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THE ROLE OF MOLECULAR BIOLOGY APPLICATION ON SUSTAINABLE FOOD SECURITY MANAGEMENT: CASE STUDY ON HERBAL PLANT PRODUCTS

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Abstract

Background: Food security is a crucial national and global issue. Various efforts have been made to meet food needs in quantity and quality. Herbal products are part of functional food products that must be managed sustainably. On the other hand, the development of molecular biology has enormous potential to be applied in various fields, one of which is an effort to achieve food security. Nonetheless, molecular biology has implications for food security, particularly in managing herbal products. Therefore, a thorough study to identify the various application roles of molecular biology application on herbal plant product management supporting food security goal is essential.

Methods: This study adopts a literature review method with four basic steps: search, appraisal, synthesis, and analysis.

Results: Several studies showed that molecular biology techniques have been developed and used in herbal plant product management. Some of these are the use of molecular markers and DNA barcoding for medicinal plant identification and herbal product authentication, bioassay and gene expression analysis for understanding the use of plant metabolites in curing complex diseases, genetic engineering for plant-derived bioactive compounds production through plant tissue culture, et cetera. Besides, there are challenges following that potential, i.e., sample quality and quantity, genetic variability, method reliability, regulation and standards, community acceptance, and dependence on technology.

Conclusion: Based on the reviewed data, it is clear that molecular biology application has significant roles in herbal plant product management that will lead to sustainable food security through natural resource availability and economic improvement through several herbal product innovations and high production.

Keywords: Molecular biology, food security, herbal plant

INTRODUCTION

Food security has become a national and global strategic issue. The experience of Indonesia's development history shows that the problem of food security is closely related to economic stability, aggregate economic production costs, and national political stability. Therefore, food security is an absolute requirement for the implementation of national development (Chaireni et al., 2020). In order to achieve food security, the Indonesian government has developed a pack of strategy to resolve food security strategic issues, including (1) incorporating food security into the 2022-2023 national development agenda, namely prioritizing programs to increase availability, access, and quality of food consumption; and (2) development of Indonesia 2045 the second pillar "Sustainable Economic Development" point 2.5 namely strengthening food security and increasing the welfare of farmers. Besides, food security is included in the SDGs agenda, in goal number 2, namely ending hunger, achieving food security, improving nutrition, and promoting sustainable agriculture.

The Law of the Republic of Indonesia number 18 of 2012 defines food security as a condition of fulfilling food for the state down to individuals, which is reflected in the availability of sufficient food, quantity, and quality, safe, diverse, nutritious, equitable, and affordable and does not conflict with beliefs and culture. Communities to be able to live healthy, active, and productive lives in a sustainable manner (Hadi et al., 2019). In other words, national food security can be interpreted as independence in food supply (Pinstrup-Andersen, 2009). According to the Life Science Research Organization (LSRO), food security is the availability of access for the community to obtain sufficient food, including safe and nutritionally adequate food and the guaranteed ability to obtain socially acceptable food (Devi et al., 2020). It means that food security does not only focus on the quantity, but also the quality defined as safe and nutritional food. Herbal products, including medicinal plants, are functional food products that must be managed sustainably. Herbal plants act as raw materials for herbal medicines and develop herbal products. In this case, herbal plants contribute to food security by providing alternative sources of medicine and income for households (BPPT, 2017; Suryadarma et al., 2014). In addition, the cultivation of herbal plants can be integrated into sustainable agricultural practices, improving soil health, reducing synthetic fertilizers and pesticides, and promoting biodiversity (Radji, 2005).

The application of molecular methods at this time is increasingly being studied and applied to various studies, one of which is carried out to help achieve food security, including for medicinal plants. Molecular biology is a branch of biology that studies the molecular and biological activities within and between cells, including synthesis, modification, mechanisms, and molecular interactions (Alberts et al., 2008). One aspect of molecular biology is the application of genomic tools, where genomic information is manipulated and analyzed. This application, known as agricultural genomics, aims to improve agricultural productivity to ensure food security and safety (Wang et al., 2017). A study showed that genomic technologies such as molecular marker-assisted selection have been reported to be quite efficient in increasing productivity, especially in developing countries (Eichler, 2019). Developments of genomics, informatics, analytical chemistry, and synthetic biology have opened avenues in which the medicinal properties of plants can be discovered, utilized, and further expanded (F.-S. Li & Weng, 2017). DNA barcoding technology is currently used

as an efficient tool to help identify herbal plants (Mishra et al., 2016), followed by several molecular techniques that can be used in analyzing chemical compound of certain medicinal plant. Herbal plants contain bioactive components that may have pharmacological benefits, such as antimicrobial, anti-inflammatory, and antioxidant properties. Therefore, herbal plants contribute to food security by improving health and reducing the risk of illness (Sugiharto, 2021).

The application of molecular biology still needs improvement due to gaps between researchers, stakeholders, and society. Nonetheless, biomolecular technology has enormous potential to be applied in various fields, as well as the challenges. In the future, the application of molecular biology will have implications for food security, particularly in developing herbal products, improving crop productivity, preserving biodiversity, quality control, and sustainable agriculture. A thorough study to identify various roles in the application of molecular biology on herbal plant product management is essential. Comprehensive understanding on the role of molecular biology application in managing herbal plant product sustainably will give a future great impact on general food security.

METHODS

This research uses the method of reviewing the literature study. This method has four basic steps: search, appraisal, synthesis, and analysis (Mengist et al., 2020). Firstly, articles related to the research topic are collected from electronic databases. Secondly, articles are selected according to predetermined criteria (related to the research topic and journal articles published in the last ten years). Thirdly, the data were extracted and categorized, then finally, report the findings and formulate conclusions.

RESULTS

Table 1 shows several studies on molecular biology applications with the object of medicinal plants. These articles focus on molecular biology applications in medicinal plant research, which practically impact herbal plant product management and review particular method applications. Meanwhile, other studies about molecular biology applications on herbal plants that still focus on basic research still need to be explained in Table 1. However, they are still reviewed in this research, such as research about method adjustment, bio-compound identification and analysis, medicinal plant biodiversity research, et cetera.

Table 1. Researches about Molecular Biology Application on Herbal Plants

Molecular Biology Techniques	Case/ Topic	Citation	Research Area
DNA Barcoding	Revealing Adulteration of traded medicinal plant raw drugs	(Nithaniyal et al., 2017) (Santhosh Kumar et al., 2018)	India

Molecular Biology Techniques	Case/ Topic	Citation	Research Area
		(Sheidai et al., 2019)	Iran
	Identification of medicinal plants and their geographical pattern	(Gong et al., 2016)	China
	Identification of medicinal plants	(Jamdade et al., 2022)	UAE
Molecular (DNA) markers	Reviewing and describing molecular markers used in medicinal plants authentication	(Ganie et al., 2015)	-
New-biotechnology based breeding method (plant tissue culture with targeted genome editing method using next generation sequencing/ NGS)	Reviewing the application of genetic and biotechnology for improving medicinal plants	(Niazian, 2019)	-
In vitro production of plant-derived medicinal compounds	Reviewing general origin of plant secondary metabolites, the techniques used, the recent advances and challenges of the technology.	(Cardoso et al., 2019)	-
In vitro plant tissue culture	Reviewing novel methods on plant tissue culture using gene editing	(Espinosa-Leal et al., 2018)	-
Bioassay approach (including gene expression analysis)	Investigating apoptosis mechanism from plant-derived product	(Arbab et al., 2013) (Ho et al., 2011) (Isa et al., 2013)	Malaysia
		(Jin et al., 2018)	USA
Autophagy analysis	Reviewing autophagy using plant-derived product	(Husen et al., 2020)	Indonesia
Genomics and synthetic biology	Reviewing evolutionary and historical perspective of several medicinal properties of plants for human complex diseases.	(F.-S. Li & Weng, 2017)	USA (and global analysis)
Overexpression of gene for metabolites production	Semi-synthetic production of potent antimalarial artemisinin	(Paddon et al., 2013)	-
RNA interference (RNAi) pathway regulation	Reviewing the development of RNAi based-drugs	(Setten et al., 2019)	-

Molecular Biology Techniques	Case/ Topic	Citation	Research Area
Genome editing (CRISPR-Cas9)	Targeted mutagenesis in the medicinal plant *Salvia miltiorrhiza*	(B. Li et al., 2017)	-

DISCUSSION

Based on the data in Table 1, it is evident that molecular biology application plays essential roles in herbal product management globally. This research identifies and highlights many points, including the potential and challenges of molecular biology application on herbal product management. Those researches are not only developed in specific areas but worldwide. The molecular biology application has been spreading widely as a global tool for medicinal plant analysis as part of herbal plant product management.

Potential of Molecular Biology Application on Herbal Product Management

Species identification and authentication

DNA barcoding analysis has been rapidly developed to identify medicinal plants to prevent substitution, species mixture, and adulteration, especially for dried herbal products. Several studies have revealed a lot of medicinal plant adulteration since morphological features are often not included in the final product distributed to consumers. It is possible through DNA Barcoding analysis, using short sequences of DNA to identify and discriminate medicinal plants that are genetically different. Research showed about 20% adulteration of the raw drugs, of which 6% were entirely different species, and it may lead to harmful or toxic products (Nithaniyal et al., 2017). Another research also showed that DNA barcodes could confirm that approximately 12% of the herbal products in the South Indian market were adultered. It also indicates substitution ranged from 20% to 100% (Santhosh Kumar et al., 2018), followed by the subsequent research, which showed another adulteration or false labeling of the Momordica charantia sample (Kumar et al., 2020). Moreover, several studies have shown similar cases (Sagar, 2014; Sheidai et al., 2019; Srirama et al., 2017; Zhou et al., 2014).

Breeding and increasing content of bioactive compounds

The development of several molecular biology techniques allows for the breeding of more valuable medicinal plants, as it has been reviewed by research before (Niazian, 2019).. The development of genetic engineering allows the enhancement of bioactive compounds in medicinal plants, one of which is through plant tissue culture. Breeding on medicinal plants mainly focuses on their bioactive compounds for health

purposes. Plant tissue culture benefits medicinal plant conservation and enhances their active secondary metabolites, opening the way for engineered molecule production (Espinosa-Leal et al., 2018). In vitro techniques can produce higher medicinal compounds in sterile and controlled environmental conditions compared to conventional cultivation in a greenhouse or field (Cardoso et al., 2019). Besides, plant DNA extraction, PCR amplification, electrophoresis, and next-generation sequencing (NGS) commonly used nowadays allows us to do several kinds of treatment for further studies on medicinal plants.

Knowledge of autophagy also adds a new dimension to herbal medicine and can be applied in the pharmaceutical industry (Husen et al., 2020). A study showed that several herbal plants have the potential to cure cancer through apoptosis mechanisms that can be understood using bioassay through gene expression analysis. Some of these plants include *Muniziqi Granule* as an anti-cancer (Zou et al., 2017), *ginseng* for colorectal cancer (Jin et al., 2018), *Paeonia suffruticosa* root bark for pancreatic cancer (Liu et al., 2018), *Radix Stephaniae tetrandrae* for breast cancer cells (Wong et al., 2017), *Elephantopus scaber* for breast cancer (Ho et al., 2011), *Glycyrrhiza uralensis Fisch* for lung cancer (Tang et al., 2016), *Boesenbergia rotunda* for lung cancer (Isa et al., 2013), *Gnetum cleistostachyum* for bladder cancer (Liang et al., 2016), *Murraya koenigii* for the treatment of liver cancer (Syam et al., 2011), and *Clausena excavate burm* for prostate cancer (Arbab et al., 2013), et cetera. These findings triggered more research to produce plant-derived products used for health care through genetic engineering and genome editing. With the development of genomic and synthetic biology research in this omics era, it is possible to produce specific metabolites, even increasing the quantity. Several studies have been conducted to increase metabolite production using molecular biology techniques, such as overexpressed gene (Paddon et al., 2013), RNA interference (RNAi) (Setten et al., 2019), genome editing (CRISPR-Cas9) (B. Li et al., 2017) et cetera.

Quality control

Apart from being used for authentication, molecular biology analysis can also be used to control the quality of herbal products in terms of the quality and purity of their specific bioactive compounds, as explained above. It is essential to avoid the presence of contaminants or unwanted compounds. The use of the DNA barcoding method is one of the examples, as explained before. Molecular biology techniques also enable the identification of genes involved in the biosynthesis of specific bioactive compounds in medicinal plants, opening up opportunities to modify its production system through genetic engineering. It aligns with a research recommendation to do the correct identification and purity analysis of the minimum concentration of bioactive compounds in certain medicinal plants to guarantee their quality (Brandão et al., 2013).

Challenges of Molecular Biology Application on Herbal Product Management

Sample quality and quantity

Most medicinal plants are distributed in the market as dried products in the form of powder or dried whole plants. Therefore, the quality and quantity of medicinal plant samples used in molecular biology analysis must be optimal for accurate and

representative results, especially for the samples collected from the traditional raw drug market.

Genetic variability

A deep understanding of genetic variation patterns for medicinal plants should be provided through comprehensive molecular biology analysis. It is related to the vast and unspecified genetic variability of medicinal plants regarding geographic and socio-cultural reasons. Researchers should have enough species data collection before analyzing unknown or unconfirmed medicinal plants. Therefore, building a biodiversity data bank that can be accessed globally is essential, allowing researchers worldwide to provide and be provided with any data from one another. The National Center for Biotechnology Information (NCBI) exemplifies this. However, the number of species data collected remains challenging, especially if it is specific to medicinal plants. Research also suggested that this kind of library can benefit all stakeholders, including consumers, traders, and regulatory agencies (Nithaniyal et al., 2017). A local research team can also contribute to building a specific library for their local medicinal plants together, like in India (Vassou et al., 2016).

Method reliability

As a new and still developing method, molecular biology analysis is an essential challenge in herbal product research and development. It is necessary to ensure the reliability and reproducibility of the specific technique used through continuous representative research. As an example, a DNA barcode can differentiate one species from another. However, it can not differentiate different organs from the same plant species (Ganie et al., 2015), so we can not apply it to choose a dried herbal product in which each part has a different functional value. Conversely, no consensus exists about specific DNA loci that can be used for plant discrimination at all taxa levels. Therefore, research about several loci's efficacy on specific plant group are still being conducted, such as on *Asteraceae* (Gong et al., 2016), *Schinsandraceae* (Zhang et al., 2015), *Apocynaceae* (Selvaraj et al., 2015), *Caryophyllales* (Jamdade et al., 2022), and others. Moreover, this method should be developed well first until it can be used globally. WHO also recommends using DNA barcode identification associated with chemical analysis to guarantee their quality (Palhares et al., 2015). Nowadays, there has also been metabarcoding, a combination of DNA barcode and high-resolution melting (HRM) by the use of next-generation sequencing (NGS) that can identify species in mixed samples successfully (Yu et al., 2021). Thus, the research on the method reliability of molecular biology applications should be developed continuously, as well as knowledge and technology development. Besides, the relatively high cost of molecular biology techniques application is a big challenge. Review research also concluded that the higher production cost of medicinal plants in vitro production, followed by the need for specialized labor, contributes to the low number of large-scale, profitable production systems producing plant-derived medicinal compounds (Cardoso et al., 2019).

Regulation and Standards

The regulation and standards between research and industry always become a big challenge in forwarding knowledge to practice, including the use of molecular biology techniques in the pharmaceutical industry. Therefore, it is crucial to

synchronize the standards and regulations between the ongoing research and industry needs. On the other hand, a national regulatory framework for authenticating raw herbal trade in the country should be developed.

Community acceptance and dependence on technology

In the end, public acceptance is essential in applying molecular biology to herbal product management, especially concerning environmental and health impacts. The use of genetically modified engineering species for food also still has pros and cons in society, so molecular biology techniques should pay attention to its long-term impact and be socialized clearly before its widespread Application. Besides, applying molecular biology techniques may make modern society more dependent on high technology. In contrast, the scaling-up mechanism of such technology globally needs time, resources, and high cost.

Implications of Molecular Biology Application on Herbal Product Management for sustainability of food security

The application of molecular biology to herbal product management can provide significant benefits for the sustainability of the food security system through enhanced production and quality control technology, followed by increasing medicinal plant utilization. Sustainable management of medicinal plants as part of food or categorized as functional food allows the achievement of sustainable food security by providing more varied, qualified, and sustainable food resources in the long term. It can be explained as follows:

Increasing herbal plant production and availability = Sustainability of natural resources

Medicinal molecular plant breeding increases its yields and productivity, increasing the availability of raw materials for herbal products and many kinds of foods. In this modern era, fast food is proliferating as the priority for daily needs. It is also followed by nutrition fulfillment through instant dietary products such as food supplements or vitamins in capsules, powder, instant drinks, et cetera. The high production and availability of medicinal plants through molecular biology applications provide more natural resources as a good choice for dietary nutritional fulfillment.

Product innovation and added value = Increasing local economic value

Researching bioactive compounds in specific medicinal plants can lead to product innovation of functional food with particular efficacy. Designing a custom product through genetic and biochemical analysis, such as nutritional supplements, is possible. The research described that new-biotechnology-based breeding methods, such as targeted genome editing, allow us to create custom-designed herbal plants with specific bioactive compounds profile (Niazian, 2019). It is also possible to produce a certain kind of food with a specific function for health care, such as herbal modern drinks. This condition allows the increase of local economic values through the use and trade of herbal products. Moreover, the high production of bioactive ingredients in pharmaceutical industries will undoubtedly lead to economic improvement globally.

Conflicts of Interest

The authors declare that there is no conflicts of interest related to this research.

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