Applying DNA Chip Technology to Distribution of Agricultural Products[1]

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Abstract—**Toshiba invented an electrical current detection type of DNA (deoxyribonucleic acid) chip technology, and holds the basic patent. However, penetration has not been quick. The reason lies in the difficulties found in the business model for medical DNA testing of the human body. Difficulties concerning a social consensus on genetic testing, finding applications, and pharmaceutical approval are major cost factors. So the Ministry of Agriculture, Forestry and Fisheries, Toshiba, and several researchers plan to apply this technology to value-added branding for agricultural product exports to create more business opportunities. Another aim is to improve agricultural productivity by prevent highly infectious diseases. A questionnaire survey of agricultural producers was completed, and more than 70% of respondents supported application of this technology to agriculture. However, where should this technology be introduced in the very long supply chain of the agricultural export market? According to our findings, we should try to introduce this technology into wholesaler sectors of local governments in Japan, as well as quarantine authorities at export destination. This finding offers significant suggestion for thinking about where the technology should be inserted in the supply chain in order to promote market penetration.**

I. INTRODUCTION

There has been a marked rise in the tendency of consumers to err on the safe side in their approach toward food, and one factor hindering food safety and security is the problem of "false labeling" [1]. There are Beef Traceability Act and other methods of establishing production location, but cases have revealed fraudulent certificates and other improprieties. The construction of a sampling and inspection system is considered effective in deterring false labeling. In light of such circumstances, measures such as spot-check DNA (deoxyribonucleic acid) inspections have been adopted. However, current genetic evaluation procedures require special technology and a few days before results can be obtained, so such methods have not been widely adopted. These sorts of issues will likely become more difficult to address as export counterparts become entangled in the TPP (Trans-Pacific Strategic Economic Partnership Agreement) and other advances expected in the future for increasing globalization. On the other hand, the DNA Chip testing system developed by Toshiba using its proprietary technology [2] [3] allows for genetic testing to be performed on site without requiring any specialized knowledge and days.

From the results of a survey conducted entitled "Survey on the Potential Popularization of DNA Chip Inspection Machines in the Agricultural Product Export Market" as part of our previous research project in 2011 [4], we found that DNA chip testing systems were effective for inspecting agricultural and livestock products, and were rated highly also in terms of operability, speed, and ease with which results could be understood. Offering such a system at a low price would likely make it possible to identify cattle varieties at the local government level also.

II. FORMER STUDIES AND COLLABORATIONS

Hideyuki Mannen has promoted research on livestock genomes. He and his team have developed an evaluation method for identifying varieties of domestic cattle (Japanese black cattle, Holstein, F1 (crossbreed of the aforementioned two varieties)) and an evaluation method for distinguishing between domestically-produced cattle and foreign-produced cattle (Australian and United States) [5]. He also has information on markers necessary for identification [6]. In this study, DNA chips were developed for detecting markers used in these evaluation methods.

Yuichi Washida worked on the survey as part of our previous research project in 2011 [4], so he was accustomed with the penetration of new technologies such as the DNA chips [7], and continued to collaborate with this assignment as well.

III. EFFORTS FOR EMPIRICAL VALIDATION

A. Development of DNA Chip for Identifying Cattle Varieties

Markers for distinguishing between domestically-produced and foreign-produced cattle have been reported, but cattle genomes were added with the aim of practical application. Japanese black cattle and Holstein genome samples (50 head each) were used to conduct analyses performed with bovine 50k high-density SNP (Single Nucleotide Polymorphism) arrays. Also, prototypes were developed of DNA chips for detecting the markers already reported.

B. Specifications of Simplified DNA Testing System and Validation of Utilization Feasibility

Opinion exchange meetings, which comprised demonstrations and interviews, were held at seven locations in Japan (Hokkaido, Iwate Prefecture, Tokyo Metropolis,

[1] Supported by Ministry of Agriculture, Forestry and Fisheries, Japan

Aichi Prefecture, Kumamoto Prefecture, Miyazaki Prefecture, and Okinawa Prefecture), shown in *Fig.1*, to demonstrate the simplified DNA testing system and hear what sort of requests or needs people had. Through these sessions, information about the system was disseminated, and, through interviews, we heard opinions offered regarding actual points for improving the system and presumed methods of use.

C. Proposal for Development of Beef Variety Testing System

665 people involved with livestock were sampled from panels put forward by two major Japanese research panels. A quantitative survey was conducted over the internet. Also, together with the results of the survey of 136 people conducted in section III. *B.* shown above, a study was conducted of what sort of system for testing cattle varieties would be effective and feasible. Based on these results, opinions were solicited from interested local parties at opinion exchange sessions and from outside experts, and a proposal was prepared.

Fig.1 Opinion exchange meeting in Okinawa Prefecture

IV. RESULTS AND DEVELOPMENTS IN PROGRESS

A. Development of DNA Chip for Identifying Cattle Varieties

Characteristics of Toshiba DNA chip testing system are shown in *Fig.2*. Multiple SNP markers are chemically produced and settled as the probe DNAs on electrodes. A set of those probe DNAs are called a DNA chip. Investigators can sprinkle target DNAs from target specimens. If some target DNAs can fit SNP markers, they can hybridize and become double strands (hybridization). The system sprinkles a special intercalating agent on the DNA chip. This intercalating agent can bind with only double strand DNAs and become electrochemically active. Investigators can easily detect which probe DNAs become double strands by measuring electric current on each electrode.

In this study, cow genomes were analyzed and 35 new markers (all are SNP markers) found with additional applicability to more precise evaluation methods. Also, prototypes were developed of DNA chips with the capability to simultaneously detect the five SNPs, which have already been reported.

B. Specifications of Simplified DNA Testing System and Validation of Utilization Feasibility

The opinion exchange sessions disseminated information about the simplified DNA testing system to people involved with agriculture and promoted public awareness about production region brands.

In addition by using meat from the market to demonstrate the technologies capability to identify meat varieties right in front of the session participants, showing that testing can be performed simply, easily and quickly without a laboratory. The survey results also made it clear that attitudes can be changed about the convenience and compactness of the testing equipment *(Fig.3*). An issue that remains to be addressed is the cost of the testing equipment and the price per test, but improvements are planned with new technology from Toshiba.

C. Proposal for Development of Beef Variety Testing System

Surveys were conducted of 801 people (opinion exchange sessions: 136; Online survey: 665). Opinions were able to be gathered from people in a wide-range of fields. Including the results shown in *Fig. 4*, there were many comments at opinion exchange sessions as well that such testing should be introduced in the public sector at the national and prefectural levels.

Also, in prefecture where there was a positive approach toward branding (Tokachi in Hokkaido, Kumamoto Prefecture, Miyazaki Prefecture, Okinawa Prefecture, etc.), there was a positive attitude toward realizing such testing. However, evaluation results require official certification, and a framework is needed in which a third-party organization grants certification and the results obtained are then validated.

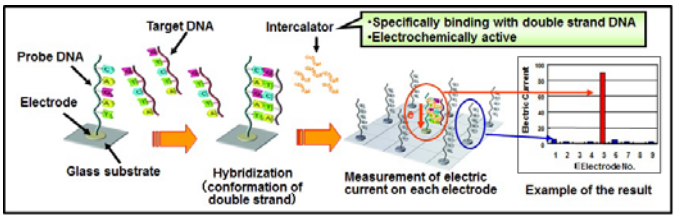

Fig.2 Characteristics of Toshiba DNA chip testing system

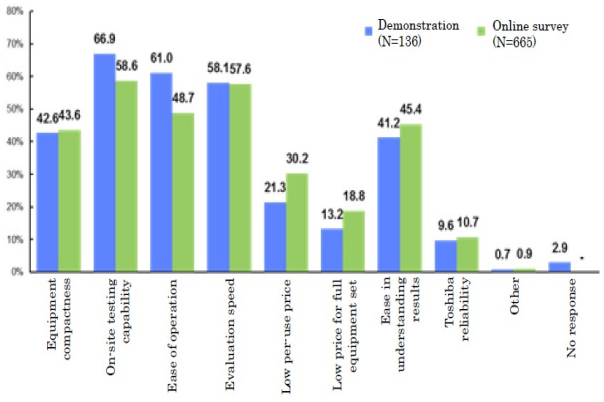

Fig.3 Comparison of Survey Results for "Equipment Attractiveness"

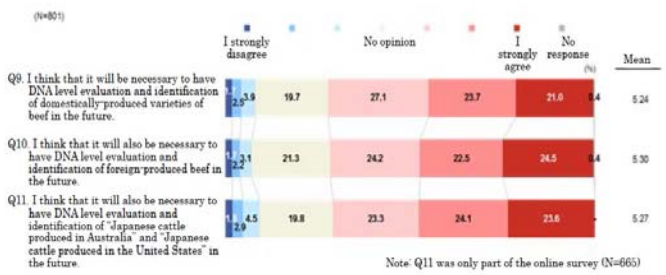

Fig.4 Survey Results for "Testing Technology"

V. FUTURE CHALLENGES AND DISCUSSIONS

At the prefectural level where there is a proactive stance toward branding, the construction and verification of a system, which utilizes this technology, for evaluating and protecting varieties needs to be promoted and proven results obtained. Along with cooperating and facilitating such efforts, it would be desirable to have a national policy that establishes a certification scheme. In addition, promotion of the TPP and other such arrangements are intertwined with future expansion of beef exports. As shown in *Fig.5*, the percentage of people who feel it necessary to have DNA level evaluation of foreign-produced Japanese beef had the highest percentage of responses in agreement with approximately 70 percent respondents concurring. The establishment of such an identification method has also been cited as a new issue to be addressed.

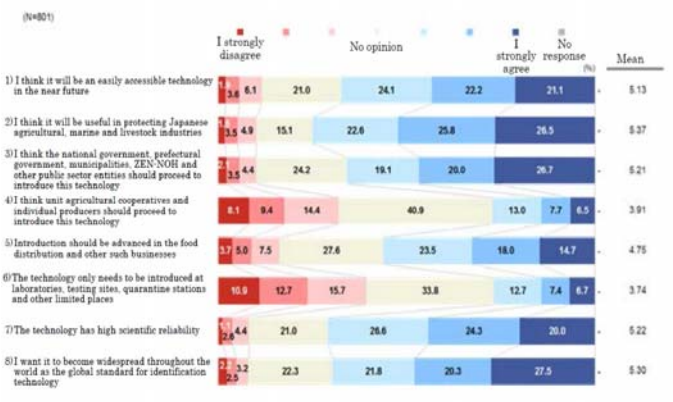

Fig.5 Survey Results for "Necessity for Identification of Foreign Beef"

After solutions to these issues have been found, it is necessary to have national government support to make such testing the global standard by reconciling inspection rules with partner countries so that the system is utilized for imports and exports. In addition, this system will have considerable ramifications as it can be used not only for livestock, but the same platform is also available for conducting GMO (genetically modified organisms) testing, testing for food-poisoning sources and other inspections. Thus, it has the feasibility to also serve as a total solution for realizing food safety and security.

VI. THEORETICAL AND GENERAL IMPLICATIONS

The survey results indicate that this type of technology should be applied as a "public goods" to a society, instead of as an "innovation for private enterprises". It means that, in the stage of practical utilization, this type of technology should be certified by a third party organization. In application of this technology, these suggestions imply us aspects of both positive and negative, as follows.

As the positive side, we can say that this technology can contribute to social innovation that aim at improving quality of lives of all social classes or income levels. Low cost DNA inspections for agricultural products can improve safety of our everyday dietary lives. Theoretically speaking, by applying DNA chip technology to the agricultural industry its potential profit opportunity can be dramatically expanded, even though a price of single test will be reduced.

As a negative aspect however, introducing this technology into present agricultural production and distribution chain can require our society a big institutional change. In such case, the realization of innovation takes a lot of times. The actor of the innovation has to negotiate with various stakeholders. In order to succeed such difficult negotiations, a high level standardization of the technology is also required. If Japanese government hopes to utilize this technology, political efforts to share mutual merits by this technology with agricultural trading counterpart countries seem to be indispensable. Such a political aspect is not considered important in the innovation studies than technological development. We should rethink the theoretical framework of innovation studies when the target technology aims at such social innovations.

VII. CONCLUSION

In this study, along with the development of a DNA chip for identifying cattle varieties, we were able to validate that utilization of a simplified DNA testing system is possible at the field level, but we also found that introduction in the public sector and certification by an official organization are very important in implementing such testing.

Policies for achieving widespread use, challenges lying ahead and plans for their resolution are clearly defined as we head toward practical implementation of the simplified DNA testing system. Relationships are also being constructed with prefectures that have taken a proactive approach toward such realization. In the future, along with working toward resolving issues which have come into focus in this assignment, the creation of a national framework will become increasingly important, as such we will seek action so that support is obtainable in the form of a national policy.

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