



Nutrients in Matoa for Health and Exercise Performance: A Literature Study

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ABSTRACT

Matoa is an endemic plant in Indonesia that has great potential in the health sector. This study aims to examine the antioxidant potential of matoa through a narrative review approach. The literature search method was carried out on the Google Scholar and Research Gate databases with the keywords "matoa", "immunity", "health" and "exercise performance" limited to the last 10 years of publication. Of the 65 articles identified, 9 met the inclusion criteria for in-depth analysis. The results showed that matoa contained various bioactive compounds, especially phenolic groups that played a role in antioxidant, anti-inflammatory, cardiovascular and exercise performance. The use of matoa has been developed in various forms, ranging from health supplements to functional food products. This study also identifies the need for further research related to long-term safety evaluation and clinical validation to optimize the use of matoa in the health sector.

INTRODUCTION

Matoa (*Pometia pinnata*) is an endemic fruit plant in Indonesia that is widespread in Papua and its surroundings. Several health studies have shown the benefits and content of matoa fruit, including its leaves. The content of matoa bioactive compounds is diverse, especially phenolic compounds that play an important role in its biological activity (Ambarsari & Dayanti, 2023; Darwis, 2022; Djabar, 2021; Islami et al., 2024; Jayanto, 2024; Poli et al., 2022). These studies have identified several major groups of phenolic compounds in matoa, including flavonoids (such as quercetin, rutin, and kaempferol), phenolic acids (gallic acid, chlorogenic acid, and ferulic acid), and tannins (condensed and hydrolyzed tannins). Another study showed that the content of compounds in matoa had an effect on pasteurized milk, and proved that matoa leaves in certain doses strengthened the aroma and taste of milk which ultimately supported healthy dairy industry innovation (Malaka et al., 2023).

The phenolic content in matoa has been proven to have significant antioxidant activity. This compound works by donating hydrogen atoms to free radicals, so that it can neutralize the damaging effects of these free radicals on body cells. Matoa extract has a strong free radical antidote ability, which is measured by the DPPH (2,2-diphenyl-1-picrylhydrazil) method. This antioxidant activity plays an important role in preventing cell damage and protecting the body from oxidative stress that can trigger various degenerative diseases. (Rumainum & Tuhumena, 2018). So that matoa has attracted a lot of attention from researchers because of its diverse bioactive potential. Recent research shows that matoa contains various important compounds such as alkaloids, saponins, tannins, flavonoids, phenolics, terpenoids, and vitamins A, C, and E that play an important role in the immune system.

In addition to its antioxidant effects, the phenolic compound matoa also shows promising anti-inflammatory potential. A study conducted by Winarti et al. (2018) revealed that matoa extract can inhibit the production of inflammatory mediators such as prostaglandins and pro-inflammatory cytokines. This anti-inflammatory effect contributes to reducing swelling and preventing chronic inflammation that is often a trigger for various diseases.

In the context of cardiovascular health, the phenolic compound matoa has shown beneficial effects. Research by Hasanah et al. (2023) proves that regular consumption of matoa extract can help lower blood pressure and improve blood lipid profiles. The phenolic compounds in matoa work by protecting blood vessels from oxidation and increasing the elasticity of blood vessels, ultimately contributing to heart health and blood circulation.

In addition to modern medicine, the use of matoa has been traditionally carried out by the local community in various forms of treatment. Almost all parts of the matoa plant, from leaves, fruits, bark, to roots, have been used as traditional medicine (Haerudin & Farida, 2017). Phytochemical analysis of various parts of the matoa plant shows the presence of secondary metabolite compounds that have the potential to be natural antioxidants and other benefits.

Saponins, one of the important compounds contained in matoa which in addition to being beneficial for the body's immune system, this substance is also good for supporting exercise performance and maintaining muscle mass during overtraining. The potential of matoa as a plant that is very beneficial for human life has begun to be revealed, but a systematic study is still needed to analyze and integrate various existing research results to provide a comprehensive understanding of the potential of matoa and direct further development as a raw material for health and fitness products.

THEORETICAL REVIEW

Characteristics of Matoa Leaves

Pometia pinnata or what is known as matoa is a tropical plant from the Sapindaceae family which has a wide distribution in Indonesia, especially in Papua (Fatimah et al., 2021). Matoa leaves have long been used by local people as traditional medicine because they contain various bioactive compounds. Research shows that matoa leaves contain various secondary metabolite compounds such as saponins, terpenoids, flavonoids, alkaloids, tannins and coumarins (Sihotang et al., 2017; Basyuni et al., 2019). The process of extracting bioactive components from matoa leaves is generally carried out using the maceration method using various types of solvents such as ethanol, distilled water, n-hexane, and ethyl acetate (Kuspradini et al., 2016). The choice of solvent in the extraction process greatly influences the amount and type of bioactive compounds that can be isolated from matoa leaves.

Bioactivity of Matoa Leaf Extract

Matoa leaf extract has been proven to have a variety of biological activities that are beneficial for health. In terms of antibacterial activity, matoa leaf extract is able to inhibit the growth of various types of bacteria, both gram-positive and negative, with minimum inhibitory concentrations that vary depending on the type of extract and target bacteria (Pirdina et al., 2021; Rossalinda et al., 2021). The antioxidant activity of matoa leaf extract is also very promising, especially the ethanol extract which shows a lower IC₅₀ value than vitamin C (Islami et al., 2021). In vivo studies demonstrated the anti-hypertension potential of matoa leaf extract, with the best results found at a dose of 300 g/kg body weight in experimental mice (Elisa et al., 2020). Effect

The nephroprotective and hepatoprotective properties of matoa leaf extract have been proven through various studies, where administration of the extract can protect kidney and liver function from damage induced by various toxic compounds (Adrian et al., 2021; Sihotang et al., 2017).

Application in Food Products

In the field of food technology, matoa leaf extract has been applied in various products. The use of matoa leaf water extract as a supplement to pasteurized milk has been proven to improve product quality by inhibiting the growth of pathogenic bacteria such as *S. aureus* and *E. coli* (Triana et al., 2020). As a natural preservative for animal products, matoa leaf extract can extend

shelf life by inhibiting the growth of spoilage microorganisms. In preserving tilapia fish, the use of matoa leaf water extract is effective in reducing the Total Plate Count (TPC) value during storage and can maintain the organoleptic quality of the product for 12 hours at a concentration of 15% (Sulistijowati et al., 2020; Ladja et al., 2020).

METHODOLOGY

This study uses the narrative review approach as a secondary research method to assess the potential of matoa. Data collection was carried out through a literature search from two electronic sources, namely Google Scholar and Research Gate using the keywords "matoa", "immunity", "health" and "exercise performance". The inclusion criteria used are original and full-text research articles published within the last 10 years. The feasibility of an article is assessed based on the reputation and credibility of the journal publisher to ensure the quality and relevance of the data used. The collected data was then extracted and summarized systematically to obtain a comprehensive picture of the potential of matoa as a food ingredient and supplement to improve health status and exercise performance.

RESULTS AND DISCUSSION

Based on the results of filtering data sources from google scholars, research gates and other libraries such as eBooks, 65 articles were obtained that raised the theme of matoa. However, of the 65 themes, articles were issued that were in accordance with the objectives of this study, so that only 9 articles were obtained that represented the benefits of matoa for health and exercise performance.

No	Researcher/Year	Research Title	Research Results
1	Panggulu Utoro, Ahmad Ramadhani, Jatmiko Eko Witoyo, Muhammad Alwi/2022	A brief literature review of the bioactivity of matoa leaf extract (<i>Pometia pinnata</i>) from Indonesia and its application in food products	Matoa leaves are useful for lowering blood pressure, treating diabetes, gastric diseases (diarrhea and dysentery), gynecological diseases. Development of matoa leaves as a supplement or fortification in milk
2	Ira Oktavia, Fitria, Faizatul Arifah, Farida Noor/2023	Analysis of Carbohydrate and Ascorbic Acid Content in Matoa Fruit Juice (<i>Pometia pinnata</i>) by Qualitative Method	The carbohydrate content in matoa fruit adds a new flavor to the making of ice cream and syrup.
3	Ismi Dwi Widayanti, Maryati Maryati/2023	Antibacterial activity of bay leaf extract (<i>Syzygium polyanthum</i>) and matoa leaf (<i>Pometia pinnata</i> j.r.forst & g.forst) against <i>Shigella sonnei</i> and <i>bacillus cereus</i> bacteria	Matoa leaf extract contains compounds and antibacterial activity tannins that prevent one of the causes of diarrhea.

4	Thomas, Nur Ain, Pakaya Mahdalena Yayah/2022	Formulation and Physical Evaluation of Ethanol Extract Mouthwash Preparations of Matoa Fruit Peel (<i>Pometia Pinnata</i>)	Matoa fruit peel with phenolic compounds, saponins, tannins, flavonoids and terpenoids is antibacterial to prevent tooth decay and oral health care.
5	Rosdiani Azis/2024	Testing of Activity of Matoa Herbal Drink Powder (<i>Pometia Pinnata</i>) by Physical Method and Spectrophotometer Method	Qualitatively, Matoa plants are rich in functional food components. Matoa leaf extract is useful as an alternative to functional foods and drinks for freshness and immunity.
6	Siti Hajar, Widya Rahmah, Erlisa Maharani Putri, Sylvan Septian Ressaydy, Hasyrul Hamzah/2021	The Potential of Matoa Fruit Extract (<i>Pometia Pinnata</i>) as a Source of Antioxidants: A Literature Review	Matoa fruit peel and matoa fruit contain vitamin C which works as an antioxidant to increase the immune system, in addition to that, it is also known that matoa stem and peel extracts obtained an IC50 value of more than 70 ppm where at this value the antioxidant activity is relatively strong
7	T.K. Lim/2016	Edible Medicinal And Non-Medicinal Plants Volume 6, Fruits	There is a new triterpeonin of saponins called pomiten, which is the result of the isolation of the bark of the matoa.
8	Toshikazu Zusuki, Mayumi Nagata, Natsuko Kagawa, Shiori Takano, Nahrowi, Jun Nomura/2021	Anti-Obesity Effects of Matoa (<i>Pometia pinnata</i>) Fruit Peel Powder in High-Fat Diet-Fed Rats	The abundant hexagenin saponin in MPP (Matoa Peel Powder) is a potential anti-obesity substance. These results will contribute to the development of functional foods with anti-obesity effects by using matoa fruit peels.
9	Yiang Lin, Oian Wang, Xiaohui Wang, Liang-Nian Song/2016	Effects of <i>Tribulus terrestris</i> saponins on exercise performance in overtraining rats and the underlying mechanisms	The purpose of this study is to determine the effect of <i>Tribulus terrestris</i> L. (TT) saponins on exercise performance and other mechanisms. The results

			showed that TT saponins increased performance, body mass, and gastrocnemius mass in overtrained mice, which may be caused by changes in the androgen-AR axis and IGF-1R signaling.
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Based on the description of the table above, research on matoa plants shows significant development in recent years, focusing on different parts of the plant and their potential applications. Based on a literature review conducted by Panggulu Utoro et al. (2022), matoa leaves have various pharmacological properties, including being able to lower blood pressure, treat diabetes, and overcome digestive disorders such as diarrhea and dysentery. This study also examines the potential for the development of matoa leaves as a supplement or fortifying ingredient in dairy products.

Recent developments, as reported by Rosdiani Azis (2024), show innovations in the processing of matoa into herbal drink powder. This research emphasizes the potential of matoa plants as a functional food source that can be developed into beverage products to improve health and immunity.

Literature research by Siti Hajar, et al. (2021) shows that in matoa fruits, fruit lectures, stems and matoa stem bark there are substances that are strong antioxidants. In terms of nutrition, research conducted by Ira Oktavia et al. (2023) revealed the significant carbohydrate and ascorbic acid content in matoa juice, so that it has the potential to provide diversification in the development of food products, especially in ice cream and syrup formulations. The microbiological perspective is contained in the research of Widayanti and Maryati (2023) which identified antibacterial activity in matoa leaf extract, especially tannin compounds that effectively inhibit the growth of diarrhea-causing bacteria. Furthermore, Thomas et al. (2022) explored the practical application of matoa fruit peel in mouthwash formulations, utilizing the content of bioactive compounds such as phenolics, saponins, tannins, flavonoids, and terpenoids for oral health.

T.K. Lim (2016) through a book entitled *Edible Medicinal And Non-Medicinal Plants Volume 6, Fruits*. Studies on matoa fruits show that the results of the isolation of matoa stem bark produce a new saponin triterpeonidar named pomiten. In addition to oral health, saponins are also useful as anti-obesity.

Tozhikasu Zusuki, et al. (2021) Research on the skin and skin of matoa fruit shows that matoa plants are rich in phenolic compounds/polyphenols with antioxidant properties and have the potential to have beneficial effects on obesity and obesity-related non-communicable diseases. This study investigated the anti-obesity effects of the peel of matoa (*Pometia pinnata*) and salak (*Salacca zalacca*). Neither matoa bark powder (MPP) nor salak bark powder (SPP) affected body weight, visceral fat weight, or serum glucose or

lipid levels of Sprague–Dawley rats when taken as 1% (w/b) of a high-fat diet (HFD). However, MPP significantly lowers liver lipid levels. MPP with a dose of 3% (w/b) HFD decreased weight, visceral fat, and serum triglyceride levels as well as liver lipid content. The inhibitory effect of MPP on liver lipid accumulation did not increase when its concentration was increased from 1% to 3% of HFD. The anti-obesity effect of matoa is partly explained by the inhibitory effect of matoa bark extract on fatty acid-induced secretion of ApoB-48 protein, a marker of intestinal kilomicros, in a single layer of differentiated Caco-2 cells. We identified the abundant hederagenin saponins in MPP as a potential anti-obesity substance. These results will contribute to the development of functional foods with anti-obesity effects by using matoa fruit peels.

Regarding fitness or exercise performance, Yiang Lin, et al (2016) revealed that the saponin *Tribulus terrestris* L. (TT) has a good effect on exercise performance and other mechanisms due to exercise. The results showed that TT saponins increased performance, body mass, and gastrocnemius mass in overtrained mice, which may be caused by changes in the androgen–AR axis and IGF-1R signaling. It was further explained that rats that underwent overtraining and were given TT saponins significantly improved exercise performance, reflected in prolonged time to fatigue, with simultaneous increases in body mass, relative mass, and gastrocnemius protein levels. Overtraining alone causes a significant decrease in serum testosterone levels. In contrast, treatment with TT saponins dramatically increased serum testosterone levels in overtrained mice by about 150% of the control group and 216% of the overtrained group.

This series of studies collectively shows that matoa is a plant species that has multifunctional value, both from a pharmacological perspective and the development of functional food products.

Future Research Agenda: Long-Term Evaluation and Clinical Validation of Matoa

Based on the review of various existing studies, there is a significant gap in the long-term safety and clinical validation of matoa. Both the study of Suzuki, et al. (2021) showing antiobesity effects and the study of Yiang Lin, et al (2016) showing that the TT saponins contained in matoa have a good effect on promising exercise performance in rats. The transition from animal models to applications in humans requires a more comprehensive set of research stages. The complexity of this process reflects the fundamental challenges in developing products based on natural ingredients, where the balance between therapeutic potential and safety aspects is a key consideration (Prihanti et al., 2020; Putri et al., 2023).

Preclinical studies that have been conducted on matoa show a range of interesting pharmacological potentials, including antioxidant, anti-inflammatory, and lipid metabolism modulation activities (Malaka & Maruddin, 2020; Marsiati et al., 2023; Purwidyaningrum et al., 2016). The content of bioactive compounds such as flavonoids, tannins, and saponins has

been identified as the main components contributing to its therapeutic effects. However, in-depth characterization of the molecular mechanisms and biological interactions of each of these compounds still requires further research. A long-term safety framework in the use of matoa requires a systematic evaluation of chronic toxicity, including monitoring of cumulative effects in biological systems (Sihotang et al., 2017). In addition, the long-term framework requires a comprehensive analysis of potential interactions with different types of drugs, as well as in-depth studies of their effects on vital organ function. In this context, subchronic and chronic toxicology studies need to be conducted with a minimum duration of 90 days to 12 months to identify potential toxic effects that may not be detected in acute studies (Suzuki et al., 2021). Parameters that need to be evaluated include changes in blood biochemistry, liver and kidney function, hematological profile, and histopathological examination of the target organ.

The pharmacokinetic aspect is a crucial component in the safety evaluation, considering the complexity of the compound matrix in matoa extract (Wahyuni et al., 2024). ADME (Absorption, Distribution, Metabolism, and Excretion) studies need to be conducted to understand the fate of bioactive compounds in the body, including the identification of potential metabolites that may have their own biological activity or toxicity (He et al., 2011). The use of modern technologies such as LC-MS/MS and isotope labeling techniques can provide detailed information about the metabolic profile and network distribution of target compounds. Herbal-drug interactions are an often overlooked but crucial aspect in safety evaluations. Matoa, like other natural substances, has the potential to affect the activity of drug metabolic enzymes such as cytochrome P450, which can result in significant changes in the effectiveness or toxicity of drugs taken concomitantly. In vitro studies using liver microsomal systems or primary hepatocytes can provide preliminary information about the potential for these interactions, which then need to be validated through in vivo studies.

This aspect cannot be separated from the urgency of determining safe doses for sustainable consumption, which requires long-term empirical data taking into account variations in individual responses and factors that can affect the metabolism of the active compound matoa in the body. Determination of minimum effective dose (MED) and maximum tolerated dose (MTD) is an important basis for developing a safe dosage regimen. Factors such as genetic polymorphism in metabolic enzymes, individual physiological conditions, and variations in the composition of the gut microbiota need to be considered in establishing a safe dosage range.

Standardization in the extraction and production process is an important prerequisite to ensure the consistency of the bioactive compound content and product safety profile. This includes the development of validated analytical methods for the quantification of marker compounds, the determination of raw material specifications, and the implementation of good manufacturing practices (GMP). The variability of bioactive compound content due to

environmental factors, harvest time, and processing methods needs to be overcome through strict standardization.

The implementation of clinical research in humans is a crucial step that requires a series of systematic studies, starting from evaluating the bioavailability of active compounds to understand the level of absorption and distribution in the human body, followed by pharmacokinetic and pharmacodynamic studies to understand the mechanism of action and duration of their effects. Proper clinical study design, taking into account inter-individual variability and factors that can influence therapy response, is key to successful clinical validation.

Phase I clinical trials need to focus on evaluating safety and tolerability in a healthy group of volunteers, with special attention to pharmacokinetic parameters and identification of potential side effects. Phase II and III studies can further evaluate effectiveness in target populations with specific conditions, such as obesity or other metabolic disorders. The use of robust study designs, such as randomized controlled trials (RCTs) with adequate sample sizes, is the gold standard in validating therapeutic claims.

This process needs to be supported by an evaluation of effectiveness in different demographic groups to understand the variation of responses based on age, gender, and health conditions, as well as the identification of potential contraindications that may arise in certain groups. Stratifying the population based on genetic characteristics, health status, and risk factors can help optimize the use of matoa in the group most likely to benefit with minimal risk.

Special considerations in the use of matoa require deep attention to the safety of use in vulnerable groups such as pregnant women, the elderly, and children, who have certain physiological characteristics and needs. Safety studies in this particular population require careful study design with strict inclusion and exclusion criteria, as well as more intensive safety monitoring. This evaluation should include an analysis of potential allergenicity to identify possible adverse reactions in individuals with specific sensitivities. The development of reliable allergenicity screening methods, such as in vitro immunological testing and sensitization studies in animal models, can help identify potential allergy risks prior to testing in humans.

An in-depth understanding of the stability of active compounds in various dosage forms is essential to ensure the effectiveness of the final product. A comprehensive stability study needs to include an evaluation of the effects of temperature, humidity, light, and other storage conditions on the degradation of bioactive compounds. Developing the right formulation with compatible excipients can help maintain the stability and bioavailability of the active compound.

The regulatory aspect plays an important role in the widespread application of matoa. This includes meeting food safety standards through a series of rigorous and standardized tests, such as evaluating microbiological contamination, heavy metals, and pesticide residues. The development of comprehensive product specifications and validated analytical methods is an integral part of meeting regulatory requirements.

The determination of the maximum daily consumption limit based on comprehensive toxicological and pharmacological data is an important component in the regulatory aspect. The calculation of Acceptable Daily Intake (ADI) needs to consider adequate safety factors and population variability. The development of evidence-based use guidelines that healthcare practitioners and industry can rely on should include information on indications, contraindications, potential interactions, and dosage recommendations based on the patient's specific condition.

This process must end with safety certification for various forms of products, which guarantees that every matoa derivative product on the market has undergone a comprehensive series of safety tests and meets applicable regulatory standards. The implementation of a post-market surveillance system is also necessary to identify long-term adverse effects or adverse events that are not detected during the product development phase.

The development of an effective pharmacovigilance system for matoa-based products is an integral component in ensuring the safety of long-term use. The system must be able to collect, evaluate, and communicate information about adverse events that may be associated with the use of Matoa products. Collaboration between manufacturers, health practitioners, and regulatory bodies in the implementation of pharmacovigilance systems will help ensure continuous safety monitoring. The sustainability aspect in the use of matoa also needs special attention. The increasing demand for matoa raw materials can put pressure on natural populations and ecosystems. The development of sustainable cultivation practices, conservation of genetic resources, and the implementation of Good Agricultural and Collection Practices (GACP) standards are important to ensure the availability of quality raw materials in the long term without sacrificing environmental sustainability.

Finally, education to health practitioners and the public about the proper use and potential risks of matoa-based products is an important component in optimizing benefits and minimizing risks. A comprehensive educational program should include information about the exact indications, recommended dosages, potential interactions with medications, and the importance of reporting possible side effects.

CONCLUSION

Based on the results of this narrative study, it can be concluded that matoa has promising potential as a source of natural antioxidants and raw materials for health products, including for exercise performance. Its content of bioactive compounds, especially phenolic groups, contributes to a wide range of therapeutic effects including antioxidant, anti-inflammatory, cardiovascular and muscle mass improvement activities. Recent research shows a wide range of applications for matoa, from the development of health supplements to the fortification of food products. However, more research is still needed, especially in terms of long-term safety, clinical validation in humans, product standardization, and compliance with regulatory aspects to ensure optimal and

safe use of methanol. The development of standard use protocols and evaluations in specific population groups is also a priority for future research.

RECOMMENDATION

Based on the review that has been carried out, recommendations for the sustainability of matoa can be formulated in several important aspects. The sustainability aspect of matoa production needs serious attention considering the potential for increased demand along with the development of research and application of matoa in various health and functional food products.

First, developing sustainable cultivation practices is a top priority to ensure the availability of sustainable raw materials. This includes implementing an agricultural system that pays attention to ecological aspects, such as the use of organic fertilizer, integrated pest control, and proper crop rotation. These cultivation practices must be documented in the form of comprehensive Standard Operating Procedures (SOP) that can be implemented by matoa farmers.

Conservation of matoa genetic resources is the second crucial aspect for sustainability. Conservation programs must include in-situ preservation in natural habitats and ex-situ through the development of gene banks. This is important to maintain the genetic diversity of matoa which can support future breeding programs and anticipate adaptation to climate change. Mapping and documentation of local matoa varieties also needs to be carried out to protect germplasm wealth.

FURTHER STUDY

Based on the systematic study that has been carried out, this article has limitations in empirical studies and further proof in the laboratory. So that several important recommendations for further research can be formulated. First, a series of clinical trials in humans are needed to validate the various effects of matoa which have so far only been proven in experimental animal models, especially regarding its potential to improve sports performance and anti-obesity effects. These clinical trials must be designed with rigorous methodology, involve adequate sample sizes, and use appropriate research designs such as randomized controlled trials (RCTs).

Future research also needs to focus on comprehensive pharmacokinetic aspects to understand the mechanisms of absorption, distribution, metabolism and excretion (ADME) of matoa bioactive compounds in the human body. This includes the identification of potential metabolites and their interactions with the body's biological systems. Studies on herbal-drug interactions are also important to identify potential interactions of matoa with various types of drugs, especially those commonly consumed by the target population.

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