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Opinion

AI-Bioinformatics May Transform *Jamu* for Smarter Indonesian Healthcare: A Perspective

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Introduction

Degenerative diseases in Indonesia continue to increase, including cardiovascular (hypertension and coronary heart disease), diabetes, cancer, and joints (osteoporosis, osteoarthritis, and rheumatoid arthritis), with the quality of life of Indonesian people at 53.5% (good quality of life) and 46.5% (poor quality) (Juanita et al., 2022). Degenerative diseases in Indonesia tend to increase with the aging population, especially ischemic heart disease, stroke, lung cancer, lower back pain, Alzheimer's, and dementia. This phenomenon is caused by a shift from infectious diseases to degenerative diseases, which can cause death and disability in the population (Sitohang, 2023). Based on the latest data, degenerative diseases in Indonesia are the leading causes of death, with prevalence percentages including cardiovascular disease at 35%, cancer at 12%, and diabetes at 6% (Arifin et al., 2022).

The challenge of the number of degenerative diseases in Indonesia must go hand in hand with national resilience in the pharmaceutical product sector. The rules governing national resilience are contained in Minister of Health Regulation Number 88 of 2013, regulating the master plan for developing raw materials for traditional medicines, and Regulation Number 17 of 2017, regulating the action plan for developing the pharmaceutical and health devices industry (Minister of Health of the Republic of Indonesia, 2017; Minister of Health of the Republic of Indonesia, 2013). However, up to now, 90% of the raw materials for pharmaceutical products in Indonesia come from imports, causing high drug prices and drug shortages if the supply of raw materials is disrupted, as in the case of the COVID-19 pandemic (Grumiller et al., 2021; Siagian et al., 2021).

Indonesia has the most significant mega biodiversity in the world with bioactive content from plants, animals, and microorganisms, which has been proven empirically (local wisdom has been passed down from generation to generation) and based on research results, is useful as medicine (Sanka et al., 2023). Indonesia has 30,000 species of plants and animals that have potential as medicine (Illian et al., 2021). There are more than 5 million small molecules, >407,270 unique natural products/herbs, >29,812 compound isolates, >9,643,763 proteins, and >2,031 organisms related to drugs from natural products to treat various diseases. They have yet to be utilized optimally (W. Chen et al., 2023).

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Jamu is a traditional Indonesian medicine that has been used for generations to maintain health and treat various diseases. Data shows that in Indonesia, more than 9,600 species of plants and animals are known to have medicinal properties but still need to be used optimally. The factors that cause this are limited accessibility and convenience, cultural shifts and perceptions, and the perception that *Jamu* lacks scientific evidence and presentation/packaging that is still traditional and not integrated with the formal health service system (Illian et al., 2021).

Opportunities for the use of medicines derived from natural products in Indonesia are supported by the growth of the Gross Domestic Product (GDP) in the pharmaceutical and traditional medicine sectors. Data on GDP growth for this sector (2022) in Indonesia is 235.48 trillion rupiahs with an average growth in the last five years (2018-2022) of 5.35%, more significant than the average GDP growth for all sectors (3.43%) (Sadya, 2023). The opportunity for artificial intelligence (AI) technology to solve problems in various sectors more quickly than other methods is quite promising, with an accurate percentage of >78% (Ahad et al., 2023).

The artificial intelligence technology used in optimizing *Jamu* into products that can be accepted in modern health services is clinical bioinformatics in intelligent healthcare systems with diversification of the uses and sales methods.

System Innovation

Modernization of *Jamu* Transformation

The raw materials for *Jamu* use ingredients from natural products that have been proven ethnomedicinally and have been empirically used for generations by ethnic groups in Indonesia (Hidayat et al., 2021). Using *Jamu* based on ethnomedicine makes it easier to filter the toxicity of natural products (Pasaribu & Waluyo, 2020). However, *Jamu* is not widely used in modern health services and is sold using the traditional system through mobile *Jamu* sellers using bicycles or carried on the seller's back, namely *Jamu gendong* (Elfahmi et al., 2014). The transformation of *Jamu* needs to be carried out in two ways: diversification of the uses and sales methods. Sales methods are transformed into outlets with a coffee shop concept (*Jamu* space) in the pharmacy store.

The transformation of *Jamu* from the usability aspect includes its use for minor illnesses and complementary and functional food (Alostad et al., 2020; Wahab et al., 2021). The classification of *Jamu* will have implications for the broader use of *Jamu* in pharmacy stores, whether for a single treatment, combined with modern medicine (complementary), or to function to increase the body's immune system (functional food). The *Jamu* classification encourages policymakers to map the use of *Jamu* based on its classification. It makes it easier for patients to choose *Jamu* for self-medication, especially *Jamu* classified as a minor illness and functional food, and pharmacists determine the patient's treatment for complementary medicine or a single treatment.

The transformation of *Jamu* into modern medicine is based on data on the high demand for drugs for degenerative diseases. Data on patients with degenerative diseases is based on a comparison of the number of patients and the population, including diseases hypertension by 34.1% (2018) (Kurnianto et al., 2020), diabetes by 10.6% (aged 20-79 years in 2021) (International Diabetes Federation, 2021), joints of 12.7% (women) & 15.8% (men) in 2022 (Sananta et al., 2022), and cases of cancer in Indonesia amounting to 946,088 (2016-2020) (Globocan, 2020).

Empirical scientific evidence (ethnic use), the basis of *Jamu*, cannot yet be applied in modern health services such as pharmacy stores. Scientific evidence based on safety and efficacy (preclinical) must be the basis for *Jamu*. Bioinformatics has been used in many traditional herbal medicines, such as Shuang-Huang-Lian (SHL). Shuang-Huang-Lian (SHL) as an antipneumonia was explored through a bioinformatic approach to obtain information on drug targets, distribution of pharmacological activity, practical components, and mechanisms. A bioinformatics approach for clinical application to patients, or clinical bioinformatics, integrates herbal medicine biologic data and information with the patient's clinical condition (B. Zhang et al., 2015). The clinical bioinformatics cycle is connected to the database system contained in the intelligent healthcare system.

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Integration of Clinical Data and Bioinformatics

Intelligent healthcare systems combine several systems in one device, including clinical and bioinformatics data (Y. Chen et al., 2022; Rustandi et al., 2023). Applications integrate clinical data, such as electronic health records, clinical information, and patient health information, to promote the treatment of patients (Dash et al., 2019; Zhou et al., 2021). Bioinformatics data consists of bioinformatics databases, Indonesian ethnomedicine, and tools for data analysis, which can be seen in **Table 1**.

Table 1. Clinical Bioinformatics Tools in *Jamu* Selection

Database/ Tools	Function	Description	Web Link	Ref.
HerbalDB	Database	Indonesian medicinal plant database	https://herbaldb.farmasi.ui.ac.id/	(Syahdi et al., 2019)
Chembl	Databases	Database containing data on bioactive molecules with drug-like properties	https://www.ebi.ac.uk/chembl/	(Zdrazil et al., 2024)
PubChem	Databases	Database containing chemical information, including bioactive data from *Jamu*	https://pubchem.ncbi.nlm.nih.gov/	(Kim et al., 2016)
Drugbank	Databases	Database containing drugs and drug targets needed for analysis of *Jamu*'s potential bioactive	https://go.drugbank.com/	(Wishart et al., 2018)
Coconut	Databases	Database containing bioactive Natural Products (NPs)	https://coconut.naturalproducts.net/	(Sorokina et al., 2021)
KNApSAcK	Databases	Database containing metabolite data contained in plant species	https://www.knapsackfamily.com/KNApSAcK/	(Hossain et al., 2021)
Dgidb	Databases /Tools	Database containing interactions between Drug-Gene that have the potential as drugs	https://www.dgidb.org/	(Freshour et al., 2021)
Cytoscape	Databases /Tools	Tools/Database used to visualize interaction networks and biological pathways	https://cytoscape.org/	(Mousavian et al., 2021)
FordNet	Tools	A formula recommendation system based on deep learning (FordNet) is used to determine the best Traditional Chinese Medicine (TCM) formula that can be applied to selecting *Jamu* formulas.	Not Available	(Zhou et al., 2021)

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Database/ Tools	Function	Description	Web Link	Ref.
WEKA	Tools	One of the tools based on artificial intelligence includes machine learning and deep learning, which are used to analyze data	https://ml.cms.waikato.ac.nz/weka/	(Guedes et al., 2021)
String	Tools	Tools/Database used to analyze protein-protein interactions	https://string-db.org/	(Viacava Follis, 2021)
SWISS ADME	Tools	Tools used to evaluate through prediction methods to obtain pharmacokinetic profile data, drug-likeness, and medicinal chemistry friendliness of small molecules	http://www.swissadme.ch/index.php	(Daina et al., 2017; Ibrahim et al., 2021)

Indonesian ethnomedicine, originating from the diverse ethnic groups of Indonesia, encompasses traditional knowledge recorded in texts such as the Serat Centhini and Serat Primbon Reracikan books (Taek et al., 2019; R. Zhang et al., 2019). The combination of these two systems (clinical data and bioinformatics data) is called clinical bioinformatics. The clinical bioinformatics data was further analyzed at the network pharmacology stage, as shown in **Figure 1**(A). This stage systematically reviews information on the patient's genes, proteins, diseases, and clinical conditions to obtain data conclusions on the compatibility of Jamu, target prediction of Jamu, and network toxicity. This method is an experience-based approach to evidence-based medicine (R. Zhang et al., 2019; Zhou et al., 2021).

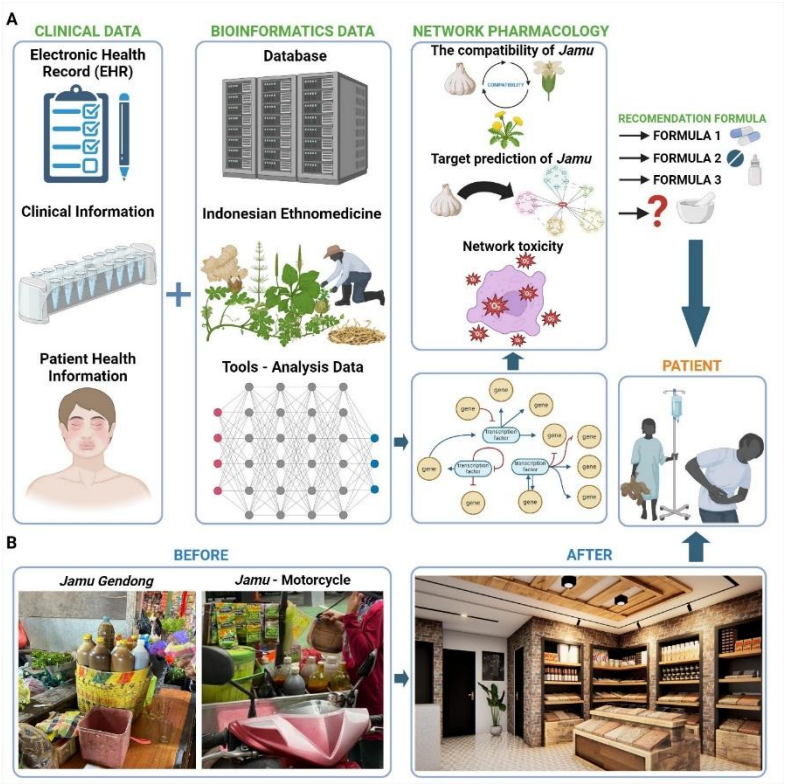

Figure 1. Clinical Bioinformatics Tools in *Jamu* Selection

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Bioinformatics databases are not commonly used in pharmaceutical services in pharmacy stores but are widely used in developing new drugs. However, this transformation needs to involve clinical bioinformatics, which combines clinical data on patients and bioinformatics data on *Jamu* to obtain optimal outcomes. Bioinformatics data on *Jamu* can increase the accuracy of disease targeting (Lee et al., 2019; Mbah & Okorie, 2019; Rai et al., 2023). Systematically, clinical bioinformatics can be observed in **Figure 1** (A).

Jamu Interior Design Innovation

The influence of interior design in accelerating patient recovery has been proven in several health services, such as hospitals. Therapeutic effects resulting from interior design include biophilic design (plant and decor), which can reduce stress and improve well-being, and lighting, which can reduce pain, fatigue, and depression (Huntsman & Bulaj, 2022). Based on previous research, this aspect is essential in *Jamu* transformation, namely the correlation between the influence of colors and art used in hospitals on the healing rate of total hip or knee arthroplasty patients. This research shows a positive correlation to the patient's quality of life and can be applied to essential aspects of *Jamu* transformation (Eminovic et al., 2022). The transformation of the *Jamu* interior design can be seen in **Figure 1** (B). Design recommendations for *Jamu* space design are equipped with a ceiling with wooden ornaments to strengthen the rustic interior of the room. This rustic concept is hoped to make *Jamu* patients and buyers feel comfortable indoors because of the calming natural elements. The color combination used can use light colors, which can have a calming effect (Eminovic et al., 2022).

The application of interior design significantly influences the increase in Jamu users. Previous studies have shown that interior design or interior healthscape design is related to increasing TCM users. This study can be applied to the use of *Jamu* in Indonesia because it has the same characteristics, namely the use of natural products for complementary or alternative medicine. Using the right interior design will significantly influence consumer perceptions and expectations (Caskey et al., 2019).

Conclusion

Jamu has become a part of the culture of society and tribes in Indonesia. It has been used for thousands of years and must remain relevant to current conditions. The transformation of traditional Indonesian medicine called *Jamu*, sold using traditional systems such as *Jamu gendong* or a slightly modern system using motorbikes, requires a strategic approach. The relevance of *Jamu* in medicine and one aspect of health services must be seen as necessary, as *Jamu* must be on par with modern medicine to compete internationally. Apart from that, the potential of biodiversity as a source of *Jamu* must be utilized to address health problems.

The transformation of *Jamu* includes the use of *Jamu* in conjunction with modern medicine as complementary medicine or for the use of minor illnesses and functional foods. *Jamu* must be packaged and rebranded with a modern appearance to increase people's interest in buying it, like food and beverage products currently available. *Jamu* must be easy to use and obtain by placing the *Jamu* in the pharmacy store through the *Jamu* space concept. Another transformative step is modernizing *Jamu* with renewable and scientific technology, namely an intelligent healthcare system that utilizes bioinformatics databases and clinical analysis of patients.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

Tedi Rustandi: Writing – original draft, review & editing, conceptualization, methodology, software, data curation, visualization; **Fariz Nizar:** Writing – review & editing, validation, formal analysis, visualization; **Regina Nastasya:** Writing – review & editing.

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The figure was made using BioRender (https://app.biorender.com).

Declaration of artificial intelligence use
We hereby confirm that no artificial intelligence (AI) tools or methodologies were utilized at any stage of this study, including during data collection, analysis, visualization, or manuscript preparation. All work presented in this study was conducted manually by the authors without the assistance of AI-based tools or systems.

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