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Trends and Emerging Frontiers in Sago (*Metroxylon Sagu*) Research: A Comprehensive Bibliometric Review

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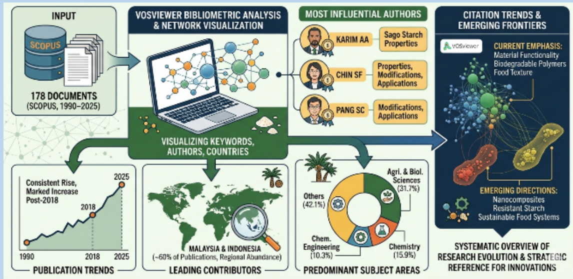
Abstract: Sago starch, derived from *Metroxylon sagu*, has garnered significant scientific and industrial interest as a sustainable carbohydrate source for food and non-food applications. This study conducted a comprehensive bibliometric analysis of global research on sago starch from 1990 to 2025 using VOSviewer and the Scopus database. A total of 178 documents were identified, indicating a consistent increase in publications, with a marked rise post-2018. Approximately 60% of publications originate from Malaysia and Indonesia as the leading contributors, reflecting the regional abundance of sago resources and expanding research initiatives in Southeast Asia. The predominant subject areas include Agricultural and Biological Sciences (31.7%), chemistry (15.9%), and Chemical Engineering (10.3%), underscoring the multidisciplinary nature of sago research. Karim AA, Chin SF, and Pang SC. were recognized as the most influential authors, significantly contributing to studies on sago starch properties, modifications, and applications. Citation trends demonstrate a strong emphasis on material functionality, biodegradable polymers, and enhancing food texture. The overlay visualization further identifies emerging research frontiers, such as nanocomposite development, resistant starch formation, and the application of sago in functional and sustainable food systems. Overall, this bibliometric assessment provides a systematic overview of the evolution of research, key contributors, and thematic transitions in sago starch studies. These findings serve as a strategic reference for future research directions and interdisciplinary collaborations in developing high-value sago-based innovations.



Keywords: sago starch, bibliometric analysis, research trends, global collaboration, functional applications, sustainable bioresources

Introduction

Sago (*Metroxylon sagu* Rottb.) is a tropical palm renowned for its starch production and plays a pivotal role in food security and bioresource sustainability, particularly in Southeast Asia and the Pacific regions (1). Unlike annual crops, sago thrives in swampy and marginal lands that are unsuitable for other staple crops, offering a resilient and renewable starch source with minimal agricultural inputs (2). The extracted sago starch serves not only as a traditional food ingredient but also as a promising raw material for developing biodegradable polymers, functional foods, and industrial biomaterials (3,4). From a food perspective, sago starch has been traditionally consumed in various local forms, such as *papeda*, *linut*, and *bubur sagu*. Beyond its traditional use, sago starch possesses physicochemical and functional properties that are comparable, and in some cases superior, to those of conventional starches such as cassava, corn, and potato (5). It has a high amylopectin content, low gelatinization temperature, and excellent paste clarity, making it suitable for a wide range of food applications, such as thickeners, stabilizers, sweetener and gelling agents (6,7). In addition, recent studies have explored sago starch as a raw material for functional foods because of its potential to form resistant starch fractions that improve glycemic control and gut health (8).

Economically, sago plays an essential role in supporting rural livelihoods and small-scale industries in regions such as Eastern Indonesia and Sarawak (Malaysia). The sago-based value chain from palm cultivation and starch extraction to derivative product development has the potential to strengthen local economies while contributing to food security and circular bioeconomy (9). Environmentally, sago plants contributes to sustainable land use by maintaining wetland ecosystems and preventing peat degradation. Consequently, sago aligns well with the global agenda for low-carbon and sustainable food production systems (10).

However, despite its economic and environmental relevance, global scientific attention to sago starch remains relatively limited. This disparity can be attributed to several structural constraints. The cultivation of sago palm (*Metroxylon sagu*) is largely confined to Southeast Asia, limiting its global visibility and research participation. In addition, the relatively underdeveloped industrial processing infrastructure and lower global commercial demand have contributed to reduced research investment. Furthermore, technical and logistical challenges in harvesting and starch extraction continue to hinder large scale utilization. Compared with the vast research output on cassava, corn, and potato starches, which dominate the starch-based food and biomaterial industries, sago starch has received modest international visibility (11). For instance, cassava starch research has produced thousands of indexed publications focusing on modification technologies, industrial

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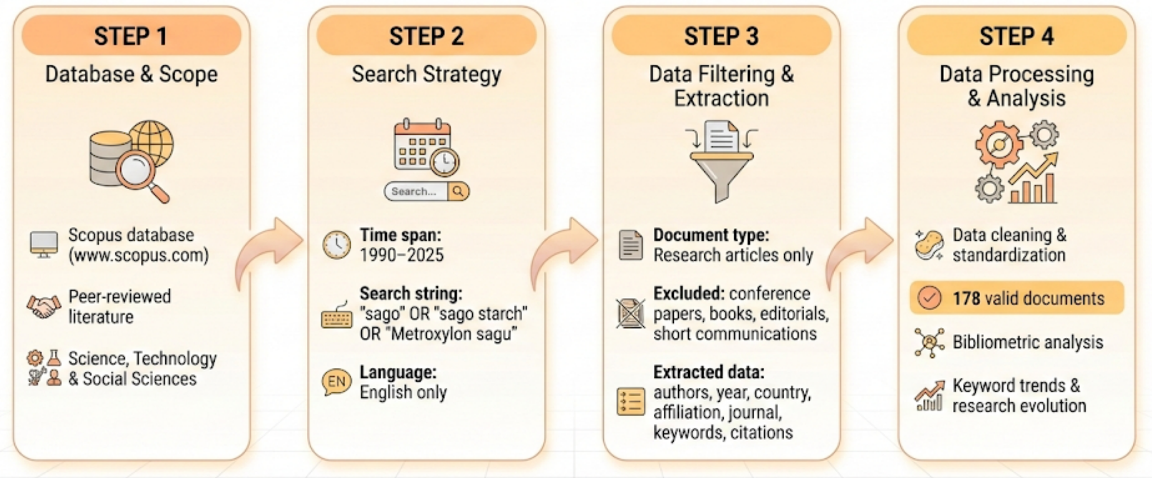

Figure 1: Flowchart of bibliometric data collection and analysis for global sago starch research (1990–2025).

applications, and functional characterization, whereas sago starch-related studies represent only a small fraction of this volume of research (12). This disparity indicates a research gap and underrepresentation of sago starch in global starch science, despite its promising characteristics and regional importance.

Scientific investigations on sago starch have expanded gradually over the past three decades, particularly after 2010, coinciding with increased awareness of sustainable resources and renewable biomaterials in the field. The growing number of studies covers diverse topics, including starch extraction methods, structural and rheological characterization, chemical and enzymatic modifications, and applications in biodegradable packaging, hydrocolloids, and functional food. However, the knowledge generated remains fragmented and regionally concentrated, with limited collaboration between Southeast Asian researchers and international institutions. Consequently, the scientific development of sago starch lags behind its potential value as a renewable, functional ingredient and biomaterial source. These limitations highlight that sago starch remains an underexplored research area, thereby justifying the need for a comprehensive bibliometric analysis. In this context, there is a strong need to systematically map and evaluate the development of global research on sago starch (13).

Bibliometric analysis provides an effective method for achieving this goal by quantitatively examining publication patterns, research networks, and thematic evolution within a specific field. Bibliometrics goes beyond conventional reviews by integrating statistical and visualization techniques to identify key trends, influential authors, core journals, and emerging themes (14). It can reveal how a field has evolved over time, which topics dominate the discourse, and where new opportunities for collaboration and innovation exist. Several previous bibliometric reviews have been conducted on related topics such as starch modification, food hydrocolloids, and biodegradable materials; however, no comprehensive bibliometric mapping has been dedicated to sago starch research. Such a review is essential to establish a holistic understanding of how the field has progressed, to pinpoint scientific hotspots, and to project the direction of future research. By examining global publication data, this study aimed to uncover how sago starch research aligns with contemporary challenges in food technology, material science, and sustainable resource management.

Therefore, this study aims to provide a comprehensive bibliometric overview of sago starch research published between 1990 and 2025. Using the Scopus database as the primary data source, this study integrates VOSviewer to visualize patterns in publication trends, co-authorship networks, country collaborations, keyword co-occurrences, and citation impacts. This approach identifies the major contributors, key research themes, and emerging scientific frontiers that define the evolution of sago starch research. The findings are expected to serve as a valuable reference for researchers, industries, and policymakers by highlighting potential directions for innovation, interdisciplinary collaboration, and sustainable utilization of sago starch in food and non-food applications. While sago starch is currently a regionally significant resource, it holds strong potential for global applications, particularly in sustainable food systems and bio-based materials.

Scientific literature research

Data Collection

The bibliometric data for this study were sourced from the Scopus database (www.scopus.com), which is renowned for its extensive coverage of peer-reviewed literature in the fields of science, technology, and social sciences (Figure 1). The search spanned 1990 to 2025, aiming to capture the long-term evolution of global sago starch research. The search string employed was "*sago*" OR "*sago starch*" OR "*Metroxylon sagu*", ensuring the inclusion of both general and specific terminologies related to sago palm and its starch. To maintain the consistency and quality of the bibliometric data, only research articles published in English were included. Non-indexed materials, such as conference proceedings, books, editorials, and short communications, were excluded to prevent duplication and ensure data accuracy. The retrieved records contained information on the authors, publication year, country of origin, institutional affiliations, source titles, keywords, and citation counts. Following data cleaning and standardization, 178 valid documents were identified.

Data Processing

The bibliographic data exported in CSV format were analyzed using VOSviewer (www.vosviewer.com) version 1.6.15. These analytical tools facilitate the visualization and quantification of structural relationships within datasets (15). Four primary analyses were conducted: (1) publication trend

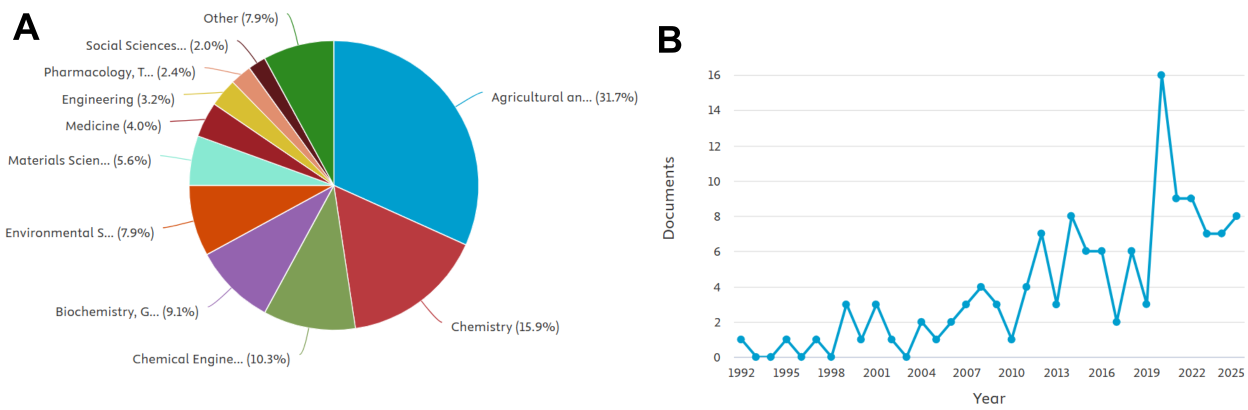

Figure 2: The main research topic related to sago (A) and annual scientific production of articles on sago (B) in Scopus

analysis, aimed at identifying temporal growth and research dynamics; (2) co-authorship and country collaboration network analysis, which examined research partnerships among authors and institutions; (3) keyword co-occurrence and thematic mapping, designed to detect major research themes and emerging frontiers; and (4) citation and source impact analysis, which determined the most influential publications, authors, and journals contributing to sago starch research. The integration of these analyses provides a comprehensive overview of the intellectual structure, collaboration patterns, and thematic evolution of global sago starch studies.

Analysis of publications

General analysis

The search method described above outlined the disciplinary distribution of 178 Scopus-indexed publications related to sago starch research which were divided into 11 categories of research topics (Figure 2). Most studies were categorized under Agricultural and Biological Sciences (31.7%), indicating a predominant focus on plant physiology, starch extraction, and the utilization of *Metroxylon sagu* as an agricultural commodity. The second-largest category was Chemistry (15.9%), which reflects research centered on the molecular structure, composition, and modification of sago starch for industrial or food applications. Chemical Engineering (10.3%) and Biochemistry, Genetics, and Molecular Biology (9.1%) also constitute significant portions, suggesting an increasing interdisciplinary interest in starch conversion processes, enzymatic hydrolysis, and biopolymer innovation. Studies in Environmental Science (7.9%) demonstrate a growing interest in the environmental sustainability and material functionality of sago-derived starch products, such as biodegradable films and renewable bio-based materials. Smaller yet noteworthy contributions were observed in medicine (4%), engineering (3.2%), and pharmacology (2.4%) collectively underscoring the potential of sago starch in biomedical, pharmaceutical, and health-related research. The remaining publications social science (2%) and other fields (7.9%), illustrating the broad and multidisciplinary scope of sago starch research, which integrates food security, economic value, and sustainability.

The temporal distribution of publications on sago starch research from 1990 to 2025 is depicted in Figure 2. The trend indicates a gradual increase in research activity over the past three decades, with a significant surge in publication output post-2010, reflecting the growing scientific and industrial interest in *Metroxylon sagu* as a sustainable starch source. Early studies conducted between 1990 and 2005 were sporadic, yielding fewer than five papers annually, and primarily focused on starch extraction and basic characterization. A notable acceleration occurred between 2010 and 2020, coinciding with advancements in bioprocessing, food hydrocolloid modification and sustainable biopolymer applications. The year 2019 marked a peak in publications, with 16 articles, suggesting intensified research collaborations and broader recognition of the potential of sago starch in food and material sciences. Although the number of publications slightly declined after 2020, the continued output through 2025 indicates persistent and expanding interest in this topic. This temporal pattern underscores the transition of sago starch research from a regional or agricultural focus to a multidisciplinary scientific domain involving chemistry, biotechnology, and environmental sustainability issues.

Research Trend

Comprehensive bibliometric analysis revealed that research on sago starch is predominantly situated within the realms of agricultural and biological sciences, with subsequent contributions from chemistry, chemical engineering, and biochemistry. This distribution highlights the sustained scientific interest in uncovering the core properties of *Metroxylon sagu* starch, such as its physicochemical attributes, pasting behavior, and rheological characteristics, which serve as a foundation for its diverse functional applications. Current research efforts are largely focused on modification techniques aimed at enhancing the technological capabilities of sago starch, including chemical and physical modifications, enzymatic hydrolysis, nanoparticle integration, and the creation of resistant starch (16). These strategies are intended to enhance key properties, such as viscosity stability, gel strength, thermal resistance, and digestibility, thereby enabling starch to fulfill the demands of emerging food sectors (17).

Although interest in sago starch has persisted for over 30 years, the number of publications has surged in the last decade, reflecting a growing acknowledgment of sago as a sustainable tropical starch with distinct ecological and economic benefits. The introduction of advanced analytical methodologies, such as DSC, FTIR, XRD, and response surface methodology, has propelled further research aimed at optimizing extraction processes and customizing functional properties for specific

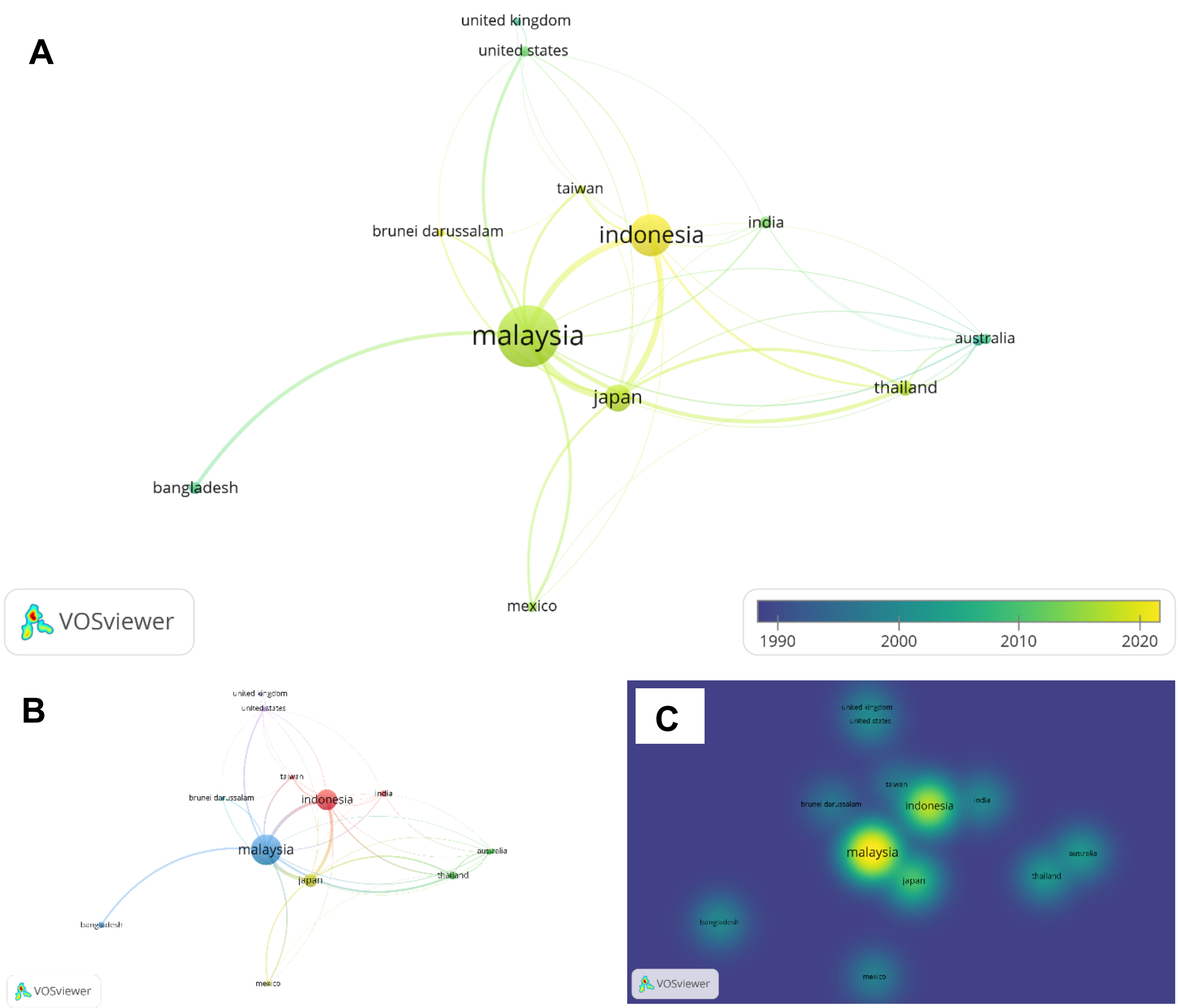

Figure 3: Collaborative networks among the most prolific countries in sago research, as determined by a VOSviewer bibliometric analysis of the Scopus database Overlay by year (A), network (B), and density visualization (C).

uses (18). Despite its industrial promise, bibliometric data indicate that sago starch remains underexplored compared to global staples, such as tapioca, maize, and potato starch. Recent research has increasingly targeted value-added applications, particularly the development of biodegradable films, starch-based hydrogels, slow-digesting carbohydrates, and prebiotic formulations (19). The utility of sago starch is influenced by its amylopectin-rich composition, granule morphology, enzymatic responsiveness, and compatibility with biopolymer blends (20). To broaden its applicability, researchers have employed molecular modifications, hybridization with other polysaccharides processing technologies, mirroring the innovation trajectory observed in other industrial starches. Overall, the analysis indicates that sago starch research is evolving from basic characterization to advanced material development and health-focused These trends suggest that sago starch is becoming more significant in global discussions on sustainable resources, functional ingredients, and bio-based materials.

Top research institutions and countries

A VOSviewer bibliometric analysis of 178 Scopus-indexed publications identified distinct geographical clustering in global sago starch research. The top 15 contributing countries account for the majority of these documents, with research activity predominantly concentrated in Southeast Asian nations, where sago is naturally cultivated. Malaysia has emerged as the foremost contributor, producing over 40% of all publications (n ≈ 72), followed by Indonesia with approximately 20% (n ≈ 36). Japan ranks third with 15% (n ≈ 17), reflecting its strong, long-standing engagement in tropical agriculture and carbohydrate chemistry (Figure 3). Other contributing countries, including Thailand, Bangladesh, India, Australia, and Papua New Guinea, collectively contribute a smaller yet significant proportion of global output. Institutional analysis further underscores the regional concentration of expertise (15). The top 10 institutions represent a substantial share of all publications and are predominantly located in Malaysia, Indonesia, and Japan countries with active sago cultivation, processing industries, and relevant research infrastructure.

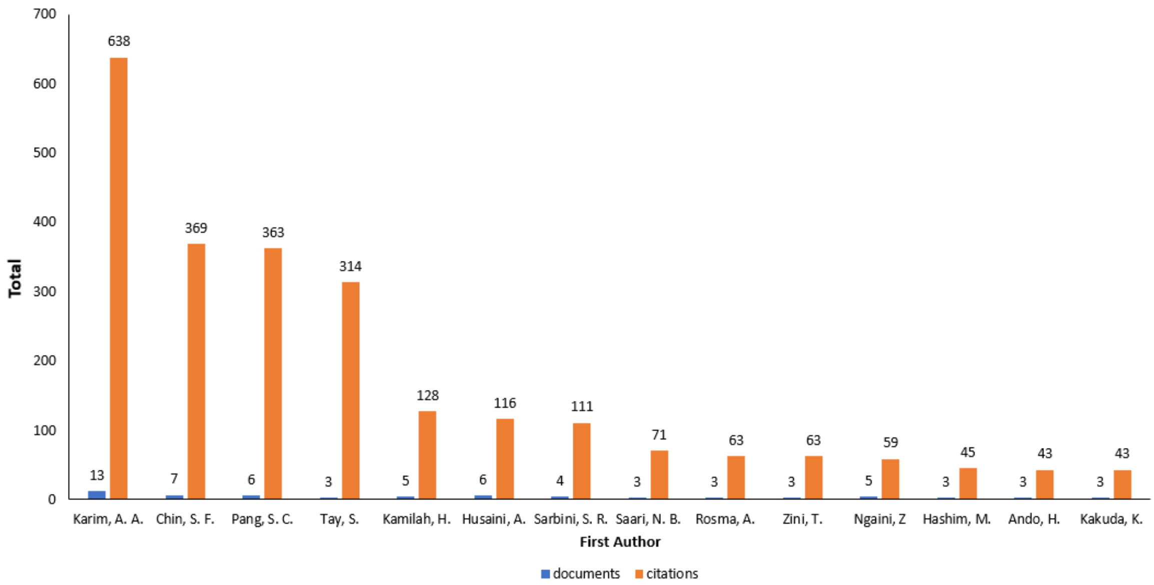

Figure 4: The most influential authors and highly cited contributions

Universiti Malaysia Sarawak (UNIMAS) leads with the highest number of publications (n ≈ 27), reflecting its strategic positioning within Malaysia's sago production region in Sarawak. This was followed by Universiti Putra Malaysia (UPM) and the School of Industrial Technology, Universiti Sains Malaysia (USM) both of which have contributed extensively to research on starch modification, food applications, and biopolymer development. Indonesian institutions, such as Universitas Gadjah Mada also feature prominently, supported by the country's expanding research on food technology and agricultural commodity utilization. Japanese universities, including Nagoya University, Yamagata University, and Ibaraki University, form the second major cluster of leading institutions, emphasizing Japan's continuing interest in starch science, biopolymer engineering, and tropical agriculture. Notably, several countries with substantial research capacity (e.g., the United States, the United Kingdom, and Canada) do not feature prominently among the top institutions, indicating that global expertise in sago starch research remains highly localized and tied to regions with strong environmental, cultural, and economic relevance.

Most global cited documents

We analysed the citation performance of articles in the sago starch research domain to identify the most influential authors and highly cited contributions. The findings indicate that highly cited publications are typically linked to authors who have produced foundational or widely referenced studies, which are often published earlier and frequently cited in subsequent research. As illustrated in Figure 4, Karim AA emerged as the most influential author, contributing 13 documents and amassing the highest number of total citations 638. This research article titled "Pasting and retrogradation properties of alkali-treated sago (*Metroxylon sagu*) starch" have significant citation impact suggests that Karim's work has been pivotal in shaping research directions related to the physicochemical properties, modification, and functional applications of sago starches with 185 citations (21). The second most cited author, Chin SF produced seven documents with 369 citations, followed closely by Pang SC with six documents and 363 citations.

These authors are commonly associated with studies on starch characterisation, modification techniques, and material functionality, indicating that research focusing on structure function relationships and applied starch science has garnered significant scholarly attention (22,23). Tay S also demonstrated a notable citation impact despite contributing only three documents, which collectively received 314 citations, highlighting that citation influence is not solely dependent on publication quantity but also on the scientific relevance and novelty of the work. The second tier of influential contributors includes Kamilah H, Husaini A, and Sarbini SR, each of whom produced between four and six documents and accumulated between 110 and 130 citations. Their research primarily addresses enzymatic modification, resistant starch development and nutritional functionality, reflecting the growing interest in the health-oriented and value added applications of sago starch.

Authors such as Saari, N.B., Rosma, A., and Zini, T. demonstrated moderate citation counts (approximately 60–70 citations), indicating consistent but more specialised research contributions. Overall, the citation distribution reveals a highly skewed pattern in which a small number of authors account for a disproportionately large share of the total citations. This pattern suggests that sago starch research has been strongly influenced by a limited number of seminal studies, particularly those addressing fundamental starch properties and processing strategies of sago starch (24). These findings underscore the importance of these key contributors in advancing the scientific understanding and industrial relevance of sago starch, while also highlighting opportunities for emerging researchers to expand the field through novel applications and interdisciplinary research approaches.

Most relevant authors

Based on the bibliometric analysis of author productivity and citation impact (Figure 5), Karim AA emerges as the most influential and highly cited author in this research field. Karim AA

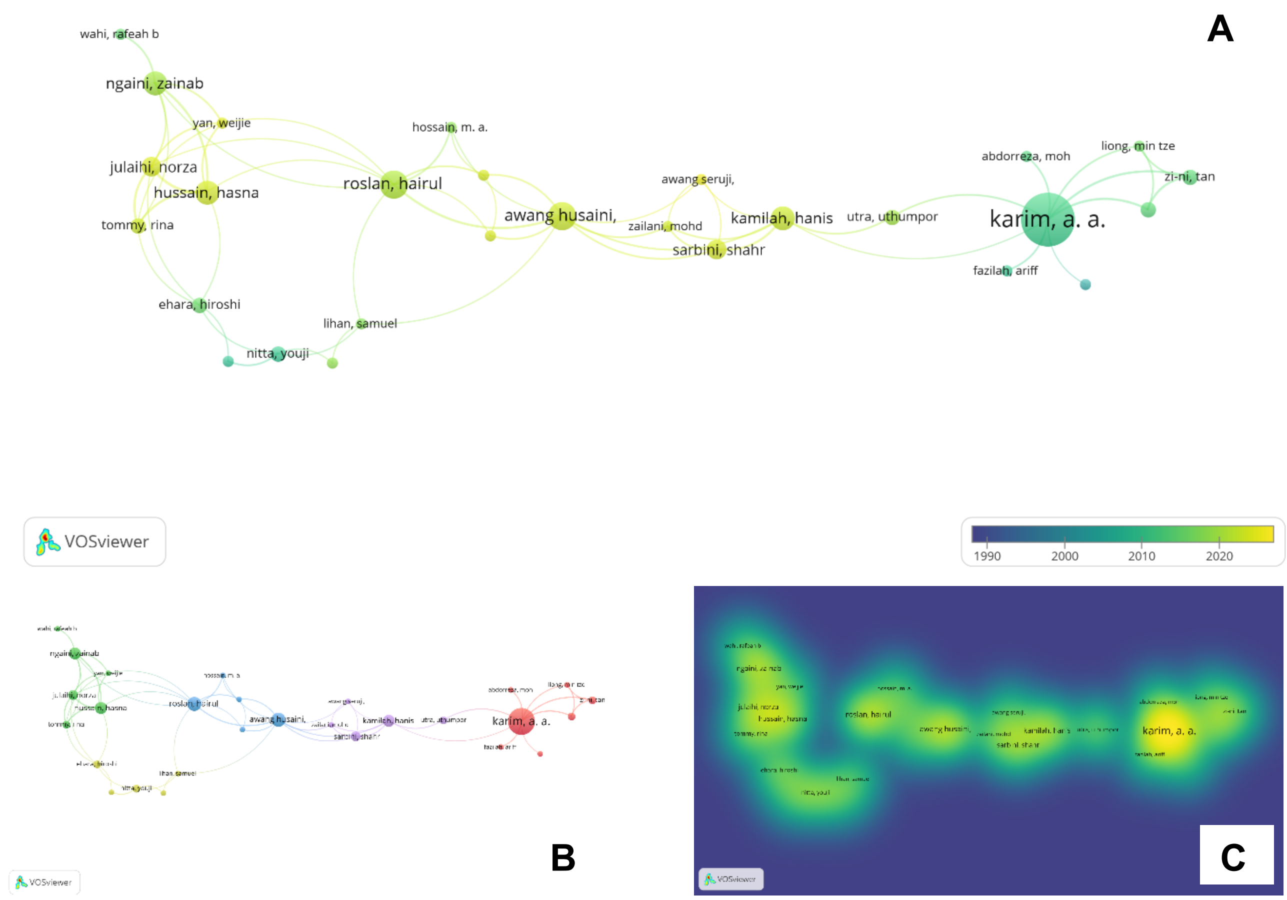

Figure 5: Collaborative networks among the author in sago research, as determined by a VOSviewer bibliometric analysis of the Scopus database Overlay by year (A), network (B), and density visualization (C).

has published 13 documents, which collectively received 638 citations, indicating a strong and sustained academic influence. His prominent position is also clearly reflected in the co-authorship network visualization, where he appears as the largest node, highlighting both his productivity and central role in scholarly collaborations (25). Several of his publications have become key references, particularly those focusing on functional properties and applications of bio-based materials, which have been widely cited by subsequent studies. The collaborative network among authors was further examined using VOSviewer, revealing several interconnected clusters that indicate established research groups and cross-institutional collaborations (15). The network visualization highlights Karim AA as a central hub, strongly connected with authors such as Kamilah H, Saribini SR., and Zilani M, suggesting long-term collaborative relationships. Another prominent cluster is centered around Roslan H and Awang H, who are closely linked with multiple co-authors, indicating an active collaborative subgroup contributing to thematic continuity in the field.

Additionally, a distinct cluster comprising Ngaini Z, and Hussain H reflects a tightly connected research team, possibly originating from shared institutional affiliations or research projects (26,27). Smaller clusters involving authors such as Ehara H, Nitta Y, and Lihan S suggest international collaboration, particularly linking Asian research institutions (1,7,28). Overall, the author-based bibliometric findings demonstrate that the field is driven by a combination of highly productive core authors and strategic collaborative networks. Senior authors with high citation counts act as intellectual anchors, while interconnected clusters facilitate knowledge exchange and thematic expansion. This collaborative structure has contributed significantly to the growth, visibility, and scientific maturity of the research domain.

Most relevant journals

The source analysis indicates that publications related to sago and sago starch research are moderately concentrated within a limited number of core journals. As illustrated in Figure 6, the top 10 journals collectively account for approximately 55–60% of the total Scopus-indexed documents, demonstrating the presence of dominant publication outlets while still reflecting a relatively diversified dissemination pattern typical of an interdisciplinary research field. Among these sources, *Starch/ Stärke* emerged as the most productive journal with 10 publications, contributing the highest share among all outlets (Table 1). This finding confirms the central role of this journal in disseminating studies focused on starch structure, physicochemical properties, gelatinization behavior, and starch

Table 1: Top 10 Most productive journals and their contribution to total publications for sago research

Rank	Journal	Country	Publisher	Impact Factor	Cite Score	H-index	Articles	Estimate Contribution
1	Starch/Stärke	Germany	Wiley-VCH GmbH	2.7	5.9	105	11	10.5%
2	IOP Conference Series: *Earth and Environmental Science*	UK	IOP Publishing	N/A	1.3	58	8	7.6%
3	Biodiversitas	Indonesia	Society for Indonesian Biodiversity	N/A	1.7	33	7	6.7%
4	AIP Conference Proceedings	USA	American Institute of Physics	0.1	0.7	90	5	4.8%
5	Plant Production Science	Japan	Taylor and Francis Ltd.	1.3	4.5	65	4	3.8%
6	Journal of Sustainability Science and Management	Malaysia	Universiti Malaysia Terengganu	0.8	1.5	24	4	3.8%
7	Journal of Food Processing and Preservation	UK	John Wiley and Sons Inc	2.5	6.9	71	4	3.8%
8	Food Hydrocolloids	Netherlands	Elsevier B.V.	21.7	12.4	235	4	3.8%
9	IOP Conference Series: *Materials Science and Engineering*	UK	IOP Publishing	N/A	0.5	74	4	3.8%
10	Rasayan Journal of Chemistry	India	Rasayan Journal of Chemistry	0.5	1.8	35	4	3.8%

modification topics that also dominate the main keyword clusters identified in the co-occurrence analysis. The IOP Conference Series: Earth and Environmental Science ranked second with 8 documents, followed by *Biodiversitas* with 7 publications. Together, the top three journals contributed nearly 30% of the total publications, indicating their strong influence on shaping the scientific discourse in this field.

The prominence of conference proceedings suggests that sago-related research is frequently communicated through applied, exploratory, and regionally driven studies, which are often presented in conference-based outlets prior to journal expansion. Journals contributing 4–5 documents, including *AIP Conference Proceedings*, *Food Hydrocolloids*, *Journal of Food Processing and Preservation*, and *Journal of Sustainability Science and Management*, collectively accounted for approximately 20% of the total output. These sources predominantly publish studies aligned with applied food technology, hydrocolloid functionality, sustainability assessment, and processing optimization, reinforcing the interdisciplinary nature of sago research. Overall, the distribution of publications across journals indicates that the field is still developing rather than mature, with no single high-impact journal monopolizing output. This pattern is consistent with emerging research domains that bridge food science, carbohydrate chemistry, agricultural systems, and environmental sustainability.

Keyword trends analysis

Keyword co-occurrence analysis was conducted to identify research trends and thematic structures in sago-related studies, as illustrated in Figure 6. to ensure clarity, only frequently occurring keywords were included, and general search terms were excluded from the interpretation. The analysis revealed five main keyword clusters, indicating distinct but interconnected research themes within the field. According Table 2, the first cluster is associated with resistant starch, *amylose*, *hydrolysis*, *microwave*, and *extrusion*, highlighting studies focused on starch modification and nutritional functionality, particularly the development of low-glycaemic and health-promoting starch products. The second cluster centers on sago starch, emphasizing *gelatinization*, *pasting*, and *rheological properties*, which reflect fundamental investigations into the physico-chemical behavior of sago starch during processing.

The third cluster focuses on sago palm (*Metroxylon sagu*) and includes keywords such as *genetic diversity*, *trunking*, and *extraction*, indicating research on botanical characteristics, genetic resources, and starch yield optimization. The fourth cluster relates to physicochemical properties and chemical modification processes, including *esterification* and *adsorption*, suggesting increasing interest in non-food and industrial applications. The fifth cluster links starch with enzymatic and bioprocess-related terms such as *glucoamylase* and *lactic acid*, reflecting the growing application of sago starch as a substrate for bioconversion and value-added products. Overall, the keyword network demonstrates a research shift from basic starch characterization toward functional, biotechnological, and sustainable applications of sago and sago starch.

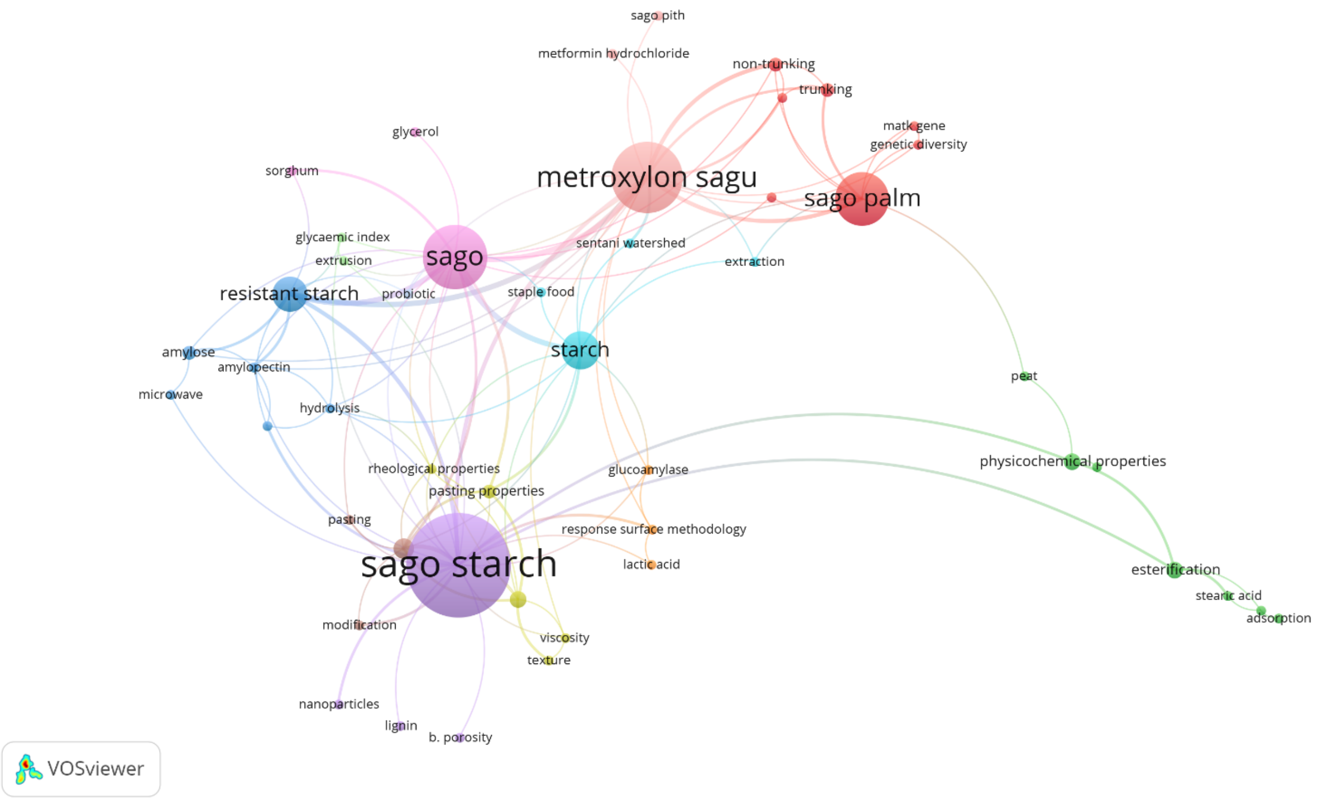

Figure 6: The keyword co-occurrence network of scientific publications on sago research generated using VOSviewer bibliometric analysis by density visualization of the Scopus database (1990–2025)

The keyword co-occurrence analysis revealed five distinct thematic clusters, indicating that sago research is structured around (i) sago palm biology and genetics, (ii) food and nutritional applications, (iii) starch structure and modification, (iv) physicochemical and functional properties of sago starch, and (v) chemical modification and environmental aspects. The dominance of the sago starch cluster confirms that physicochemical characterization and functional performance remain the primary research focus, while emerging clusters related to sustainability and environmental integration reflect recent research trends.

Table 2: Keyword clusters analysis of scientific publication of sago research in the Scopus collection database (1990–2025)

Cluster	Item
1	*sago palm*, *Metroxylon sagu*, *trunking*, *non-trunking*, *genetic diversity*, *extraction*
2	*sago*, *staple food*, *glycemic index*, *extrusion*, *probiotic*
3	*resistant starch*, *amylose*, *hydrolysis*, *microwave*
4	*sago starch*, *gelatinization*, *pasting properties*, *rheological properties*, *viscosity*, *texture*
5	*physicochemical properties*, *esterification*, *adsorption*, *stearic acid*, *peat*

Conclusion

This bibliometric review systematically maps the global research landscape on sago starch using Scopus-indexed publications. The results indicate a gradual but consistent increase in research output, particularly in recent years, reflecting growing interest in sago starch as a functional and sustainable carbohydrate source. However, compared with major commercial starches such as maize, cassava, and potato, sago starch remains relatively underrepresented in the global literature. The analysis reveals that research is primarily concentrated on physicochemical properties, gelatinization behavior, and starch modification, with these themes forming the core knowledge structure of the field. Emerging topics related to resistant starch, enzymatic processing, and value-added applications suggest a shift toward health-oriented and industrially relevant research directions. Publication and collaboration patterns further indicate that studies are dominated by a limited number of countries, with fragmented international collaboration networks.

Overall, the findings highlight significant opportunities for future research, particularly in advanced material applications, bioprocessing, and comparative performance studies with established starch sources. Strengthening interdisciplinary and international collaborations will be critical to accelerating innovation and enhancing the global utilization of sago starch.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

All research articles and review records analyzed in this study were downloaded from the Scopus database in CSV format and are provided as supplementary materials. This link yielded all of the evaluated search results. https://www.scopus.com/term/analyzer.uri?sort=plf-f&src=s&sid=7994214c71dd132782c8b79df9b6f700&sot=a&sdt=a&cluster=scosubtype%2c%22dp%22%2cf%2c%22ch%22%2cf&sl=87&s=%28TITLE-ABS-KEY%28sago%29+AND+TITLE-ABS-KEY%28sago+starch%29+AND+TITLE-ABS-KEY%28metroxylon+sagu%29%29&origin=resultslist&count=10&analyzeResults=Analyze+results

Author's contribution

The authors confirm contribution to the paper as follows: MA Islamy, contributed to the study conception and design, data collection, bibliometric analysis, and visualization. He performed data processing, interpretation of results, and manuscript drafting. The author reviewed and approved the final version of the manuscript.

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Conflicts of interest

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

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References

1. Ehara H, Toyoda Y. Sago Palm: Multiple Contributions to Food Security and Sustainable Livelihoods. Johnson D, editor. Springer Open. Gateway East: Springer Nature; 2018. https://doi.org/10.1007/978-981-10-5269-9
2. Sunarti TC, Dwiko M, Derosya V, Meryandini A. Effect of Microwave Treatment on Acid and Enzymes Susceptibilities of Sago Pith. Procedia Chem. 2012;4:301–7. http://dx.doi.org/10.1016/j.proche.2012.06.042
3. Karim AA, Tie AP, Manan DMA, Zaidul ISM. Starch from the Sago (*Metroxylon sagu*) Palm Tree Properties, Prospects, and Challenges as a New Industrial Source for Food and Other Uses. Compr Rev Food Sci Food Saf. 2008;7(3):216–78. https://doi.org/10.1111/j.1541-4337.2008.00042.x
4. Du C, Jiang F, Jiang W, Ge W, Du S kui. Physicochemical and structural properties of sago starch. Int J Biol Macromol. 2020;164:1785–93. https://doi.org/10.1016/j.ijbiomac.2020.07.310
5. Thompson MS, Hui-Yan T, Kathleen MM, Shamsudin SM, Abd Rashed A, Sarbini SR. An in vivo study: Prebiotic evaluation of the resistant Starch from *Metroxylon sagu* on obesity using fat-induced rats. Bioact Carbohydrates Diet Fibre. 2023;30. https://doi.org/10.1016/j.bcdf.2023.100365
6. Zhu F. Recent advances in modifications and applications of sago starch. Food Hydrocoll. 2019;96(May):412–23. https://doi.org/10.1016/j.foodhyd.2019.05.035
7. Nitta Y. Morphological and anatomical characteristics of sago palm starch. Sago Palm Mult Contrib to Food Secur Sustain Livelihoods. 2018;(D):181–9. https://doi.org/10.1626/pps.5.139
8. Wahjuningsih SB, Marsono Y, Praseptiangga D, Haryanto B. Resistant starch content and glycaemic index of Sago (*Metroxylon spp*.) starch and red bean (*Phaseolus Vulgaris*) based analogue rice. Pakistan J Nutr. 2016;15(7):667–72. https://doi.org/10.3923/pjn.2016.667.672
9. Nishimura Y. Sago starch: Transformation of extraction and consumption processes in traditional Indonesian societies. Sago Palm Mult Contrib to Food Secur Sustain Livelihoods. 2018;221–9. https://doi.org/10.1007/978-981-10-5269-9_16
10. Ehara H, Toyoda Y, Johnson D V. Sago palm: Multiple contributions to food security and sustainable livelihoods. Sago Palm: Multiple Contributions to Food Security and Sustainable Livelihoods. 2018. 1–330 p. https://doi.org/10.1007/978-981-10-5269-9
11. Adawiyah DR, Akuzawa S, Sasaki T, Kohyama K. A comparison of the effects of heat moisture treatment (HMT) on rheological properties and amylopectin structure in sago (*Metroxylon sagu*) and arenga (*Arenga pinnata*) starches. J Food Sci Technol. 2017;54(11):3404–10. https://doi.org/10.1007/s13197-017-2787-1
12. Wardis G. Socio-economic factors that have influenced the decline of sago consumption in small islands: a case in Rural Maluku, Indonesia. South Pacific Study. 2014;34(2):99–116.
13. Dimara PA, Purwanto RH, Auri A, Angrianto R, Mofu WY. Production potential of sago forests in different habitat types in Sentani watershed, Papua, Indonesia. Biodiversitas. 2023;24(7):3924–31. https://doi.org/10.13057/biodiv/d240731
14. Bartol T, Mackiewicz-Talarczyk M. Bibliometric Analysis of Publishing Trends in Fiber Crops in Google Scholar, Scopus, and Web of Science. J Nat Fibers. 2015;12(6):531–41. https://doi.org/10.1080/15440478.2014.972000
15. Che HA, Leong WY. Thermostable enzyme research advances: a bibliometric analysis. J Genet Eng Biotechnol. 2023;21(1):37. https://doi.org/10.1186/s43141-023-00494-w
16. Zaman SA, Kamilah H, Seruji AZR, Pa'ee KF, Sarbini SR. Physicochemical properties and the functional food potential of resistant sago (*Metroxylon sagu*) starch type IV produced by phosphorylation/acetylation treatment. J Food Meas

Charact. 2022;16(2):1702–9. https://doi.org/10.1007/s11694-021-01263-4

17. Tuan Mohamood NFAZ, Zainuddin N, Ahmad AM, Tan SW. Preparation, optimization and swelling study of carboxymethyl sago starch (CMSS)-acid hydrogel. Chem Cent J [Internet]. 2018;12(133):1–10. https://doi.org/10.1186/s13065-018-0500-8
18. Abiddin NFZ, Yusoff A, Noorlaila A. Preparation and physicochemical properties of octenyl succinic anhydride (OSA) modified sago starch. Malaysian J Anal Sci. 2016;20(4):806–11. http://dx.doi.org/10.17576/mjas-2016-2004-13
19. Nozaki K, Nuyim T, Shinano T, Hamada S, Ito H, Matsui H, et al. Starch properties of the sago palm (*Metroxylon sagu* Rottb.) in different soils. Plant Foods Hum Nutr. 2004;59(3):85–92. https://doi.org/10.1007/s11130-004-0031-4
20. Sulaiman TNS, Wahyono null, Bestari AN, Aziza FN. Preparation and Characterization of Pregelatinized Sago Starch (PSS) from Native Sago Starch (NSS) (*Metroxylon* sp.) and its Evaluation as Tablet Disintegrant and Filler-Binder on Direct Compression Tablet. Indones J Pharm. 2023;33(2):251–60. https://doi.org/10.22146/ijp.3543
21. Karim AA, Nadiha MZN, Chen FK, Phuah YP, Chui YM, Fazilah A. Pasting and retrogradation properties of alkali-treated sago (*Metroxylon sagu*) starch. Food Hydrocoll. 2008;22(6):1044–53. https://doi.org/10.1016/j.foodhyd.2007.05.011
22. Chin SF, Romainor ANB, Pang SC, Lee B, Hwang SS. pH-Responsive Starch-Citrate Nanoparticles for Controlled Release of Paracetamol. Starch/Staerke. 2019;71(9–10). https://doi.org/10.1002/star.201800336
23. Tay SH, Pang SC, Chin SF. A facile approach for controlled synthesis of hydrophilic starch-based nanoparticles from native sago starch. Starch/Staerke. 2012;64(12):984–90. https://doi.org/10.1002/star.201200056
24. Hunyek A, Sirisathitkul C, Mahaphap C, Boonyang U, Tangwatanakul W. Sago starch: Chelating agent in Sol-gel synthesis of cobalt ferrite nanoparticles. J Aust Ceram Soc. 2017;53(1):173–6. https://doi.org/10.1007/s41779-017-0022-1
25. Saavedra-Cordova MA, Mosilot-Acosta VS, Grandez-Yoplac DE, Chavez SG, Guadalupe GA. Advances in Resistant Starch Research from Agro-Industrial Waste: A Bibliometric Analysis of Scientific Trends. Foods. 2025;14(16):1–19. https://doi.org/10.3390/foods14162815
26. Ngaini ZB, Noh F, Wahi RB. Esterified sago waste for engine oil removal in aqueous environment. Environ Technol. 2014;35(22):2761–6. https://doi.org/10.1080/09593330.2014.920051
27. Hussain H, Mustafa Kamal M, Al-Obaidi JR, Hamdin NE, Ngaini ZB, Mohd-Yusuf Y. Proteomics of Sago Palm Towards Identifying Contributory Proteins in Stress-Tolerant Cultivar. Protein J. 2020;39(1):62–72. https://doi.org/10.1007/s10930-019-09878-9
28. Lihan S, Benet FB, Awang Husaini AAS, Apun KA, Roslan HA, Hassan H. Isolation and identification of plant growth promoting rhizobacteria from sago palm (*Metroxylon sagu*, rottb.). Trop Life Sci Res. 2021;32(3):39–51. https://doi.org/10.21315/tlsr2021.32.3.3