Final Report on Technology Transfer on Edible Mushroom Cultivation to Cuba and Nepal

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Implementing Institute: Asia Pacific Edible Mushroom Training Center

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I. Background and Introduction

Mushrooms, as edible macro-fungi harvested in a way of wild collecting or man cultivating, are consumed globally. More than 100 species of them are cultivated economically, about 60 of which are done commercially. Mushrooms are an important and agricultural resource. Among the cultivated mushrooms, some of them are a food of good nutritional value and some have medicinal value as dietary supplements. There are some that have both of these properties. These mushrooms contain proteins far more than vegetables, more than 8 sorts of amino acids and many kinds of trace elements. Mushroom cultivation is to use a wide variety of lignocellulosic waste and is considered a very efficient way to recycle agro-residues and to produce food. Therefore, it is a modern farming with high efficiency, low-carbon, circularity and sustainability, which, as an industry, has ecological, social and economic benefits. It is of significance in rural area to relieve food shortage and to increase employment and income.

Awareness of nutritional and medicinal values of mushrooms varies from one country to another, and understanding significance of their cultivation to agricultural sector differs from country to country. Actually, many countries boast the potential natural and social conditions to develop mushroom industry, which usually starts from mushroom cultivation.

Cuba, located in tropical area, boasts mild annually average temperature and plentiful rainfall, biodiversity and available land and labor. It has good conditions to develop mushroom cultivation to meet the challenge of food supply that the country has long faced for decades. Urban Agriculture Movement, which is still an ongoing national-level program, was launched for overcoming the challenge in 1990s and gained great achievements in solving the problems of food shortage, unemployment of community and insufficiency of agricultural input. Mushroom of different species can be candidates for list of cultivated crops in Urban Agriculture because mushroom cultivation meets requirements of production in the movement.

Nepal, perching on south slope of Himalayas range, boasts multiple types of climate, rich water resource, and plentiful labor. Nepal embarked on mushroom cultivation in 1970s, having great potential advantages, such as congenial agro-climate, assorted raw substrates, and plentiful labor. However, major species of mushrooms nowadays cultivated in Nepal are only oyster mushroom (*Pleurotus spp*) and button mushroom (*Agaricus bisporus*). The former species takes up 86% of cultivation and the latter 10%. The cultivation is done in small-scale, namely household production. Expecting the 2 species, straw mushroom and Ganoderma are cultivated too. Off-season cultivation was done in mountainous area. Nepalese mushroom consumption increased greatly in past 2 decades and market demand of mushroom has been growing.

The past 4 decades witnessed great development of Chinese mushroom cultivation, which has been an important agricultural sub-sector. In 2014, following grain, oil crop, fruit and vegetable, mushroom became the fifth crop for its yield and output value in China. In Chinese rural areas, it has become a mainstay sector and a wide-spread way to relieve poverty. FAO statistical data shows that in recent years, China was the world's biggest producer of commercially cultivated mushroom, and its yield of the mushroom took up about 80% of global yield.

In China the cultivated species are diverse, and both wood rotting and grass rotting mushroom are produced, such as shiitake mushroom, oyster mushroom, and straw mushroom. Some precious species, such as morel and boletus, are in pilot cultivation. Generally, almost 60 species of mushroom are cultivated commercially in China.

With development of mushroom cultivation in past decades, China has been at high technical level in the cultivation. According to gradient theory of technology transfer, technology can be transferred to the area with low technical level. Therefore, cooperation on mushroom cultivation technology became possible between China and other developing countries.

II. Implementation of Technology Transfer on Edible Mushroom Cultivation to Cuba and Nepal

1. The Cooperators of the Project

-- Asia Pacific Edible Mushroom Training Center

Located in Fuzhou, China, Asia Pacific Edible Mushroom Training Center (hereinafter referred to as APEMTC) boasts strong technical forces and comprehensive ability to implement large-scale international project. APEMTC employs substitute cultivation technology of edible mushroom in many mushroom projects in which many kinds of waste crop materials, such as tree branches, bran and cotton seed hull, are used to cultivate edible mushroom. It provides an operable model for sustainable development. To implement this project, APEMTC organized a four-person expert group.

-- Institute of Fundamental Research on Tropical Agriculture

Located in Havana, Cuba, Institute of Fundamental Research on Tropical Agriculture (hereinafter referred to as INIFAT) is the one of two institutions in Cuba that does research of mushrooms cultivation. INIFAT carried out the project of mushroom by courtesy of FAO in 2006 (FAO TCP/CUB/3001 for oyster mushroom cultivation in handing bags modalities). The project introduced new cultivation of oyster mushroom to Cuba. It has a mushroom section to do research and technology extension and houses the headquarter of National Group of Urban Agriculture that is the interdisciplinary and inter-institutional department to lead the Urban Agriculture Movement around the country. INIFAT appointed the director of its mushroom section as project coordinator.

-- Agro Business Center for Research and Development Pvt. Ltd

Situated in Kathmandu, Nepal, Agro Business Center for Research and Development Pvt. Ltd. (hereinafter referred to as ABCRD) does the research on micro-propagation of horticulture and foliage plantation crops and develops various types of mushroom spawns in laboratory under the request of different organizations, companies, and individuals. It has a capacity to produce 2 million tissue cultured plants and thousands of pkts of mushroom spawns annually. Its high-quality mushroom spawns are extended all over the country. ABCRD appointed its consultant as project coordinator.

APEMTC, INIFAT and ABCRD got acquainted each other for the Training Course on Mushroom Technology for Developing Countries, which was held from 2009 to 2014 by APEMTC and to which INIFAT and ABCRD sent their technical personnel. Based on each party's intention of cooperation for developing mushroom cultivation, the three parties worked together to propose and implement the project.

2. Purpose of the Project

Technological advancement of mushroom cultivation plays vital role in the development of mushroom industry; to some extent, it is more important than capital investment. Low technological level of the cultivation is one of bottlenecks in the development. For eliminating the bottleneck in Cuban and Nepal, the technology of mushroom cultivation is transferred from China to Cuba and Nepal. The purpose was that by the transferring, cultivation of mushroom was popularized, the technical level of the cultivation was improved, and strains of mushrooms are increased. Thus, mushroom growers in the countries increased and yield of their mushroom rose, which could improve local employment and diversify food supply.

From the micro perspective, the project aimed to enhance technical efficiency of mushroom cultivation in the two countries by improving mushroom growers' knowledge and management in the cultivation and by offering fine strains that have merits, such as resistance to adversity and higher yield.

3. Transferring Mechanism of Mushroom Cultivation Technology

Generally, technology transfer of the cultivation is the process through which technical elements in China flow to Nepal and Cuba to combine rationally with the productivity factors and to improve technology and productivity in the countries. Material resources, human resources, information management, and other factors constitute technology transfer; they are the carriers of technology.

APEMTC was the supplier of mushroom cultivation technology and INIFAT and ABCRD were the recipients of that. Specializing in mushroom sector, INIFAT and ABCRD had their readiness to receive technology. The point-to-point model of technology transfer was adopted in the project.

The major technical elements of the cultivation were transferred horizontally (region to region): fundamental and detailed knowledge, management experience and skill, talents and fine strains. These elements were the carriers of the cultivation technology transfer. They flowed from APEMTC in China to INIFAT in Cuba and ABCRD in Nepal. Afterwards, the two recipients diffused the cultivation technologies nationwide. The transferring was therefore realized.

4. Breakdown of Mushroom Cultivation Technology

In the view of technology transfer theory, information is a main carrier of transferring. The information includes four kinds: conceptual and awareness knowledge, detailed knowledge about the design or function, behaviors associated with its use, technology or knowledge embodied in physical form. Therefore, mushroom cultivation technology can be transferred through information flowing.

In mushroom cultivation, the conceptual and awareness knowledge is Biology of Mushroom; the detailed knowledge and the behaviors are cultivation technologies of different mushroom species and control of pest and disease; the physical forms are strains of mushroom species, which require ad hoc methods suitable for different growth conditions.

5. Methods of the Transferring

The transferring of mushroom cultivation technologies was actualized through making the said technical elements flow to the destinations. Namely, APEMTC transferred the information and capability of the cultivation to INIFAT and ABCRD. The information entailed know-how, formula and biological knowledge and the other forms of knowledge. The capability, i.e., "technology-mind", was the transfer of technical talents for they were the "living" carriers of technical ability and basis roles of technical development.

The three parties of cooperation materialized the transferring of information and capabilities through the three ways: technical training, on-site guidance and introduced strains for pilot cultivation.

6. Technical Training for the transferring

It was a consensus agreed by APEMTC, INIFAT and ABCRD that appropriate technologies of mushroom cultivation were transferred. The appropriate technologies meant that the technologies could be adopted to realize the advancement of local mushroom cultivation in the native conditions, and they should be relatively advanced and locally viable.

6.1 Design Syllabus for the Training

6.1.1 The Syllabus for Cuba

APEMTC and INIFAT worked together to design syllabus of the training. Natural and social conditions were analyzed for deciding what technologies to be transferred in the training.

The conceptual knowledge of the technologies of mushroom cultivation was biological knowledge of mushroom. It offered our learners further awareness of mushroom. It laid foundation of cultivating for the learners.

Considering oyster mushroom and button mushroom being consumed globally, their cultivation technologies were included in training.

Since it sits tropical area where temperature is mildly high in wet season and cool in dry season and is lower in mountainous area, Cuba has suitable environment to cultivate them. Natural cave and dugout or air-raid shelter in urban or suburban area can be transformed to mushroom house. Therefore, there are good venues to cultivate button mushroom that require relative low temperature while some strains of oyster mushroom can be suited to relative high temperature.

Straw mushroom (*Volvaria volvacea*) can grow in environment of high temperature and humidity. For cultivating the species, Cuba has good natural environment and suitable agricultural waste, such as straw and stalk of cash crops. Delicious taste of the species is another factor to include it in our curriculum.

Though it is hardly consumed in Cuba, shiitake mushroom, which has its special flavor, is considered as a new species to be introduced to the country. For its pilot cultivation, the mushroom is expected to be consumed widely.

Prevention and control of pest and disease is a necessary part in the syllabus as pest and disease are inevitable in cultivation, which are main reasons to incur loss.

6.1.2 The syllabus for Nepal

APEMTC and ABCRD worked together to design the syllabus and curriculum of the training. Natural and social conditions were considered in designing the syllabus.

Biological knowledge of mushroom was included for the same reasons as that in the case of INIFAT.

Species of mushroom cultivated in Nepal are mainly oyster mushroom and button mushroom. Though cultivation of the former prevailed, there was much room for improvement in its substrate formula, cultivation model and management, and publicizing its biological knowledge in growth. The latter took up small share in cultivation and much room was seen to improvement in publicizing its biological knowledge, compost making and cultivation management. Therefore, the cultivation technologies of the two species were focused on the improvements.

As Nepal has its tropic area in south where temperature is beyond 30 centigrade in summer and abundant substrates are provided from agricultural wastes, such as rice straw, corn cob and stalk, straw mushroom was considered to be a good species for the area. The technology of its cultivation was thus included in our syllabus.

Shiitake has been cultivated in small scale in Nepal and local cultivation usually takes long eight months from inoculating to harvest. Its long term of its cultivation daunts small farmers because they, whose economic backgrounds are weak, must take risk in paying back their loan, owing to the long cultivation. Chinese cultivation of shiitake usually is from two to 4 months because fine strains, proper substrates and scientific management are adopted. Therefore, Nepalese shiitake cultivation can be improved in the said aspects. The technology of shiitake cultivation was in the list of our syllabus.

King oyster mushroom (*Pleurotus eryngii*) was suggested to an addendum because some mushroom growers in Nepal has begun its cultivation. The species has good mouthfeel and grows in low temperature. Nepalese mountainous area can offer proper natural environment to its cultivation. It was regarded as an optional to diversify the cultivated species in the country.

Prevention and control of pest and disease is certainly included.

6.2 Curriculums of the Training

Based on the said syllabuses, the curriculums of the training are designed to publicize the awareness of the mushrooms and their cultivations in farmers and technicians. It covered followings:

-- Biological Basis of Edible Fungi

It offers concept of mushrooms, their taxonomy, morphology, propagation, life circle, required nutrition and effects of environmental conditions. These are fundamentals of the cultivation.

-- High-Efficient Cultivation Technology of *Agaricus bisporus* (button mushroom)

It offers biological characteristics and nutrients, spawn making, building of mushroom house, composting of substrates, inoculation, cultivation management and problem shooting.

-- Cultivation of *Pleurotus ostreatus* (oyster mushroom)

It offers biological characteristics and nutrients, introduction to strains, selecting cultivation site, cultivation in cold frame with unsterilized substrates. The cultivation in cold frame needs simple facility and less cost and labor.

-- Cultivation of *Volvariella volvacea* (straw mushroom)

It offers biological characteristics and nutrients, growth conditions, introduction to strains, indoor bed cultivation, frame-field cultivation, bag cultivation and problems solving.

-- Cultivation of *Lentinus edodes* (shiitake mushroom)

It offers biological characteristics and nutrients, growth conditions, introduction to strains, cultivation models and their managements, and problems solving.

-- Prevention and Control of Pest and Disease

It offers concepts of pest and disease, reasons for pest and disease, measures of prevention and control.

Additionally, cultivation of *Pleurotus eryngii* was an optional curriculum for Nepal after the above curriculums were finished.

The curriculums were developed in electronic formation for it was easy to make the formation diffuse around. Curriculums were written in English and Spanish so that they are readable to farmers and technicians in the two countries.

6.3 Doing the Technical Training

From 2017 to 2019, APEMTC held two trainings on mushroom cultivation along with China aid human resource training program. ABCRD sent four technicians to the training and INIFAT did six. They completed the curriculum and gained certificate of the training. Beside the abovementioned curriculums, they learnt more – process of mushroom, cultivation machinery, development of industry.

APEMTC planned outreach trainings in Nepal and Cuba in the end of 2019 and would start them in following years. Due to outbreak of COVID-19 pandemic in 2020, the training had to be suspended in 2020 and 2021. The lasting of the pandemic in following years made APEMTC shift the training to online holding. The three cooperators consolidated their effort to meet the challenge of the shifting. They circulated questionnaire on online training for holding dates, training time, training software, and more related issues. With fully discussion, they decided to hold the online training in 2022 when China still employed the dynamic zero COVID-19 strategy to tackle the pandemic. INIFAT and ABCRD organized total 30 their staffs (15 for each) to participate in the online trainings via Zoom.

After they were trained, the trainees from INIFAT and ABCRD carried out outreach programs of training local farmers in main mushroom production areas of Nepal and in area of mushroom cultivation extension of Cuba. In Cuba, Ciénaga de Zapata County and Camarioca County of Matanzas Province and Havana City were the extension area, where the three outreach programs of training were done in the cities, training total 45 farmers. In Nepal, Kathmandu Valley was the major area and Chandragiri Municipality in the valley gathered main mushroom farms. The four outreach programs were done in Chandragiri, training total 50 farmers. The outreach programs had therefore diffused major technical elements of the cultivation to materialize the transferring.

6.4 Online Guide to On-site Cultivation

Online guide to on-site cultivation provided by APEMTC expert group was complementary to the training in the technology transfer while the guide had its own merits that the training could not had. Namely it was substantial and practical in grasping the technologies of cultivation. It could not be replaced with the training. Owing to COVID-19 pandemic, the guide had to done online in past 3 years. At the mushroom farms in the two countries, the mushroom growers (the trainees) usually confronted problems in cultivation of oyster mushroom and they presented the problems which INIFAT and ABCRD collected, so the expert group analyzed them and offered solutions to them.

The problems were described by the growers through text, photo and video, which were collected for the expert group's analysis. Afterwards, the group offered the causes of them and the solutions to them. The problems in cultivation of oyster mushroom were summarized as followings:

-- Unqualified substrate ingredients

The ingredients, such as rice straw or sawdust, were moldy, or were not sterilized completely; therefore, substrates were infested with harmful fungi and pests.

Its solution was to select fresh ingredients and to strictly follow the procedure of sterilizing with qualified sterilization equipment.

-- Substrates decaying

In phase of mycelia colonizing, substrates decayed and soured. Its causes were mainly followings: in the phase, substrates temperature went high, but no measure was taken to lower the temperature, which invited harmful fungi and bacteria; high humidity in substrate incurred inadequate air inside, which caused anaerobic fermentation, so it made substrates go bad.

Its solution was to desert the decayed substrate with proper ways.

-- Mycelia withering or not germinating

Its causes included substrates decaying and harmful fungi infesting, too high or low humidity in substrates, aged spawn, too high or low temperature, and high pH value.

Its solutions include using fresh substrate and robust spawn, monitoring humidity and temperature in substrate and environment and taking measures of ventilation or watering to keep them at proper level, and testing pH value before adding lime to keep the value at 7-8.

-- Mycelia slow colonizing in the late phase

Its cause was insufficient oxygen in substrate, as the bags were sealed too tight.

Its solution was to loosen the seal thread or to puncture the bags.

-- Premature fruiting when mycelia did not colonize substrates completely

Its causes included too strong light in cultivation site, low temperature or big temperature difference between day and night.

Its solutions were followings: adding shade at mushroom house or tunnel by covering shade net or equivalence, increasing temperature by closing ventilation vent, and reducing the difference by closing ventilation vents in the evening. However, the closing is not all the time while ventilating cultivation site some time to keep carbon dioxide, oxygen, humidity and temperature at right level.

-- No fruiting

Its causes were followings: improper strain, unqualified mother culture, contamination by harmful fungi, impact by fungicide, wrong substrate formula, inappropriate humidity in substrate and environment, and insufficient light for primordia differentiating.

Its solutions were followings: selecting strains of right temperature types for environment, using robust mother culture to produce spawn; properly using fungicide, adopting right substrate formula, controlling humidity and temperature in substrates and environment, increasing temperature difference between day and night, cutting off or puncture the bags.

-- Misshapen fruit bodies

The misshapen included shrunken cap, long stipe, and stipe without cap. The shrunken cap was caused by high temperature and low humidity; stipe without cap by poor ventilation and high concentration of carbon dioxide; long stipe by insufficient light.

Its solution were followings: controlling temperature in cultivation site at 15-28 centigrade; offering 200 Lux light, keeping air humidity at 90%; properly ventilating to keep dioxide carbon less than 0.1%.

The problem solving was a practice to assimilate and apply the knowledge learned in the training. The analysis of causes and solution measures resulted from the understanding and application of the expertise in the training. By the guide, the growers could grasp what they learnt and knew how to resolve the problems in the future. Therefore, their levels of cultivation technologies were further improved.

6.5 Providing Strains of the Said Species

In cultivation, fine strains are the key to good harvest and in the technology transfer, they are material carrier to make technology progress. The fine strains that were selected for Cuba and Nepal had their merits: adoption to low and high temperature, resistance to diseases, high yield and short cultivation period. The merits were achievements of mushroom breeding technology that benefited the cultivation. With the strains, mushroom growers in the countries could save labor and cultivation time and gained high yield.

According to cultivation situation in Cuba, APEMTC and INIFAT decided to use following strains for pilot cultivation.

-- Oyster Mushroom

Strain Xiaping 27: fruiting temperature 10-36 centigrade, tolerance of high temperature, white fruit body, high yield.

Strain Gaoping 05: fruiting temperature 12-36 centigrade, tolerance of high temperature, resistance to diseases, high yield and short interval between flushes.

-- Straw Mushroom

Strain Dacao 32: big and gray fruit body, high yield, resistance to diseases, and late cap opening.

-- Shiitake mushroom

Strain Xing 939: fruiting temperature 6-28 centigrade, 90-120 day to harvest, resistance to disease and high yield.

Strain Wuxian 211: fruiting temperature 6-28 centigrade, early-maturing (60-70 days to harvest), high yield in first flush.

According to cultivation situation in Nepal, APEMTC and ABCRD decided to use following strains for pilot cultivation.

-- Oyster mushroom strains

Strain You 88: fruiting temperature 4-33 centigrade, quick colonizing of mycelia, resistance to diseases, quick fruiting and big fruit body.

Strain Xinping 51: fruiting temperature 2-32 centigrade, quick colonizing of mycelia and 20 days to harvest, even size of fruit body.

-- Straw mushroom

Strain Dacao 32: see the above.

-- Shiitake mushroom

Strain Zaoyou 1: fruiting temperature 5-26 centigrade, early-maturing (60 days to harvest).

Strain Xing 939: see the above.

-- King oyster mushroom

Strain Xinbao 01: fruiting temperature 8-20 centigrade, robust stipe, good mouthfeel.

The above-mentioned strains from commercial spawn supplies in China were used in commercially cultivation for long term. Their mother cultures were collected by APEMTC and offered in past years to the cooperators in Cuba and Nepal for pilot cultivation and afterwards they were expected to indigenize and extend.

Among the said strains, Goaping 05 of oyster mushroom and Dacao 32 of straw mushroom were the main strains that were expected to extend in Cuba. For their merits, the two strains could play good roles in mushroom sector of Cuban Urban Agriculture. APEMTC and INIFAT anticipated a new project that further realized Cuban domestication of the strains after the pilot cultivation.

Zaoyou 1 and Xing 939 of shiitake mushroom were expected highly to play their roles in Nepalese mushroom cultivation, as the strains boasts their cultivation periods much shorter than that of Nepalese strains. With the cultivation technology learned in the trainings, the strains were anticipated to reduce the risk of defaulting loan payment for shiitake cultivation, the big challenge in household cultivation of shiitake. Moreover, it was expected that shiitake growers would increase for the risk reduced and shiitake share would rise in Nepalese mushroom cultivation. APEMTC and ABCRD will plan a project for localization and extension of the strains.

III. Conclusion

This project was carried out to advance Cuban and Nepalese technology of mushroom cultivation. With united effort of APEMTC, INIFAT and ABCRD, this project realized transfer of the cultivation technology of the said species to Cuba and Nepal by training, guide of on-site cultivation and pilot cultivation of the strains. It actualized technology progress of mushroom cultivation in the two countries.

Technology progress of mushroom cultivation played vital role in the development of mushroom industry, as was proved in China in past decades. To some extent, its importance outdoes capital. Gaining of technology and management knowledge was the way to materialize the progress.

The technology progress of mushroom cultivation indicates improvement of three aspects: knowledge and knacks of cultivation, quality of laborer and manager, and yield and quality of fruit body. The technical trainings and on-site guide aimed to improve the knowledge, knacks and the quality of labor and manager. The selected strains of mushrooms were the material carriers of the progress because of their merits. With the improved quality and knack of the trained mushroom growers, the strain can shorten cultivation period and improved quality and yield of fruit body.

The project brought to Cuban and Nepal two types of technology progress: neutral and labor-saving progresses.

The neutral progress meant that under the condition that labor and work time were kept unchanged, the mushroom growers adopted new technological elements of the cultivation to improve quality of fruit body and raise its yield. The elements covered the scientific management method, the cultivation models, and the new formula. The management method was to exactly control the humidity and temperature of substrate and environment and do prevention of disease and pest for ensuring sound growth of mycelia and fruit body. The method indicated changing extensive farming to intensive one. Cultivation models were selected to suit different cultivation field. For examples, bag cultivation of shiitake mushroom could be done in mushroom house, tunnel or shed, and frame cultivation of oyster mushroom could make use of spare or unfertilized field. The new substrate formula could offer total nutrients required by growth of mycelia and fruit body.

Labor-saving progress meant that new technological elements were adopted to reduce labor and work time. The technological element was the new strains with the said merits. Merit of early maturing of shiitake mushroom shortened months of cultivation period and made the growers have competitive edge in market. Tolerance of high temperature or low temperature could reduce the labor to control temperature. High yield rewarded the growers for their unchanged labor and work time.