

The Study on Innovation Hub for Biomaterial Research and Business Development in Korea

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Abstract—Korean bio-industry has come to bear the additional burden due to the new Nagoya Protocol on access to genetic resources and benefit sharing (ABS). The need to develop materials and products using domestic natural bio-resource are increasingly highlighted in Korea. Therefore Korea urgently needs to arrange to assist for localization of alternative sources as core material in alignment with the Nagoya Protocol and help expand the biotechnology industry. The study has been implemented to arrange ‘Innovation Hub for Biomaterial Research and Business Development (IHBRBD)’ which has the potential to support for Small and Medium sized Enterprises (SMEs) manufacturing biomaterial and bio-products. This paper investigates four main questions; (1) Is there any government policy and research institutes related to IHBRBD?; (2) Where can we obtain natural bio-resource in Korea?; (3) What is trend of biotechnology research and development?; (4) What do SMEs want to IHBRBD? The analysis of government policy and research institutes related to IHBRBD was conducted through literature search. The main area providing bio-resource was searched through the data provided by Statistics Korea. The trends of biotechnology research and development were analyzed through 108 papers of NDSL and patent during 1992 to 2013. The SMEs’ demand for IHBRBD was surveyed from 32 companies that wished to develop and produce functional materials made of natural products as raw materials. Our results from the investigation of four questions show that the main role of IHBRBD is to support SMEs through 13 processes from excavation of useful material to development and commercialization of new products.

Index Terms—nagoya protocol, biomaterial, biotechnology, innovation hub, commercialization, bioconversion technology

I. INTRODUCTION

As the Nagoya Protocol entered into force on October 2014, the rights to biological resources have been verified. One of the major topics of the Nagoya Protocol, access to genetic resources and benefit sharing (ABS) means fair and equitable sharing of the benefits arising from utilization and pre-activity such as sampling for the use of genetic resources. In other words, the sovereign right of a country’s living resources are recognized and if any other countries wish to import the resources from these organisms to develop and produce materials for sale, the

revenues arising from such activity should be shared with the source country [1]-[4]. The size of biomass market that related to Nagoya Protocol is estimated to be about 7,600 billion US dollars and portions for each industry are as follows: 5,460 billion dollars for Medicines, 100 billion dollars for Natural medicine, 30 billion dollars for Seed, 14 million dollars for Gardening items, 72.3 billion dollars for Industrial biotechnology and 12 billion dollars for Cosmetics. In 2014, the size of the Korea Bio Industry market was estimated to be about 9 trillion won (7.5 billion dollars). Korean Bio-industry has to bear responsibility for the additional burden of about 500 billion won (0.4 billion dollars) due to the Nagoya Protocol [5]. As a result, the need to develop materials and products using domestic natural bio-resource are increasingly highlighted in Korea. Therefore Korea urgently needs to arrange to assist for localization of alternative sources as core material in alignment with the Nagoya Protocol and help expand the biotechnology industry. Across the country, there are 19 domestic support research institutions related to technology development and commercialization of biotechnology industries in Korea. However none of these organizations collectively supports analysis, evaluation and commercialization on technology development. Additionally, most of the institutions that support the technology development and commercialization have their limitations on technology discovery and production support that are reflect the globalized needs of the consumer. The object of this assessment is to discover the needs of the consumer and to arrange ‘Innovation Hub for Biomaterials Research and Business Development (IHBRBD)’ that allows SMEs with technology development and analysis, evaluation, and commercialization spanning the entire industry value chain. This paper investigates four main questions; (1) Is there any government policy and research institutes related to IHBRBD?; (2) Where can we obtain natural bio-resource in Korea?; (3) What is trend of biotechnology research and development?; (4) What do SMEs want to IHBRBD? The status of bio-industrial policy and existing research institutes were analyzed to find political needs of IHBRBD through literature search. The survey of bio-resource production area was focused on northern Gyeongsangbuk-do estimated to be the largest producing area of bio-resource in South Korea. Investigation and analysis for the bio-related research and

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technology development trends were conducted through search for related papers and technical patents. Finally, the survey for SMEs needs was conducted, and the result was reflected in major fields and function of IHBRBD.

II. DATA AND METHODS

An analysis of Korea bio-industrial policy was conducted through literature search of Park Geun-hye administration's national goals and challenges and the central government's policy. Central government agencies surveyed are as follows: Ministry of Trade, Industry and Energy (MOTIE), Ministry of Science, ICT and Future Planning (MSIP), Ministry of Agriculture, Food and Rural Affairs (MAFRA) and Ministry of Land, Infrastructure and Transport (MOLIT). The survey of the status of domestic bio-related research institutions focused on major research areas and main achievements through 19 research institutions scattered throughout the country.

Among the 9 provinces (Gangwon-do, Gyeonggi-do, Chungcheongbuk-do, Chungcheongnam-do, Jeollabuk-do, Jeollabnam-do, Gyeongsangbuk-do, Gyeongsangnam-do, Jeju-do) of South Korea, Gyeongsangbuk-do that has the highest product output of domestic natural production has been selected as the candidate for IBHFBBD, and the main crops and medicinal plants were checked for their growth status through the data provided by the Statistics.

Survey for trends of biotechnology research was conducted through 108 copies of the National R&D research reports and recorded in the National Digital Science Library (NDSL). First, main keywords such as 'specialized crops', 'medicinal crop', 'natural products', 'fermentation', 'fermentation techniques', 'biological conversion' and 'functional material' were researched, and categorized them into two areas of medicinal plants and fermentation for further analysis by year of study, subjects of studies, study organizers and research contents. To search for the trends in biotechnology development, patent research of medicinal plants filed during 1992 to 2013 were analyzed. Survey was performed via the patent information search site WIPSON and focused on South Korea, United States of America, Japan, China, PCT.

Corporate demand was surveyed from 32 companies that wished to develop and produce functional materials made of natural products as raw materials, via IHBRBD. These companies have demanded for IBHFBBD and require cooperation with external agencies to develop and commercialize new biomaterial and products. Survey questionnaire for corporate demand consisted of 10 questions. Each question aims to identify necessary supports for development and commercialization of functional biomaterial by taking advantage of the natural products. The features of IBHFBBD have been set through the survey results.

TABLE I. 19 BIOTECHNOLOGY RESEARCH INSTITUTES IN KOREA

	Title of Research Institutions	Research Focus Area
(1)	Korea Food Research Institute	Identify functional foods & Research and development of new materials and new processes
(2)	Gyeonggi Bio Center	Development New drugs, new biotechnology materials, cell therapy
(3)	Daegu Techno Park, Oriental Medicine Industry Support Center	Oriental clinical assessment skills development and support
(4)	Traditional Micro-biology Resource Development and Industrialization Center	Superior microorganisms development
(5)	Bio-Health Convergence Center	New materials and biotechnology drug development
(6)	Daegu University of Oriental Medicine, Oriental Life Resources Research Center	Natural drugs, functional cosmetics, functional food development
(7)	Korea Institute of Oriental Medicine	Oriental Medical source technology development
(8)	Chungbuk Technopark Bio Center	Oriental Natural Products development
(9)	Oriental Bio Industry Clinical Support Center	Clinical efficacy and safety testing Oriental products
(10)	Gangwon Wellness Specialties Industrialization Regional Innovation Centers	Fermentation-based new materials development
(11)	Gangneung Branch, Korea Institute of Science and Technology	Natural Products Drug Development
(12)	Gyeongbuk National Bio-Industry Research	Health food and drug development
(13)	Korea Oriental Medicine Industry Development Institute	Medical materials and functional food development
(14)	Gyeongbuk Institute of Marine Bio Industry	Functional Materials Development
(15)	Imsil Cheese Science Laboratory	Healthcare Materials Industrialization
(16)	Jeonbuk Bioindustry Development Institute	Component inspection and safety assessment
(17)	Food Industry Research Institute	Functional Materials and Food Research
(18)	Chonnam National Institute for Oriental Medicine Industry	Health food, herbal cosmetics, natural products drug discovery
(19)	Jeju Technopark Bio Convergence Center	Anti-cancer food, drug development

III. RESULTS AND FINDINGS

A. *The status of Bio-industrial Policy and Bio-technology Research Institutes in Korea*

In order to achieve the national vision of ‘public happiness and new era of hope’, Park Geun-hye administration set up the 4 national trends, including economic revival, public happiness, and established 14 sectorial strategies and 140 national tasks. Among these, national task No. 12 of Future growth and industrialization of agriculture, food and rural affairs industry, associated with bio-industry policy, aims to expand support for R&D of agricultural food, and to develop cutting-edge industry of agricultural food by fostering the global high-tech food industry. Park Geun-hye administration also established various national objectives for regional development policy plans to identify new growth engines and support development of food-product-specialized industry and associated facilities. In accordance with Park Geun-hye administrative policy of regional development, MOTIE established regional economic commission and selected, for each region, the industry to focus its development efforts on. Looking at the results, biomaterials sector was given to Gyeongsangbuk-do. Building on this, MOTIE will promote ‘Functional Biomaterial Industry’ centering on the area of Gyeongsangbuk-do with the support budget for local projects [6], [7]. The comprehensive implementation plan of science and technology research and development projects for 2014 established by MSIP

includes utilization of useful genetic resource technology, development of natural products drug, and development of functional materials. Based on the national tasks of Park Geun-hye administration, MAFRA focus on the development of 6th industrialization of agriculture, the food industry, and extended agri-food export industry [8]. MOLIT has established the comprehensive plan for the region of Kangwon-do, Chungcheongbuk-do, Jeollabuk-do, Jeollanam-do, Gyeongsangbuk-do, and Gyeongsangnam-do, to develop these areas as important economic bloc and global eco-tourism are through a comprehensive development plan of Baekdudaegan Mountain range. This is expected to create a ‘high value-added, herbal cluster’.

In South Korea, there are 19 of industrial research institutions, support agencies and techno parks that are associated with biotechnology, and these 19 lead bio-related technology developments and clustering of related industries. Table I lists 19 Biotechnology research institutes in Korea. These agencies are mostly developing functional materials using raw materials specialized in each region such as regional medicinal plants and food crops. Areas that are associated with the development of functional materials are herbal drugs, food ingredients, and cosmetics sectors. Although each research institution is situated in geographically convenient place to take advantage of the regional specialized crops and natural products, each of them has played a part in technical support for the development and commercialization of functional materials within preperiodic process as well.

TABLE II. PRODUCTION OUTPUT OF 5 MEDICINAL CROP IN KOREA

Name of crop	(A) National production output (million tons)	(B) Production output in Northern region of Gyeongsangbuk-do (million tons)	100B/A (%)
Dioscorea	8,500	6,885	81
Cnidium	888	808	91
Rehmania	1,135	454	40
Korean angelica root	1,626	374	23
Milk vetch root	708	156	22

B. *Northern Gyeongsangbuk-do as the Largest Producing Area of Biomaterial*

Gyeongsangbuk-do can be divided into 4 regions of eastern, western, southern and northern, northern region being the mountainous area with lowest financial independency in Gyeongsangbuk-do. GRDP (Gross Regional Domestic Product) per capita is only half the average of Gyeongsangbuk-do and up to approximately 90% of the total manufacturing industries are concentrated in the food manufacturing industry. The food manufacturing companies are mostly small businesses that depend on the simple processing of the raw material. Although northern region of Gyeongsangbuk-do, having the poorest condition for manufacturing remains the highest producing in terms of output of natural products nationwide, and in particular, variety of medicinal plants is cultivated. Northern region

of Gyeongsangbuk-do is suitable for the production of medicinal crops because its topographical characteristics of mountainous in formed with hilly land at altitude between 100 to 500 meter and climatic conditions with daily fluctuations of temperature in a great range. Production output of medicinal crop is 24,448 tons in 2012, has been accounted for 27.3% of the national production output. 5 of medicinal crops produced in the northern region of Gyeongsangbuk-do are Dioscorea, Cnidium, Rehmania, Korean angelica root and Milk vetch root. Dioscorea and Cnidium are accounting for 81% and 91% of national production output respectively, as shown in Table II. Besides, production output of natural products such as beans, peanuts, melons, pumpkins and buckwheat are the highest nationwide as well. Although northern Gyeongsangbuk region is rich in natural raw materials giving it the name of the nation's largest specialty crop growing region, activities for the

development and production of high value-added materials are poor compared to other regions. It is all-the-more necessary to promote business that uses natural products from northern Gyeongsangbuk area by combining these natural products with fermentation technology and functional materials for more balanced development of the region.

C. Trends of Biotechnology Research and Development

Patent Status of 5 medicinal plants by country reveals that the number of patents for Korean angelica root (2,723 cases) is the highest, and Rehmania (1,231 cases), Dioscorea (1,176 cases), Cnidium (1,013 cases), Milk vetch root (589 cases) were in the order. China is reported as the country with the highest number of patents, including the largest number of patents in all 5 medicinal plants, followed by Korea. The number of patent for 5 medicinal crops by year increased by more than 300 times (from 42 cases in 1992 to 1,317 cases in 2013), and an annual average growth rate was accounted for 19%. For the case of Cnidium and Milk vetch root, in the early 2000s, South Korea's patents are the most common. However China's patent number has been increased rapidly since 2010 and it was accounted for more than 80% of the total patents by 2013. The degree of patent maturity is analyzed through numbers of patent filed over analysis and changes in applicants for patent. This can be categorized as follows: development phase, maturity phase, declining phase and maturity phase. The degree of patent maturity has been analyzed in three-year phase, and the results reveal that all 5 medicinal plants were in the development phase. Therefore, the number of patents for 5 medicinal crops is expected to increase somewhat.

Among 108 copies of registered report on the NDSL, 37 were for 5 medicinal crops (Korean angelica root, Rehmania, Dioscorea, Cnidium, Milk vetch root) research and 40 were about fermentation-related research in South Korea. Looking at the research trends of 5 medicinal crops by year (2005 to 2014), 2013 had the highest reported cases of 11. When 37 studies of 5 medicinal crops are divided into 6 research subjects such as species development, production technology development, materials development, quality management technology, component analysis and product development, the materials development is the highest in numbers as shown in Fig. 1.

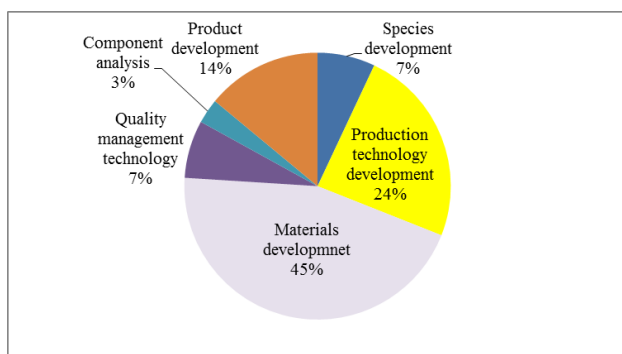


Figure 1. Research portion of six subjects for 5 medicinal crops in Korea (by 2005 to 2014)

According to the result of analysis for the trend in study organizers, since 2010, application research institutions and universities became the center of studies on 5 medicinal plants and later in 2013, the research became more active with full-fledged participation of corporations. The proportion of study subjects for 5 medicinal plants for 10 years, research institutions were the most common at 62%, and enterprises and universities were in similar level at 17%. Looking at the yearly trends over 40 research projects related to fermentation, similarly, the study of 5 medicinal plants was the highest with 15 cases in 2013, and the material development assessment was ranked in top by topic wise. In contrast in case of 5 medicinal plants research, corporations accounted for the greatest number as sponsored agencies of research projects related to fermentation. Researches on 5 medicinal plants was mainly driven by research institutions while fermentation-related research was actively promoted by corporations, showing that the research needs of enterprises is concentrated in the fermentation studies. Bio-based materials obtained by the present innovation are made in bioconversion technology by utilizing fermentation, enhancing the added value through providing functionality and versatility of the material.

D. Function of IHBRBD

32 SMEs were involved in demand survey for features of IHBRBD. Considering the size of the companies that participated in the survey, 53.1% have less than 100 employees, and 53.1% have less than one billion won on Sales. Looking at the number of researchers in companies, less than 5 people was common in 45.5%. For distribution of company types by products, the food related one was the most common in 53.3%, and followed by cosmetics sector in 23.1%. In an investigation of number of product types that these companies are producing, the largest number of companies with 84.4% were producing only one type of product. 62.5% of the companies involved with the survey were developing functional biomaterials made of natural products with fermentation technology and, the rest 37.5% of them were planning for future studies. These companies were asked for the requirement for external cooperation during the development product and commercialization process for functional materials made of natural product with fermentation technology. In order to develop and commercialize products using functional biomaterials made from natural fermentation, support is required in 5 levels: 1) useful material excavated, 2) fermentation, 3) analysis, 4) evaluation of the developed material, and 5) commercially available. In order to identify the corporate demand, the 5 levels were subdivided into 13 processes; 1) Support for the material selected by using the functional material DB, 2) Support stable supply of natural for the development of commercialization, 3) Support for the extraction process, 4) Support to select the optimum strain for biotransformation of the extract, 5) Support for optimization in bioconversion process, 6) Elemental analysis, such as polysaccharides, lipids, proteins, 7) the standardization of substance, 8) Evaluation for Safety and

validation of materials in development, 9) Evaluation for commercialization, 10) Evaluation for stability, 11) Animal studies and clinical trials for functional recognition, 12) Support for standardization and scale-up in manufacturing process, 13) Support for prototype manufacturing through GMP facility. Based on the results of survey of 13 processes stated above, 'Animal studies and clinical trials for functional recognition' was found to be the most desired support for needs of the enterprises. As a result, SMEs require that IHBRBD provides total

periodic supports from obtaining raw material to commercializing products, as well as in researching and developing stages. The growing complexity, huge budgets and risks related to innovation, the increased knowledge intensity, and the mounting competitive pressure for developing new products and processes, forces SMEs to look externally [9], [10]. Particularly, the new Nagoya Protocol on ABS encourages them to collaborate with the outside such as IHBRBD.

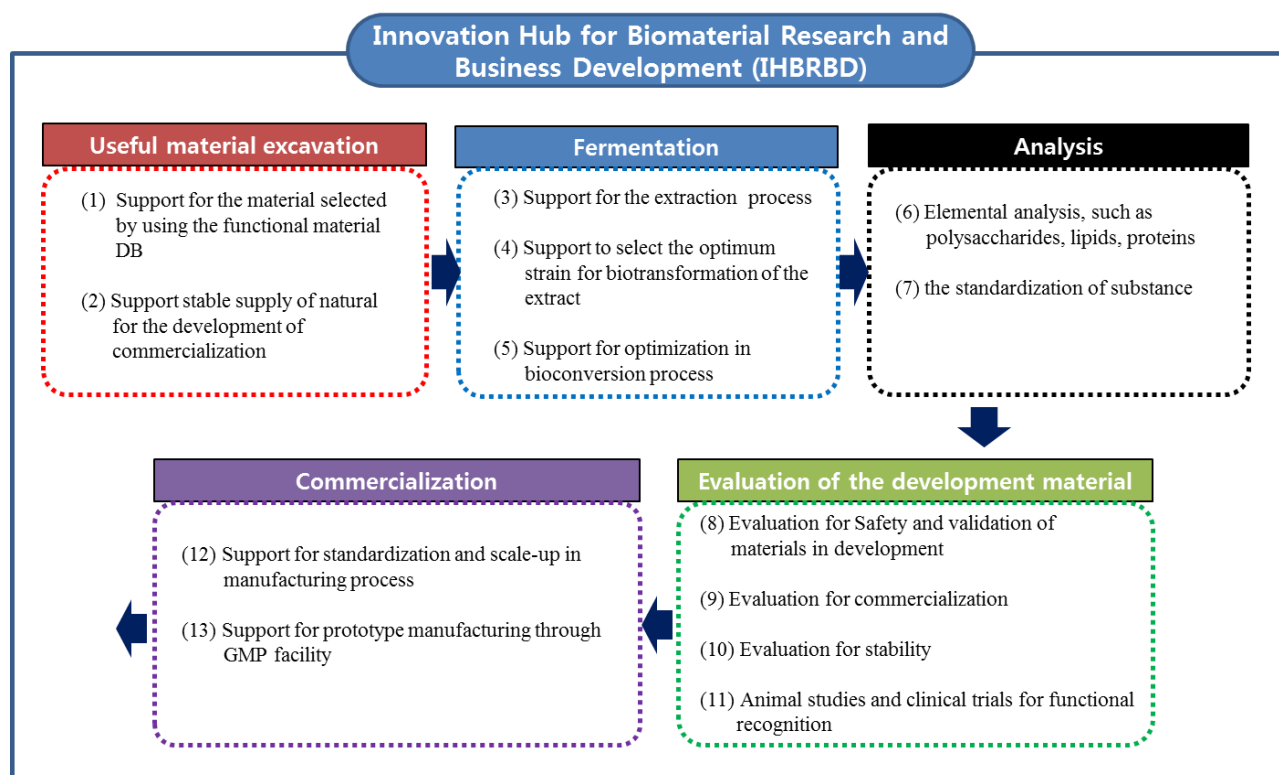


Figure 2. The function of IHBRBD (Innovation Hub for Biomaterial Research and Business Development)

IV. SUMMARY

SMEs in bio-industry are becoming increasingly interested in researching and developing new biomaterial and products using domestic natural bio-resource with the Nagoya Protocol entered being in effective since October 2014. In support of this, Korean Government has funded research and development activities of SMEs, and established many industrial research institutes. 19 research institutes have made efforts to collaborate with SMEs in field of biotechnology in South Korea. However, most of institutions face limitation in receiving comprehensive support through the entire process of obtaining raw material to commercializing new products for SMEs. SMEs need to begin by researching valuable biomaterial excavation using domestic natural bio-resource. This paper identified the function of IHBRBD through investigating and analyzing four main questions of governmental policy, the status of research institutes and production area, the trend of biotechnology research and development, and SMEs demands. The establishment of IHBRBD corresponds to Park Geun-hye

administration's national task No.12, because the main role of IHBRBD is to innovate SMEs manufacturing biomaterial and bio-products. The function of IHBRBD includes 13 processes demanded by SMEs and makes up for the weak points of existing research institutes that have partially supported for SMEs (Fig. 2). Northern Gyeongsangbuk-do, which has plenty of bio-resource, is considered as one location proposed site of IHBRBD. 5 medicinal plants produced mostly from Northern Gyeongsangbuk-do have been researched and developed as new functional biomaterial in the fields of well-being foods in Korea. Bioconversion technology using 5 medicinal plants has to be selected a main field to focus research activities of IHBRBD of. New biomaterial excavation that utilizes fermentation will enhance the added value by providing functionality and versatility of the material.

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