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Bioactive Compounds and Health Benefits of Wasabi (*Eutrema Japonicum*): Antibacterial, Cytotoxic, and Anti-inflammatory Properties of Root and Leaf Extracts

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Abstract

Background of study: *Eutrema japonicum*, commonly known as wasabi, is a perennial plant native to Japan and a member of the Brassicaceae family. Traditionally used as a pungent condiment in Japanese cuisine, wasabi has garnered scientific interest for its wide array of bioactive compounds with potential therapeutic properties. While its rhizome (commonly referred to as the "root") is the primary component used in culinary applications, recent studies suggest that both the root and leaf extracts may serve as sources of valuable phytochemicals with health-promoting effects.
Aims and scope of paper: The aim of this study is to investigate and compare the antibacterial, cytotoxic, and anti-inflammatory properties of root and leaf extracts of *Wasabi (Eutrema japonicum)*, with a focus on identifying key bioactive compounds responsible for these biological activities. The study seeks to evaluate the therapeutic potential of both plant parts to support their application in functional foods, nutraceuticals, or natural health products.
Methods: This review aims to find scientific evidence in order to support claims related to *Eutrema japonicum*. As a consequence, it is very important to gather studies related to the functional properties of butterfly pea from scientific research.
Result: The study revealed that both root and leaf extracts of *Eutrema japonicum* (wasabi) are rich in key bioactive compounds, including isothiocyanates, phenolics, and flavonoids, which underlie their biological effects. The root extract showed notably stronger antibacterial effects, along with greater cytotoxicity toward human cancer cell lines such as HeLa, MCF-7, and A549. Although the root was more biologically active overall, the leaf extract also demonstrated promising therapeutic potential. These results highlight the value of both plant parts as potential sources of functional ingredients for the development of nutraceutical and pharmaceutical applications.
Conclusion: This study highlights the significant health-promoting properties of *Eutrema japonicum* (wasabi) through the evaluation of its root and leaf extracts. Both plant parts were found to be rich in bioactive compounds, particularly isothiocyanates, phenolics, and flavonoids, which are responsible for their observed antibacterial, cytotoxic, and anti-inflammatory activities.

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INTRODUCTION

Wasabi (*Eutrema Japonicum*, **Fig 1.**), a cruciferous plant native to Japan, widely known for its pungent flavor used as culinary spice. Other than its culinary application, Wasabi has also gained attention for its potential health-promoting properties. In particular, the roots and leaves of Wasabi contain a variety of bioactive compounds that contribute to the plant's therapeutic effects. The roots are the primary storage organ for nutrients, and the leaves are rich in secondary metabolites, both are important to Wasabi's survival and medicinal efficacy. These bioactive compounds, including glucosinolates, flavone glycosides, phenylpropanoid glycosides, and hydroxycinnamic acids, are of specific interest due to their diverse pharmacological activities, such as antioxidative, antibacterial, anti-inflammatory, and cytotoxic effects (Di et al., 2022).

Figure 1. Image of root and leaf of wasabi (Bae, Ahn, Kim, Park, & Kim, 2025)

Recent scientific investigations regarding the phytochemical composition of Wasabi have revealed that there are several bioactive molecules with significant potential for health applications. Glucosinolates, a group of compounds containing sulfur, are found in high concentrations in *Eutrema Japonicum*, and it has been associated with anticancer, antibacterial, and antioxidative properties. Other phytochemicals, such as flavone glycosides and phenylpropanoids also contributes to the plant's broad spectrum of bioactivities. These compounds have been associated with a lot of therapeutic effects, including the modulation of oxidative stress, suppression of inflammation, and inhibition of microbial growth. The synergistic effects of these compounds suggested that Wasabi extract offers a promising alternative or complementary treatment for a variety of health conditions, from chronic inflammation and infection to cancer (Park et al., 2022).

Despite the growing interest in the medicinal properties of Wasabi, the majority of research has mostly focused on the bioactive potential of its root extract. However, significantly less attention has been given to the potential health benefits of the leaves, which contain a diverse array of bioactive compounds, although it is in a different proportions and possibly with distinct biological effects. As a result, there is a gap in the literature regarding the comparative bioactivity of Wasabi root and leaf extracts, which could provide valuable insights into the full medicinal potential of this plant (Kim, Truong, & Jeong, 2022).

While numerous studies have investigated the antioxidant, antibacterial, and anticancer properties of Wasabi root extracts, a more comprehensive evaluation that compares these effects in both the roots and leaves of Wasabi remains relatively rare. It is crucial to recognize that the bioactive profiles of these extracts may be different depending on several factors, including the growth stage of the plant, the specific part of the plant used, and the method of extraction. For instance, roots may give a higher number of concentrations of glucosinolates, compound that have been extensively studied for their anticancer and antimicrobial properties, while the leaves may contain other phytochemicals such as flavonoids and phenolic compounds. These differences highlight the importance of investigating both plant parts to obtain a fuller understanding of their complementary therapeutic potential (Mi ekus et al., 2020).

The extraction method plays a significant role in determining the bioactive compound profile of plant materials. Ethanol-based extraction is particularly effective for isolating both hydrophilic and lipophilic compounds, such as flavonoids, glucosinolates, phenolic acids, and other secondary metabolites, which enhance the therapeutic potential of the extracts. Given its proven efficacy with Wasabi, this study aims to investigate the antibacterial, anti-inflammatory, and cytotoxic properties of ethanol-extracted Wasabi root and leaf extracts (Di et al., 2022).

The current study aims to evaluate and compare the bioactive compounds and health benefits of extracts derived from both the roots and leaves of *Eutrema Japonicum*. Using advanced chromatographic and mass spectrometric techniques, including LC-DAD-IT-MS and LC-Q-TOF-MS, a detailed chemical profile of the extracts will be generated to identify key bioactive compounds. The biological activities will be tested through in vitro assays, including antibacterial tests against pathogenic and probiotic bacterial strains, anti-inflammatory assays, and cytotoxicity screening on human colon adenocarcinoma cells. Preliminary findings suggest that extracts from the roots of biennial Wasabi plants, particularly those extracted with 60% ethanol, exhibit potent antibacterial, anti-inflammatory, and cytotoxic properties. This study will build on these results to explore the molecular mechanisms behind these bioactivities and assess the potential of Wasabi extracts as natural therapeutic agents. Given the growing interest in natural products for treating inflammatory diseases, infections, and cancer, the outcomes of this research could offer new insights into the medicinal potential of *Eutrema japonicum* (Phan et al., 2021).

By investigating both root and leaf extracts, this study will expand the understanding of *Eutrema japonicum* as a valuable source of bioactive compounds with diverse therapeutic effects. The findings may also pave the way for future clinical research, particularly in the fields of antimicrobial resistance, cancer treatment, and inflammation regulation. Furthermore, this research may shed light on the synergistic effects of the plant's bioactive components, offering a comprehensive view of Wasabi's pharmacological potential in modern medicine.

The therapeutic properties of Wasabi are mainly filled with bioactive compounds. The roots, which serve as the plant's nutrient storage organ, are particularly high in glucosinolates. Which this compound contained sulfur that are well known for their anticancer, antibacterial, and antioxidative properties. While the leaves contain high levels of flavonoids and phenolic compounds, which contribute to their antioxidant and anti-inflammatory activities. It is also found in both parts that there is hydroxycinnamic acids that have potent antioxidant effects, helping to protect cells from oxidative damages (Dufour, Stahl, & Baysse, 2015).

2.1 Isothiocyanates

In the process of hydrolysis, glucosinolates break down into bioactive isothiocyanates that are typically catalyzed or physically separate from myrosin cells containing the enzyme myrosinase. These isothiocyanates such as allyl isothiocyanate (AITC) are particularly significant for their anticancer and antimicrobial properties (Tarar, Peng, Cheema, & Peng, 2022). It has been shown in studies that 6-methylsulfinylhexyl isothiocyanate (6-MSITC) which is an allyl of isothiocyanates that is a potent analogue of sulforaphane (SFN) can inhibit cancer cell proliferation, induces apoptosis (programmed cell death), autophagy, and sensitizes cancer cells to therapies that have been shown to inhibit cancer cell proliferation and microbial growth (Wiczk, Hofman, Konopa, & Herman-Antosiewicz, 2012). These compounds could also work effectively in supressing the growth of various bacteria by disrupting their cellular membranes and inhibiting the key microbial enzymes.

2.2 Flavonoids

Flavonoids like quercetin and kaempferol protect cells from oxidative damage by acting as antioxidants. Free radicals and reactive oxygen species (ROS) can harm DNA, proteins, and lipids, that could also leads to diseases like cancer and heart disease. Flavonoids neutralize these harmful molecules by donating electrons, stabilizing them, and preventing further damage. They also chelate metal ions involved with ROS production and inhibit enzymes that generate ROS (Speisky, Arias-Santé, & Fuentes, 2023). By protecting cellular structures, flavonoids help prevent oxidative stress-related conditions and support overall health. In Wasabi, these flavonoids contribute to its therapeutic properties offering protection against oxidative damage and related diseases.

2.3 Phenolic Compounds

Phenolic compounds like catechins and lignans also enhance the oxidative effects of Wasabi by neutralizing free radicals (Bolat et al., 2024). In addition, they help modulate inflammation by inhibiting pro-inflammatory enzymes and cytokines which are involved in inflammatory response. This reducing oxidative damage and inflammation makes phenolic compounds valuable for preventing chronic disease related to inflammation such as arthritis and cardiovascular conditions (Ambriz-Pérez, Leyva-López, Gutierrez-Grijalva, & Heredia, 2016).

2.2 Hydroxycinnamic Acids

Both the roots and leaves of Wasabi contain hydroxycinnamic acids which is a group of phenolic compounds that have potent antioxidant properties. Hydroxycinnamic acids like caffeic acids and ferulic acid can help to protect cells from oxidative stress which is implicated in the development of a range of chronic disease including cancer, cardiovascular diseases, and neurodegenerative disorders (Sova & Saso, 2020). By reducing oxidative damage, these compounds contribute to the overall health promising effects of Wasabi.

METHOD

Research Design

The research design employed for this study is a comprehensive literature review. This approach was chosen to systematically gather, evaluate, and synthesize existing scientific evidence pertaining to the bioactive compounds and health benefits of *Eutrema japonicum* (wasabi).

Instrument

In the context of this literature review, the primary "instruments" for data collection were existing scientific databases and search engines. The authors gathered research related to the functional properties of wasabi from various scientific studies through this approach. While not directly used by the review authors, the article also highlights that advanced chromatographic techniques such as liquid chromatography combined with diode array detection-ion trap mass spectrophotometry (LC-DAD-IT-MS) and liquid chromatography quadrupole time-of-flight mass spectrometry (LC-Q-TOF-MS) are valuable methods that can be employed by researchers to evaluate the antibacterial, cytotoxic, and anti-inflammatory properties of wasabi root and leaf extracts. Similarly, studies utilizing *in vitro* assays, including antibacterial tests against pathogenic and probiotic bacterial strains, anti-inflammatory assays, and cytotoxicity screening on human colon adenocarcinoma cells, were considered integral to the body of literature reviewed. These methods in the primary research sources allowed for the isolation and identification of bioactive compounds and the testing of biological activities.

Procedures and if relevant, the time frame

The procedure for this literature review involved several key steps. First, the research scope was defined, focusing on investigating and comparing the antibacterial, cytotoxic, and anti-inflammatory properties of root and leaf extracts of *Wasabi (Eutrema japonicum)*, with the aim of identifying key bioactive compounds. This was followed by a comprehensive literature search and collection, gathering scientific studies related to the functional properties of wasabi to find evidence supporting claims about *Eutrema japonicum*. Subsequently, a process of synthesis and comparison was undertaken, involving a review of the collected studies to compare the properties of the root and leaf extracts and identify the bioactive compounds responsible for the observed biological activities. Finally, the findings were discussed, integrating results from various studies to highlight the therapeutic potential of both plant parts. The specific time frame for conducting the literature search and review is not explicitly stated within the provided text, beyond the acceptance date of the article, which is June 03, 2025.

Analysis plan

As a literature review, this study did not involve primary data analysis or statistical tests. Instead, the analysis plan centered on the qualitative synthesis and comparative analysis of findings from existing scientific literature. This involved the identification of bioactive compounds, compiling information on compounds detected in wasabi extracts such as isothiocyanates, phenolics, flavonoids, glucosinolates, flavone glycosides, phenylpropanoid glycosides, and hydroxycinnamic acids. The study revealed that both root and leaf extracts of *Eutrema japonicum* are rich in key bioactive compounds, including isothiocyanates, phenolics, and flavonoids, which underline their biological effects. The analysis also included a systematic comparison of biological activities, noting the reported antibacterial, cytotoxic, and anti-inflammatory effects of root and leaf extracts. This involved highlighting differences in potency and efficacy between the two plant parts; for example, the root extract showed notably stronger antibacterial effects and greater cytotoxicity toward human cancer cell lines such as HeLa, MCF-7, and A549, while the leaf extract also demonstrated promising therapeutic potential. Furthermore, the analysis focused on the correlation of compounds with effects, linking specific bioactive compounds to their observed health benefits. For instance, isothiocyanates are significant for their anticancer and antimicrobial properties, flavonoids like quercetin and kaempferol protect cells from oxidative damage by acting as antioxidants, and phenolic compounds like catechins and lignans enhance antioxidative effects and help modulate inflammation. Hydroxycinnamic acids contribute to overall health by protecting cells from oxidative stress. Finally, the analysis included the identification of research gaps, highlighting areas where further research is needed, such as the comparative bioactivity of wasabi root and leaf extracts, given that significantly less attention has been given to the potential health benefits of the leaves.

Scope and/or limitations of the methodology you used

The methodology employed in this study, being a literature review, has inherent limitations. Firstly, the findings are entirely dependent on the quality and availability of prior research, as the review itself cannot generate new experimental data. Secondly, there is a potential for publication bias, meaning the review can only synthesize what has been published, which might lean towards studies with positive results. Thirdly, variability across primary studies presents a challenge; differences in experimental methodologies, plant growth conditions, extraction methods, and analytical techniques (such as LC-DAD-IT-MS and LC-Q-TOF-MS) among the reviewed studies may introduce heterogeneity and complicate direct comparisons. For instance, the extraction method significantly influences the bioactive compound profile. Additionally, the review acknowledges that biological activities in the primary studies will be tested through *in vitro* assays, which may not always directly translate to *in vivo* efficacy in humans. Finally, while comprehensive in its stated aims of

investigating antibacterial, cytotoxic, and anti-inflammatory properties, the review's scope is limited to these specific areas and may not cover all potential health benefits of wasabi.

RESULTS AND DISCUSSION

Results

Advanced chromatographic techniques, such as liquid chromatography coupled with diode array detection-ion trap mass spectrophotometry (LC-DAD-IT-MS) and liquid chromatography quadrupole time-of-flight mass spectrometry (LC-Q-TOF-MS), have been instrumental in evaluating the properties of *Eutrema japonicum* extracts. These methods allow researchers to isolate and identify bioactive compounds from both root and leaf extracts with high precision (Dos Santos Szewczyk et al., 2023). It has been identified a wide array of bioactive components in Wasabi extracts with 42 distinct compounds detected across both root and leaf extracts. These include glucosinolates, flavonoid glycosides, phenylpropanoids, and hydroxycinnamic acids. The identification and profiling of these compounds have allowed for a comprehensive comparison of the bioactivities of the root and leaf extracts.

Phenolic compounds such as catechins and lignans further contribute to Wasabi's antioxidative effects by neutralizing free radicals (Bolat et al., 2024). Beyond their antioxidant properties, these compounds also help regulate inflammation by inhibiting the activity of pro-inflammatory enzymes and cytokines which play a key role in the body's inflammatory response. This combination of antioxidative and anti-inflammatory actions make phenolic compounds important for preventing or managing chronic conditions linked to inflammation such as arthritis, cardiovascular disease, and other inflammatory disorders (Direito, Rocha, Sepodes, & Eduardo-Figueira, 2021).

Wasabi root and leaf extracts both exhibit significant antibacterial activity attributed to the presence of bioactive compounds such as glucosinolates in the roots. These glucosinolates break down into isothiocyanates such as ally isothiocyanate, which disrupt bacterial cell membranes and interfere with essential cellular processes. Root extracts with higher concentration of glucosinolates show stronger antibacterial effects and its effective against a broad range of bacteria including both Gram-positive and Gram-negative strains (Tarar et al., 2022). Although the leaf extracts demonstrate less potent antibacterial effects, they still exhibit notable antimicrobial activity. This suggest that Wasabi leaves may serve as a useful addition to natural antimicrobial formulations. Furthermore, combining leaf extracts with other natural antimicrobial agents could enhance their efficacy making Wasabi a potential valuable component in multi-ingredient treatments aimed at removing bacterial infections (Lu et al., 2016).

Wasabi root extracts exhibit strong cytotoxic effects particularly against human colon adenocarcinoma cells (HT-29). The key bioactive compounds responsible for this activity are isothiocyanates such as allyl isothiocyanate. These compounds induce apoptosis in cancer cells, inhibit cell proliferation, and prevent metastasis, making Wasabi root extracts a promising source of natural anticancer agents. Additionally, isothiocyanates have been shown to enhance the effectiveness of other chemotherapeutic agents potentially improving cancer treatment outcomes (Peña et al., 2022). While the leaf extracts show less pronounced cytotoxicity they do still offer other beneficial effects. The flavonoids and phenolic compounds in the leaves may help reducing oxidative stress and protect healthy cells from damage during cancer treatment. This suggests that Wasabi leaf extracts could serve as a complementary therapy providing additional support for cancer patients by modulating immune responses and alleviating inflammation associated with cancer treatment (Dos Santos Szewczyk et al., 2023).

Roots extract of Wasabi is more potent to exhibit anti-inflammatory properties rather than leaf extracts. The bioactive compounds responsible for these effects including flavonoids, phenolic acids, and glucosinolates work by inhibiting pro-inflammatory cytokines and modulating immune responses. The root extracts, which contain higher concentrations of glucosinolates are particularly effective at inhibiting inflammation related pathways making them suitable for treating chronic inflammatory conditions such as arthritis and inflammatory bowel disease (IBD). While the anti-inflammatory effects of leaf extracts are less potent than the roots they still provide valuable benefits. The flavonoids and phenolic acids in the leaves help reduce inflammation and could be useful in preventing or managing conditions linked to chronic inflammation. Combining Wasabi leaf extracts with other anti-inflammatory treatments could enhance their therapeutic potential making them a valuable addition to inflammation-regulation therapies (Saleh, Yousef, & Abdelnaser, 2021).

Discussion

The comprehensive analysis of *Eutrema japonicum* through advanced chromatographic techniques confirms the presence of a diverse range of bioactive compounds in both its root and leaf extracts. The identification of 42 distinct compounds, including glucosinolates, flavonoids, phenylpropanoids, and hydroxycinnamic acids, underscores the plant's rich phytochemical profile. This robust identification provides a strong foundation for understanding the observed biological activities.

The superior antibacterial efficacy of Wasabi root extracts, particularly due to higher concentrations of glucosinolates and their breakdown into potent isothiocyanates like allyl isothiocyanate, highlights its potential as a natural antimicrobial agent. The mechanism of action, involving disruption of bacterial cell membranes, aligns with established knowledge of isothiocyanate properties. While leaf extracts demonstrate lesser potency, their continued antimicrobial activity suggests their value, especially when combined with other natural agents. This points to a broader utility beyond the more concentrated root.

The significant cytotoxic effects of Wasabi root extracts, especially against human colon adenocarcinoma cells, further emphasize its therapeutic promise. The role of isothiocyanates in inducing apoptosis and inhibiting proliferation and metastasis positions Wasabi root as a compelling natural anticancer candidate. The potential for isothiocyanates to enhance the effectiveness of conventional chemotherapeutic agents is a particularly noteworthy finding, suggesting a synergistic role in cancer treatment. The observation that leaf extracts, despite lower cytotoxicity, may offer supportive benefits through oxidative stress reduction and immune modulation, opens avenues for their complementary use in cancer therapy.

The anti-inflammatory prowess of Wasabi, particularly its root extracts, is a crucial finding. The action of flavonoids, phenolic acids, and glucosinolates in inhibiting pro-inflammatory cytokines and modulating immune responses provides a clear mechanistic understanding of its anti-inflammatory effects. The higher concentration of glucosinolates in root extracts makes them especially effective against chronic inflammatory conditions. Although the anti-inflammatory effects of leaf extracts are less pronounced, their contribution to reducing inflammation, potentially through flavonoids and phenolic acids, still offers valuable health benefits. This suggests a graded therapeutic potential across different parts of the plant, with the root offering more potent anti-inflammatory effects and the leaves providing a milder, yet beneficial, contribution.

Overall, the findings consistently demonstrate that while Wasabi root exhibits more pronounced antibacterial, cytotoxic, and anti-inflammatory properties due to higher concentrations of key bioactive compounds, the leaf extracts also possess considerable therapeutic potential. This nuanced understanding of the distinct, yet complementary, bioactivities of different parts of theabi plant underscores its holistic value.

Implications

The findings of this literature review have several significant implications. Firstly, the confirmation of diverse bioactive compounds and their associated health benefits in *Eutrema japonicum* reinforces its value as a functional food and a source of natural therapeutic agents. This could encourage further development of Wasabi-based products for health and wellness. Secondly, the differentiated strengths of root and leaf extracts—with roots demonstrating stronger antibacterial, cytotoxic, and anti-inflammatory effects, and leaves offering milder yet beneficial properties—suggests optimized utilization of the entire plant. This could lead to specialized applications for different parts of Wasabi, minimizing waste and maximizing its economic and health potential. Thirdly, the potential of Wasabi compounds, particularly isothiocyanates, to act as natural anticancer agents and enhance chemotherapy efficacy has profound implications for pharmaceutical research and the development of novel cancer treatments. Finally, the observed anti-inflammatory properties of both root and leaf extracts underscore Wasabi's potential in managing chronic inflammatory conditions, contributing to a natural approach to health maintenance and disease prevention.

Research Contribution

This literature review makes several key research contributions by providing a comprehensive overview of *Eutrema japonicum* bioactivities, synthesizing existing knowledge on the antibacterial, cytotoxic, and anti-inflammatory properties of both Wasabi root and leaf extracts to offer a consolidated resource. It also contributes to the identification and profiling of bioactive compounds, highlighting the wide array of 42 distinct bioactive compounds present in Wasabi and directly linking them to their observed health benefits, thereby enriching the understanding of Wasabi's phytochemical profile. Furthermore, the review offers a comparative analysis of root versus leaf efficacy by systematically comparing the potency and efficacy of root and leaf extracts across different biological activities, providing a nuanced understanding of the distinct therapeutic potentials of each plant part and addressing a gap in the literature that often focuses solely on the root. It also

excels in highlighting therapeutic mechanisms, elucidating the mechanisms by which various compounds, such as isothiocyanates, flavonoids, and phenolic acids, exert their antibacterial, cytotoxic, and anti-inflammatory effects. Finally, a significant contribution is the identification of future research directions, as the review clearly outlines areas where further research is needed, particularly regarding the comparative bioactivity of Wasabi root and leaf extracts and *in vivo* studies, thereby guiding future scientific inquiry.

Limitations

This research review, while providing valuable insights, comes with several inherent limitations that warrant careful consideration. Primarily, its findings are directly dependent on the quality and methodology of the existing primary research studies it synthesizes, as the review itself does not generate new experimental data. There's also a potential for publication bias, meaning the review might inadvertently present an incomplete picture by predominantly including studies with positive or significant results. Furthermore, heterogeneity among the primary studies – stemming from diverse experimental methodologies, plant growth conditions, extraction techniques, and analytical methods – can introduce variability and make direct comparisons challenging. For instance, the chosen extraction method can significantly influence the resulting bioactive compound profile. Crucially, the review acknowledges a limited amount of *in vivo* evidence, with many reported biological activities based solely on *in vitro* assays; therefore, the translation of these effects to human efficacy requires further investigation. Finally, the review has a specific scope, focusing exclusively on antibacterial, cytotoxic, and anti-inflammatory properties, meaning it doesn't encompass all potential health benefits or applications of *Eutrema japonicum*.

Suggestions

Building upon the insights and recognizing the limitations of current research, future investigations into *Eutrema japonicum* (Wasabi) should prioritize several key areas. Crucially, comprehensive *in vivo* studies are needed to validate the antibacterial, cytotoxic, and anti-inflammatory properties observed in *in vitro* settings for both root and leaf extracts, ultimately aiming to establish their therapeutic efficacy in living systems. To refine our understanding of its distinct components, comparative studies directly assessing the bioactivity of Wasabi root and leaf extracts under standardized conditions will be essential for quantifying their relative potencies and identifying optimal applications for each part of the plant. Further efforts should focus on isolating and characterizing individual bioactive compounds from both extracts to precisely determine their mechanisms of action and explore potential synergistic or antagonistic effects when combined. Should promising *in vivo* results emerge, the next logical step would be human clinical trials to rigorously assess the safety, efficacy, and optimal dosages of Wasabi extracts for various health conditions, particularly chronic inflammatory diseases and as a complementary cancer therapy. Beyond the current scope, research should also expand to investigate other potential health benefits of Wasabi, such as its effects on cardiovascular health, neurological function, or metabolic disorders. To ensure consistency and reproducibility across studies and products, standardized and optimized extraction methods for both root and leaf extracts are vital. Finally, given the promising, albeit less potent, health benefits of Wasabi leaf extracts and their potential for sustainable utilization, exploring their integration into functional food products presents an exciting avenue for development.

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CONCLUSION

Wasabi is a highly promising plant with a diverse phytochemical profile including glucosinolates, flavonoids, phenolic compounds, and hydroxycinnamic acids. Which contribute to its notable therapeutic properties such as anticancer, antibacterial, and anti-inflammatory effects. While roots extracts demonstrate stronger bioactivity, particularly in terms of antibacterial, cytotoxic, and anti-inflammatory actions, leaf extracts still offer significant antioxidant and anti-inflammatory benefits. Advanced chromatographic techniques have revealed distinct bioactive components in both parts, with the root extracts being especially

promising for cancer treatment and bacterial infection, while the leaf extracts provide additional therapeutic value. Overall, Wasabi shows great potential as a natural source of medicinal compounds and future research should further explore its diverse applications in healthcare and herbal medicine.

AUTHOR CONTRIBUTION STATEMENT

Rafaella Daniella: Conceptualization, Investigation, and Writing. **Wenbin Wang:** Conceptualization. **Bernhard Hellmann:** Visualization. **Steven Suryoprabowo**: Resources, writing-review & editing

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