HOW CAN THE WORLD OVERLOOK *Sapindus rarak* BIOPROSPECTION? A NICHE FOR INDONESIA

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ABSTRACT

Sapindus rarak, a native plant of Indonesia, is renowned for its saponin-rich fruit, acting as a natural detergent for *Batik* and baby cloth diapers. This study aims to determine the trends in *S. rarak* research through a dual approach: bibliometrics and scoping review. The bibliometrics analysis involved defining search keywords, extracting publications, refining results, compiling metadata, and mapping authors, keywords, and collaborations. The scoping review meanwhile included determining research objectives and questions, defining the scope, selecting studies through an iterative team approach, extracting data, summarizing qualitative and quantitative analysis, reporting results, and preparing the considerations of implications in research. Scopus identified 32 publications related to *S. rarak* by 23 authors from 1992 to 2022, accumulating 387 citations. Google Scholar reported 201 publications with 1176 citations. Notably, Indonesia, the Indonesian Research Institute for Animal Production, and Elizabeth Wina emerged as the most influential country, institution, and author, respectively. Research findings were clustered into chemistry, biology, medicine, and physics. However, the bioprospection of *S. rarak* fruit mainly focused on livestock supplementation. Surprisingly, no studies on the efficacy of *S. rarak* as a detergent, so far, were found in any reputable international journals. All articles exclusively discussed about *S. rarak* fruit or seed, neglecting any exploration of the leaves, indicating an overlooked potential. Future research should comprehensively explore the *S. rarak* for additional valuable phytochemicals beyond saponin, positioning it as a signature bioresource with significant economic value, expanding beyond its current detergents use within society.

Keywords: bibliometrics, bioprospecting, knowledge structure, roadmap research

INTRODUCTION

Bioprospection involves discovering natural products from unstudied species for developing new valuable nutraceuticals, bioactive constituents, and medicines (McClatchey & Stevens 2001; Purkayastha 2016). The Convention on Biological Diversity emphasizes the importance of biodiversity conservation for sustainable bioresources utilization. Benefit sharing is embedded to the responsibility of safeguarding bioresource, and commercialization interests must guarantee the public access to intangible benefits (McClatchey & Stevens 2001).

Bioprospection is related to, but not limited to, drug discovery. Orchestrated plant secondary metabolites are excellent entities against various diseases. This process involves systematic sampling, investigation, purification, and the development of semi-synthetic or synthetic derivative compounds to stabilize efficacy, reduce negative impacts, and increase profitability (McClatchey & Stevens 2001). However, the development of commercial products from natural organisms requires prolonged research with uncertain results (Lichota & Gwozdzinski 2018).

Sapindus rarak DC. is a native Indonesian plant cultivated by the community and is recognized for its saponin-rich fruit, which is used as a natural detergent for both *Batik* and baby cloth diapers. Unfortunately, research on the medicinal properties of *S. rarak* is limited, even though saponins are recognized for treating various diseases, such as antibacterial (Wei *et al.* 2021), antifungal (Coleman *et al.* 2010), anticancer (Xu *et*

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al. 2013), antioxidant, antidiabetic (Salahuddin *et al.* 2020), and antiviral (Pu *et al.* 2015). Besides fruits, their leaves also contain saponin, although their potency is still overlooked (Pratiwi & Nurlaeni 2022).

Internet technology has provided access to scientific publications, enabling structured review to evaluate research progress, identify gaps, and plan a roadmap. Bibliometrics is an approach that allows for data collection and comprehensive analysis of a field, covering the most influential research, research evolution, and insights for future research (Fahimnia *et al.* 2015). As of 2023, no bibliometrics analysis for *S. rarak*'s bioprospecting exists, but insights from other species illustrate how the bibliometrics approach can reveal research trends, gaps, and opportunities for further exploration. A notable success story in bibliometrics analysis for plant bioprospection is the research of *Moringa oleifera* Lam. Over the past 20 years, research on *M. oleifera* has rapidly developed, marked by the emergence of thousands of publications. Future research trends are predicted to focus on important compounds isolation from *M. oleifera* for use as food additives and in phytoremediation (George *et al.* 2021).

Various approaches, including meta-analysis, systematic literature review, and scoping review, contribute to understanding research trends. While meta-analysis and bibliometrics handle large datasets and focus on quantitative empirical evidence in a broader field, systematic reviews manually investigate fewer documents (tens or fewer than 300) to qualitatively examine trends in a niche field. Combining several methods may offer unique results (Donthu *et al.* 2021). An interesting example of combining bibliometrics with a literature review is research on cactus mucilage —we mention this, considering the limited review on *S. rarak* itself, revealing the prospect of its carbohydrates, proteins, minerals, and fatty acids for functional products. Research trends regarding cactus mucilage include its applications in food, cosmetics, and medicine, encompassing microencapsulation, biofilms, and biocoagulants (de Andrade Vieira & Cordeiro 2023).

Scoping review, a novel approach for determining knowledge gaps without critical appraisal, contrasts with a systematic review, which summarizes the best available research (Pham *et al.* 2014). Due to the limited literature on *S. rarak*, the adoption of a scoping review approach, as exemplified in cannabis research, proves invaluable for identifying gaps in existing knowledge and paving the way for future investigations. For instance, a scoping review on cannabis highlighted Cannflavins as anti-inflammatory agents, demonstrating how this method reveals novel extraction protocols and biosynthetic pathway maps (Erridge *et al.* 2020). This underscores the significance of employing a scoping review for *S. rarak*, where its application could uncover untapped potential, guide forthcoming research endeavors, and contribute to a comprehensive understanding of its bioresources.

This paper aims to evaluate *S. rarak* research trends through a dual approach of bibliometrics and scoping review, offering a comprehensive and objective assessment. Network analysis in bibliometrics captures established publications, research groups, and emerging trends. The exploration of *S. rarak* bioresource is expected to be progressive, enhancing Indonesia's competitiveness in the global academic community.

MATERIALS AND METHODS

This research, conducted in January–February 2023, employed a bibliometrics analysis method by following the approaches of Fahimnia *et al.* (2015); Ma *et al.* (2022); and Nurfauzan & Faizatunnisa (2021) with some modifications. The methodology included defining search keywords, extracting initial data, refining results, compiling metadata, and mapping authors, keywords, and collaboration networks (see Figure 1).

The research employed Scopus and Google Scholar for data search, and Harzing's Publish or Perish software (Harzing 2007) for data extraction. The results were saved in RIS and CSV formats and imported into the reference manager Zotero (Roy Rosenzweig Center for History & New Media 2016). After obtaining a list of articles, we excluded patents, irrelevant studies, or duplicate literature, resulting in a final dataset containing information such as the number and list of authors, titles, year of publications, publishers, article type, total

citations, and citations per document. Data compilation was performed using Microsoft Excel™ 2013 (Microsoft Corporation).

Furthermore, bibliometric analysis was conducted based on Scopus. The world map depicting the number of publications for each country was derived through the online application (www.datawrapper.de). Meanwhile, author mapping, keywords, and collaboration networks were visualized using VOSviewer (van Eck & Waltman 2018). Author and country mapping provided information about disciplinary leaders, while keywords indicated the hot topics. Collaboration patterns and citation networks represented teamwork and primary literature from different periods, describing the field's evolution and projecting future developments (Ma *et al.* 2022).

Meanwhile, the scoping review included determining research objectives and questions, defining the scope, selecting studies through an iterative team approach, extracting data, summarizing qualitative and quantitative analysis, reporting results, preparing the considerations of implications in research, and optionally consulting with stakeholders (Levac *et al.* 2010). The purpose and scope of this review were to map *S. rarak* bioprospection. The dataset inputted for the bibliometrics was also involved in the scoping review, although no stakeholder consultation occurred during this process.

RESULTS AND DISCUSSION

Defining the Appropriate Search Keywords

The preliminary bibliometrics analysis started with the keywords 'Sapindus rarak' AND 'leaves' to investigate the overlooked bioprospection of *S. rarak* leaves. Despite expecting abundant data, Scopus identified only three articles. Expanding the keyword to 'Sapindus rarak' increased the total to 32 documents, which was unexpectedly low (Table 1). Meanwhile, on Google Scholar, using the keywords 'Sapindus rarak' AND 'leaves' yielded 39 documents, and the keyword 'Sapindus rarak' alone retrieved 221 documents. Although this number was smaller compared to bibliometrics analyses for other plants like *M. oleifera*, which reached 2,345 documents (George *et al.* 2021), the limited global publications on *S. rarak* allowed an opportunity for an in-depth review.

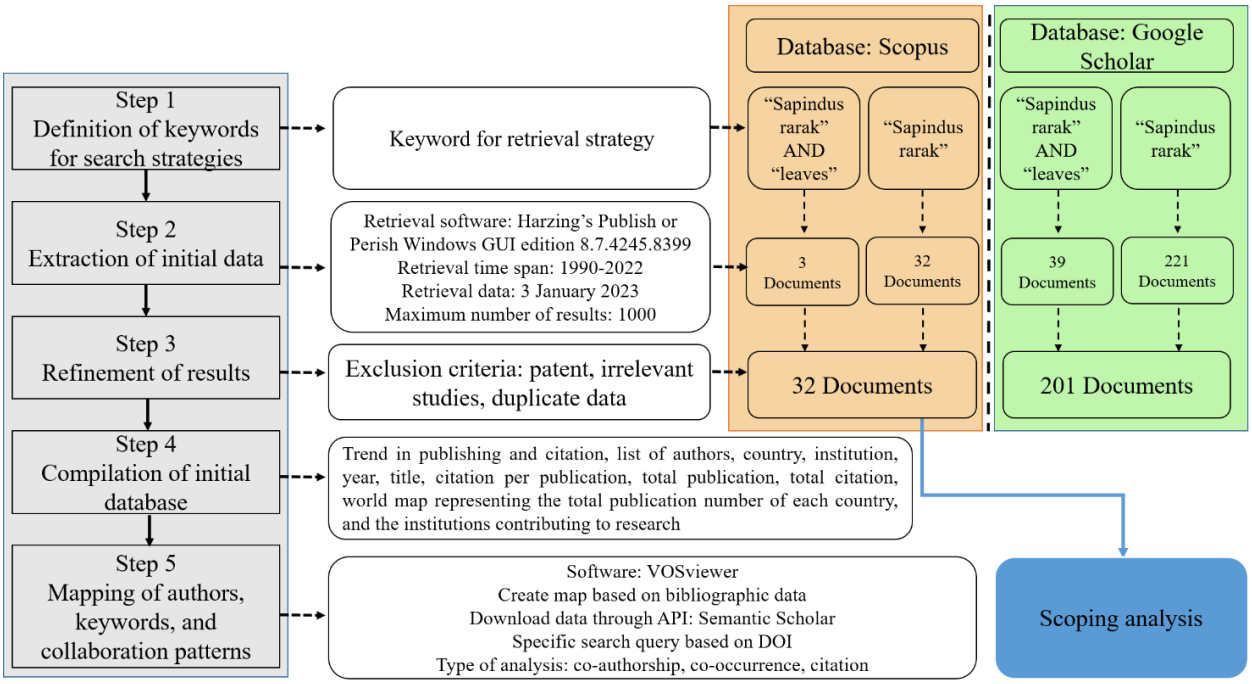

Figure 1 Flowchart of bibliometrics and scoping review (Fahimnia *et al.* 2015; Ma *et al.* 2022; Nurfauzan & Faizatunnisa 2021 with modification)

Table 1 The number of publications from Scopus for each search argument

Database	Number of documents for search argument		Number of documents retained
	Sapindus rarak AND leaves	Sapindus rarak	
Scopus	3	32	32
Google Scholar	39	221	201

Extracting the Initial Data

Scopus (https://www.scopus.com/), managed by Elsevier publishing, was selected over Web of Science (WoS) (www.clarivate.com). Although both are widely recognized inputs for bibliometrics analysis, the analysis based on each can provide different results (Echchakoui 2020). Despite WoS being established earlier in 1997 than Scopus in 2004, Scopus accommodates a broader range publications from developing countries, encompassing non-English language. WoS covers 54% of journals indexed by Scopus, while Scopus contains 84% of journals indexed by WoS (Gavel & Iselid 2008). This research specifically utilized Scopus considering its expected wider coverage compared to WoS.

Utilizing Harzing's Publish or Perish (Harzing 2007) for Scopus with 'a title' and 'a keyword' queries, 32 documents were obtained. Additionally, we retrieved publications from Google Scholar for comparison, considering the limited global research related to *S. rarak* in Scopus. Here, Google Scholar showed numerous interesting local publications on *S. rarak* bioprospection.

Refining Results

All 32 documents from Scopus met the requirements, with no irrelevant or duplicated data, resulting in a total retention of 32 documents (100%). In contrast, Google Scholar indexed numerous redundant documents, leading to a final result of 91% documents with 1176 citations (Table 1). Despite recording a higher publication count than Scopus, Google Scholar included national publications, majority in Indonesian (Table 2), highlighting the predominant local development of *S. rarak* research in Indonesia. For rigorous data analysis, further bibliometrics analysis was performed using Scopus.

Compiling Initial Metadata

The literature on *S. rarak* involves 23 authors in 32 documents spanning 20 years (1992–2022), accumulating 387 citations. Initiated by Matthias Hamburger in 1992 (Figure 2), the study of *S. rarak* progressed slowly until 2004, experiencing a crucial development from 2005–2010. This phase saw significant contributions from Elizabeth Wina, Toshio Morikawa, and Yosunabu Asao. Elizabeth Wina emerged as the most influential author, holding the highest citation rank. Substantial contributions from Evi Maryanti and Sri Suharti occurred from 2011–2019. While several researchers began to contribute during this period, their impact was relatively modest.

Table 2 The percentage of documents indexed by Google Scholar written in several languages

	Language		
	Indonesian	English	Japanese
The document written in several languages (%)	60.7	38.8	0.5

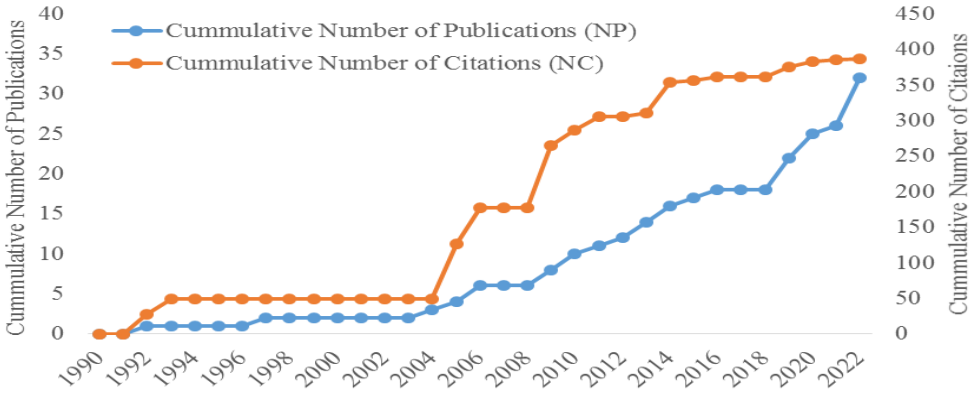

Figure 2 The trend in publishing and citation about *S. rarak* based on Scopus

Sixteen institutions contributed to this field with the Indonesian Research Institute for Animal Production (Indonesia) standing out as the most influential. While Kinki University, Université de Lausanne, and the University of Illinois at Chicago published fewer articles, their citation number was notably high (Table 3). Indonesia led the research on *S. rarak* (Figure 3), which is not surprising given that the plant is native to Indonesia, widely cultivated, sold in markets throughout the year, and commonly used by the community as a natural detergent. Due to the excellent potency and existence of *S. rarak* in Indonesia, it holds the potential to become a point of Indonesian competitiveness.

Table 3 The compilation of publications about *S. rarak* based on Scopus

No	Author	Country	Institution	Year	C	TP	TC
1	Elizabeth Wina	Indonesia	Indonesian Research Institute for Animal Production (IRIAP)	2004	0	4	128
				2005	77		
				2006a	39		
				2006b	12		
2	Toshio Morikawa	Japan	Kinki University	2009	56	2	71
				2010	16		
3	Evi Maryanti	Indonesia	University of Bengkulu (UNIB)	2014	40	1	40
4	Yasunobu Asao	Japan	Kyoto Pharmaceutical University	2009	32	1	32
5	Sri Suharti	Indonesia	Bogor Agricultural University (IPB)	2010	6	3	29
				2011	19		
				2019	4		
6	Matthias Hamburger	Switzer-land	Université de Lausanne	1992	27	1	27
7	Myung-Sook Chung	USA	University of Illinois at Chicago	1997	22	1	22
8	Sylvia Utami Pratiwi	Indonesia	Gadjah Mada University	2020	8	1	8
9	Aininu Nafiunisa	Indonesia	Diponegoro University	2019	6	1	6
10	Caribu Hadi Prayitno	Indonesia	Jend. Soedirman University	2013	4	2	6
				2015	2		
11	Mardiati Zain	Indonesia	Andalas University	2016	5	1	5
12	Pristian Yuliana	Indonesia	IPB	2019a	2	2	4
				2019b	2		
13	Inarah Fajriaty	Indonesia	Tanjungpura University	2014	4	1	4
14	Nita Aryanti	Indonesia	Diponegoro University	2020a	0	2	3
				2021b	3		
15	Salprima Yudha S.	Indonesia	UNIB	2022	1	1	1
16	Aminah Umar	Indonesia	University of Indonesia (UI)	2013	1	1	1
17	Lueangkaew Koysap	Thailand	Mahidol University	2022	0	1	0
18	T. Pasaribu	Indonesia	IRIAP	2022	0	1	0
19	Hidayat Pujisiswanto	Indonesia	University of Lampung	2022	0	1	0
20	Sekar Arum	Indonesia	President University	2022	0	1	0
21	Charles Banon	Indonesia	UNIB	2022	0	1	0
22	Antonius H. Cahyana	Indonesia	UI	2020	0	1	0
23	Amonrat Khayungar-nnawee	Thailand	Thailand Institute of Scientific & Tech. Research	2012	0	1	0
			Total		**387**	**32**	**387**

Note: C = Citation, TP = Total Publication, TC = Total Citation.

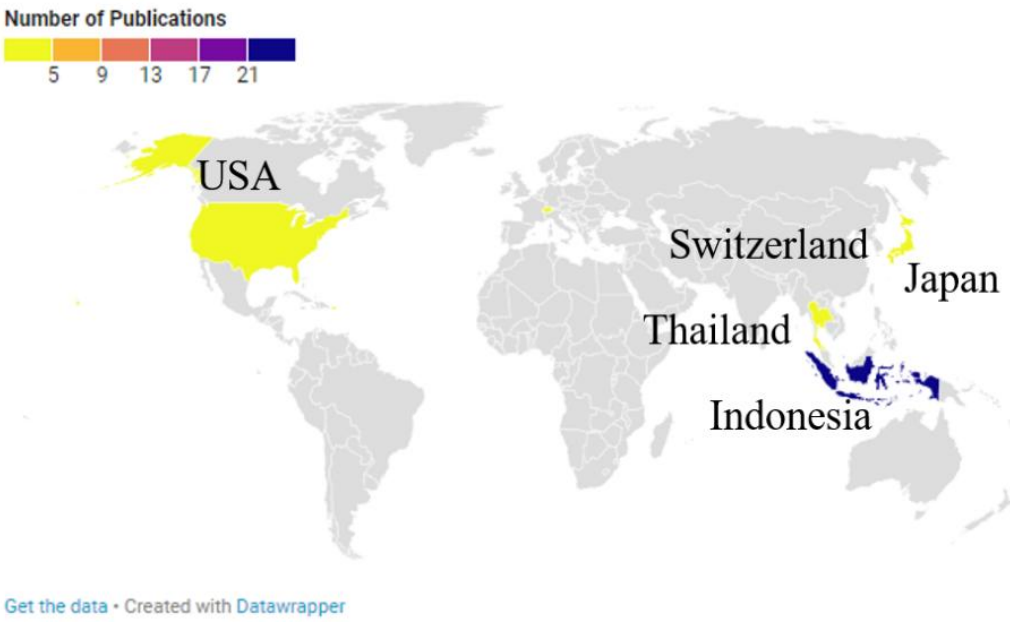

Figure 3 A world map representing the total publications of each country about *S. rarak* based on Scopus

Mapping Authors' Collaboration, Keywords, and Field Evolution Patterns

Co-authorship network analysis revealed the collaboration trend and the leader in a particular field (Fonseca *et al.* 2016). Elizabeth Wina from Indonesia was the most influential author (Figure 4). Indonesian researchers (S. Suharti, D. Astuti, A. Kurniawati, and T. Toharmat) were interconnected with foreign researchers (S. Muetzel, K. Becker, E. Hoffmann, and H. Makkar) through this author.

Research on *S. rarak* focused on four hot topics: chemistry, biology, medicine, and physics. Based on its chronological development, research on the biological aspect was developed first, followed by the exploration of the medicinal aspects, deepening into chemistry, and lastly, the investigation of physical properties. Furthermore, chemistry became the most developed field compared to other topics (Figure 5).

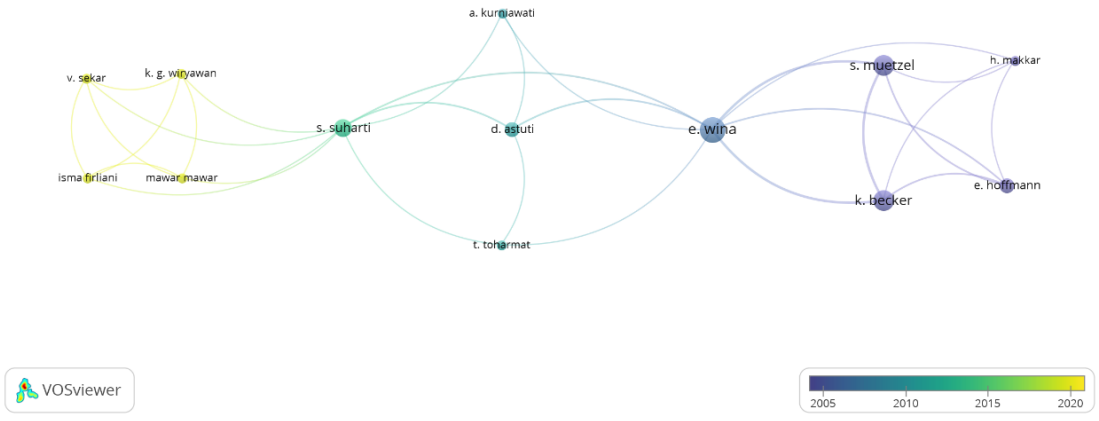

Figure 4 Overlay visualization of co-authorship analysis to revealing the leader

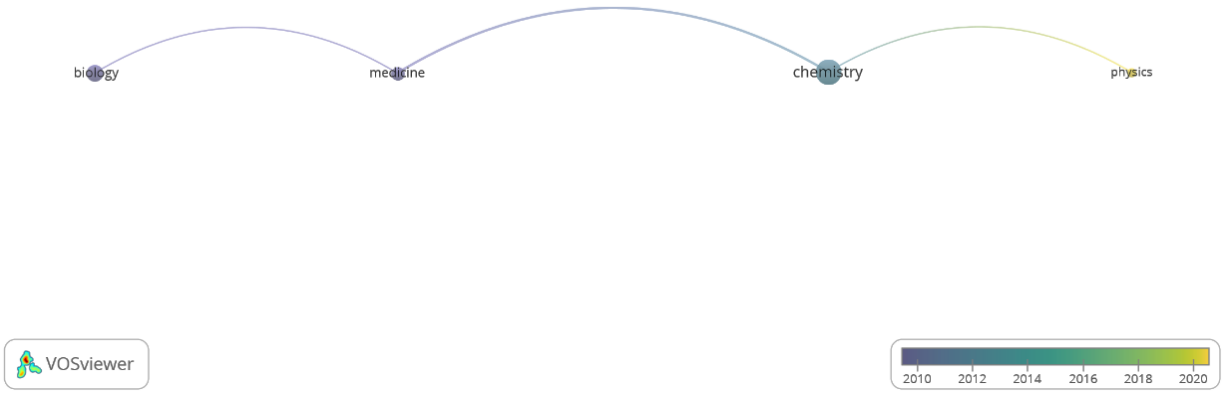

Figure 5 Overlay visualization of co-occurrence analysis to reveal the popular keywords

The most prominent author network, centered on Elizabeth Wina, focused on the study of microbial population dynamics and animal rumen fermentation due to the supplementation of *S. rarak* fruit extract. The Morikawa, Asao, and Chang group explored the chemical structure and *in vitro* biological activity of *S. rarak* phytoconstituents. Koysap contributed to bridging the evolution of the interlinked field between medicine and phytochemicals (Figure 6).

Scoping Review Analysis

An in-depth review of 32 publications revealed the diverse potentials of *S. rarak*. Table 4 presents a summary of the scoping review analysis results, including the primary utilization aspect of *S. rarak*, identifying alternative sources of *S. rarak* beyond the fruit, evolving extraction techniques, common form of *S. rarak*, and regions contributing the most in providing *S. rarak* materials.

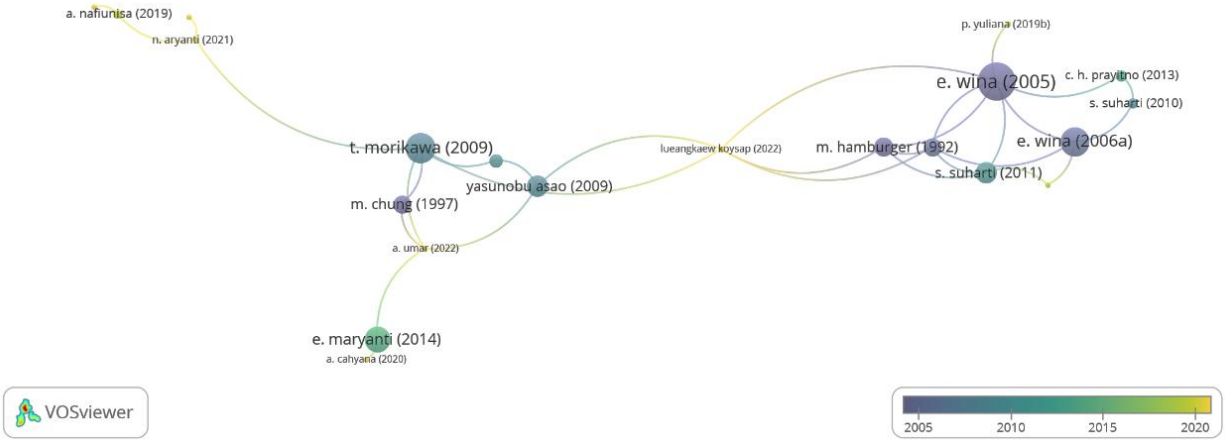

Figure 6 Overlay visualization of collaboration patterns revealing the field evolution and projecting future developments

Table 4 Scoping analysis compilation

Aspect	Number of document
Utilization	Livestock supplement (12), molluscicide (2), herbicide (1), antimicrobe (2), antitumor (1), anti-obesity (3), nanoparticle (3), anti-inflammatory (1), soil remediation (1), surfactant (4), catalyst (1), sweetener (1)
Organ source	Seed (3), fruit (30)
Extraction technique	Maceration with ethanol (4), methanol (15), aqua (8), Ultrasound-assisted extraction (3)
Form	Crude extract (17), powder (1), pure saponin (4), biochar (1)
Origin of sample	Indonesia (24), Thailand (4)

As shown in Table 4, *S. rarak* research focuses on its potential as livestock supplementation (12 documents), alongside applications as molluscicide, herbicide, antimicrobial, antitumor, anti-obesity, anti-inflammatory agents, nanoparticle, soil remediation, surfactant, catalyst, and sweetener. All studies exclusively reported on fruit and seed of *S. rarak*, neglecting the potential of leaves, despite significant biological activity in other Sapindaceae species leaves. For instance, *Litchi chinensis* leaves exhibit anti-inflammatory effect (Besra *et al.* 1996), *S. mukorrossi* demonstrates antioxidant activity (Singh & Kumari 2015), and *S. saponaria* shows antimicrobial (Garcia *et al.* 2012) and antiulcer (Meyer Albiero *et al.* 2002) activity. While *S. rarak* leaves contain fewer saponins than fruit (Pratiwi & Nurlaeni 2022), exploring their potential extends beyond saponin extraction to uncover other beneficial phytochemical groups. The leaves, being abundant organs that do not compete with reproductive functions, warrant consideration (Chen *et al.* 2016).

Additional *S. rarak* research discussed the extraction method. To enhance saponin yield, a variety of solvents were considered, with methanol frequently chosen. Ultrasound-assisted extraction (UAE), particularly green UAE, and raising the extraction temperature were able to increase saponin yield (Aryanti *et al.* 2020, 2021; Nafiunisa *et al.* 2019). The prevalent use of crude extract over powder, pure saponin, and biochar is noted. Consistent with bibliometrics results, the majority of samples sourced from Indonesia.

While the discussion regarding the efficacy of *S. rarak* as a detergent material is limited in internationally reputable publications, numerous national publications on Google Scholar address this aspect. *S. rarak* fruit, whether in its raw form, boiled, or incorporated into soap with additional additives, is widely sold throughout the year in the Indonesian market for washing *Batik* and baby cloth diapers (Muttafaq *et al.* 2019; Nia *et al.* 2018). Detergent formulated from *S. rarak* is safe for clothing fiber and color, effectively removing any stains compared to conventional detergents (Muttafaq *et al.* 2019). Moreover, the environmental friendliness of *S. rarak* is noteworthy as the fruit generates abundant foam with just water soaking (Pratiwi & Nurlaeni 2022), eliminating the need for resource-intensive processes like detergent manufacturing, known for their high carbon footprint (de Koning *et al.* 2010). The formulated *S. rarak* detergent has a potential to replace non-renewable petroleum-based detergents (Maurad *et al.* 2017) and excess phosphates often used as detergent builders, contributing to water eutrophication (Kogawa *et al.* 2017). Additionally, detergent waste from *S. rarak* will easily decompose in the environment.

To gain a broader perspective, we suggest future exploration using Google Scholar to understand national research trends, particularly regarding the application of *S. rarak* as a detergent. This database can also reveal information about Indonesian scientist teams involved in *S. rarak* research for various applications. In the field of *S. rarak* as livestock supplementation, Elizabeth Wina is a notable figure, but not the first Indonesian scientist in this domain. The team from the Indonesian Research Institute for Animal Production, including Mohammad Winugroho, Amlius Thalib, Yeni Widiawati, and Dwi Yulistiani, initiated the research.

In terms of feedstock supplementation, saponin impacts rumen fermentation by modifying the microbial community's structure and activity, acting as a defaunation agent that suppresses protozoa without affecting bacterial growth, leading to improved fiber digestion efficiency or decreased protein degradation (Wina *et al.* 2005). However, saponin's toxicity negatively impacts beneficial bacteria and fungi and their enzyme activity in an *in vivo* study using rumen liquor from goats fed *S. rarak* extract (Wina *et al.* 2004). Conversely, a moderate level of *S. rarak* reduced the protozoa community from cow rumen cultured *in vitro* without affecting fibrolytic bacterial and fungi (Wina *et al.* 2005). Further study showed that short-term saponin exposure in goat reduced xylanase activity and *Ruminococcus*, but *Fibrobacter*, being Gram-negative, resisted saponins. Long-term exposure in sheep rumen depressed protozoa and fibrolytic enzyme carboxymethylcellulase (CMC) activity but had no effect on *Ruminococcus*, suggesting potential bacterial adaptation mechanism (Wina *et al.* 2006b).

The disparity in results between *in vitro* and *in vivo* studies triggers the idea of interval feeding (Wina *et al.* 2006a), although *S. rarak* reduces protozoa in both feeding methods with no significant differences at any dose. CMC and

xylanase activity decreased in both regimes, and higher doses led to lower enzyme activity. Although high saponins doses tended to reduce ammonia concentration, nitrogen balance remained unaffected, and the decrease in fibrolytic enzymes did not impact the digestive tract (Wina *et al.* 2006a).

The *S. rarak* supplement has been introduced in various formulations, including mineral blocks (Suharti *et al.* 2010), microencapsulation with canola oil (Suharti *et al.* 2019), and combination with garlic extract for ammoniated rice straw substrate enrichment (Prayitno *et al.* 2013), in addition to oil palm frond substrate, and *Saccharomyces cerevisiae* fermentation with *S. rarak* extract (Zain *et al.* 2016). Furthermore, the addition of *S. rarak* has been tested in cassava leaf diets (Yuliana *et al.* 2019a) and incorporated with *Hibiscus rosa-sinensis* in the cassava leaf silage (Yuliana *et al.* 2019b). These efforts have increased beneficial bacterial communities, enhanced protein flow from the rumen to the blood, and improved ammonia concentration, dry matter, and organic matter digestibility, body weight gain, and suppression of protozoa populations.

The decreased protozoa, as host for methanogenic bacteria, suppress methane production, the second most impactful greenhouse gas after CO_2, with a higher global warming potential. Ruminant methane (CH_4) emissions harm the environment, increase the greenhouse impact, and reduce animal energy and production efficiency. Therefore, ruminant methane emissions must be reduced (Sun *et al.* 2021). The dynamics of the methanogenic bacteria within the rumen undergo a shift from methane to propionate production (Suharti *et al.* 2011). Hence, saponin indirectly contributes to mitigating climate change by reducing methane emission (Króliczewska *et al.* 2023).

Although *S. rarak* fruit can improve fermentation performance in the digestive tract of goats, sheep, dairy, and beef cattle, the results can vary dependent upon saponin type, dosage, fermentation substrate, and combination with other ingredients. Further research is required to develop patented feed supplementation products, exemplified by the patent for the 'Complete Rumen Modifier' formula (certificate number IDP000057123), a feed additive for ruminant livestock that has the potential to enhance their growth while reducing enteric methane production (Thalib *et al.* 2010).

S. rarak exhibits molluscicidal properties attributed to four newly identified triglycoside saponins (Hamburger 1992). Meanwhile, the *S. rarak* extract serves as a repellent and induces mortality in giant african land snails (*Lissachatina fulica*) without harming vegetable *Brassica rapa* L. (Koysap *et al.* 2022). Additionally, it demonstrates herbicidal activity against *Leptochloa chinensis* and *Fimbristylis milacea* weeds. The aqua extract has no adverse effects on rice growth, while the methanol extract inhibits rice height without affecting root length and leaf number (Pujisiswanto *et al.* 2022).

In terms of antimicrobial properties, the ethanol extract of *S. rarak* seeds effectively degrades extracellular polymeric substances in pathogenic polymicrobial biofilms, as observed by scanning electron microscopy (Pratiwi & Hamzah 2020). Furthermore, *S. rarak* microparticles administered in drinking water perform similarly to commercial anticoccidials in reducing *Eimeria* sp. and *E. coli* (Pasaribu *et al.* 2022). Coccidiosis is an important enteric health problem in poultry, leading to reduced feed efficiency, weight gain, bloody stools, and mortality. The gastrointestinal tract in chickens has a wide range of microorganisms that play a vital part in the processes of digestion and defense. The infection of *Eimeria* spp. parasites disrupts the gut environment, leading to an imbalance in intestinal homeostasis. This imbalance promotes the growth of pathogens, including *Clostridium* species (Madlala *et al.* 2021). *S. rarak* as a natural antibiotic potentially can replace the banned feed additives containing anticoccidial agents due to the risk of multidrug resistance (Han *et al.* 2022).

The alternative use of antibiotic growth promoters (AGP), such as *S. rarak* saponin, is crucial due to the prohibition on AGP. These alternatives should easily blend with feed, lack tissue residual effects, and improve feed intake, gain, and conversion rates. Additionally, they should enhance immunity and digestion, nutrient availability, possess antimicrobial effects, maintain unaffected carcass characteristics, act as antioxidants and anti-inflammatory agents, compete against stress factors, and provide wholesome organic products for human consumption (Abd El-Hack *et al.* 2022). As the

emphasis on a healthy lifestyle and organic farming grows, consumer preferences are increasingly favoring products from antibiotic-free livestock (Seidavi *et al.* 2021).

S. rarak presents sesquiterpene saponins inhibiting tumor necrosis factor-α-induced cytotoxicity in L929 fibrosarcoma cells (Morikawa *et al.* 2010). It also demonstrate anti-obesity effects by inhibiting pancreatic lipase activity (Morikawa *et al.* 2009) and has passed toxicity tests, suggesting potential benefits in weight management (Asao *et al.* 2009; Fajriaty *et al.* 2014). Moreover, *S. rarak* finds application in the synthesis of silver (Yudha *et al.* 2013) and ZnO nanoparticles (Maryanti *et al.* 2014), useful for photo-degrading rhodamin B as environmental pollutants (Umar *et al.* 2022). It can also be synthesized with sulfur as a catalyst (Banon *et al.* 2022). Additionally, its derivative compounds exhibit potential as acid surfactants (Cahyana *et al.* 2020) and sweet principles (Chung *et al.* 1997). Lastly, scoping review showed that *S. rarak* biochar has the potential to improve andosol soil quality (Arum & Wikaningrum 2022).

CONCLUSION

The substantial number of publications written in Indonesian, as indexed by Google Scholar, highlights the enthusiastic involvement of Indonesian researchers in the exploration of *S. rarak* bioprospection. Scopus indexed 32 scientific articles regarding *S. rarak*, composed by 23 authors between 1990 and 2022, with a cumulative citation count of 387. Notably, Indonesia, the Indonesian Research Institute for Animal Production, and Elizabeth Wina stand out as the most productive country, institution, and author, respectively. The research is clustered based on chemistry, biology, medicine, and physics approach. The bioprospection of *S. rarak* fruit encompasses various applications, including animal feed supplementation, molluscicide, herbicide, antimicrobial, antitumor, anti-obesity, surfactant, catalyst, nanoparticle, and soil remediation. Surprisingly, research on the efficacy of detergents derived from *S. rarak* has not been published in a highly reputable international journal, despite its traditional utilization over an extended period. Despite the exclusive focus on *S. rarak* fruit or seed as promising organ in all articles, none have addressed leaves or other plant organs. In the future, Indonesian researchers are encouraged to comprehensively explore the potential of *S. rarak*, especially its leaves, for additional valuable phytochemicals beyond saponin. This exploration could position *S. rarak* as a signature bioresource with significant economic value, serving as a source for medicine, animal feed supplements, and organic pesticides, expanding beyond its current use in detergents within society.

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