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Phytochemical Testing, Antioxidant Activity and Determination of Specific and Non-Specific Parameters of Secang Wood Extract (*Caesalpinia sappan* L.)

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Abstract: *Caesalpinia sappan* L., commonly known as sappanwood, has been used in traditional medicine across Southeast Asia for centuries. The objective was to clarify the sappanwood extract's phytochemical profile, antioxidant activity, specific and non-specific parameters. The extraction was performed via maceration using 96% ethanol as the solvent. Phytochemical screening to identify the presence Phytochemical content. Antioxidant activity was assessed using the DPPH assay, yielding an impressive activity of 80%, comparable to the positive control, vitamin C. Phytochemical screening identifed the presence of bioactive compounds such as alkaloids, flavonoids, triterpenoids, and phenolics, while saponins and tannins were notably absent. Specific parameters, including total phenolic content, were quantified using the Folin-Ciocalteu method, while non-specific parameters encompassed moisture content (11%), extract yield (20%), neutral pH (6), and density (0.7 g/cm³). The physical characteristics of sappanwood were described as cylindrical, measuring approximately 10 cm in diameter and 1 m in length, with a reddish-brown to dark red hue and a rough, porous texture. Importantly, the extract was found to be free from hazardous heavy metals, including lead, arsenic, mercury, cadmium, and chromium. In conclusion, these findings underscore the potential of sappanwood as a safe and beneficial natural resource for health and industrial applications.

Keywords: Antioxidant; Non-specific parameters; Phytochemical; Secang wood extract (*Caesalpinia sappan* L.); Specific parameters

Introduction

This Research clarify the sappanwood extract's phytochemical profile, antioxidant activity, specific and non-specific parameters. The exploration of the phytochemical properties and antioxidant activities of Caesalpinia sappan L., commonly known as secang wood, has garnered significant attention in recent years. This interest is largely due to its traditional use in various medicinal applications, particularly in Southeast Asia. Despite the wealth of studies highlighting its bioactive compounds, such as brazilin and brazilein, there remains a notable gap in comprehensive research that systematically evaluates the full spectrum of its phytochemical constituents alongside their specific and non-specific biological activities.

In addition to the antioxidant properties, the anti-cancer potential of secang wood extracts has been a focal point of several studies. Research has demonstrated that extracts from Caesalpinia sappan can inhibit the proliferation of various cancer cell lines, including breast and colon cancer cells (Jenie et al.,

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2018; Rachmady et al., 2017). However, the mechanisms underlying these effects, particularly the role of apoptosis and cell cycle regulation, require further elucidation. For example, the study by Hanif et al. (2019) highlights the cytotoxic effects of secang wood extracts on breast cancer cells, yet the specific apoptotic pathways involved remain to be characterized. This presents an opportunity for innovative research that could explore the molecular mechanisms of action in greater depth.

Moreover, the immunomodulatory effects of Caesalpinia sappan have been noted, particularly in relation to its ability to modulate inflammatory responses in conditions such as rheumatoid arthritis (Jung et al., 2015). However, the scope of these studies has often been limited to specific inflammatory markers, leaving a broader understanding of its immunomodulatory potential underexplored. Investigating the effects of secang wood extracts on various immune cell populations and their functional responses could yield valuable insights into its therapeutic applications in autoimmune diseases.

One of the primary research gaps lies in the limited understanding of the specific phytochemical profiles of secang wood extracts. While previous studies have identified key compounds like brazilin, which have been shown to exhibit significant anti-inflammatory and antioxidant properties (Iqbal et al., 2023; Lee et al., 2015), there is a lack of detailed investigations into the synergistic effects of these compounds when combined. For example, the study by Iqbal et al. (2023) suggests that brazilin may act synergistically with other unidentified compounds within the extract to inhibit proprotein convertase subtilisin/kexin type 9 (PCSK9), a key regulator of cholesterol metabolism. This indicates a potential for enhanced therapeutic effects that have not yet been fully explored.

The novelty of this research lies in its comprehensive examination of the phytochemical constituents of *Caesalpinia sappan* L. (secang wood) and their synergistic effects on biological activities, particularly antioxidant and anti-inflammatory properties. Previous studies have identified key compounds like brazilin, which exhibit significant antioxidant effects (Masturi et al., 2021; Nirmal & Panichayupakaranant, 2015), but there remains a lack of systematic investigation into the interactions among these compounds and their collective impact on health outcomes. This research is crucial for two primary reasons such as therapeutic potential and functional food development.

Furthermore, while the antioxidant activity of *Caesalpinia sappan* has been documented, the methodologies employed in these studies often lack standardization, leading to variability in results. For example, the antioxidant properties of secang wood extracts have been attributed to their high phenolic content, yet the specific mechanisms by which these compounds exert their effects remain poorly understood (Hanif et al., 2019; Ningsih & Churiyah, 2018). A systematic approach using advanced techniques such as high-performance liquid chromatography (HPLC) coupled with mass spectrometry could provide a clearer picture of the phytochemical composition and its correlation with antioxidant activity.

Another significant gap is the exploration of the non-specific health benefits of *Caesalpinia sappan*, particularly in relation to metabolic disorders such as diabetes. While some studies have indicated potential anti-diabetic effects through mechanisms such as xanthine oxidase inhibition (Ningsih & Churiyah, 2018; Sakir & Kim, 2019), comprehensive studies examining the effects of secang wood extracts on glucose metabolism and insulin sensitivity are lacking. This area presents a promising avenue for research, particularly given the rising prevalence of diabetes globally.

Furthermore, the traditional use of secang wood in treating various ailments suggests a need for ethnopharmacological studies that bridge the gap between traditional knowledge and modern scientific validation. While several studies have begun to address this by examining the antimicrobial properties of *Caesalpinia sappan* against specific pathogens (Puttipan et al., 2017; Budi et al., 2020), a more holistic approach that encompasses its use in traditional medicine could enhance the understanding of its therapeutic potential.

While substantial progress has been made in understanding the phytochemical properties and biological activities of *Caesalpinia sappan* L., significant research gaps remain. By addressing these gaps, researchers can unlock the full potential of *Caesalpinia sappan* as a valuable resource in the development of novel therapeutic agents. The objective was to clarify the sappanwood extract's phytochemical profile, antioxidant activity, specific and non-specific parameters.

Method

Extraction Method

The extraction method of sappanwood is carried out through a maceration process using 96% ethanol solvent. This process aims to dissolve the active compounds contained in sappanwood. After extraction, phytochemical tests are carried out to identify chemical compounds, including alkaloids, flavonoids, saponins, and tannins. Antioxidant activity tests are carried out using the DPPH method, where the results are compared with positive controls, namely vitamin C, to assess the antioxidant potential of the extract. Determination of specific and nonspecific parameters is also carried out; specific parameters include total phenolic content measured by the Folin-Ciocalteu method, while non-specific parameters include water content, drying loss, and total ash content. All of these parameters provide important information regarding the quality and biological potential of sappanwood extract. The extraction results are then evaporated using a rotary evaporator to obtain a thick extract ready for further analysis.

Ethanol is selected as the solvent for the extraction of sappanwood due to its polar nature, which facilitates the dissolution of various bioactive compounds such as flavonoids, tannins, and phenolic compounds that are prevalent in plant materials. The choice of 96% ethanol specifically enhances the extraction efficiency of these polar phytochemicals, as higher concentrations of ethanol can effectively disrupt cell walls and release intracellular compounds. Additionally, ethanol's ability to extract a wide range of metabolites, including both hydrophilic and lipophilic compounds, makes it an ideal solvent for comprehensive phytochemical analysis.

Materials and Tools

In this study, the materials utilized were sappan wood, scientifically identified as *Caesalpinia sappan* L. The specific part of the plant employed for the research was the wood, which is known for its bioactive compounds. The samples were procured from Traditional Markets located in Bandung City, Indonesia, during the month of October 2023. The tools employed in the study included a dryer for moisture removal, a grinder for particle size reduction, an extraction tool for isolating phytochemicals, and a phytochemical test tool for analyzing the presence of specific compounds. This methodological approach ensures the integrity and reproducibility of the research findings.

Sample Collection and Preparation

Samples of sappanwood and cinnamon were obtained from local markets. Then, the samples were cleaned from dirt and cut into smaller sizes. After that, the samples were processed into fine powder through a grinding process. The resulting fine powder is then ready to be used for the next maceration process.

Extraction Stage

The maceration process employed for the extraction of sappanwood involved several critical steps to ensure optimal extraction efficiency. Initially, fine sappanwood powder was prepared and placed in a suitable container. To ensure complete submersion of the powder in the 96% ethanol solvent, the solvent was added to a height of approximately 1 cm above the sample. This was crucial to maximize the contact surface area between the solvent and the plant material. During the maceration process, which was conducted at room temperature for 24 hours, a magnetic stirrer was utilized intermittently to enhance the mixing of the solvent and the powder. This agitation facilitated the penetration of the solvent into the plant matrix, thereby promoting the extraction of soluble compounds. After each 24-hour period, the mixture was filtered using a Buchner funnel to separate the solid residue from the liquid extract. The filtrate was subsequently concentrated using a rotary vacuum evaporator, yielding a thick extract rich in bioactive compounds. This method was similarly applied to the cinnamon sample to ensure consistency in the extraction process.

Phytochemical Testing Stage

The phytochemical test stage is an important step in identifying bioactive compounds in plants. The alkaloid content test is carried out by mixing the sample with chloroform and ammonia, then heating and filtering. The resulting filtrate was tested with Mayer, Wagner, and Dragendorf reagents; the formation of orange, white, and brown precipitates indicates the presence of alkaloids. The steroid test uses the Lieberman-Burchard reagent, where a color change from purple to blue or green indicates a positive result. For triterpenoids, mixing the sample with chloroform and concentrated H_2SO_4 produces a reddish-brown color at the interface. The phenolic test involves the addition of $FeCl_3$, where green, blue, or black colors indicate the presence of phenolic compounds. The saponin test is carried out by boiling the sample in water; the formation of stable foam indicates the presence of saponins. Finally, the tannin test is carried out by adding $FeCl_3$ to the filtrate, where a greenish-brown or blackish-blue color indicates the presence of tannins. This method provides a strong basis for phytochemical analysis.

Phytochemical testing is essential for identifying bioactive compounds in plants, relying on specific chemical reactions to indicate the presence of various classes of compounds.

Alkaloid Test: Alkaloids are basic nitrogen-containing compounds. The test involves mixing the plant sample with chloroform and ammonia, which facilitates the extraction of alkaloids. The subsequent addition of Mayer, Wagner, and Dragendorf reagents results in colored precipitates, indicating the presence of alkaloids due to their reactivity with these reagents.

Steroid Test: The Lieberman-Burchard reagent reacts with steroids to produce a color change. The formation of a blue or green color upon the addition of this reagent indicates the presence of steroid compounds, based on the structural characteristics of steroids that allow for such reactions.

Triterpenoid Test: Triterpenoids, similar to steroids, can be identified by mixing the sample with chloroform and concentrated sulfuric acid (H_2SO_4). The reddish-brown color at the interface results from the reaction between triterpenoids and sulfuric acid.

Phenolic Test: The presence of phenolic compounds is indicated by the formation of colored complexes when $FeCl_3$ is added, as phenolics can form stable complexes with iron ions.

Saponin Test: Saponins are glycosides that produce stable foam when boiled in water, indicating their surfactant properties.

Tannin Test: The addition of $FeCl_3$ to the filtrate produces a greenish-brown or blackish-blue color, indicating the presence of tannins, which can form complexes with iron.

Antioxidant Activity Test Stage of Ethanol Extract of Secang Wood

The antioxidant activity test stage of sappanwood extract is: the mother liquor is made by dissolving 0.01 grams of ethanol extract of sappanwood with ethanol pa in a 100 mL measuring flask, then the test solution is made from the mother liquor at concentration variations of 10, 25, 50, 75, and 100 ppm. From each variation of the concentrated solution, after that 300 µl is taken which is then put into a small dark-colored vial and 3 mL of 0.004% DPPH solution is added and shaken vigorously then left for 30 minutes in a dark room. Furthermore, the absorbance is measured at λ max 516 nm. The same treatment is carried out on the control where the sample solution is replaced with ethanol. Then the % reduction value (%P) of the DPPH solution absorbance and the IC50 value are determined.

To prepare a 0.004% DPPH (2,2-diphenyl-1-picrylhydrazyl) solution, the following procedure is typically employed. First, the appropriate mass of DPPH is calculated based on the desired final concentration. For a 0.004% (w/v) solution, this equates to 0.004 grams of DPPH per 100 mL of solvent. Therefore, to prepare 100 mL of the solution, 0.004 grams of DPPH is weighed accurately and dissolved in ethanol (the same solvent used for the sappanwood extract) to achieve the final volume. Ethanol is chosen as the solvent due to its ability to dissolve both the DPPH and the bioactive compounds present in the sappanwood extract, ensuring compatibility in the antioxidant activity assay. The solution is then mixed thoroughly until the DPPH is completely dissolved, resulting in a homogeneous solution ready for use in the antioxidant activity test.

Result and Discussion

Table 1 presents the results of phytochemical tests of the ethanol extract of sappanwood, which indicates the presence of various chemical compounds. The alkaloid test showed positive results with the presence of orange, white, and brown deposits, indicating the presence of alkaloid compounds. In contrast, the steroid test showed no color change, so it was declared negative. The triterpenoid test showed brownish at the interface, which was also positive. The phenolic test produced a brownish black color, indicating the presence of phenolic compounds, which was positive. The flavonoid test showed an orange color, which was also positive. However, the saponin and tannin tests each showed negative results, with saponins producing unstable foam and tannins showing no color change. Overall, these test results indicate that the ethanol extract of sappanwood contains several bioactive compounds, which have the potential for applications in the health and pharmaceutical fields.

Table 1. Phytochemical test results of ethanol extract of secang wood

Content Test	Results	Conclusion
Alkaloids	There are orange, white and brown deposits	Positive (+)
Steroid	No color change	Negative (-)
Triterpenoid	Browning on the surface	Positive (+)
Phenolic	Brownish black in color	Positive (+)
Flavonoid	Orange Colored	Positive (+)
Saponins	Unstable foam	Negative (-)
Tannin	No color change	Negative (-)

Table 2 presents the results of the examination of specific parameters of sappan wood (*Caesalpinia sappan*), which is an important source of raw materials in the wood industry and traditional medicine. The first parameter, shape, shows that this wood has a cylindrical shape, which is common to many types of wood. The size of the wood is shown in 10 cm diameter and 1 m length, providing an idea of the physical dimensions relevant for industrial applications. The color of sappan wood varies from reddish brown to dark red, which is an important characteristic for aesthetic assessment and sales value. The rough and porous texture indicates that this wood has a structure that can affect the processing and use processes. The sweet and slightly bitter aroma and the bitter and slightly sweet taste indicate potential use in the culinary and pharmaceutical fields. The structure of the wood consisting of xylem and phloem cells reflects the biological function of wood in the transport of water and nutrients. Finally, the rough and irregularly oriented wood fibers can affect the strength and durability of the wood in construction applications.

Table 2. Results of specific parameter examination of secang wood

Parameter	Results
Form	Wood, Cylinder
Size	Diameter: 10 cm; Length: 1m
Color	Brownish red, Dark red
Texture	Rough and porous
Aroma	Sweet and a little bitter
Flavor	Bitter and a little sweet
Wood Structure	Consists of xylem and phloem cells
Wood fiber	Rough and irregularly oriented

Table 3 presents the results of the non-parametric examination of sappanwood, indicating various physical and chemical parameters relevant for the characterization of this material. The moisture content of 11% indicates that sappanwood has relatively low humidity, which is important for the stability and durability of the material. The extract content of 20% indicates the potential for active compounds to be extracted, implying its use in the pharmaceutical or cosmetic industry. The pH value of 6 indicates a neutral nature, which may affect its interaction with other materials. The density of 0.7 g/cm^3 and the specific gravity of 0.9 g/cm^3 indicate that this wood is relatively light, which may affect its application in construction or crafts. The hardness of 4 on the Mohs scale indicates that this wood is quite hard, providing resistance to scratches. The resistance to weather changes indicates the durability of the material, while the good absorption capacity of water and ethanol solvents indicates potential applications in the extraction of bioactive compounds. Analysis of heavy contaminants shows that sappanwood is free from lead, arsenic, mercury, cadmium, and chromium, indicating the safety of the material for further use.

The results of the phytochemical tests conducted on the ethanol extract of sappanwood (*Caesalpinia sappan*) reveal a diverse array of bioactive compounds, which are significant for their potential applications in health and pharmaceuticals. The presence of alkaloids, triterpenoids, phenolics, and flavonoids, as indicated by positive test results, suggests that sappanwood may possess various therapeutic properties. Conversely, the absence of steroids, saponins, and tannins highlights the selective nature of the phytochemical profile of this plant.

The positive identification of alkaloids is particularly noteworthy, as these compounds are known for their pharmacological activities, including analgesic, anti-inflammatory, and antimicrobial effects (Sazali et al., 2024). The presence of orange, white, and brown deposits during the alkaloid test indicates the successful extraction of these compounds, which have been documented in other studies as contributing to the medicinal properties of various plants (Nugroho et al., 2023). For example, alkaloids from different sources have been shown to exhibit significant antibacterial and antifungal activities, reinforcing the potential of sappanwood as a source of natural antimicrobial agents (Hugar et al., 2023; Sazali et al., 2024).

Table 3. Results of non-specific parameter examination of secang wood

Parameter	Results
Water content	11%
Extract content	20%
pH	6
Density	0.7 g/cm^3
Violence	4 mohs
Resilience	Long-lasting against weather changes
Absorption capacity	Good results against water and ethanol solvents
Specific gravity	0.9 g/cm^3
Lead (Pb)	0 ppm
Arsenic (As)	0 ppm
Mercury (Hg)	0 ppm
Cadmium (Cd)	0 ppm
Chromium (Cr)	0 ppm

The pharmacological potential of sappanwood (*Caesalpinia sappan*) is underscored by its rich phytochemical profile, particularly the presence of brazilin, which has demonstrated significant anti-inflammatory, analgesic, and antioxidant activities (Jung et al., 2015; Salma et al., 2023). Studies indicate that brazilin can inhibit pro-inflammatory cytokines such as TNF-α, thereby alleviating conditions like rheumatoid arthritis (Jung et al., 2015). Additionally, the antioxidant properties of sappanwood have been linked to its flavonoid content, which plays a crucial role in mitigating oxidative stress and inflammation. Research has also highlighted the antimicrobial effects of sappanwood extracts, reinforcing its traditional use in herbal medicine. The presence of various bioactive compounds, including alkaloids and flavonoids, contributes to its efficacy against bacterial and fungal pathogens. Collectively, these findings suggest that sappanwood is a promising candidate for further exploration in the development of natural therapeutic agents targeting inflammation and infection.

In contrast, the steroid test yielded negative results, indicating that sappanwood does not contain steroid compounds. This finding is consistent with other studies that have reported similar outcomes in various plant extracts (Hugar et al., 2023). The absence of steroids may limit certain therapeutic applications, particularly those related to hormonal modulation; However, the presence of other bioactive compounds can compensate for this limitation by providing alternative health benefits (Oladele et al., 2021). The investigation into the chemical composition of sappanwood has yielded significant insights, particularly regarding the absence of steroid compounds. The negative results from steroid testing indicate that sappanwood does not possess these compounds, which aligns with findings from Hugar et al. (2023), who also reported similar outcomes in their studies of various plant extracts. This absence of steroids may indeed pose limitations for certain therapeutic applications, especially those that rely on hormonal modulation, as steroids often play critical roles in such processes (Bollinger et al., 2024). However, it is essential to recognize that the lack of steroids does not negate the potential health benefits of sappanwood. Other bioactive compounds present in sappanwood may provide alternative therapeutic effects. For instance, Oladele et al. (2021) suggest that various phytochemicals found in plant extracts can offer significant health benefits, including anti-inflammatory, antioxidant, and antimicrobial properties (Gómez-Pérez et al., 2023). These compounds can compensate for the absence of steroids by contributing to overall health and wellness through different mechanisms (Gómez-Pérez et al., 2023). Moreover, the therapeutic potential of sappanwood may be enhanced by its traditional uses in herbal medicine, where it has been employed for various ailments. The ethnobotanical knowledge surrounding sappanwood indicates that its application extends beyond hormonal modulation, encompassing a range of health benefits that are attributed to its diverse phytochemical profile (Wang et al., 2023). This highlights the importance of exploring the full spectrum of bioactive compounds in sappanwood, as they may offer valuable alternatives in therapeutic contexts where steroids would typically be utilized.

The positive result for triterpenoids, evidenced by browning at the interface during testing, suggests that sappanwood contains compounds that may have anti-inflammatory and antioxidant properties (Mitani et al., 2012). Triterpenoids are known for their ability to modulate various biological pathways, making them valuable in the development of therapeutic agents (Djaeni et al., 2021). The identification of these compounds in sappanwood aligns with findings from other studies that emphasize the importance of triterpenoids in traditional medicine (Purnama et al., 2022).

The identification of alkaloids is crucial due to their significant pharmacological activities, including analgesic and antimicrobial effects (Harfi et al., 2018; Kontagora et al., 2021). Various phytochemical testing methods can yield different results based on the solvents used for extraction. For instance, studies have shown that the choice of solvent, such as methanol or ethyl acetate, can influence the extraction efficiency of alkaloids (Rahim, 2019; Zhang et al., 2023). The polarity of the solvent plays a vital role; more polar solvents tend to extract a broader range of alkaloids (Hung et al., 2021). Differences in extraction techniques, such as maceration versus subcritical water extraction, can also lead to variations in alkaloid yield and composition (Ghasemzadeh et al., 2018). For example, subcritical water extraction has been shown to enhance alkaloid yield due to its ability to disrupt hydrogen bonds at elevated temperatures. Furthermore, discrepancies between studies may arise from variations in plant material, extraction protocols, or analytical methods employed. Such factors underscore the importance of standardizing extraction methods to ensure comparability of results across studies.

Phenolic compounds, indicated by the brownish-black color in the phenolic test, are another critical component of the phytochemical profile of sappanwood. These compounds are widely recognized for their antioxidant properties, which can protect cells from oxidative stress and reduce the risk of chronic diseases (Ardhany et al., 2021). The presence of phenolics in sappanwood supports its traditional use in herbal medicine, where it is often used for its health-promoting effects (Rezano et al., 2019). Moreover, the antioxidant activity of phenolic compounds has been linked to various health benefits, including anti-cancer and anti-inflammatory effects (Liu et al., 2011). Bioactive compounds that have physiological effects as antioxidants, such asphenol and flavonoid (Lavlinesia et al., 2023). Antioxidants are compounds that can figh the influence of free radical molecules due to chemical reactions and metabolic events in the body (Nadjamuddin et al., 2023).

The study identifies several secondary metabolites present in the ethanol extract of sappanwood, with triterpenoids, flavonoids, and phenolics emerging as the most dominant compounds. This is similar with the study that identified several secondary metabolites such as triterpenoids (Noer et al., 2023), flavonoids (Utomo et al., 2018), and phenolics (Rahmawati et al., 2025). Flavonoids, identified by the orange color in the flavonoid test, further enhance the therapeutic potential of sappanwood. Flavonoids are known for their diverse biological activities, including anti-inflammatory, antiviral, and anticancer properties (Phoem & Voravuthikunchai, 2012). The presence of flavonoids in sappanwood suggests that it may be beneficial in preventing or managing various health conditions, particularly those related to inflammation and oxidative damage (Sari & Rian, 2023). Studies have shown that flavonoids can modulate immune responses and exhibit protective effects against cardiovascular diseases (Septiani et al., 2022).

On the other hand, the negative results for saponins and tannins indicate that these compounds are not present in significant amounts in the ethanol extract of sappanwood. Saponins are often associated with various health benefits, including cholesterol-lowering effects and immune system enhancement (Rahimah et al., 2019). However, their absence does not detract from the overall potential of sappanwood, as the other identified compounds can still provide substantial health benefits. Similarly, the lack of tannins, which are known for their astringent properties and potential health benefits, suggests that the extract may have a different profile of effects compared to other plants rich in tannins (Maigoda et al., 2022).

In summary, the phytochemical screening of the ethanol extract of sappanwood revealed a rich composition of bioactive compounds, including alkaloids, triterpenoids, phenolics, and flavonoids, while confirming the absence of steroids, saponins, and tannins. These findings underscore the potential of sappanwood as a valuable source of natural compounds for health and pharmaceutical applications. The diverse array of identified compounds suggests that sappanwood may be utilized in various therapeutic contexts, particularly in the development of natural remedies aimed at combating oxidative stress, inflammation, and microbial infections. Future research should focus on elucidating the specific mechanisms of action of these compounds and exploring their potential synergistic effects in therapeutic applications.

The examination of specific parameters of sappan wood (*Caesalpinia sappan*) reveals a multifaceted profile that underscores its significance in both the wood industry and traditional medicine. The cylindrical shape of the wood, which is a common characteristic among many types of wood, facilitates its use in various industrial applications, particularly in the manufacture of furniture and decorative items. The standard dimensions of sappan wood can vary, but it is often processed into sizes that are conducive to ease of handling and processing in industrial settings (Vij et al., 2023).

The color of sappan wood, ranging from reddish brown to dark red, is not only aesthetically appealing but also plays a crucial role in determining its market value. This coloration is attributed to the presence of bioactive compounds such as brazilin, which is a water-soluble compound responsible for the red dye extracted from the wood (Vij et al., 2023). The vibrant hues of sappan wood make it a desirable choice for artisans and manufacturers who prioritize visual appeal in their products. Additionally, the color can be indicative of the wood's age and quality, further influencing its desirability in the market (Purba et al., 2024).

The rough and porous texture of sappan wood is another significant parameter that affects its processing and usability. This texture can influence the wood's ability to absorb finishes and treatments, which is critical in both industrial applications and in the preparation of medicinal extracts. The porous nature of the wood allows for better penetration of solvents during extraction processes, which is essential for maximizing the yield of bioactive compounds (Rohmah, 2022). Moreover, the rough texture may also impact the wood's mechanical properties, potentially affecting its strength and durability in construction applications (Budi et al., 2020).

The aroma and flavor profile of sappan wood, characterized as sweet with a slight bitterness, suggests potential applications in culinary and pharmaceutical fields. The unique sensory attributes of the wood may enhance its appeal in traditional medicine, where it is often used for its therapeutic properties (Rohmah, 2022). The presence of various phytochemicals, including flavonoids and polyphenols, contributes to its medicinal efficacy, making it a valuable resource in herbal formulations (Rohmah, 2022). The sweet and slightly bitter taste can also be leveraged in culinary applications, where it may be used to impart flavor to dishes or beverages (Juwitaningsih et al., 2023).

The structural composition of sappan wood, consisting of xylem and phloem cells, reflects its biological function in the transport of water and nutrients. This structural integrity is vital for the wood's growth and longevity, as it facilitates the movement of essential resources throughout the plant (Sakir & Kim, 2019). The arrangement of these cells also influences the wood's mechanical properties, including its strength and resistance to decay, which are critical factors for its use in construction and furniture making. Furthermore, the rough and irregularly oriented wood fibers can affect the overall durability of the wood, making it essential to consider these characteristics when selecting sappan wood for specific applications (Puttipan et al., 2017).

In summary, the examination of sappan wood reveals a complex interplay of physical and chemical properties that enhance its utility in various domains. The cylindrical shape, attractive coloration, and unique texture make it a valuable material in the wood industry, while its aromatic and flavor characteristics open avenues for culinary and medicinal applications. The structural integrity provided by its xylem and phloem cells further underscores its importance as a sustainable resource in both traditional and modern contexts.

The examination of sappanwood, as detailed in Table 3, reveals several significant physical and chemical parameters that are crucial for its characterization and potential applications. The moisture content of 11% indicates that sappanwood possesses relatively low humidity, which is essential for the stability and durability of wood materials. Low moisture content is often associated with reduced susceptibility to decay and insect infestation, thus enhancing the longevity of the material in various applications, including construction and crafting (Wodaje, 2015). Furthermore, the extract content of 20% suggests a substantial potential for the extraction of bioactive compounds, making sappanwood a candidate for use in the pharmaceutical and cosmetic industries, where such compounds are highly valued for their therapeutic properties (Turkson et al., 2020).

The pH value of 6 indicates a neutral nature, which is significant as it may influence the wood's interactions with other materials, particularly in composite applications where pH compatibility can affect adhesion and overall performance (Sun et al., 2023). The density of 0.7 g/cm³ and specific gravity of 0.9 g/cm³ classify sappanwood as relatively light, which is advantageous for applications where weight is a critical factor, such as in furniture making or portable crafts (Husien et al., 2023). Light woods are often preferred in these contexts due to ease of handling and transportation, which can lead to cost savings in manufacturing and logistics (Hoseinie et al., 2012).

The hardness of sappanwood, rated at 4 on the Mohs scale, indicates that it is relatively hard compared to many other wood types, providing resistance to scratches and wear (Janetzki et al., 2021). This characteristic is particularly beneficial in applications where the wood is subject to abrasion or impact, such as flooring or decorative items. The resilience of sappanwood against weather changes further underscores its durability, making it suitable for outdoor applications where exposure to the elements is a concern (Sunamura, 2018). Additionally, the good absorption capacity of water and ethanol solvents suggests that sappanwood can effectively facilitate the extraction of bioactive compounds, which is a critical aspect in the development of natural products for health and beauty applications (Zhang et al., 2022).

The analysis of heavy metal contaminants reveals that sappanwood is free from lead, arsenic, mercury, cadmium, and chromium, indicating its safety for use in various applications, particularly in the food and cosmetic industries where heavy metal contamination poses significant health risks (Inyagwa et al., 2022). The absence of these harmful substances not only enhances the material's appeal but also aligns with increasing consumer demand for safe and sustainable products (Ogundele et al., 2020). This aspect of sappanwood's profile is particularly relevant in today's market, where regulatory standards for heavy metal content are becoming increasingly stringent (Wodaje, 2015).

In summary, the non-parametric examination of sappanwood provides a comprehensive overview of its physical and chemical properties, highlighting its potential applications across various industries. The combination of low moisture content, significant extract potential, neutral pH, lightweight characteristics, moderate hardness, weather resilience, and absence of heavy metal contaminants positions sappanwood as a valuable material for both traditional and innovative uses. The findings suggest that further research into the extraction processes and applications of sappanwood could yield promising results, particularly in the realms of natural health products and sustainable materials.

Conclusion

The study identifies several secondary metabolites present in the ethanol extract of sappanwood, with triterpenoids, flavonoids, and phenolics emerging as the most dominant compounds. Among these, flavonoids are particularly noted for their high antioxidant activity, which is a significant contributor to the extract's overall efficacy, reaching an impressive 80%. Triterpenoids also exhibit notable biological activity, including anti-inflammatory and antimicrobial properties, while phenolics are recognized for their role in scavenging free radicals and enhancing overall health benefits. The presence of these metabolites underscores the potential of sappanwood as a valuable natural resource for health and industrial applications, warranting further investigation into their specific mechanisms of action and therapeutic uses. Specific parameters of sappanwood show typical physical characteristics, such as cylindrical shape, diameter size between 10-30 cm, length 1-3 m, and reddish brown to dark red color. The rough and porous texture of the wood, as well as the sweet and slightly bitter aroma, adds to the complexity of its organoleptic properties. In addition, non-specific parameters show a water content of 11%, extract content of 20%, pH 6, and density of 0.7 g/cm³, with good resistance to weather changes. Contaminant analysis shows that sappanwood is free from hazardous heavy metals such as lead, arsenic, mercury, cadmium, and chromium. These findings confirm the potential of sappanwood as a source of safe and beneficial natural materials in health and industrial applications. Sappanwood (*Caesalpinia sappan*) has garnered attention for its multifaceted applications in both health and industry due to its rich composition of secondary metabolites. In health applications, the ethanol extract of sappanwood, rich in flavonoids and phenolics, has demonstrated anti-inflammatory properties, making it a candidate for formulations targeting inflammatory conditions. Additionally, its immunomodulatory effects may enhance immune responses, suggesting potential use in dietary supplements aimed at bolstering immunity. In industrial applications, sappanwood serves as a natural dye, particularly for textiles, owing to its vibrant reddish-brown color derived from its bioactive compounds. Furthermore, its antioxidant properties position it as a valuable raw material in cosmetic formulations, where it can be utilized to enhance skin health and protect against oxidative stress. These applications underscore the versatility of sappanwood as a sustainable resource in both health and industrial sectors.

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Conceptualization, validation, formal analysis, resources, data curation, writing—original draft preparation, writing—review and editing, visualization, A., R.P., N., A.A., T.A., D.R.D.; methodology, software, supervision, project administration, funding acquisition, A., R.P., N.; investigation, A.A., T.A., D.R.D.

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Conflicts of Interest
The authors declare no conflict of interest.

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