Project 3-1 New approach of a long-time storage of fruit for exports

Rating and Comments of the Evaluation Committee

With the decline in domestic fruit consumption, Japan's high-quality fruits are being exported. Therefore, storage and transportation technology need to be improved; however, this project, in general, lacks innovation; thus, it is essential to note the following points.

1) For the 1-MCP treatment of apples, it is necessary to ascertain why cold pretreatment improves the effectiveness of the 1-MCP treatment. It is also essential to conduct experiments on potentially exported varieties and varieties preferred by consumers, which requires pilot-scale experiments.
2) Fruit storage is practical, but there is no clear cooperation with commercial storage companies to work towards a practical use of storage. It is also necessary to understand issues associated with the post-harvest storage of each fruit because problems vary depending on the type of fruit.
3) Grape packaging seems to be very practical and useful, but the packaging and wrapping must be clear to enable verification of the freshness of the grapes.
4) On-tree ethanol-sticker treatment in persimmons to remove astringency incurs high-labor costs, and it is more practical to spray ethephon or ethanol on fruits.

The rating is: **B – fair quality and moderate revision needed.**

NARO Response to the Comments of the Evaluation Committee

1) Application of cold pre-treatment has been confirmed to result in decreases in the quantity of ethylene produced and increases in the quantity of ethylene receptor mRNA, effects presumed to increase the freshness-preserving action of 1-MCP. Among the predominant apple varieties produced in Japan, the effects of cold pre-treatment have been studied especially with respect to the “Tsugaru” variety, in which the effect of 1-MCP is low. In the future, we would like to select varieties based on assessments of consumer demand in exporting countries, implement effective treatment methods for the relevant varieties, and implement pilot-scale tests in cooperation with the apple production areas.
2) As the characteristics of storage differ greatly depending on the species of fruit tree, species-specific countermeasures are currently being studied. Information on the optimal storage technology for each tree species is provided individually, and cooperation in the form of

conducting verification tests at storage facilities of storage companies and distributors is ongoing. NARO will continue to work closely with distribution sites to develop more site-optimized technologies.

3) Techniques for preventing damage during transportation of grape shipments have become more advanced in recent years. In the future, NARO is considering advancing the development of a packaging method that meets these standards while securing visibility by incorporating the input of actual consumers and those involved in the distribution of agricultural products.
4) In the conventional method of on-tree persimmon treatment to remove astringency, it is necessary to cover the fruits with polyethylene bags containing solid alcohol. The ethanol-sticker treatment method of on-tree persimmon treatment to remove astringency involves attaching an adhesive seal to fruits, which is simpler and less labor-intensive than the conventional method. When spraying ethanol directly on the fruit, it is necessary to seal the fruits individually in plastic bags immediately after treatment, which requires more labor than the adhesive on-tree ripening method, resulting in higher labor costs.

Project 3-2 Physiological function of citrus and apple ~Its utilization for the new system of "Foods with Function Claims"

Rating and Comments of the Evaluation Committee

Citrus fruit and apples contain polyphenols and carotenoids, which are beneficial for health. The promotion of the consumption of foods with functional claims may extend the healthy life expectancy. This is also important because it will create economic benefits for agricultural producers. The foods with functional claims used in this project are based on a collaborative effort between industry and academia, and this is an optimal project for NARO to play a leading role, but it is essential to note the following points.

1) Does implementing foods with functional claims (FFC) actually increase the consumption? If so, is the profit distributed to marketers and growers? Consumer surveys are needed to confirm that foods with functional claims actually increase the consumption, and economic research is needed to demonstrate the added value in the food value chain from production to consumption.
2) A large intake of citrus fruit leads to an excess sugar intake. Can the same effect be expected from citrus-like products, such as the freeze-dried products? Additionally, owing to a high β-cryptoxanthin content in the rind than in the flesh of citrus fruits, is there a way to use this in the future?
3) Collaboration with overseas organizations is expected. Are there international standards for the amount of procyanidins that elicit an effect?

The rating is: **A – good quality and minor revision needed.**

NARO Response to the Comments of the Evaluation Committee

1) Retail sales of apple products with foods with functional claims (FFC) are now in their second year, and sales of such products are increasing. In addition, although retailers are selling such products at prices ranging from 20% to 30% higher than apples without FFC, increasing the price at which Japan Agriculture (JA) purchases from growers will ensure that these products are not profitable only in the retail and distribution sectors, but for growers as well. In addition, as a result of a survey conducted by NARO, "Yutai Fuji" apples (bagged 'Fuji') can be expected to be targeted as a new candidate for FFC, which will contribute to a decrease in bagged 'Fuji' production and increased profits, thereby increasing the motivation of producers.
2) The "Guideline: Sugars Intake for Adults and Children" (WHO, 2015) does not specify intake standards for sugars, but the Japanese Dietary Intake Standards (2015) recommends that free sugars (monosaccharides and disaccharides) comprise less than 10% of daily calorie intake. At present, the daily recommended intake of β-cryptoxanthin specified in FFC of unshu mikans (270 g over approximately 3 fruits) does not result in excessive intake of saccharides. It may be difficult to use only fruit residue such as the skin, but it is possible to mix these components with the fruit's juice to make processed products. In fact, juices produced from squeezed fruit residue, such as POM's "*ashita no karada*" are already available for retail purchase.
3) Although there is currently no international standard for the amount of procyanidin necessary to ensure its desired level of functionality, procyanidins are found not only in apples but also in many other foods such as other fruits and chocolate, and cooperation with overseas entities is possible.