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The Potential of *Jamu* Traditional Herbal Drink from Indonesia as Anti-Inflammatory: A Review

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Abstract: *Jamu* is a form of local wisdom that has been passed down from one generation to the next through both oral traditions and written records. The ingredients of *Jamu* include *Curcuma mangga* Val., *Curcuma longa* L., and *Curcuma xanthorrhiza* Roxb. During the Majapahit kingdom, *Jamu* was only used for the nobility. However, it became more widely accessible during the Mataram Islamic Kingdom as part of the cultural heritage. Techniques such as blanching and drying with a black cloth cover are useful for preserving the bioactive components and maintaining the quality of the dried herbs, which contain various bioactive compounds, including curcumin, xanthorrhizol, total phenolics, flavonoids, and alkaloids. These compounds in herbs have the potential to act as anti-inflammatory, immunomodulatory, antidepressant, and anticancer agents. Farmers can cultivate herbal plants organically in the mountains. Innovation, product diversification, and the application of technologies enhance the quality and competitiveness of herbal products in the international market. Therefore, this review discusses the history of *Jamu*, the production process, nutritional content, and bioactive components. It also outlines the health benefits and clinical trials of *Jamu*, as well as potential hazards, prospects, challenges, and inflammatory mechanisms associated with it. *Jamu* contains bioactive compounds such as curcuminoids and xanthorrhizol, which have shown anti-inflammatory effects.

Keywords: anti-inflammatory; cultural heritage; herbal drink: *Jamu*; traditional medicine.

1. Introduction

Jamu, an Indonesian cultural heritage known for its health-promoting properties, has become an integral part of the daily lives of the Indonesian community. It represents local wisdom and reflects the harmonious relationship between humans and nature through the use of herbal ingredients. *Jamu* has been passed down through generations via oral and written

recipes, incorporating various societal elements, from farmers supplying raw materials to compounders preserving the authenticity of traditional formulations. It is known for its anti-inflammatory and immune-boosting properties as well as its role in preventing diabetes, hypertension, hypercholesterolemia, and atherosclerosis. *Jamu* has garnered national and international attention as society's demand for natural medicine continues to rise. Scientific research supports the efficacy of traditional herbs by identifying bioactive compounds, such as antioxidants, in herbal formulations. This creates opportunities to develop *Jamu* as a science-based health solution, reinforcing Indonesia's cultural identity on the global stage. Various herbal plants, including white, yellow, and Javanese turmeric, are key ingredients in *Jamu* and are recognized for their health benefits. White turmeric is known to be anticancer and anti-inflammatory [1]. Turmeric typically contains curcuminoids, which serve as antioxidants [2]. Javanese turmeric, in particular, contains xanthorrhizol, which is effective in improving digestion and liver function [3]. The existence of these herbal plants reflects Indonesia's rich biodiversity.

Traditional communities have developed various methods to process herbal materials, including blanching, slicing, drying into simplicia, grinding, and fermentation, to enhance effectiveness. Simplicia refers to natural materials, such as spices, that have been dried for medicinal use without further processing from their original form [4]. The claims of traditional *Jamu* are increasingly supported by scientific research and advancements. For instance, white turmeric *Jamu* processed into instant powder is preferred for its mild taste and longer shelf life [5]. The potential of herbal plants not only supports health but also holds high economic value for development in the health industry and modern *Jamu.* The natural medicine system has enhanced its relevance as a safe alternative to synthetic drugs with potential side effects. *Jamu* not only alleviates disease symptoms but also supports overall health, making it increasingly relevant in the modern era, particularly among health-conscious individuals who prioritize prevention through herbal remedies.

Scientific research continues to develop, including the identification of active compounds such as curcuminoids and xanthorrhizol in Javanese turmeric. Research using LC-MS Liquid Chromatography-Mass Spectrometry (LC-MS) states that yellow turmeric contains cyclocurcumin, cyclodemethoxycurcumin, and cyclobisdemethoxycurcumin [6]. Xanthorrhizol in Javanese turmeric has preventive and therapeutic activities against various types of cancer, including breast, cervical, colon, liver, lung, mouth, and esophagus, and skin cancer [7]. Modern technologies such as chromatography and spectrophotometry enable the precise identification of bioactive compounds in herbs. Clinical research has confirmed the safety and efficacy of herbs, providing a solid foundation for their integration into modern medicine. Research on the active xanthorrhizol compound shows the ability to suppress inflammatory genes in adipose tissue, liver, and muscle in patients with diabetes mellitus [8]. Treatment with xanthorrhizol inhibited the production of inflammatory cytokines in adipose tissue and the expression of tumor necrosis factor (TNF-α) [9].

Xanthorrhizol inhibits immune cell infiltration into adipose tissue, thereby downregulating the expression of inflammatory cytokine genes [10]. It can reduce serum IL-6 levels and increase transforming growth factor (TGF-β) in patients with Systemic Lupus Erythematosus (SLE) and hypovitaminosis D [11]. Xanthorrhizol also inhibits the production of proinflammatory cytokines and increases the production of anti-inflammatory cytokines [12]. Research on diabetic rats administered 4.5 g of white turmeric powder for 1 month revealed an increase in insulin levels and Superoxide Dismutase (SOD) levels, as well as a

decrease in blood glucose, IL-6, IL-8, and TNF-α levels [13]. The cultural heritage of *Jamu* offers significant health benefits supported by scientific research. It holds great potential as a global natural health solution, further strengthening Indonesia's cultural identity as a nation rich in herbal resources.

2. Methodology

This review utilized a qualitative literature-based approach to evaluate the anti-inflammatory potential of *Jamu*, a traditional Indonesian herbal formulation. The methodology consisted of structured literature identification, selection, extraction, and synthesis, with a focus on the pharmacological properties of key *Jamu* ingredients. A comprehensive literature search was conducted across several scientific databases, including PubMed, Scopus, ScienceDirect, and Google Scholar. The search covered publications from 2000 to 2025 and utilized a combination of keywords, including "*Jamu*", "traditional Indonesian medicine", "anti-inflammatory", and "herbal medicine". Specific plant ingredients: *"*Curcuma longa*" (turmeric), "*Zingiber officinale*" (ginger), "*Tamarindus indica*" (tamarind), "*Kaempferia galanga*", "*Andrographis paniculata*". Boolean operators (AND, OR) were used to optimize the search results. Only articles published in English or Bahasa Indonesia with English abstracts were included.

Inclusion Criteria have been established using peer-reviewed journal articles, theses, ethnobotanical surveys, and studies involving anti-inflammatory assays (*in vitro*, *in vivo*, or clinical). Articles focusing on the pharmacology, phytochemistry, or traditional usage of *Jamu* ingredients. Exclusion Criteria have been used for non-scientific sources, opinion pieces, or articles lacking methodological detail. Studies not directly relevant to anti-inflammatory mechanisms. Relevant data were systematically extracted, focusing on the phytochemical profiles of *Jamu* ingredients, anti-inflammatory mechanisms (e.g., inhibition of NF-κB, COX-2, and TNF-α), traditional preparation methods, and usage contexts of *Jamu* formulations, as well as preclinical and clinical evidence supporting their anti-inflammatory effects. The extracted findings were categorized by ingredient and synthesized thematically. Comparative insights were made between traditional knowledge and modern biomedical evidence. Each included study was assessed for scientific rigor, sample size, reproducibility, and clarity of reported outcomes. Preclinical studies were evaluated according to the ARRIVE guidelines, while clinical studies were assessed using the CONSORT criteria, where applicable.

3. The History and Philosophy of *Jamu*

Jamu has been known in Indonesia since the time of ancient kingdoms, including Majapahit and Mataram (Islam), as part of traditional medicine practices that rely on natural ingredients [14]. During the Majapahit kingdom, herbs were used as medicine and were also an integral part of cultural rituals associated with traditional ceremonies and daily life. This Kingdom, renowned for its excellence in culture and trade, has recognized the medicinal value of various plants. Herbal plants have been used for centuries to treat diseases and maintain health, a tradition passed down through generations by healers and herbalists. For example, yellow turmeric, javanese turmeric, and white turmeric have been used for health purposes since ancient times. This reflects the community's close relationship with the surrounding nature [15].

Archaeological evidence, such as the reliefs on the Borobudur Temple, shows scenes of herbal preparation and consumption, suggesting that the Javanese people used natural remedies [16]. These early formulations were inspired by the region's wide variety of medicinal plants and the animistic beliefs that emphasized harmony with nature. As Javanese culture evolved, external influences further enriched the development of *Jamu*. Indian Ayurveda, brought by Hindu-Buddhist merchants and scholars, introduced new concepts of health and wellness. Moreover, traditional Chinese and Islamic Unani medicine contributed to the diversity of ingredients and preparation methods.

The origins of *Jamu* can be traced back to the Mataram Kingdom era, around 1,300 years ago [17]. Archaeological results, such as stone mortars and pestles from the Liyangan site on Mount Sundoro, Central Java, suggest the early use of herbal medicine during this period. Bas-reliefs on the Borobudur Temple depict scenes of people grinding substances with stone tools, vendors selling drinks, and healers treating clients, indicating the widespread practice of herbal medicine in ancient Java. The term "*Jamu*" is believed to derive from the Javanese words "*Jawa*" (Java) and "*ngramu*" (mixing), underscoring Javanese origins [15].

During the era of the Mataram Islamic Kingdom, the use of *Jamu* became more widespread among both nobles and commoners. This practice highlights the importance of natural medicine in maintaining a balance between the body and the mind. Initially, the nobility in the palace used *Jamu* as a health remedy to preserve physical fitness, beauty, and vitality [15]. Herbal recipes were compiled over generations and kept confidential by the palace physicians. Eventually, the use of *Jamu* was not only limited to the palace but started to be accepted by the general public as part of the medical tradition. The knowledge of *Jamu*, which was initially exclusive, then spread widely and became a cultural heritage valued by all levels of Indonesian society. *Jamu* is known in various parts of Indonesia due to the development of its culture, both written and oral.

During the colonial period in Indonesia (16^{th} to 20^{th} centuries), *Jamu* underwent a significant transformation. The Dutch documented Indigenous herbal practices and incorporated them into formal medical systems. This era also marked the commercialization of *Jamu*, as colonial pharmaceutical companies started mass production and marketing. Despite these developments, *Jamu* retained its traditional essence, becoming a symbol of cultural identity and resistance to colonial influence [15]. *Jamu* is a cultural practice that reflects Javanese values of balance and harmony. Traditionally, *Jamu* is made by *"Mbok Jamu"* and then sold with *"digendong"* (strapped to the back). *Jamu gendong* is liquid *Jamu* stored in a bottle, then put into a bamboo basket and carried on their backs [18]. *Mbok Jamu* not only mixes and distributes *Jamu* but also acts as a custodian of ancestral knowledge, passing down recipes orally from one generation to the next. Common ingredients include turmeric, ginger, tamarind, galangal, and lemongrass, each offering unique health benefits. For instance, turmeric is renowned for its anti-inflammatory properties, while tamarind aids digestion [15].

The recipes of *Jamu* are passed down orally through generations, via stories, experiences, and hands-on training within the family or community. Traditional herbalists passed down information on how to make and use *Jamu* to the community. Knowledge has also been recorded in writing, allowing future generations to learn the recipes more systematically. Ancient texts, such as Balinese and Javanese manuscripts, recorded the recipes as part of traditional medicine that flourished in palaces and local communities [15,19]. Traditional herbal drinks are made simply by boiling the herbs in stone and burnt clay kitchen utensils. Before boiling, the herbs are sometimes ground with traditional stone pounders

(lumpang or cobek-ulekan), then boiled in earthenware pots (*periuk*). Currently, modern processing uses blenders for grinding and stainless-steel or ceramic pots for boiling herbs [18].

In modern Indonesia, *Jamu* continues to thrive as both a traditional practice and a commercial industry. Although many people still prepare *Jamu* at home, pre-packaged products and cafes have gained popularity, particularly among urban populations. The Indonesian government has also played a significant role in recognizing *Jamu* as a cultural heritage and supporting scientific research into its medicinal properties. Globally, *Jamu* is gaining recognition as part of the wellness trend, with consumers drawn to the natural ingredients and a holistic approach to health. However, this global popularity raises questions about sustainability and cultural preservation. Efforts are being made to ensure that commercialization does not undermine traditional roots or exploit the natural resources crucial to production [15]. The history of *Jamu* reflects the integration of local Indonesian traditions and foreign cultural influences. Initially, *jamu* was prepared using local medicinal plants; however, the influence of foreign cultures, particularly those from India, China, and Arabia, led to its widespread adoption throughout Indonesia. The processing methods increased through trade and religious propagation, such as the use of spices brought by foreign traders [15]. This cultural acculturation has made the recipes more complex and diverse, making the history not only a local tradition but also a global influence in the development of Indonesian traditional medicine. Innovation in processing supports product diversification. Hence, Indonesian *Jamu* is presently exported to various countries.

Traditionally, *Jamu* is prepared by local herbalists or healers known as *dukun*, who rely on generational knowledge passed down orally or through written recipes. The ingredients, including roots, bark, leaves, flowers, and fruits, are meticulously selected and combined to create remedies tailored to individual needs. Each preparation is accompanied by rituals and prayers, underscoring the spiritual dimension of *Jamu* as more than a physical remedy but also a means of achieving balance within oneself and the environment [20]. At the heart of the *Jamu* tradition lies the philosophy of balance, a concept deeply intertwined with Javanese spirituality and the broader Indonesian worldview. This philosophy is rooted in the principle of *Rwa Bhineda* (the quality of life), suggesting that health and well-being result from maintaining equilibrium between opposing forces, such as hot and cold, yin and yang, or light and dark [15,20].

The preparation and consumption of *Jamu* reflect the "*Rwa Bhineda*" principle. For example, certain formulations are classified as *panas* (hot), designed to invigorate the body and stimulate energy. In contrast, others are categorized as *dingin* (cool), which is intended to calm and restore balance. By addressing the unique constitution and imbalances of each individual, *Jamu* embodies a personalized approach to healing that respects the interconnectedness of mind, body, and spirit. Additionally, practitioners emphasize preventive care, in line with the Javanese proverb, *'Mencegah lebih baik daripada mengobati*' (Prevention is better than cure). This philosophy is consistent with the broader ecological perspective inherent in *Jamu*, which acknowledges humanity's dependence on the natural world. The sustainable sourcing of herbs and the preservation of traditional practices underscore the ethical dimension *of Jamu* as a form of environmental stewardship [15,19,21].

The philosophy of *Jamu* is a testament to the enduring wisdom of Indonesia's ancestral heritage. By harmonizing the physical, spiritual, and ecological aspects of healing, *Jamu* offers a profound lesson in holistic well-being. As the world increasingly searches for sustainable and integrative approaches to health. *Jamu* serves as a beacon of how ancient traditions can inspire

modern solutions. Embracing the philosophy of *Jamu* will not only honor Indonesia's cultural legacy but also reaffirm collective responsibility to nurture the delicate balance between humanity and nature [20, 22, 23].

4. Key Herbal Ingredients

4.1. Production of Jamu.

CPOTB covers various aspects of the manufacture of traditional medicines, ensuring that the products meet the required standards [24]. The BPOM number 25, dated 2011, regulates the standardization of marketed *Jamu* processing, and Codex Alimentarius regulates international standards. Standardization of processing ensures safe dosage, bioactive components, and safe consumption. The quality of *Jamu* is determined by the raw ingredients, the production process, quality control, and the equipment used in its manufacture (Table 1). The selection of raw materials is essential to ensure *Jamu*'s quality is free from chemical and microbiological contamination. Key ingredients include white saffron, Javanese turmeric, and yellow turmeric (shown in Figure 1). The raw materials are first peeled and washed with running water to remove dirt, then briefly blanched using hot water or steam. Once blanched, the materials are reduced in size by pounding or grating to facilitate extraction. Extraction is carried out by adding clean, sterile water and squeezing the mixture through a cloth to obtain the extract.

(A) **(B)** **(C)**

Figure 1. Types of spices for *Jamu* raw materials: **(A)** white turmeric; **(B)** Javanese turmeric; **(C)** yellow turmeric (source: personal documentation).

The resulting extract is boiled over medium heat until the water content is reduced to a suitable level. Earthenware or stainless-steel equipment is used to prevent contamination. Boiling continues until the liquid is reduced to three-quarters of the initial volume, at which point *Jamu* is ready for consumption. The preliminary blanching process, such as boiling, helps prevent damage to bioactive compounds in raw materials. Blanching inhibits enzyme activity, thereby protecting bioactive components and facilitating easier extraction to achieve higher yields [25]. It also improves raw material quality by inhibiting enzyme activity, reducing microbial contaminants, and enhancing extraction efficiency. Blanching has been shown to be effective in reducing microbial contamination in white turmeric simplicia [26].

Table 1. Main Ingredients of traditional Indonesian *Jamu* herbal drinks [6,9,16].

Local name	Scientific name	Common use in *Jamu*	Health benefits/functions
Kunyit	*Curcuma longa*	Kunyit Asam, Sinom	Anti-inflammatory, antioxidant, menstrual relief
Jahe	*Zingiber officinale*	Wedang Jahe, Beras Kencur	Warming agent, anti-nausea, digestive aid
Kencur	*Kaempferia galanga*	Beras Kencur	Anti-inflammatory, appetite stimulant
Temulawak	*Curcuma xanthorrhiza*	*Jamu* Temulawak	Liver tonic, anti-inflammatory, antioxidant
Asam Jawa	*Tamarindus indica*	Kunyit Asam, Sinom	Cooling agent, antioxidant, digestive support
Beras	*Oryza sativa* (Rice)	Beras Kencur	Energy source, mild thickener

Local name	Scientific name	Common use in *Jamu*	Health benefits/functions
Gula Aren	*Arenga pinnata* (Palm Sugar)	Most *Jamu* variants	Natural sweetener, source of minerals
Daun Sirih	*Piper betle*	*Jamu* Sirih	Antiseptic, antifungal, vaginal health
Lempuyang	*Zingiber zerumbet*	*Jamu* Pahitan	Appetite stimulant, anti-inflammatory
Sambiloto	*Andrographis paniculata*	*Jamu* Pahitan	Immune booster, antipyretic, bitter tonic
Sinom	*Tamarindus indica* (young leaves)	Sinom	Anti-inflammatory, rich in vitamin C
Cengkeh	*Syzygium aromaticum*	Wedang, *Jamu* variations	Antiseptic, analgesic, warming
Kayu Manis	*Cinnamomum burmannii*	Wedang Jahe, *Jamu* Rempah	Antidiabetic, antioxidant
Serai	*Cymbopogon citratus*	Wedang Jahe, *Jamu*	Antibacterial, calming, digestive

Drying is the process of reducing a product's water content to extend its shelf life. It can be carried out using a drying oven (modern drying) or traditional sun drying (conventional drying) [27]. In *Jamu* production, drying is essential for preserving quality, as it extends shelf life, concentrates bioactive compounds, and stabilizes active ingredients. Water content is a key factor in determining a product's freshness and shelf life [28]. Lower water content inhibits the enzymatic process, thereby preventing quality damage to simplicia [29]. Research has shown that the water content after drying decreased from the raw materials of star fruit leaves and turmeric, to 80.01% and 85.50%, respectively. After drying into instant powder, the water content value dropped to 4.12% [30]. Herbs with drying processes include yellow turmeric, Javanese turmeric, powdered ginger, and dried rhizomes (also known as simplicia). Generally, drying *Jamu* under a black cloth, after a blanching process, helps preserve its bioactive components. The black cloth regulates the intensity of sunlight, protecting the material from excessive UV exposure. Blanching inactivates enzymes that could degrade bioactive compounds, such as phenolics [31]. This combination is an effective method for processing *Jamu* while maintaining bioactive properties.

4.2. Nutritional content and bioactive compounds of Jamu.

Jamu is an herbal product composed of natural plant ingredients, including roots, leaves, flowers, stems, or rhizomes [16]. An important consideration during preparation is that the bioactive compounds in the ingredients must not be damaged. Bioactive compounds in herbs, such as flavonoids, alkaloids, and polyphenols, offer benefits for the body's health, but are relatively heat-resistant [32]. The health benefits of plant-derived herbal ingredients, when consumed, are referred to as pharmacological effects. As an herbal product, *Jamu* is derived from plant parts that contain vitamins, minerals, and bioactive compounds that support overall body health, prevent inflammation, increase energy, maintain immune function, and promote mental and emotional balance (Table 2). Turmeric and Javanese turmeric contain vitamin C [33]. Javanese turmeric is rich in vitamin B complex, calcium, and zinc. Free radicals, which can potentially cause oxidation in the body, have unpaired electrons that can damage body cells, DNA, and tissues. [34]. Damage caused by free radicals may induce degenerative diseases such as heart disease, cancer, Alzheimer's, and premature aging [35]. Meanwhile, certain herbs have antioxidant compounds that can provide health benefits to the body (Table 3). Antioxidants donate hydrogen atoms to fight oxidative stress caused by free radicals [36]. Herbs made from a mixture of several ingredients, such as turmeric, contain higher levels of antioxidant compounds because acids can chelate metals, thereby inhibiting oxidation. The total phenolic content of sour turmeric *Jamu* was estimated at 660-1,080 mg GAE/L [32].

Table 2. Nutritional content of selected *Jamu* traditional herbal drinks (per 200 mL serving) [6,9,16].

Jamu type	Calories (kcal)	Carbohydrates (g)	Protein (g)	Fat (g)	Vitamin C (mg)	Iron (mg)	Notes
Kunyit Asam	50–70	12–18	0.5–1	0–0.2	10–20	0.5–1	Made from turmeric, tamarind, and palm sugar
Beras Kencur	80–120	18–28	0.5–1.2	0–0.3	2–5	0.3–0.8	Contains rice, kencur, ginger, palm sugar
Temulawak	70–100	15–25	0.5–1.0	0–0.5	5–10	0.4–1.0	Based on *Curcuma xanthorrhiza*, sugar
Sinom	40–60	8–15	0.3–0.7	0–0.2	15–25	0.3–0.6	Made from young tamarind leaves, often mixed with turmeric
Wedang Jahe	60–80	14–20	0.2–0.5	0–0.1	2–4	0.2–0.5	Ginger decoction with palm sugar
Pahitan	20–40	4–6	0.5–1.2	0–0.2	1–3	0.5–1.5	Typically bitter herbs, minimal sugar

Research on *Jamu*'s bioactive components has been conducted to provide scientific validation of its properties. This includes analyzing the nutritional content, pharmacological properties, and therapeutic effects of the natural ingredients. The results provide insights that help explain the bioactive compounds present in *Jamu* and the mechanisms by which they promote health recovery. Bioactive compounds in *Jamu* play a crucial role in supporting health due to their antioxidant, anti-inflammatory, and anticancer properties. Antioxidant activity, derived from compounds such as curcuminoids, flavonoids, and phenolics, protects the body from free radical damage caused by pollution, stress, or unhealthy lifestyles [37]. These compounds help increase endurance, function as immunomodulators [38], slow the aging process, and prevent degenerative diseases [39,40]. Xanthorrhizol compounds in Javanese turmeric and curcumin in turmeric also provide anti-inflammatory effects that reduce joint pain and swelling by inhibiting the production of inflammation-triggering molecules. The main content of turmeric is curcumin and flavonoid compounds [30]. Bioactive compounds, such as ribosome-interacting proteins, found in white turmeric herbs have demonstrated anticancer potential by inhibiting cancer cell growth and promoting programmed cell death (apoptosis).

Table 3. Bioactive compounds of selected *Jamu* ingredients and their pharmacological activities [6,7,8,9,16].

Jamu ingredient	Scientific name	Major bioactive compounds	Pharmacological activities
Turmeric (Kunyit)	*Curcuma longa*	Curcumin, Demethoxycurcumin, Bisdemethoxycurcumin	Anti-inflammatory, antioxidant, antimicrobial
Ginger (Jahe)	*Zingiber officinale*	Gingerol, Shogaol, Zingerone	Anti-inflammatory, antiemetic, antioxidant
Tamarind (Asam Jawa)	*Tamarindus indica*	Tartaric acid, Flavonoids, Polyphenols	Antioxidant, antimicrobial, laxative
Galangal (Lengkuas)	*Alpinia galanga*	Galangin, Kaempferide, Flavonoids	Antibacterial, anti-inflammatory, digestive stimulant
Lemongrass (Serai)	*Cymbopogon citratus*	Citral, Limonene, Myrcene	Antioxidant, antimicrobial, anxiolytic
Temulawak	*Curcuma xanthorrhiza*	Xanthorrhizol, Curcuminoids	Hepatoprotective, anti-inflammatory, anticancer
Kencur	*Kaempferia galanga*	Ethyl p-methoxycinnamate, Flavonoids	Analgesic, anti-inflammatory, antimicrobial
Black Pepper	*Piper nigrum*	Piperine	Bioavailability enhancer, anti-inflammatory
Cinnamon	*Cinnamomum verum* / *C. burmannii*	Cinnamaldehyde, Eugenol, Coumarin	Antidiabetic, antimicrobial, antioxidant
Clove	*Syzygium aromaticum*	Eugenol, β-caryophyllene, Tannins	Antiseptic, anti-inflammatory, analgesic

Jamu contains antioxidants with great potential as anti-inflammatories, natural immunomodulators, and antidepressants. The content of polyphenols, flavonoids, and alkaloids

in spices such as turmeric and Javanese turmeric can help strengthen the immune system by stimulating the production of immune cells, including lymphocytes and macrophages [40]. Curcumin also supports mental health by increasing levels of the neurotransmitters serotonin and dopamine, which help regulate mood and reduce stress [41]. *Jamu* promotes physical health and supports mental and emotional balance with its various ingredients.

The antimicrobial properties of *Jamu* offer significant benefits in treating infections caused by bacteria, fungi, or viruses. Bioactive ingredients, such as xanthorrhizol, curcumin, and allicin, work by damaging microorganisms' cell membranes, disrupting protein synthesis, or inhibiting the action of certain enzymes [42]. Herbs have antimicrobial effects; for example, turmeric is effective against the bacteria Escherichia coli and Staphylococcus aureus, and Javanese turmeric exhibits activity against pathogenic fungi [43]. Turmeric also contains an antioxidant protein, β-turmerin, with a molecular weight of 34 kDa, which can capture reactive oxygen species (ROS) [6]. Turmeric essential oil has been shown to exhibit antibacterial and antibiofilm activity [18]. These effects make herbs a safe and natural alternative for treating minor infections without the risk of side effects often associated with synthetic antibiotics. Ginger-based herbs can also help prevent infections and support recovery, especially in areas with limited access to modern medicine.

Research has shown that bioactive compounds in herbs have real, scientifically explainable benefits. Curcumin, xanthorrhizol, and flavonoids from ingredients such as turmeric and Javanese turmeric have anti-inflammatory and anticancer effects that can boost the immune system [44]. Clinical research also reported that Javanese turmeric extract could help improve liver function in patients with gastrointestinal disorders. There is a strong scientific foundation for integrating *Jamu* into modern medicine. It is essential to transform traditional benefits into standardized health products. Curcumin has the potential to be an anti-inflammatory, antidiabetic, immunomodulatory, anticholesterol, and antidepressant agent [45]. Curcuminoids also have the potential to serve as therapeutic agents for diseases such as atherosclerosis, neurodegenerative diseases, and certain cancers [46]. The interaction of bioactive compounds from various plants often enhances therapeutic efficacy compared to the use of a single ingredient. For instance, the combination of turmeric and curcumin synergistically strengthens antioxidant activity and accelerates recovery by simultaneously mitigating oxidative stress and inflammation. This evidence underscores *Jamu* as a safe and effective natural remedy. Moreover, traditional practices not only preserve Indonesia's cultural heritage but also offer significant potential for developing modern, competitive herbal-based health products.

4.3. Limitation of Jamu.

One of the most pressing challenges in advancing *Jamu* is the lack of standardization. Unlike modern pharmaceuticals, which undergo rigorous formulation and dosing protocols, *Jamu* recipes often vary significantly by region, practitioner, or producer. Inconsistent concentrations of bioactive compounds, which can affect both efficacy and safety. Variability in raw material quality based on environmental factors, harvesting methods, and post-harvest handling (Table 4). Difficulty in conducting replicable scientific studies or comparing results across research settings due to a lack of formula uniformity. Without standardization, it is challenging to scale *Jamu* for clinical use or export to regulated international markets.

Table 4. Limitations of *Jamu* traditional herbal drinks [44–46].

Category	Limitation	Description/implication
Standardization	Lack of uniform dosage and formulation	Different preparations among regions or producers result in inconsistent therapeutic effects
	Variability in raw materials and bioactive content	Influenced by plant species, soil, harvest time, and processing
Regulation	Weak regulatory enforcement for small-scale producers	Many products are sold without BPOM certification or hygiene standards
	Registered only as traditional medicine, not therapeutic drugs	Bypasses clinical trials and pharmacological evaluation
	Limited international regulatory acceptance	Difficult to meet standards set by the FDA, EMA, etc.
Safety	Risk of contamination (microbial, heavy metals)	Poor sanitation and sourcing practices pose health risks
	Adulteration with chemical drugs (e.g., steroids, NSAIDs)	May lead to hidden side effects, dependency, or drug interactions
	Overdose or prolonged use of certain herbs	Potential for liver toxicity, allergic reactions, or hormonal effects
Scientific evidence	Lack of clinical trial data	Most claims are based on traditional use rather than modern pharmacological validation.
	Insufficient studies on pharmacokinetics and toxicology	Limits understanding of absorption, metabolism, and long-term safety
Public perception	Viewed as “alternative” or “complementary” medicine	Often not trusted by medical professionals or considered less effective

Although *Jamu* is recognized and supported by the Indonesian government, regulatory frameworks for its oversight remain fragmented and under-enforced, particularly at the small-scale production level. Many *Jamu* products are registered only as traditional supplements, exempting them from pharmaceutical-level clinical trials or pharmacovigilance protocols. Limited monitoring and enforcement by regulatory bodies (e.g., BPOM) in rural or informal markets increases the risk of the sale of unregistered or substandard products. Challenges in international registration arise because Jamu often fails to meet the scientific and manufacturing standards required by the U.S. FDA or the European EMA. These limitations restrict *Jamu*’s acceptance within modern healthcare systems and limit its competitiveness in global herbal markets (Table 5).

Table 5. Potential risks of polyherbal combinations [44–46].

Risk category	Description	Implications
Herb–Herb Interactions	Multiple herbs may interact antagonistically or synergistically	May reduce efficacy or cause unpredictable physiological effects
Overlapping Toxicity	Different herbs may contain similar toxic constituents	Increases risk of liver, kidney, or gastrointestinal toxicity
Unclear Dosage Limits	Complex combinations make it difficult to define safe and effective dosages	Higher chance of overdosing or underdosing active compounds
Bioavailability Interference	One herb may inhibit or enhance the absorption of another	Alters pharmacokinetics and therapeutic outcomes
Compounded Side Effects	Similar side effects from different herbs may be amplified	E.g., excessive sedation, blood thinning, or hormone disruption
Lack of Standardization	Variable concentrations of active compounds across different herb sources	Unreliable potency and clinical outcomes
Difficulty in Identifying the Cause of Adverse Reactions	Hard to pinpoint the offending herb in a multi-herb formulation	Delays appropriate treatment and complicates safety evaluation
Potential for Allergenic Reactions	Multiple allergens increase hypersensitivity risk	Skin rashes, respiratory issues, or anaphylaxis in sensitive individuals
Contamination and Adulteration	More ingredients = more opportunities for poor quality or contaminated material	Increases risk of microbial, heavy metal, or pesticide contamination
Regulatory Complexity	Multi-herb formulas are harder to assess and approve under existing frameworks.	Delays licensing, labeling, and international acceptance

While traditionally regarded as safe, *Jamu's* safety profile is not always guaranteed, especially under modern commercial pressures and inconsistent production practices. Some unethical producers add pharmaceutical substances such as corticosteroids, NSAIDs, or

antibiotics to enhance perceived effectiveness, leading to serious health risks when consumed unknowingly. Poor sanitation during processing or use of contaminated soil and water can lead to microbial or heavy metal contamination. Certain herbs used in *Jamu* (e.g., sambiloto, temu giring) can cause liver damage, reproductive disruption, or allergic reactions if consumed in excess or without medical guidance. There is insufficient long-term data on the pharmacokinetics and safety margins of many *Jamu* ingredients. The absence of systematic safety evaluation weakens public trust and hinders clinical integration. Most therapeutic claims associated with *Jamu* are based on empirical knowledge passed down through generations. However, the lack of well-designed clinical trials, toxicological assessments, and pharmacokinetic studies limits the evidence base for *Jamu*. As a result, medical professionals often remain skeptical about its use, and it remains marginalized within mainstream health systems.

5. Anti-Inflammatory Mechanism of Curcumin in *Jamu*

Inflammation is the body's biological response to injury, infection, or other harmful stimuli aimed at protecting the immune system and repairing damaged tissues. However, uncontrolled or chronic inflammation may lead to tissue damage and contribute to the development of degenerative diseases such as heart disease, diabetes, arthritis, and cancer. Controlling inflammation can be achieved using anti-inflammatory agents that reduce or suppress the inflammatory process. These agents include pharmaceutical drugs, natural compounds, and other therapies designed to manage inflammation (Table 6).

Curcumin is an active compound found in spices such as yellow, white, and Javanese turmeric, which are key raw materials in traditional *Jamu* production. It offers various health benefits, particularly as an anti-inflammatory agent. Curcumin reduces the production of inflammatory cytokines, such as tumor necrosis factor-alpha (TNF-α), Interleukin-1 beta (IL-1β), and Interleukin-6 (IL-6), which are produced by cells in response to harmful stimuli [56]. As a natural antioxidant, curcumin helps prevent oxidative stress, which can trigger inflammation, making it an effective natural anti-inflammatory agent. Yellow turmeric has been shown to treat several conditions, including liver disorders [57], high cholesterol [58], and indigestion [59]. It also prevents blood clots, strengthens bile function, and treats skin diseases.

Table 6. Anti-inflammatory mechanisms of curcumin in *Jamu* [56–61].

Mechanism	Target/pathway	Effect/outcome	Reference note
Inhibition of NF-κB activation	Nuclear Factor-kappa B	Reduces transcription of pro-inflammatory cytokines (e.g., TNF-α, IL-6)	Major regulator of inflammation
Suppression of COX-2 and LOX enzymes	Cyclooxygenase-2, Lipoxygenase	Decreases prostaglandin and leukotriene production	Reduces inflammation and pain
Inhibition of pro-inflammatory cytokines	TNF-α, IL-1β, IL-6	Lowers systemic and local inflammatory responses	Modulates immune signalling
Activation of the Nrf2 pathway	Nuclear factor erythroid 2–related factor 2	Enhances expression of antioxidant enzymes (e.g., HO-1, SOD)	Counteracts oxidative stress
Downregulation of TLR-4 signaling	Toll-Like Receptor 4	Blocks LPS-induced inflammation and immune overactivation	Prevents chronic inflammation
Suppression of the MAPK pathway	p38, JNK, ERK	Inhibits signal transduction related to inflammatory gene expression	Regulates cellular responses
Epigenetic modulation	Histone acetylation/DNA methylation	Alters gene expression related to inflammation	Long-term regulation

Additionally, yellow turmeric has been shown to possess antimicrobial, antidiabetic, anticancer, and antihepatotoxic properties [60]. Curcumin exerts anti-inflammatory effects by regulating signaling pathways and inhibiting the production of inflammatory mediators, as presented in Figure 2.

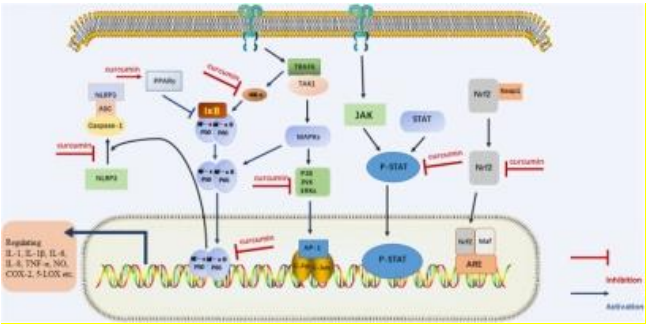

Figure 2. Mechanism of curcumin as an anti-inflammatory [61].

Curcumin binds to Toll-like receptors (TLRs). It regulates upstream signaling pathways such as Nuclear Factor kappa-B (NF-κB), Mitogen-Activated Protein Kinases (MAPK), and Activator Protein 1 (AP-1), thereby modulating inflammatory mediators and treating inflammatory diseases. It reduces NF-κB expression by activating Peroxisome Proliferator-Activated Receptor Gamma (PPARγ). Additionally, curcumin exerts anti-inflammatory effects by regulating the Janus Kinase/Signal Transducer and Activator of the Transcription (JAK/STAT) inflammatory signaling pathway. The administration of curcumin to experimental rats significantly reduced TNF-α, IL-6, and IL-17 levels, while increasing IL-10 levels. [61], and reduced IL-1β levels [62]. The decrease in TNF-α, IL-6, and IL-17 levels, along with an increase in IL-10 levels, demonstrates that curcumin can be utilized as an anti-inflammatory agent.

6. Health Benefits of *Jamu* and Clinical Trial Research Results

Jamu is often prepared from natural ingredients, including spices, roots, leaves, and bark [16]. It contains bioactive ingredients believed to enhance immunity and promote overall health. The curcumin content in turmeric functions as an anti-inflammatory agent that helps fight infections and neutralize free radicals. Drinks such as *Jamu* "kunyit asam" are often consumed to maintain stamina, particularly during extreme weather changes or when recovering from illnesses. Turmeric powder processed by steam blanching for 5 minutes contained antioxidants and normalized Serum Glutamic Pyruvic Transaminase (SGPT) and Serum Glutamic Oxaloacetic Transaminase (SGOT) levels in experimental rats [47]. Herbs are known to be good for digestive health. For example, Javanese turmeric *Jamu* contains compounds that help stimulate the production of digestive enzymes, thereby improving metabolism and nutrient absorption. Ginger is also believed to relieve indigestion, bloating, and nausea. The *in vitro* results for white turmeric obtained using the pressure blanching method are presented in Figure 3.

Herbs like white turmeric have been shown to help normalize high blood sugar levels. It is known as one of the typical herbal plants of Southeast Asia, and it has various health benefits. This plant (turmeric type) is rich in bioactive compounds, such as phenolics and flavonoids, with anti-inflammatory, antioxidant, antidiabetic, and anticancer properties. An *in vitro* test showed that white turmeric contains antioxidant compounds, including epigallocatechin gallate and phenol, based on the 2,2-diphenyl-1-picrylhydrazyl (DPPH) and

Ferric Reducing Antioxidant Power (FRAP) methods. These *in vitro* test results support the *in vivo* research that white turmeric has antiaging potential.

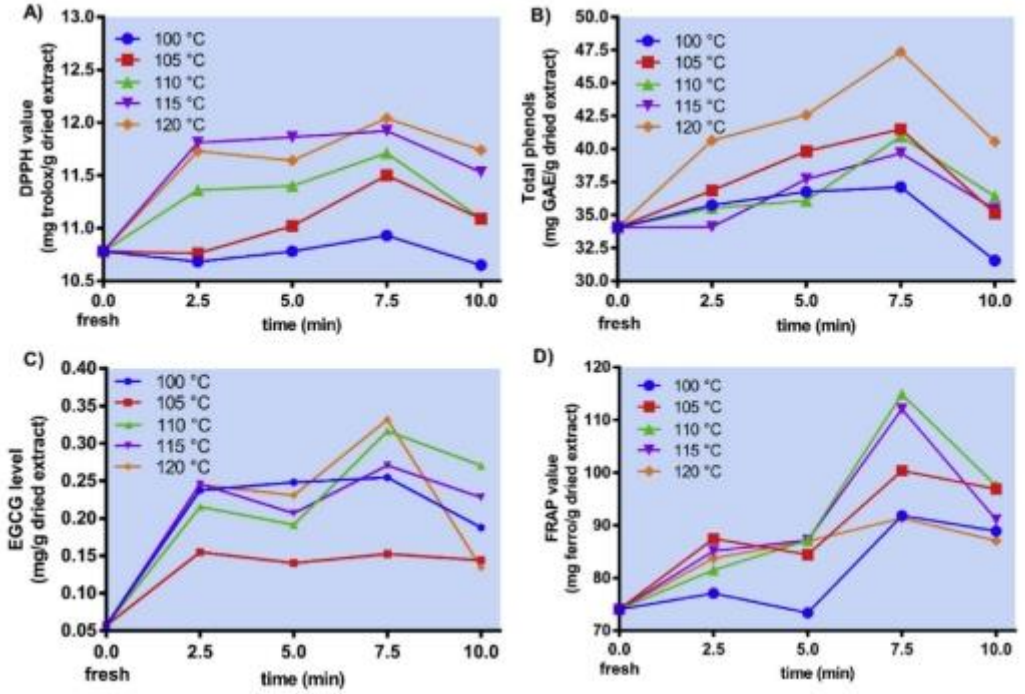

Figure 3. *In vitro* research on white turmeric that has been subjected to pressure blanching (Source: 48). **(A)** DPPH value; **(B)** total phenol; **(C)** EGCG; **(D)** FRAP value of fresh white turmeric and white turmeric pretreated at 100, 105, 110, 115, and 120°C for 2.5, 5, 7.5, and 10 minutes, respectively.

The extract effectively protected the collagen content and suppressed the expression of pro-inflammatory mediators, including Collagenase-1 (MMP-1), Stromelysin-1 (MMP-3), and Collagenase-3 (MMP-13). At a concentration of 25 µg/mL, white turmeric extract was able to maintain collagen content, with only a 26.63% decrease, compared to a 49.13% decrease in the negative control group.

Table 7. Supporting studies on *Jamu* traditional herbal drinks from Indonesia [13,16,46–49,52,53].

***Jamu* type**	**Study model**	**Key findings**	**Reference summary**
Kunyit Asam	*In vivo* (rats)	Reduced TNF-α and IL-6 levels; improved uterine inflammation	Anti-inflammatory effect via cytokine modulation
	Human clinical trial	Improved menstrual pain and mood in women with dysmenorrhea	Safe traditional remedy for female health
Beras Kencur	*In vitro* (antioxidant assays)	High antioxidant activity (DPPH, ABTS assays); phenolic-rich	Effective natural antioxidant
	In vivo (mice)	Increased endurance and reduced oxidative stress markers	Adaptogenic and stamina-enhancing properties
Temulawak	*In vivo* (rats)	Hepatoprotective against paracetamol-induced liver damage	Curcuminoids and xanthorrhizol effects
	In vitro (cell line)	Inhibited COX-2 expression; reduced NO production in macrophages	Anti-inflammatory via iNOS/COX pathways
Sinom	*In vitro* (antioxidant and antimicrobial)	Moderate free radical scavenging, mild antimicrobial activity	Rich in vitamin C and polyphenols
Pahitan (bitter *Jamu*)	*In vivo* (mice)	Lowered blood glucose in diabetic models	Antidiabetic effect of *Andrographis paniculata*
	In vitro	Cytotoxic effect against cancer cell lines	Potential anticancer agent
Wedang Jahe	Clinical observation	Improved circulation and reduced nausea in traditional use	Thermogenic and antiemetic
	In vivo (mice)	Reduced gastric ulcers; protected gastric mucosa	Gastroprotective effects of gingerols

In addition, treatment with white turmeric extract at 100 µg/mL significantly decreased gene expression of MMP-1, MMP-3, and MMP-13 by 3.65-, 34.62-, and 2.02-fold, respectively. The extract possesses antioxidant properties that function as anti-aging agents [48].

White turmeric exhibits significant antidiabetic potential, as demonstrated by research in rats induced with streptozotocin. [13]. Oral administration of the powder for one month, specifically at a dose of 4.5 g, increased insulin and SOD levels while reducing blood glucose, IL-6, IL-8, TNF-α, and MDA levels. Additionally, pancreatic tissue analysis revealed enhanced pancreatic β-cell regeneration in rats (as shown in Figure 4). Related research with white turmeric subjected to pressure blanching significantly increased antioxidant content and improved the lipid profile in Wistar rats. Treatment with pressure-blanched white turmeric significantly increased the levels of SOD, vitamin E, and HDL to 686.44 U/g Hb, 10.87 µg/mL, and 94.17 mg/dL, respectively, compared to the negative control, which had values of 405.37 U/g Hb, 7.44 µg/mL, and 43.47 mg/dL, respectively. MDA, total cholesterol, LDL, and triglyceride levels decreased significantly in the treatment group to 1.98 mmol/L, 108.74 mg/dL, 40.99 mg/dL, and 78.06 mg/dL compared to the control group with values of 8.54 mmol/L, 232.46 mg/dL, 149.17 mg/dL, and 172.61 mg/dL [49].

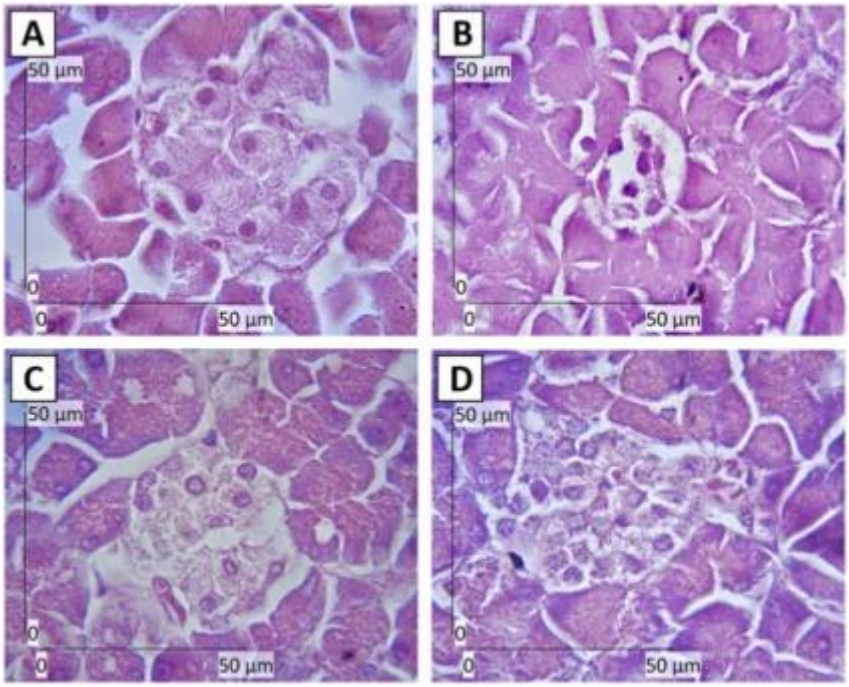

Figure 4. β-pancreas cell [13]. Hematoxylin and Eosin staining of pancreatic tissue, showing Langerhans and β-cell integrity after treatment with **(A)** positive control: non-diabetic rats; **(B)** negative control; **(C)** 1.5 g white turmeric powder for four weeks; **(D)** 4.5 g white turmeric powder for four weeks.

Herbs play a crucial role in detoxification, helping to maintain body balance. Javanese turmeric is recognized for its hepatoprotective properties, which support liver function by removing toxins [50]. Regular consumption of these herbs helps cleanse the body of harmful substances. *Jamu* also promotes skin health, with antioxidants in white turmeric helping to combat premature aging caused by free radicals. Additionally, some herbs treat skin conditions such as acne, eczema, and dull skin. The benefits extend beyond physical health to hormonal balance. Sour turmeric, commonly used by women to relieve menstrual pain, also supports reproductive health. The phytochemicals in these herbs may help regulate hormone levels and prevent hormonal imbalance (Table 7).

Clinical research on herbal raw materials has been conducted to demonstrate their health benefits scientifically. One interesting research study was on Javanese turmeric, which contains curcumin and xanthorrhizol compounds. It has a hepatoprotective effect, protecting the liver from damage caused by toxins, and the ethanol extract has the potential to act as an antioxidant. In paracetamol-induced rats, the administration of Javanese turmeric ethanol extract at doses of 270 mg/200 g, 540 mg/200 g, and 1080 mg/200 g body weight significantly reduced ALT (Alanine Aminotransferase), AST (Aspartate Aminotransferase), and MDA (Malondialdehyde) levels in blood serum. These results demonstrate the protective effect of Javanese turmeric extract on the liver against toxin damage [51].

Turmeric is also a key raw material for *Jamu*, and it has been widely investigated. Clinical research in patients with osteoarthritis has demonstrated that curcumin, a compound found in turmeric, exhibits anti-inflammatory effects that can help reduce joint pain. The effectiveness of turmeric was also compared to Nonsteroidal Anti-inflammatory Drugs (NSAIDs), and the results showed that turmeric can be a natural alternative with lower side effects. Furthermore, turmeric extract has effects comparable to paracetamol in reducing knee osteoarthritis symptoms, with Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores equivalent across all domains and superiority in lowering C-Reactive Protein (CRP) (37.21%) and TNF-α (74.81%). Turmeric extract provided significant improvements in pain, stiffness, and functional scores, with fewer side effects (5.48%) compared to paracetamol (12.68%), making it an effective natural alternative [52]. Treatment with turmeric can increase the levels of immunoglobulin E (IgE), pro-inflammatory cytokines interleukin 4 (IL-4), transforming growth factor-beta, IL-17, interferon-gamma, and type 1/type 2 (Th1)/(Th2) helper cell ratio in conditions with an impaired immune system [53]. Consuming turmeric powder has the potential to support liver health through its antioxidant properties. The powder from the main rhizome, steam-blanch for 5 min, exhibited the highest antioxidant activity based on the FRAP method, with a value of 96.89 Ferro E/g. It also had total phenolic, flavonoid, and tannin contents of 24.46 mg GAE/g, 12.05 mg QE/g, and 0.35 mg CE/g, respectively. In rats injected with Staphylococcus aureus at 1×10^8 cells/mL, the selected turmeric powder treatment increased SOD activity by 72.92%. Still, it decreased SGPT and SGOT levels to 19.50 U/L and 38.03 U/L, respectively, compared to the control group [47].

Ginger (*Zingiber officinale*) is another herbal ingredient that has been widely researched. Clinical research has shown that ginger is effective in reducing nausea, both in postoperative patients and pregnant women with morning sickness. The extract was effective in reducing postoperative nausea compared to a placebo. However, no significant correlation was found between ginger consumption and postoperative nausea and vomiting [54]. Ginger was reportedly safe and more effective than a placebo for managing nausea. The effect was attributed to gingerol compounds, which have antiemetic properties. Clinical research was also conducted on aromatic ginger (Kaempferia galanga L.), which is often used in rice *Jamu*. Aromatic ginger is known to have anti-inflammatory and analgesic effects. Patients with muscle pain show that regular consumption of aromatic ginger can reduce pain levels and improve muscle flexibility [55].

7. Potential Hazards in *Jamu*

Herbs such as curcumin naturally resist pests, thereby reducing the need for pesticides. It is crucial to select herbal ingredients that are not sourced from land exposed to pesticides or

heavy metals such as lead and cadmium. Pesticides are commonly used to protect crops from pests, but residues can remain on herbal raw materials and enter the body. This contamination can cause poisoning and long-term health problems, including liver, kidney, and nervous system damage. To mitigate risks, it is crucial to ensure that herbal raw materials originate from safe, uncontaminated sources. Good processing and cleaning of raw materials, such as proper washing and drying, help reduce the content of pesticides and heavy metals [63]. Regular testing of raw materials and final products is important to ensure that pesticide and heavy metal levels are within safe limits. Strict quality control can minimize the risk of this contamination, ensuring *Jamu* remains safe and effective for consumption (Table 8).

Table 8. Potential hazards in *Jamu* traditional herbal drinks.

Hazard Type	Source / Cause	Potential Health Risk	Notes
Heavy Metal Contamination	Soil-grown herbs, use of contaminated water	Kidney damage, neurotoxicity, chronic poisoning	Common with unregulated *Jamu* production
Microbial Contamination	Poor hygiene in processing and storage	Foodborne illness (e.g., diarrhea, typhoid)	Especially in fresh, unrefrigerated products
Excessive Use of Bitter Herbs	*Sambiloto*, *brotowali* (*Tinosporia cordifolia*)	Liver toxicity, appetite suppression	Should be used in controlled doses
Adulteration with Pharmaceuticals	Addition of steroids, NSAIDs, or antibiotics	Hidden side effects, drug interactions	Detected in some commercially sold *Jamu*
Overuse of Certain Spices	*Clove*, *cinnamon*, and *nutmeg* in large doses	Liver toxicity, blood thinning (e.g., coumarin in cinnamon)	High-dose or concentrated extracts
Alcohol Content (fermented ***Jamu***)	Traditional fermentation or spoilage	Not suitable for children or pregnant women	Rare but possible with old *Jamu* stocks
Allergic Reactions	Ginger, turmeric, or other botanicals	Skin rash, gastrointestinal discomfort, and breathing difficulty	Varies per individual
Incorrect Identification of Plants	Misidentification or substitution of herbs	Toxicity, lack of efficacy	Risk increases with wild-harvested plants
Improper Dosage/Duration	Long-term use without guidance	Accumulated toxicity, liver strain	Especially in chronic conditions

The use of synthetic additives in the manufacture of non-traditional herbs may increase consumers' risk. Some modern *Jamu* manufacturers add synthetic ingredients, such as colorants, artificial sweeteners, or preservatives, to enhance the product's visual appeal, taste, or shelf life. These ingredients may improve product quality in the short term but may cause adverse health effects when consumed in large quantities or over the long term. Artificial sweeteners such as aspartame or preservatives, including formaldehyde, when used in excess, potentially cause metabolic disorders or even increase the risk of chronic diseases.

The use of synthetic additives in *Jamu* must be strictly regulated to protect consumers' health. Clear guidelines on safe additives should be established, and manufacturers must be transparent about the ingredients they use. Additionally, consumers should be informed about the potential side effects of synthetic substances in *Jamu*, enabling them to make informed decisions. Education on these risks is crucial to minimize the health hazards associated with non-traditional ingredients. Excessive consumption of certain herbs, particularly those containing high concentrations of bioactive compounds, can lead to toxicity. For example, Javanese turmeric has beneficial active compounds but may cause adverse effects when consumed in large quantities. Therefore, proper preparation and processing of *Jamu* are necessary to ensure safety and efficacy.

Consumers should adhere to the recommended dosage to prevent toxicity, while manufacturers must provide clear information on correct dosages and potential health risks. Health authorities' oversight is crucial to regulating dosage limits and ensuring the safe use of herbal products. Consumer education is crucial in preventing misuse and promoting the

responsible consumption of *Jamu*. Many consumers consider herbal medicine to be a completely safe natural product, without considering the potential health risks. This shows the need for consumer education through public health campaigns, informative product labeling, and health counseling by medical professionals to raise awareness about the proper use of herbal medicine. Consumer education is essential for preventing misuse and promoting responsible consumption of Herbal Medicine [64]. Many consumers mistakenly believe herbal products are completely risk-free because of their natural origins. Public health campaigns, product labeling, and health counseling, including medical professionals and experts, can help raise awareness about the proper use of *Jamu*.

8. The Future Direction, Challenges, and Prospects of *Jamu*

Jamu has the potential to be integrated into the health system as part of medically recognized treatment. Scientific research and medical training can establish *Jamu* as a viable alternative treatment in health centers and hospitals. The right steps will enhance public trust and create opportunities for health insurance to cover herbal-based treatments. This integration is expected to strengthen *Jamu's* position in domestic and global markets, making it more relevant in modern healthcare. In recent years, there has been a growing shift towards natural and sustainable healthcare solutions. Consumers worldwide are increasingly prioritizing products that align with their environmental values and promote overall well-being. *Jamu*, with its rich tradition and natural formulations, fits perfectly into this trend. The potential to address conditions such as fatigue, digestive issues, and immune support has attracted wellness enthusiasts and practitioners. Countries such as China, India, and Japan have successfully globalized traditional remedies, setting a precedent for *Jamu* to emerge as Indonesia's contribution to the global herbal medicine market. Strategic branding and scientific validation could position *Jamu* alongside systems such as Ayurveda and TCM.

A major hurdle to *Jamu's* global acceptance is the lack of standardized formulations and scientific backing. Although *Jamu* has long been trusted based on tradition, modern consumers and regulatory bodies demand evidence-based results. Incorporating scientific research into production will validate efficacy, ensure safety, and maintain consistency. Standardizing production processes is crucial for achieving international certifications such as GMP and FDA approval. Collaboration between traditional practitioners and modern scientists is crucial for bridging the gap between age-old wisdom and contemporary expectations.

Challenges such as product standardization, stringent regulations, and the need for in-depth research remain to be addressed. The varying quality of raw materials necessitates standardization to ensure product consistency and safety. Inadequate regulations can hinder *Jamu*'s entry into international markets with stringent requirements. Comprehensive research is necessary to identify active compounds, determine safe doses, and assess potential side effects, thereby enhancing *Jamu*'s legitimacy as a globally recognized herbal product. Collaboration between academia and industry is key to overcoming the outlined challenges. Academia can contribute to the field through research on bioactive ingredients, while the industry should develop innovative products to meet market needs. This synergy is essential for building human resource capacity in the *Jamu* sector. With close cooperation, *Jamu* can evolve into a professional, sustainable, and competitive industry. *Jamu* has significant potential to become one of Indonesia's leading export products. The demand for herbal products in countries such as Japan, the United States, and Europe continues to grow. Export success requires effective marketing strategies, including trade diplomacy, participation in

international exhibitions, and global certifications. *Jamu* exports can boost national economic growth while promoting Indonesian culture, with a focus on quality, safety, and innovation.

Market diversification is crucial for expanding *Jamu's* reach. Herbal products are no longer limited to traditional drinks; they have evolved into supplements, cosmetics, and body care products. Innovations such as herbal teas, capsules, face masks, ready-to-drink beverages, and organic soaps appeal to younger consumers who prefer natural and practical products. This approach positions *Jamu* as part of the modern lifestyle while strengthening its presence in local and international markets. Leveraging e-commerce and digital marketing further propels *Jamu* globally. Social media campaigns, wellness influencers, and online stores can introduce the benefits to a broader audience, transforming it from a cultural artifact into a global health phenomenon.

The Indonesian government and private sector play crucial roles in shaping *the future of Jamu*. It is crucial to support small-scale producers, safeguard traditional knowledge through intellectual property rights, and promote research and development. Integrating *Jamu* into the national health system and tourism industry will also strengthen global expansion. Although *Jamu*'s future is promising, its success hinges on striking a balance between tradition and modernization. By embracing global trends, fostering innovation, and strategically addressing challenges, Jamu can serve as a symbol of Indonesian pride and a trusted remedy worldwide. This journey transcends mere product export; it also shares Indonesia's rich heritage and wisdom with the world.

9. Conclusion

Jamu has great potential for integration into the modern healthcare system. It contains bioactive compounds such as curcuminoids and xanthorrhizol, which have shown significant health benefits, including anti-inflammatory effects. The uniqueness of Indonesia's local wisdom offers significant export opportunities, particularly amid growing international demand for herbal products. Curcumin, an active compound found in spices such as yellow, white, and Javanese turmeric, is known for its anti-inflammatory properties. It reduces the production of inflammatory cytokines, including TNF-α, IL-1β, and IL-6, and acts as an antioxidant, helping prevent oxidative stress. Curcumin inhibits inflammatory signaling pathways, such as NF-κB, MAPK, and JAK/STAT, while increasing PPARγ expression, which regulates the production of inflammatory mediators.

Author Contributions

Conceptualization, D.P., C.L.S. and R.H.B.S.; methodology, D.P., C.L.S., R.H.B.S. and B.K.; software, B.K.; validation, D.P., C.L.S. and B.K.; formal analysis, B.K. and N.; investigation, C.L.S. and U.P.; resources, D.P. and E.W.; data curation, S.W.; writing—original draft preparation, D.P., C.L.S., R.H.B.S. and B.K.; writing—review and editing, U.P., N., S.W. and R.H.B.S.; visualization, S.W. and E.W.; supervision, D.P.; project administration, D.P.; funding acquisition, D.P. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Abbreviations

The following abbreviations are used in this manuscript:

Abbreviation	Definition
ALT	Alanine Aminotransferase
AP-1	Activator Protein-1
AST	Aspartate Aminotransferase
BPOM	*Badan Pengawas Obat dan Makanan* (National Agency of Drug and Food Control of Indonesia)
CPOTB	*Cara Pembuatan Obat Tradisional yang Baik* (Good Manufacturing Practice for Traditional Medicine)
DPPH	2,2-diphenyl-1-picrylhydrazyl
FRAP	Ferric Reducing Antioxidant Power
HDL	High-Density Lipoprotein
IL	Interleukin
IL-1β	Interleukin-1 beta
IL-6	Interleukin-6
IL-8	Interleukin-8
IL-10	Interleukin-10
IL-17	Interleukin-17
JAK/STAT	Janus Kinase/Signal Transducer and Activator of Transcription
Jamu	Traditional Indonesian herbal drink
LC-MS	Liquid Chromatography–Mass Spectrometry
LDL	Low-Density Lipoprotein
MDA	Malondialdehyde
MAPK	Mitogen-Activated Protein Kinase
NF-κB	Nuclear Factor kappa-light-chain-enhancer of activated B cells
PPARγ	Peroxisome Proliferator-Activated Receptor Gamma
ROS	Reactive Oxygen Species
SGOT	Serum Glutamic Oxaloacetic Transaminase
SGPT	Serum Glutamic Pyruvic Transaminase
SOD	Superoxide Dismutase
TNF-α	Tumor Necrosis Factor-alpha
WHO	World Health Organization

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