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A Bibliometric Analysis of Global Research Trends on Virgin Coconut Oil as a Functional Food

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ABSTRACT

Virgin coconut oil (VCO) is increasingly studied as a functional food due to its bioactive components, particularly medium-chain fatty acids (MCFAs) and phenolic antioxidants. This study maps the global research landscape on VCO as a functional food using bibliometric tools. Data were retrieved from the Scopus database (exported 15 December 2024) covering 2007–2024, using the query TITLE-ABS-KEY ("virgin coconut oil") AND TITLE-ABS-KEY ("food"). From 219 records, manual screening retained 190 documents for analysis. Bibliometric analyses were conducted using R (Bibliometrix/Biblioshiny) and VOSviewer, including descriptive performance analysis, citation analysis, co-authorship/country collaboration mapping, and keyword co-occurrence thematic clustering. Publication output increased over time, peaking at 30 papers in 2023. India was the most productive country (160 publications), followed by Malaysia (143) and Indonesia (142). Key thematic clusters focused on (i) VCO bioactivity and functional claims (antioxidant/anti-inflammatory and metabolic outcomes), (ii) antimicrobial properties linked to lauric acid/monolaurin, and (iii) processing and quality innovations (extraction optimization, nanoemulsion/microencapsulation, and FTIR-chemometrics for authentication). Overall, this analysis provides a roadmap for future research, highlighting the need for standardized clinical trials, harmonized quality standards, and sustainable processing innovations to strengthen evidence and translation.

1. INTRODUCTION

The increasing burden of chronic diseases such as obesity, diabetes, and cardiovascular disorders continues to dissolve any progress made in the global health scenario [1-3]. Such lifestyle-oriented diseases, alongside sedentary behavior and poor dietary habits, are the reason preventive health care measures are urgently needed. Functional foods have emerged as a potential counter to these challenges, considering that they are defined as products that have health benefits beyond basic nutrition. Such foods significantly address chronic illnesses and maintain good health by narrowing the gap between health and nutrition [4].

Virgin coconut oil (VCO) is on the rising scale of potential interest in functional foods due to its natural sources and abundance of bioactive substances. VCO has been extracted from fresh coconut kernels without cooking oil and is still pampered with medium-chain fats, antioxidants, and phenolic compounds. Such components have been proven to possess numerous health benefits, including alleviation of oxidative stress, lipid metabolism improvement, immune enhancement, and inflammation reduction [5]. Due to all these properties, VCO can be classified as an all-purpose dietary supplement, corresponding to increasing demand for natural and health-beneficial goods among consumers.

In the modern world, VCO is used in many culinary and non-culinary ways and is starting to gain recognition as a functional food [6]. Its enhanced antibacterial and antifungal properties make it a suitable candidate for improved public health outcomes because it can mitigate oxidative stress, assist in lipid metabolism, and enhance the immune system. In addition, VCO's stability and bioavailability have improved as a result of technological advancements, including nanoemulsion and microencapsulation, which extend the oil's usage in the functions of food, pharmaceuticals, and cosmetics [7]. Considering VCO's role in finding global sustainable health solutions, the increasing literature around VCO, especially in the context of health consequences, seems promising. VCO is an important ingredient in addressing global health issues defined by poor lifestyles.

The prospects of VCO as an anti-microbial, anti-inflammatory, and antioxidant agent have propelled new lines of academic research and commercial applications. Existing and forthcoming research broadly supports the ability of VCO to be useful in combatting a plethora of health conditions, such as that aforementioned, as well as several others, including

fungal infection, oxidative stress, and chronic inflammation [8]. Moreover, encouraging results render it as not only aiming at managing such conditions but also preventing lifestyle-induced diseases, increasing the value of the oil as a functional food.

Advancements in technology have positively impacted the bioavailability and applications of VCO. The use of microencapsulation and nanoemulsion has improved the stability and delivery of the bioactive constituents of VCO. Treatment with nanoemulsion technology makes the active ingredient more soluble and absorbable, while microencapsulation technology shields active substances from environmental factors to prolong the product's shelf life and allow incorporation into various foods or pharmaceuticals and cosmetics [9, 10]. Such technological improvements have increased the potential applicability of VCO in many areas and illustrate its scope as a functional food ingredient.

In line with progress, the VCO global research panorama is quite depressing as it is not holistic in a single discipline focus. The topics are diverse, covering chemical analysis, health advantages, and even new technologies. However, none contribute to the development of a coherent system that would allow one to have a clear picture or identify the main currents. This fragmentation limits the understanding of VCO's scope to address global health problems. More so, where there are no understanding or focused approaches, there is a great risk of missing some ideas for sharing, developmental content creation, and implementation, which emphasizes the necessity of an ordered structure in the appraisal of VCO studies [11]. As such, filling these gaps using systematic bibliometric analysis can offer new information as regards the present, past, and future of the underlying field of work.

Nonetheless, a broad range of issues remains in the space of VCO research, and that somewhat limits the scope of the field to reach its maximum potential. In broader terms, one of the issues involves considerable confusion, or better yet, an annual production of research work, which hampers a grasp of the turning of events in the specific field. In addition, authors, journals, institutions, and countries with a significant share in research are hardly recognized. This gap makes it difficult to identify and support the leading forces driving innovation in VCO research.

A further distinct difficulty is a disconnect between authors, institutions, and regions' cooperation networks. It substantially disentangles the prospects of synergy while inhibiting global knowledge growth. Moreover, there is an absence of mapping of global and local impactful works, which restricts the awareness of highly impactful research and its contribution to future research. Also, the more novel areas and the missing concentration subjects, like developments in nanoemulsion and microencapsulation techniques, often receive little attention within the general research context, thus deepening the fragmentation of the discipline.

To conclude, there is insufficient knowledge of interoperable networks, which are essential for VCO research and innovation. Such networks are indispensable since, without them, strategic links and cross-disciplinary research can be missed too. All these challenges indicate that it is necessary to develop a coherent strategy for assessing and bringing together the already established knowledge, understanding, new developments, and collaborative initiatives. This method helps in addressing most of the challenges to VCO research concerning achieving its full functional food potential by analyzing the history of bibliometric analysis as it streams the information regarding the research focus, influencers, and scope of the study [12].

Parallel to these challenges, a thorough and organized strategy is needed, and this is where bibliometric analysis comes in. Bibliometric analysis is a type of research that targets particular areas of academia and measures the production and citation of literature through quantitative evidence such as publication counts, keyword co-occurrences, and citation statistics networks [11]. Such provides researchers with a better comprehension of observed research trends even in the future.

A major advantage of bibliometric analysis is its utility in recognizing trends in research output and high productivity. As it delineates yearly scientific outputs and citation activity, it further delineates the growing path of a discipline. Owing to this, it also facilitates the determination of keywords, authors, journals, and institutions, allowing for the attribution of important players who contribute to the progress of VCO research. In addition, bibliometric analysis allows visualization of collaboration networks in detail, for instance, how authors, institutions, and countries operate with each other, which may assist in creating collaborative strategies and supporting cross-disciplinary research activities [13].

Bibliometric analysis also resolves the abovementioned issues by providing a holistic approach to future activities. It further elucidates scientific trends, locates key works on a global and local level, and brings to the fore developing areas of interest, including new developments in the nanoemulsion and microencapsulation sphere. In doing so, it ensures that VCO research is consistent with health and industrial-related parameters at the international level. In the same breath, it enhances the prospects of collaborative networks, facilitating innovation and better connections among isolated research efforts.

In the end, bibliometric evaluation is used as the greatest instrument in learning about the research and determining the course in which VCO shall be investigated in the future. It is through bibliometric analysis that gaps and grey areas in VCO as a functional food industry are discovered, and attention is drawn to them [11].

As such, this research aims to respond to critical research problems posed by VCO concerning the challenges and opportunities presented by the preceding studies. These problem statements aim to render a comprehensive and structured overview of the existing research status:

1. In what ways have the annual global production and provision of cities that relate to VCO differed over time?
2. Which mini-groups, including authors, journals, institutions, and countries, are pooled to enhance the VCO research paradigm?
3. What does the global map of VCO research look like regarding collaboration networks among researchers, nodes, and areas?
4. What works stand out most in the distinctive aspects of VCO research, both from a global and local perspective?
5. What branches of research, emerging areas of interest, and keyword co-occurrences seem to capture the attention of the VCO researcher today?
6. In what ways do the author and institutional collaborative networks alter the understanding and use of VCO?

This study also undertakes VCO functional food

development and growth. Through a comprehensive bibliometric analysis, this research attempts to locate the gaps in existing literature and address them, thereby enabling more targeted future research. In order to cater to global health issues and industrial requirements, a VCO development strategy is devised and followed, leaving no potential unexploited. To this end, the developed framework for VCO functional food research will aid in more integrated, relevant, and integrative research.

2. METHODS

This study employs bibliometric analysis to systematically evaluate the research landscape on VCO as a functional food. The dataset was exported from Scopus on December 15, 2024, and no subsequent updates were made to maintain consistency in the analysis. Scopus was selected as the single source of data for this study. Scopus is widely regarded as one of the most comprehensive and reliable databases for bibliometric analysis due to its extensive coverage of peer-reviewed literature across various disciplines. Scopus offers the following advantages: (1) Scopus indexes over 82 million records, spanning journals, books, and conference proceedings, with significant representation of interdisciplinary research [14, 15]; (2) Scopus provides detailed citation data, including affiliations, country contributions, and co-authorship networks, which are critical for bibliometric mapping; (3) The advanced query options in Scopus facilitate precise data retrieval, ensuring relevant and high-quality datasets for analysis [16]; and Scopus is frequently cited as a preferred database for bibliometric studies due to its robust indexing and citation analysis capabilities [17, 18].

To define a broad methodological framework, it is necessary to define a comprehensive data set with the use of sophisticated analytical instruments and apply rigorous screening standards to ensure that there is a thorough and reliable examination of the data. In Scopus, this is done using the TITLE-ABS-KEY ("virgin coconut oil") AND TITLE-ABS-KEY (food). A comprehensive search was conducted for all documents that had these words in the title, in the abstract, and in the keywords.

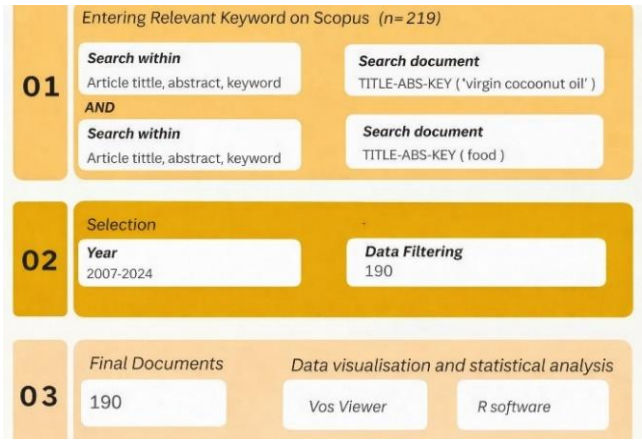

Figure 1. Document search process

This bibliometric analysis covers publications from 2007 to 2024 to provide a concise insight into research trends during this period. Language was not restricted as it ensured to capture a global perspective. Some of the documents found were published in foreign languages but had titles and abstracts in English, making it possible to include these documents in this paper. As a result of our search, 219 relevant documents were found for further evaluation. The clarity of the methodology is illustrated in Figure 1.

To ensure the dataset focuses exclusively on VCO as a functional food for human consumption, a manual screening process was conducted articles unrelated to human functional food applications, such as those focused on animal feed, aquaculture, or unrelated uses, were excluded and after rigorous screening, 190 articles were retained for the analysis, representing studies directly relevant to VCO's functional food applications for humans.

The analysis was conducted using R software, specifically version 4.4.1 (2024-06-14 ucrt), which is widely recognized for its capabilities in bibliometric analysis through the Bibliometrix package, which enables advanced operations such as co-occurrence analysis, citation mapping, and trend visualization. Its customization and flexibility allow researchers to manipulate data and create tailored visualizations that align with specific research objectives [14, 19]. Furthermore, R ensures reproducibility, as all analyses can be documented and replicated, promoting transparency and reliability in the research process [20].

In addition to R, the VOS viewer was used for network visualization, offering unique strengths in creating clear and interactive bibliometric maps. VOS viewer excels in creating intuitive visualizations, offering detailed and user-friendly maps for co-citation networks, keyword co-occurrence, and collaboration patterns. Its focus on relationships between entities such as authors, keywords, and countries helps reveal collaborative and thematic structures within research fields. Additionally, VOS viewer's scalability allows it to handle large datasets efficiently, making it an ideal tool for conducting comprehensive bibliometric studies [21-24].

3. RESULTS AND DISCUSSION

This bibliometric analysis covers the period 2007–2024, with 190 documents published across 130 sources, including journals, books, and conference proceedings (Table 1). The average document age of 4.74 years indicates that this topic remains relevant and has seen significant growth in recent years, driven by increasing interest in functional foods. A total of 812 authors contributed to this research, highlighting global collaboration and widespread attention to the bioactive potential of VCO, such as its antioxidant, antibacterial, and antiviral properties.

Table 1. Summary statistic of the articles collected

Description	Results
Timespan	2007-2024
Sources (Journals, Books, etc.)	130
Documents	190
Document Average Age	4.74
Authors	812
Article	145
Book	1
Book Chapter	5
Conference Paper	20
Conference Review	1
Review	18

Source: biblioshiny

Regarding publication types, 145 articles dominate the contributions, followed by 20 conference papers, 18 review articles, and a few books and book chapters. The prevalence of original research and reviews underscores a strong focus on experimental studies and the synthesis of existing knowledge. Overall, the data reflect a dynamic and multidisciplinary research landscape. Future studies can focus on clinical applications, bioactive mechanisms, and optimizing extraction methods to enhance VCO's functional potential.

The analysis of the annual scientific production on VCO reveals a clear trajectory of growth and increasing interest in this area of research. From its modest beginnings, VCO research has evolved into a significant field, with peaks in publication output reflecting broader trends in health and wellness. Various factors, including funding availability, research trends, and public interest, may influence the fluctuation in annual production. Overall, the data underscores the importance of VCO in contemporary scientific research and its potential implications for health and nutrition.

3.1 Annual scientific production

The effort to examine Annual Scientific Production poses a challenge, as authors and publishers must comply with minimum acceptable standards within each discipline. Within this aim, the overall research productivity and its fluctuations over time are important as they show the context and evolution of a specific area. This analysis also helps stakeholders such as researchers, policymakers, and funders to determine the phases of concentrated research, prioritize changes in research targets, and predict new pathways in research. In addition, it marks the starting point for better distribution of limited resources and for promoting collaboration to address or alleviate existing anticipated problems.

Figure 2 shows VCO research scientific publications between 2007 and 2024. It indicates significant growth starting from 2007, when only two articles were published, and culminating in his astonishing 30 articles in 2023. The rapid increase in publications from 2009 to 2023 indicates a growing awareness and recognition of VCO's health benefits and industrial applications. Interestingly, in 2008, there were no publications reflecting a possible lack of interest or knowledge related to VCO. However, in 2009, four publications marked the start of the upward trend.

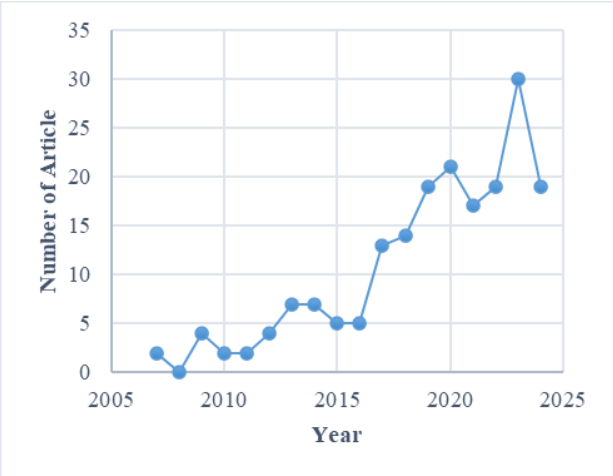

Figure 2. Trend of publications on virgin coconut oil (VCO) as a functional food (2007–2024)
The X-axis represents the years of publication, while the Y-axis indicates the number of articles.

Even further scholarly output was recorded in 2017 and 2018. Together, 27 articles were published in these two years, 13 and 14, respectively, showing sustained scholarly interest in HPVA. Widening use of VCO in the food and drug industry due to new technologies such as nanoemulsion, new microencapsulation methods [25, 26], or even new global perceptions of natural food and functional nutrition being 'better' likely increased academic and consumer interest [4], explaining the jump in publications during these years. It is attested by VCO's increasing recognition in the context of global health, as well as today's innovations. These trends further highlight the importance of VCO as an object of study. It is also the case that VCO research is more actively being undertaken, as indicated by the publication of 19 articles in 2024. That said, there is still considerable scepticism about these oscillations. This is mainly because there is a strong conviction in the importance and changing aspects of the field, as well as the need for further interdisciplinary work. If the stakeholders understood these behaviours, it would be easier for them to endorse non-cooking VCO ideas and aid in resolving contemporary health and industrial dilemmas.

3.2 Average citations per year

Examination of average citations per year is important when determining the effect and academic productivity of the research work done in a specific area. This metric sheds light on the acceptance of research output over time, revealing the most important contributions to the field and how well these contributions have been accepted in the community. In the case of VCO research, citation data serve to identify significant studies in the context of their respective fields, periods of increased attention, and disciplines in which innovations and discoveries are recognized. This also helps the stakeholders to identify barriers or saturation levels that inhibit further progress and to make sure that research activities are active and geared towards the future.

The upward trend between 2014 and 2020, as illustrated in Figure 3, depicts the increased scholarly attention and acknowledgement towards VCO research from this period onwards. The peak in 2021 averaged 8 citations per paper, clearly indicating the benefit of earlier studies, especially the ones on VCO's antimicrobial, antioxidant, and functional food properties [4]. The increase in citations can also result from the development of new technologies, such as nanoemulsion and microencapsulation, which expanded the scope of VCO's use in medicine and industry [10, 27] Also, the increased global interest in the use of natural health products and sustainable foods most probably gave rise to this attention.

However, there has been a significant drop in citations following 2021, with forecasted numbers dipping dramatically in 2024. This drop may be a result of diminished research novelty, possible overexploitation of research topics, or the limited window for citations of newly published works. The spike in 2021 indicates the potential of prior works to influence VCO research. Their relevance is established, while the dip indicates work that requires fresh perspectives to stimulate academic interest. Future research can aim to assess cross-disciplinary applications for VCO's impact to be relevant and address new global needs, for example, in advanced medicine, nanotechnology, or environmental conservation. Considering these developments and their consequences will help researchers and other VCO constituents to adapt to changes in VCO research and promote intelligent innovation.

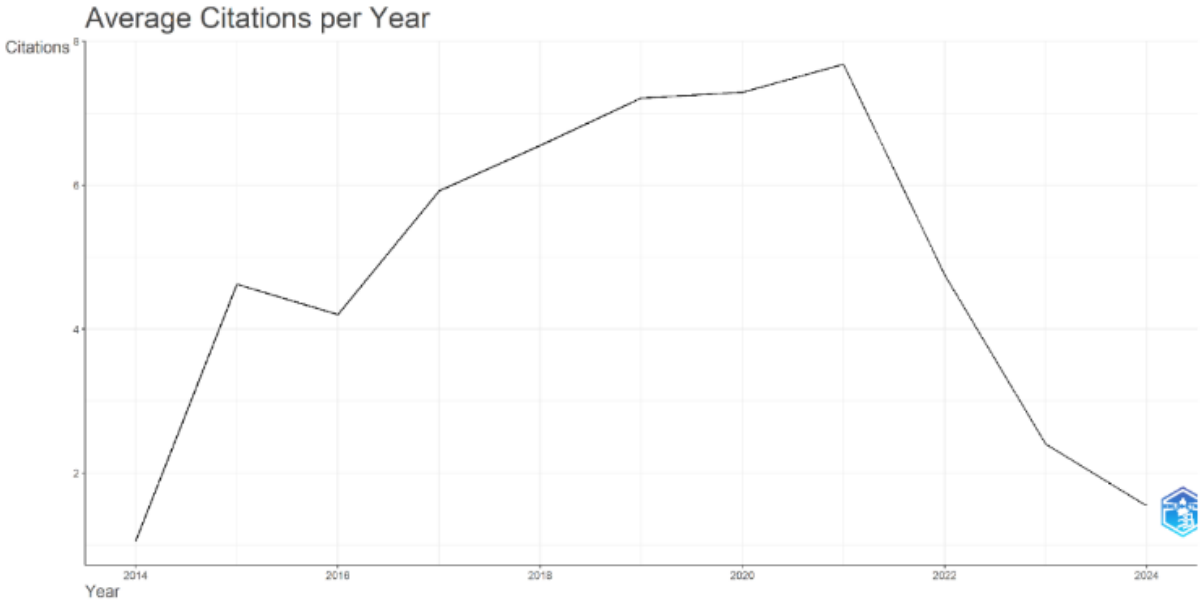

Figure 3. Average citations per year illustrate the trend in average annual citations received by publications related to virgin coconut oil (VCO) research from 2014 to 2024

3.3 Author contributions

Table 2 highlights the overall author contribution, productivity, and bibliometric impact within the research area, which follows the trends of authorship and impact. The top contributors, Illam S.P., Manikantan M.R., and Raghavamenon A.C., have published five articles, each with scores between 1.13 and 1.14, with high collaborative work in multidisciplinary fields. On the other hand, authors Koh S.P. and LONG K, with their scores of 0.99, show discrete contributions within the range of co-authored works. Highly fractionalized scorer Benjakul S, who has 1.83 out of four articles, demonstrates high leadership due to being the main author of a lot of impactful research.

Table 2. Author contributions to research on virgin coconut oil (VCO) as a functional food: Total and fractionalized articles

Authors	Articles	Articles Fractionalized
Illam S.P.	5	1.13
Koh S.P.	5	0.99
Long K	5	0.99
Manikantan M.R.	5	1.14
Raghavamenon A.C.	5	1.13
Benjakul S.	4	1.83
Chaijan M.	4	1.00
Famurewa A.C.	4	0.60
Khor Y.P.	4	0.87
Narayanankutty A.	4	0.93
Illam S.P.	5	1.13

These authors greatly contributed because they highly specialize in areas within VCO research, such as food technology, biochemistry, and health sciences. They emphasize the need to explore the application of VCO in functional foods, anti-microbial agents, and more advanced technologies like nanoemulsions. Researchers such as Benjakul S. are the most excellent among many in terms of leadership, as they take the initiative to conduct cutting-edge studies to improve the methods of extraction and new applications of VCO.

Table 3 complements this by illustrating the distribution of authors based on the number of documents written. A vast majority (90.6%) of authors contributed to only one document, highlighting the prevalence of single-time contributors in the field. A much smaller proportion of authors (6.5%) produced two documents, and only a minuscule fraction (0.6%) contributed five documents, emphasizing the significance of consistent contributors like Illam S.P. and Benjakul S., who are also prominent in the first table. This small group of core authors demonstrates sustained productivity and leadership within the research domain.

Table 3. Lotka's law distribution

Documents Written	No. of Authors	Proportion of Authors
1	741	0.906
2	53	0.065
3	9	0.011
4	10	0.012
5	5	0.006

Table 4 examines the bibliometric impact of authors through metrics such as the h-index, g-index, m-index, total citations (TC), and year of first publication (PY_start). Authors such as Benjakul S., Chaijan M., Panpipat W., and Sungpud C. show strong bibliometric performance, with an h-index of 4, g-index of 4, m-index of 0.667, and citation counts ranging from 63 to 89, indicating a balanced combination of productivity and impact. Illam S.P. and Raghavamenon A.C. also show strong performance, with an h-index of 4, g-index of 5, NP of 5, and TC of 97, reflecting both sustained output and strong scholarly influence. Similarly, Narayanankutty A. records an h-index of 4, g-index of 4, and TC of 97, suggesting notable research visibility.

In contrast, authors such as Che man Y.B. and Famurewa A.C. have relatively lower h-index values (3), although their citation performance remains notable. Che man Y.B. stands out in particular with the highest total citations (460) and the earliest publication start year (2009), indicating a long-standing influence in the field despite a smaller publication

count (NP = 3). Rohman A. also shows moderate impact, with an h-index of 4, g-index of 4, and TC of 190, although the lower m-index (0.286) suggests a longer publication timespan rather than a weaker influence.

Overall, the data suggest that a core group of authors—particularly Illam S.P., Raghavamenon A.C., Benjakul S., Chaijan M., Panpipat W., and Sungpud C.—contribute substantially to the development of this research area through consistent publication output and solid citation performance. At the same time, authors such as Che man Y.B., Rohman A., and Famurewa A.C. highlight that strong citation impact may also be achieved through longer-term scholarly contributions. These findings underline the importance of both sustained productivity and collaborative research in enhancing scientific visibility and impact.

Table 4. Bibliometric indicators of authors' local impact contributing to research on virgin coconut oil (VCO)

Author	h-index	g-index	m-index	TC	NP	PY_Start
Benjakul S.	4	4	0.667	63	4	2019
Chaijan M.	4	4	0.667	89	4	2019
Illam S.P.	4	5	0.5	97	5	2017
Narayanankutty A.	4	4	0.5	97	4	2017
Panpipat W.	4	4	0.667	89	4	2019
Raghavamenon A.C.	4	5	0.5	97	5	2017
Rohman A.	4	4	0.286	190	4	2011
Sungpud C.	4	4	0.667	89	4	2019
Che man Y.B.	3	3	0.188	460	3	2009
Famurewa A.C.	3	4	0.375	96	4	2017

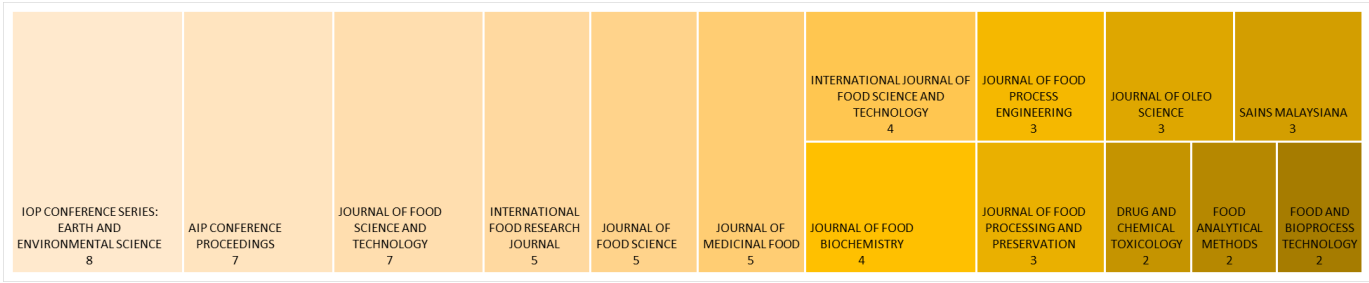

Figure 4. Treemap visualization of journals publishing research on virgin coconut oil (VCO) as a functional food
Each block corresponds to a journal, and its size reflects the number of articles published, as indicated by the numerical value within each block.

3.4 Most productive journals

The treemap above visualizes the number of articles published by various scientific journals related to research on VCO as a functional food, can be seen in Figure 4. The journal with the highest contribution is the IOP Conference Series: Earth and Environmental Science, which has published 8 articles. This is followed by the Journal of Food Science and Technology and the AIP Conference Proceedings, each contributing 7 articles. Other notable journals, such as the International Food Research Journal and the Journal of Food Science, have also made significant contributions, each publishing 5 articles. Additionally, journals like the International Journal of Food Science and Technology, Journal of Food Biochemistry, and others play an important role in disseminating research findings, although their article counts are relatively lower. This visualization highlights the focus of scientific journals on VCO research as a functional food and identifies the key platforms for publications in this field.

This distribution indicates a well-rounded research focus spanning food technology, biochemical analysis, medicinal properties, and engineering applications of VCO. The prominence of interdisciplinary and international journals further signifies the global recognition of VCO's potential as a functional food. These journals play a critical role in advancing knowledge, fostering collaborations, and disseminating findings that validate VCO's health benefits, nutritional properties, and technological applications. Collectively, this analysis underscores the growing importance of VCO research in diverse scientific fields and its increasing relevance in both food science and environmental studies.

3.5 Most relevant affiliations and affiliations

The view of the relevant organizations participating in the production of research on VCO confirms a strong global and local interest in the area (Table 5). Marine institutions did best in this area, with Universiti Putra Malaysia (UPM) leading the pack with 29 articles (4% of total publications). UPM's considerable number of publications is a characteristic feature of Malaysia's national health and industrial strategy, with an emphasis on agriculture and food science development, of which coconuts are one of the most beneficial resources. Other tertiary institutions from Malaysia have also performed reasonably well, such as Universiti Kebangsaan Malaysia (16 articles) and Universiti Teknologi Malaysia (14 articles). These data suggest a well-established and well-funded research culture that encourages collaboration. These institutions will contribute further to understanding VCO's functional and biochemical properties from the perspective of food science and bioactive compounds.

Amala University's Cancer Research Centre in India ranks second with 17 articles (2%) outside Malaysia. This may indicate concentration on VCO's medicinal uses, such as its anticancer and other therapeutic properties. More Brazilian institutions like the Federal University of Paraíba (13 articles), the Federal University of Viçosa (12), and even the University of Belgrade (16 articles) show this growing trend of

international collaboration in VCO studies. These institutions underscore the increasing interest in tapping VCO's potential benefits in sustainable food systems. Moreover, Gadjah Mada University in Indonesia and the University of Delhi are regular contributors to the field, demonstrating the regional commitment to increasing VCO research and development in Southeast Asia and the Indian continent.

The graph of affiliations' production over time (Figure 5) showcases the growth in article production from leading affiliations between 2007 and 2024. Universiti Putra Malaysia demonstrates a clear and consistent upward trajectory, beginning its contributions in 2008 and experiencing significant growth post-2015, reaching its peak in 2017 and maintaining this high output. This sustained production underscores its central role in advancing research. In contrast, Amala Cancer Research Centre only began contributing significantly in 2019 but has shown steady growth since then, reflecting a more recent but impactful participation. Universiti Kebangsaan Malaysia shows notable growth starting in 2014 and has steadily increased its contributions over time. Similarly, the University of Belgrade and Universiti Teknologi Malaysia display a gradual rise in production, particularly between 2018 and 2021, marking periods of active research engagement.

Table 5. Affiliations with the highest number of articles on virgin coconut oil (VCO) research

Affiliation	Articles	Percentage (%)
Universiti Putra Malaysia	29	4
Amala Cancer Research Centre	17	2
Universiti Kebangsaan Malaysia	16	2
University of Belgrade	16	2
Universiti Teknologi Malaysia	14	2
Universidade Federal Da Paraíba	13	2
Naresuan University	12	1
Universidade Federal De Viçosa	12	1
Universitas Gadjah Mada	12	1
University of Delhi	12	1

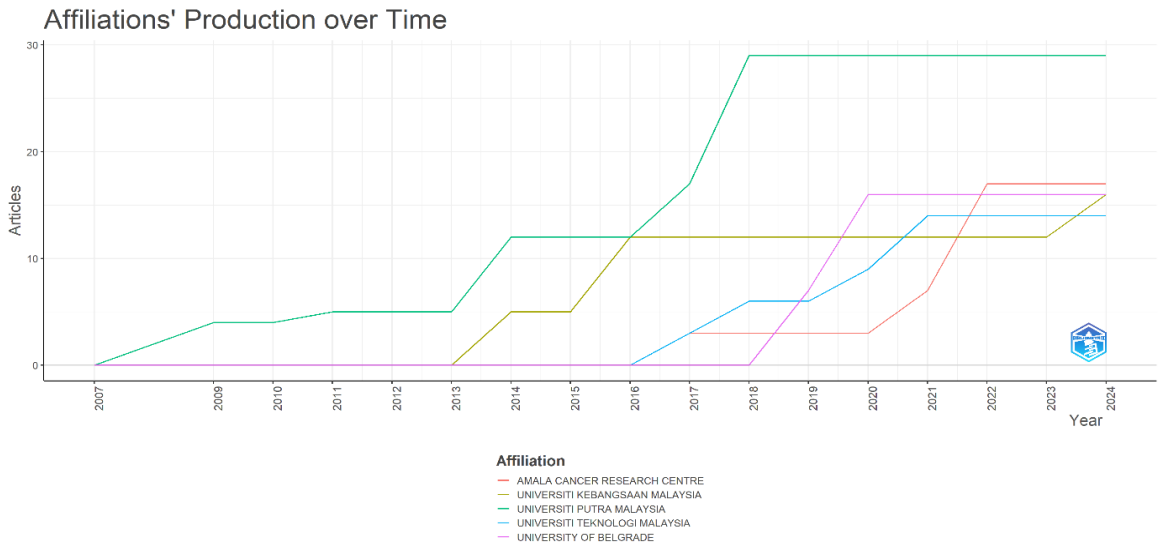

Figure 5. The affiliations' production over time graph illustrates the number of articles published by five different affiliations from 2007 to 2024

The y-axis represents the number of articles, while the x-axis shows the years.

When analyzed together, the data reveal that those Malaysian institutions—Universiti Putra Malaysia, Universiti Kebangsaan Malaysia, and Universiti Teknologi Malaysia—are dominant contributors in this research field, likely due to Malaysia's emphasis on functional food studies and its role as a major coconut producer. The recent and growing contributions from international affiliations such as Amala Cancer Research Centre (India) and University of Belgrade (Serbia) highlight expanding global collaborations and interest in the research topic. This pattern indicates a shift from localized research efforts to a broader international network, fostering interdisciplinary partnerships and advancing knowledge dissemination. Collectively, the data emphasize the importance of institutional leadership, sustained research productivity, and emerging collaborations in shaping the field's development over time.

3.6 Worldwide publications

The data offered here give a further breakdown of the country's contributions to the science of Corresponding Author's Countries (Figure 6), country Scientific Production (Table 6), Production Over Duration (Figure 7), and Most Cited countries (Table 7). All these visualizations provide information on the geographical locations, patterns of collaboration, volume, and productivity of research output, and the effectiveness of the scholarly output.

Table 6. The top ten most productive countries on VCO research

Country	Freq.	TC	Average Article Citations
India	160	449	12.80
Malaysia	143	533	17.80
Indonesia	142	317	10.60
Brazil	86	180	20.00
China	52	110	13.80
Nigeria	52	200	25.00
USA	50	207	34.50
Thailand	48	162	13.50
Serbia	29	64	21.30
Philippines	20	133	44.30

According to Figure 6, India seems to take the lead with the highest amount of documents published and, as such, makes a

very strong contribution to its research output. This is closely followed by Indonesia and Malaysia, which also make large contributions, showing the concentration and focus that seem to be exhibited by most of the Southeast Asian countries on relevant research areas. Countries such as Thailand, Brazil, China, and Nigeria have moderate contributions, while the USA and Iran, together with some smaller countries, make the least number of publications. What is quite striking is the mix of Single Country Publications (SCP) and Multiple Country Publications (MCP). India and Malaysia show strong domestic contributions (SCP), while countries such as Brazil, China, and the USA engage in collaborative research (MCP), which signals that such nations are internationally inclined.

Table 7. The most cited documents globally

Titles	Journals	TC	TCPY	NTC	Ref.
Virgin Coconut Oil: Emerging Functional Food Oil	Trends in Food Science & Technology	235	14.69	2.03	[28]
Antioxidant Capacity And Phenolic Acids of Virgin Coconut Oil	International Journal of Food Sciences and Nutrition	212	13.25	1.84	[29]
Randomised Trial Of Coconut Oil, Olive Oil or Butter On Blood Lipids And Other Cardiovascular Risk Factors in Healthy Men And Women	BMJ Open Journal	139	19.86	4.80	[30]
Descriptive Sensory Evaluation of Virgin Coconut Oil and Refined, Bleached and Deodorized Coconut Oil	LWT - Food Science and Technology	124	6.89	1.13	[31]
Antimicrobial Effects of Virgin Coconut Oil and its Medium-Chain Fatty Acids on Clostridium Difficile	Journal of Medicinal Food	112	9.33	3.50	[32]
Physicochemical Properties, Antioxidant Capacities, and Metal Contents of Virgin Coconut Oil Produced by Wet And Dry Processes	Food Science & Nutrition	107	15.29	3.70	[33]
In Vitro Anti-Microbial Properties of Coconut Oil on Candida Species in Ibadan, Nigeria	Journal of Medicinal Food	95	5.28	0.87	[34]
Infrared Spectroscopy For Quantitative Analysis and Oil Parameters of Olive Oil and Virgin Coconut Oil: A Review	International Journal of Food Properties	77	9.63	2.78	[35]
Polyphenols of Virgin Coconut Oil Prevent Pro-Oxidant Mediated Cell Death	Toxicology Mechanisms and Methods	76	9.50	2.74	[36]
Development and Characterization of Soy Protein Isolate Emulsion-Based Edible Films with Added Coconut Oil for Olive Oil Packaging: Barrier, Mechanical, and Thermal Properties	Food and Bioprocess Technology	74	7.40	1.76	[37]

TC: total citation, TCPY: total citation per year, NTC: normalized total citation

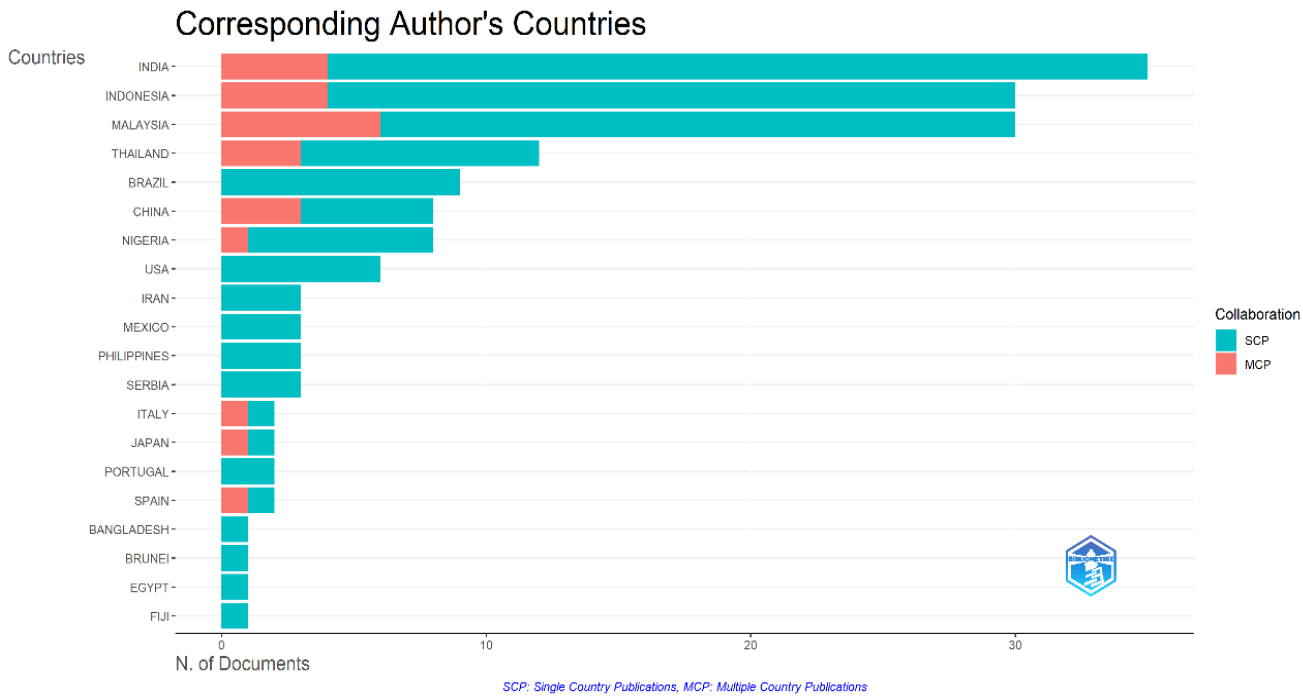

Figure 6. Corresponding author's countries
SCP: Single country publications, MCP: Multiple country publications.

The focus on the countries' contributions is crucial for examining the global research framework for VCO. It reveals regions with specialization competencies, gaps of geographic representation, and the collaboration patterns that stimulate innovations. India and Malaysia are dominant because of their agricultural linkages to coconut and existing research infrastructure. The foreign partnerships in MCPs from the USA and Brazil tell how appealing and multifaceted VCO research is. This analysis is significant for balancing the global resource allocation, building international relations, and motivating the lesser countries to embrace this new area of study.

Table 6 depicts the volume and contribution of research work done on VCO per country in terms of the frequency of publications, TC of these articles, and average citations per article published. These data are critical in understanding the contributions and academic impacts of different nations regarding VCO research.

Following India is Malaysia, focusing broadly on publications (more than 140 articles). Despite both countries having a high number of articles, Malaysia leads with a TC of over 500 and an average of 18 citations per article, demonstrating the quality of the work being published. As previously stated, this follows Malaysia's heavy agricultural and food science investment and has strong research institutions such as Universiti Putra Malaysia and Universiti Kebangsaan Malaysia. Furthermore, Malaysians prove to be superior researchers. Brazil and Nigeria rank highly due to the impact of their research on citations. With a focus on sustainable foods and bioactive ingredients in VCO, they achieved an impressive per-article average of 20 and 25 citations, respectively. Indonesia, though having low citations per article, averaging 10.6, is mid-ranked globally with 317 citations. This suggests that Indonesians conduct impactful studies. However, they are still struggling to get global recognition. They conducted a total of 142 highly impactful studies, but were still mid-ranked.

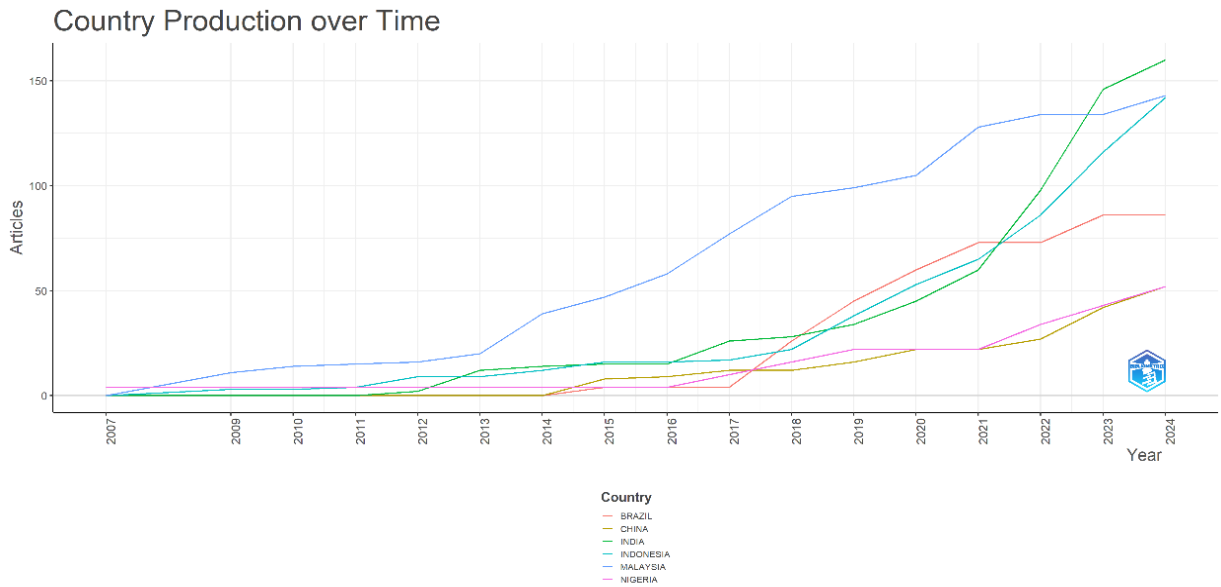

Figure 7. Country production over time

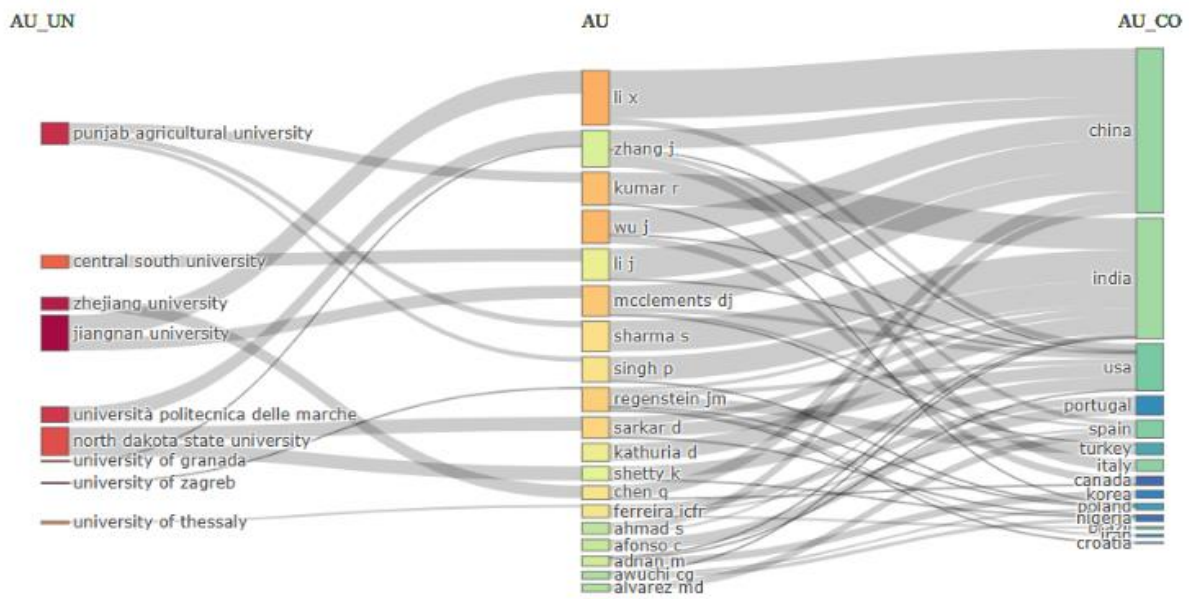

Figure 8. The three-field plot depicts the connections between institutions (AU_UN), authors (AU), and their respective countries (AU_CO)

With an admirable average per article citation of 34.5 and ranking at mid-position globally, the USA contributed only 50 articles, with a total of 207 citations. This suggests that the USA is highly impactful and issues quality publications. On the other hand, the Philippines conducted 20 studies with the highest average per article citations of 44.3; this suggests they focus on specialized studies. Thailand and China contribute moderately, with 13.5 and 13.8 average citations from 48 and 52 articles, respectively.

Serbia possesses 29 patents that earn an average of 21.3 citations each, demonstrating an increasing interest from Eastern European nations in VCO research, focusing on interdisciplinary works like health and sustainability. The grouping of contributions from these countries highlights the relevance of VCO research for areas of focus on regions and the VCO research shaping those collaborations.

The country production over time graph reveals dynamic trends in scientific productivity. India shows consistent growth, experiencing a rapid increase after 2016, firmly establishing its leadership. Malaysia and Indonesia also show notable upward trends, particularly after 2018, indicating their growing focus on VCO and related fields. Countries like Brazil, China, and Nigeria display slower but steady growth, suggesting increasing involvement in research activities. This temporal analysis highlights the expanding global interest in the research domain, particularly among emerging economies.

3.7 Three-field plot (authors, affiliations and countries)

The three-field plot in the VCO research highlights the intricate relationships between authors, their affiliations, and contributing countries, which collectively drive the production of scientific publications (Figure 8). Authors, as key knowledge contributors, play a central role in advancing VCO research as a functional food. Prominent researchers like Koh S.P., Manikantan M.R., and Pandiselvam R represent a diverse pool of expertise across food science, nutrition, and agricultural research. These authors are supported by their affiliations, such as Universiti Putra Malaysia, University of Delhi, and ICAR-Central Plantation Crops Research Institute, which serve as hubs for scientific activity by providing infrastructure, funding, and collaborative networks. The strong presence of Malaysian institutions reflects the country's commitment to leveraging its abundant coconut resources for functional food research. In contrast, Indian institutions demonstrate significant contributions, particularly in exploring VCO's nutritional and medicinal benefits.

At a broader level, the countries involved—Malaysia, India, Thailand, Nigeria, Indonesia, and Japan—showcase the global scale of collaboration in this research domain. Malaysia emerges as a leading contributor, driven by its major coconut producer role and strategic investment in functional food innovation. India follows closely, with its institutions and researchers focusing on VCO's health applications. Other countries, such as Thailand and Indonesia, utilize their coconut production industries to contribute meaningfully to the research. At the same time, nations like Nigeria and Japan underscore the growing international interest in functional foods beyond traditional coconut-growing regions. This interconnected framework demonstrates how authors, institutions, and countries collaborate to advance scientific knowledge on VCO, combining expertise, resources, and geographic advantages to produce impactful publications. Such collaboration not only fosters innovation but also enhances the global understanding of VCO's potential as a functional food, contributing to its recognition as a valuable solution for nutrition and health.

3.8 Most globally cited documents

The top ten globally cited papers on VCO as a functional food have significantly contributed to advancing the understanding of its health benefits, chemical properties, and therapeutic applications (Table 8). Marina et al. [28] in *Trends in Food Science and Technology* provided a comprehensive review of VCO's physicochemical properties, antioxidant activity, and its potential as an emerging functional food oil. In another study published in the *International Journal of Food Science and Nutrition,* Marina et al. [29] further explored VCO's chemical composition, demonstrating its higher antioxidant capacity compared to refined coconut oil. Similarly, Khaw et al. [30] in *BMJ Open* conducted a randomized trial comparing VCO, olive oil, and butter, concluding that VCO does not adversely affect lipid profiles, thus supporting its inclusion in a balanced diet.

Villarino et al. [31] in *LWT - Food Science and Technology* focused on the sensory characteristics of VCO, highlighting its distinct flavor profile, which may influence consumer preference. Shilling et al. [32] in *Journal of Medicinal Food* investigated the antimicrobial effects of VCO and its fatty acids against *Clostridium difficile*, revealing significant antimicrobial activity that positions VCO as a potential therapeutic gent. Ghani et al. [33] in *Food Science & Nutrition* compared VCO produced through wet and dry extraction methods, emphasizing how production processes impact antioxidant properties and quality, which are critical for functional food applications. Ogbolu et al. [34] in *Journal of Medicinal Food* examined VCO's antifungal effects against *Candida* species, demonstrating its efficacy in combating drug-resistant strains, thus offering potential as a natural antifungal agent. Rohman [35] in *International Journal of Food Properties* discussed the application of Fourier Transform Infrared (FTIR) spectroscopy for authenticating functional oils, including VCO, underscoring its role in ensuring quality and detecting adulteration. Illam et al. [36] in *Toxicology Mechanisms and Methods* explored the protective effects of VCO polyphenols against oxidative stress-induced cell death, attributing VCO's functional benefits to its antioxidant properties. Lastly, Carpiné et al. [37] in *Food and Bioprocess Technology* assessed the quality of VCO produced using various extraction methods, emphasizing the importance of extraction techniques in maintaining its physicochemical integrity and functional properties.

Collectively, these studies highlight VCO's chemical composition, antioxidant activity, antimicrobial properties, and therapeutic potential, reinforcing its role as a functional food [38, 39]. The findings have laid a strong foundation for future research. They focus on its applications in nutrition, disease prevention, and food quality enhancement, solidifying VCO's global recognition in the functional food industry [40, 41].

3.9 Most locally cited documents

The most locally cited papers on VCO as a functional food provide a comprehensive understanding of its health benefits, chemical composition, and practical applications, contributing significantly to scientific advancements in this area (Table 8).

Marina et al. [28] in *Trends in Food Science & Technology* conducted a literature-based review on VCO as an emerging functional food oil. They highlighted its unique physicochemical properties, antioxidant activity, and medium-chain fatty acid (MCFA) content, positioning VCO as a promising functional food to combat oxidative stress-related diseases. In another study published in the *International Journal of Food Science and Nutrition* [29], the chemical properties of VCO were analyzed using gas chromatography, revealing higher levels of phenolic compounds and antioxidants compared to refined coconut oil, reinforcing its superior health-promoting potential. Villarino et al. [31] in *LWT – Food Science and Technology* explored the sensory attributes of VCO compared to refined coconut oil through descriptive sensory evaluation, showing that VCO's distinct aroma and flavor enhance its consumer acceptance and marketability. The physicochemical properties, antioxidant capacities, and metal content of VCO are produced via wet and dry processing methods [42]. Their findings indicated that wet-processed VCO retains superior antioxidant capacity and lower metal content, emphasizing the impact of extraction methods on VCO quality. Famurewa et al. [43] in *Experimental and Therapeutic Medicine* explored VCO's immunomodulatory effects using in vivo models, demonstrating its potential to enhance immune function and reduce inflammation, further solidifying its functional food status. Similarly, Illam et al. [36] in *Toxicology Mechanisms and Methods* investigated the antioxidant effects of VCO polyphenols on oxidative stress-induced cell death in vitro. The results confirmed that VCO polyphenols effectively inhibit reactive oxygen species (ROS) production, providing cellular protection against oxidative damage [44].

Rohman et al. [5] in *Food Reviews International* focused on the application of Fourier Transform Infrared (FTIR) spectroscopy for authenticating functional oils, including VCO. This study demonstrated FTIR's accuracy and reliability in detecting adulteration, offering an essential tool for quality assurance. Yeap et al. [42] in *Journal of Medicinal Food* tested the antifungal properties of VCO against *Candida* species using in vitro methods. They found that VCO effectively inhibits *Candida*, including drug-resistant strains, positioning it as a natural antifungal alternative. Dayrit et al. [45] in *Journal of Dietary Supplements* evaluated VCO's antioxidant and anti-inflammatory properties in animal models, showing that it reduces oxidative stress and inflammation, supporting its role in preventing chronic diseases. Finally, Ahmad and Ayub [46] in *Pure and Applied Chemistry* analyzed the quality of VCO compared to refined coconut oil, confirming that VCO retains natural bioactive components like polyphenols and MCFAs, which are often lost in refining processes. This finding underscores VCO's superior quality and position as a premium health oil.

These studies demonstrate VCO's diverse health benefits, ranging from its antioxidant, anti-microbial, and immunomodulatory effects to its superior chemical composition and sensory properties. These papers provide a strong foundation for further research and reinforce VCO's status as a functional food with significant potential for human health by addressing key aspects such as production methods, quality assurance, and therapeutic applications.

Table 8. Top locally cited documents on virgin coconut oil

Titles	Journals	Y	LC	GC	LC/GC Ratio (%)	NLC	References
Antioxidant Capacity and Phenolic Acids of Virgin Coconut Oil	International Journal of Food Sciences and Nutrition	2009	35	212	16.51	2.09	[29]
Virgin Coconut Oil: Emerging Functional Food Oil	Trends in Food Science & Technology	2009	31	235	13.19	1.85	[28]
Descriptive Sensory Evaluation of Virgin Coconut Oil and Refined, Bleached and Deodorized Coconut Oil	LWT - Food Science and Technology	2007	17	124	13.71	1.42	[31]
Physicochemical Properties, Antioxidant Capacities, and Metal Contents of Virgin Coconut Oil Produced By Wet and Dry Processes	Food Science & Nutrition	2018	14	107	13.08	7.00	[33]
Antistress And Antioxidant Effects of Virgin Coconut Oil in Vivo	Experimental and Therapeutic Medicine	2015	11	73	15.07	3.67	[42]
Polyphenols of Virgin Coconut Oil Prevent Pro-Oxidant Mediated Cell Death	Toxicology Mechanisms and Methods	2017	10	76	13.16	6.50	[36]
Virgin Coconut Oil: Extraction, Physicochemical Properties, Biological Activities and its Authentication Analysis	Food Reviews International	2021	7	49	14.29	10.82	[5]
In Vitro Antimicrobial Properties Of Coconut Oil On Candida Species In Ibadan, Nigeria	Journal of Medicinal Food	2007	7	95	7.37	0.58	[34]
Dietary Supplementation With Virgin Coconut Oil Improves Lipid Profile and Hepatic Antioxidant Status and Has Potential Benefits On Cardiovascular Risk Indices in Normal Rats	Journal of Dietary Supplements	2018	6	43	13.95	3.00	[44]
Quality Characteristics of Virgin Coconut Oil: Comparisons With Refined Coconut Oil	Pure and Applied Chemistry	2011	6	31	19.35	1.71	[45]

Y: year, LC: local citation, GC: global citation, NLC: normalized local citation.

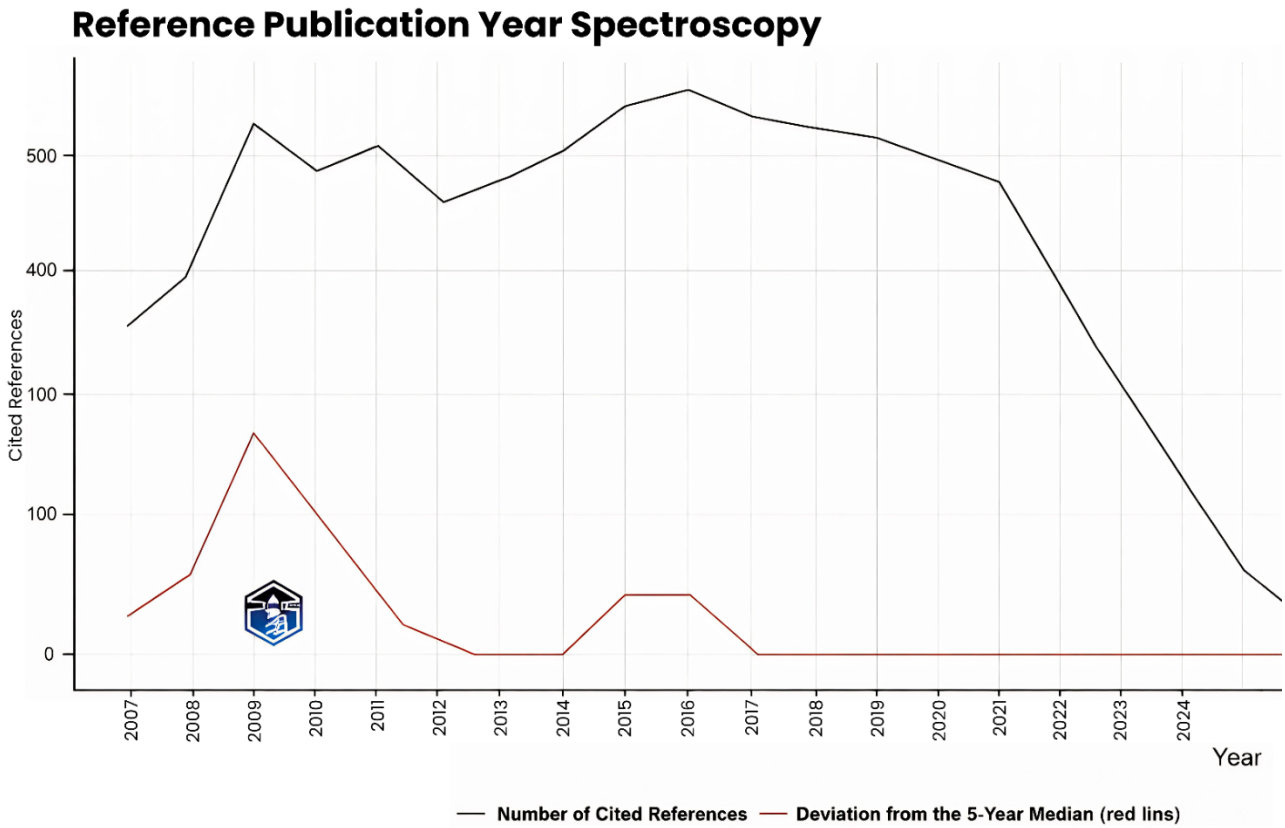

Figure 9. Reference publication year spectroscopy

The black line represents the number of cited references for each publication year. The red line shows the deviation from the 5-year median, highlighting significant shifts or trends in citation patterns. The x-axis indicates the publication year of cited references, while the y-axis shows the count of cited references.

3.10 Reference spectroscopy

Figure 9, the reference publication year spectroscopy, has been used to demonstrate the focus on the distribution of citation references concerning the publication years. The black line depicts the total number of cited references. In contrast, the red line depicts the deviations from the five-year median, giving a more dynamic perspective on referencing VCO studies. The number of cited references grew considerably during 2008 - 2015, with the highest level around 2013 – 2015. It was a period of intense research activity. During this period, spectroscopy techniques such as Fourier Transform Infrared (FTIR) and Nuclear Magnetic Resonance (NMR) were widely used to examine VCO and estimate its chemical composition, purity, and bioactive compounds. The peak also reflects the active years when a standard method was developed to characterize VCO and its functional properties, including medium-chain fatty acids (MCFAs) and antioxidants.

The period after 2016 has seen a decline in cited references, which has deepened since 2020. This development could be symptomatic of a particular research emphasis, where new techniques or cross-disciplinary VCO approaches have supplemented spectroscopy. The drop such applications suffered could equally account for the citation decline, given how many years it has been since this field matured. Also, the recent publication's reference quota will likely suffer because of the ever-expanding timeframe for citation accumulation.

The red line, which denotes deviations concerning five-year medians, demonstrates a robust peak around 2009. This corroborates claims regarding introducing whole new realms of applied spectroscopy or bold new studies and initiatives. In 2015, only minimal deviations were noticed after such activities, which indicates a steady state in the introduction of references to papers for VCO. Citation decline notwithstanding, spectroscopy remains a vital technique in studying VCO, albeit more often than not in conjunction with other newer methods, like those employing nanoemulsions and bioinformatics.

The development of the VCO goes hand in hand with the development of physicochemical characterization tools and techniques such as spectroscopy. VCO had a peak referencing period, and advances in VCO research were significantly aided by FTIR and NMR. These techniques served as vital approaches and laid a strategic foundation for further research. With the integration of complementary scientific disciplines with spectroscopy, the method continues to be a centrepiece in expanding research and innovation. Supporting this analysis, studies [46, 47] emphasize the continued relevance of spectroscopy in truly functional food research on quality control and bioactive VCO.

3.11 The three-field plot

Figure 10 presents three field plots illustrating the connection structure among Sources (SO), Authors (AU), and Keywords/Research Themes (DE) involved in the scientific publishing of VCO. This visualization depicts the scholarly ecosystem in which research on the functional and medicinal properties of VCO is conducted and developed. The leftmost column highlights the primary SO journals where VCO-related studies have been published, including Food Analytical Methods, Journal of Medicinal Food, Journal of Food Biochemistry, and the International Food Research Journal. These journals focus on food science, biochemistry, and toxicology, reflecting the multidisciplinary nature of VCO research and its relevance to both food and health sciences.

For instance, the journal Food Analytical Methods has some notable interests in VCO, such as its uses and benefits, specifically towards the verification methods using sophisticated analytical techniques, including the FTIR Spectroscopy, which establishes the genuineness, purity, and quality of VCO [48-50]. Besides that, VCO has also been reported in the Journal of Medicinal Food, paying attention to its health-promoting factors, such as antioxidants and anti-inflammatories, which are essential in functional food [28, 51, 52]. In addition, the International Food Research Journal has also looked at VCO for its physicochemical properties and recent use in various food and pharmaceutical preparations [53, 54]. This diverse set of publications confirms the nutritional qualities of VCO and its technological uses, demonstrating the multidisciplinary focus of these journals – VCO connects food science with medicine and technology.

The first column shows key authors related to VCO research, such as Illam S.P., Koh S.P., Rohman A., Raghavamenon A.C., and Pandiselvam R., who work in the area of food chemistry, bioactive compounds, and analysis. The authors [54] established a practice in the industry by using FTIR spectroscopy alongside chemometric analysis to verify the quality of VCO. The authors [32] have also discussed how MCFAs can help lipid metabolism and oxidative stress, while Raghavamenon AC worked on VCO's anti-inflammatory properties and oxidative damage. The therapeutic scope of VCO has also increased because of the research done by the authors [55, 56] on nanoemulsions, improving the bioavailability and stability of the VCO.

The right column illustrates major scientific issues, such as VCO, antioxidants, MCFAs, oxidative stress, anti-inflammatory properties, and nanoemulsions. The studies VCO's multidimensional role as a functional food are further proven by advanced analytical methods and bioactive-focused innovations.

The strong connections between authors and themes like antioxidants, oxidative stress, and anti-inflammatory activities highlight VCO's growing recognition as a functional food with significant health benefits, particularly in combating inflammation, lipid imbalances, and oxidative damage. Additionally, emerging research themes such as nanoemulsions and FTIR Spectroscopy underscore the application of advanced technologies in analyzing and improving VCO's efficacy and bioavailability. This visualization also highlights the critical role of journals in disseminating findings across scientific communities, as leading publications like the Journal of Food Science and Technology and the International Journal of Food Science and Technology are central platforms for researchers.

In summary, the Three-Field Plot illustrates how scholarly publications on VCO are shaped by the interplay between specialized journals, contributing authors, and targeted research themes. The concentration of studies around VCO's antioxidant and anti-inflammatory properties, coupled with technological advancements such as nanoemulsions, signifies the multifaceted nature of VCO research. This interconnected system reflects the global effort to validate VCO as a functional food and its applications in improving human health and nutrition.

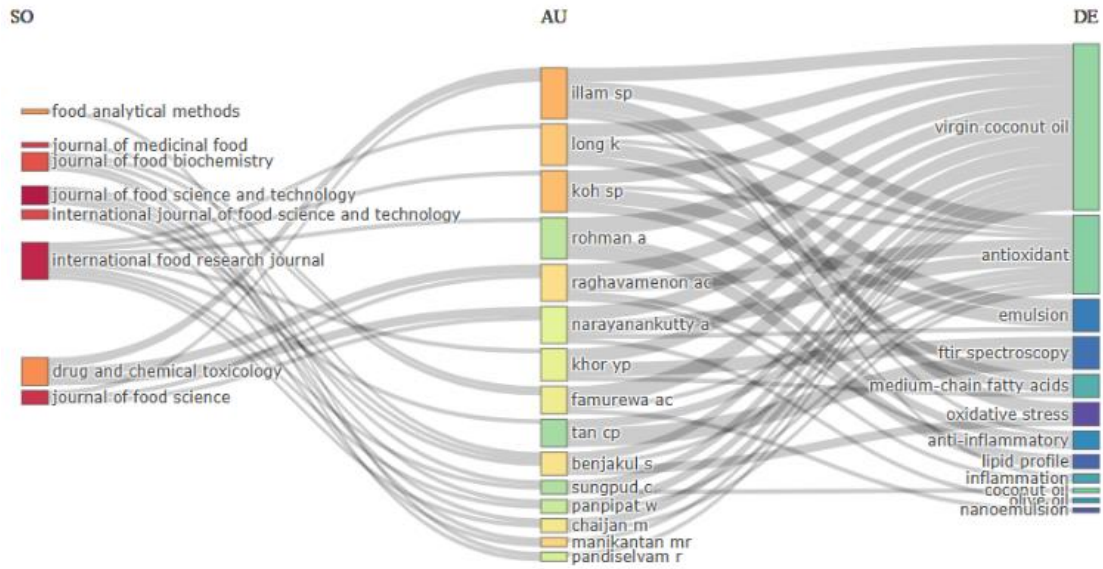

Figure 10. The three-field plot depicts the connections between source (SO), authors (AU), and their respective descriptors (DE)

3.12 The trend topics graph

The trend topics in Figure 11 showcase the evolving landscape of research on VCO, revealing how the focus has shifted over time to address both its analytical properties and its growing role as a functional food. The period from 2014 to 2018 witnessed an emphasis on technology and composition analysis of VCO for research with keywords such as "FTIR spectroscopy, "chemometrics," and "physicochemical properties." These studies focused on corroborating and certifying VCO quality, purity, and chemical composition to make claims about "VCO" as a natural product. For instance, in 2020, Amit et al. [54] used Fourier Transform Infrared (FTIR) spectroscopy to check for adulteration in VCO, which illustrated its use during quality control processes. In the same vein, Mulia et al. [55] used FTIR and chemometrics to study VCO's physicochemical properties and proved its applicability for VCO quality control in the industry. In parallel to this, Mousa et al. [50], who had studied the fatty acid profile and antioxidant activity of VCO, confirmed the existence of MCFAs and phenolic compounds, which serve as functional food components. Such findings were of vital

importance for bringing VCO quality to international standards and enhancing its credibility for it to be a tradeable and functional food-grade product.

The word ‘antioxidant’ has become more and more prominent after 2018 as scientists shifted their attention toward the capacity of VCO to reduce oxidative stress, which leads to chronic conditions such as heart disease, diabetes, and inflammatory conditions [57-60]. This change in research focus indicates heightened attention to the bioactive components of VCO, such as the phenolic MCFAs that are active at low concentrations and possess powerful antioxidant functions. For example, the studies [61, 62] showed that free radical neutralization and oxidative damage mitigation by VCO are possible due to its rich antioxidant content. These findings solidified VCO’s role in promoting health and preventing chronic diseases by exploiting its therapeutic potential. Likewise, the studies [29, 63] focused on VCO’s high-phenolic content and antioxidant activity and suggested its use in Functional Foods and Nutraceuticals.

Further research was conducted on VCO's traceability and oil processing methods in addition to quality validation. Studies [62, 63] were able to establish a primitive methodology for tracing the origin of VCO through the use of FTIR Spectroscopy and Principal Component Analysis (PCA), which helped in the formulation of traceability systems that increased VCO’s integrity as a natural product. At the same time, Amit et al. [54] investigated how various methods of extraction changed the VCO’s physiochemical properties, which can serve as a guide for producers to refine the processing methods without affecting the active ingredients. Their contribution assisted these researchers in defining the quality requirements for VCO and pointing out the importance of certain technological and compositional features for it to be accepted in the international markets. The application of FTIR Spectroscopy, coupled with chemometrics and PCA, lays the foundation for much more advanced studies integrating the chemistry of VCO with medicine, cosmetics, and nutritional science, thereby increasing the range and scope of the global marketplace for VCO.

As the field progressed, the spotlight began to shift toward the health and nutritional benefits of VCO. Starting around 2016, terms such as "lipid profile," "cholesterol," and "MCFAs" emerged prominently, signaling a growing interest in VCO's impact on cardiovascular health, lipid metabolism, and obesity. Researchers increasingly explored the role of MCFAs, particularly "lauric acid," in modulating lipid profiles and reducing cholesterol levels. By 2020, these topics reached their peak, reflecting VCO’s rising popularity as a natural solution to combat metabolic disorders and lifestyle-related diseases.

The growing attention to bioactivity is accentuated even further as the term “antibacterial” has emerged in recent years, testimony to the increasing studies on the antimicrobial character of VCO. Most of the claimed antibacterial activity of VCO is believed to be due to the presence of lauric acid, which has been well-documented to possess potent antibacterial and antifungal features [64, 65]. The study [8] and other studies showed that VCO is effective against pathogens like Staphylococcus aureus and Candida albicans, supporting its traditional application in medicine. Additionally, the studies [66, 67] discussed the importance of monolaurin, a lauric acid derivative, which disintegrates microbial cell membranes, further supporting the usage of VCO against infections and increased immune defence.

The graph further demonstrates cross-comparison analysis, including the early availability of the benchmark ‘olive oil’ along with VCO, which depicts attempts to benchmark VCO's health advantage against the other popular oils. Comparative studies on VCO and olive oil have concerned lipid and cardiovascular profiles, showing that VCO helps lower cholesterol and improve lipid metabolism [68]. For instance, the study [69] reported that both VCO and olive oils caused a decrease in LDL cholesterol and an increase in HDL cholesterol in animals, which suggests each may have some benefit to heart health.

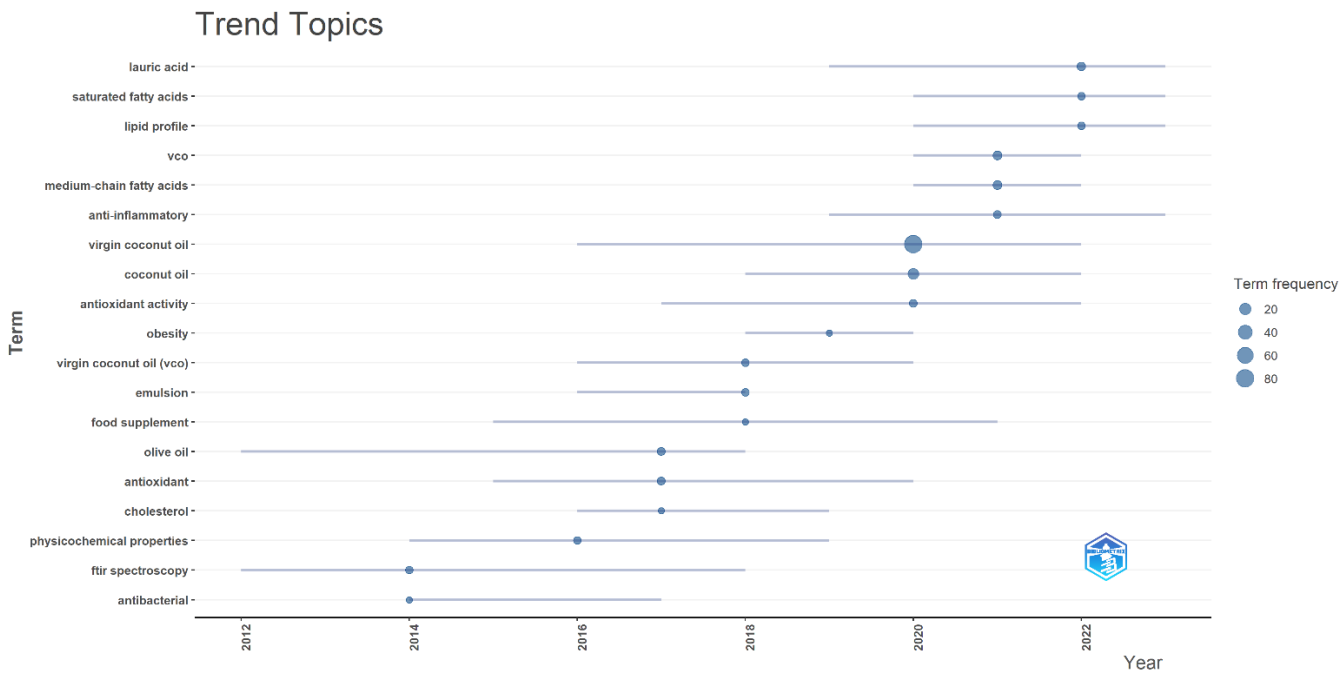

Figure 11. Trend Topics illustrates the evolution of research terms related to coconut oil and associated topics over time

VCO also has growing applications, as well as nutritional, in the modern market, and this commercial film from the mid-2010s coincided with the use of words such as "food supplement". Its application in functional diets and food fortification has been examined. The study [41] focused on incorporating VCO into enriched food products and discussed its beneficial bioactive properties. Such practices respond to the international market seeking healthier foods that are safe and sustainable.

What emerges from the Trend Topics graph is how VCO research has shifted from its primary focus on the analytical procedures and quality control for VCO to studies that elaborate on the health benefits and therapeutic applications of the VCO [53, 70]. The increasing use of the terms "antioxidant," "lipid profile," and "medium-chain triglycerides" depicts the changing perception of the scientific community towards VCO as an important functional food to overcome many contemporary health issues. This changing focus is not surprising given the recent volume of literature on VCO's health-beneficial properties, which supports its use as a natural health product of global significance [44, 71].

3.13 Co-occurrence network analysis of author keywords

The network map presented in Figure 12 shows 11 central and interconnected themes related to research on VCO, with each cluster reflecting a distinct research stream that collectively explains how the field has evolved from foundational compositional studies toward (i) evidence-based functional claims and (ii) technology-driven innovations for quality, delivery, and product development.

This cluster highlights the use of advanced analytical approaches for VCO integrity, traceability, and quality assurance. Cluster 2 concentrates on adulteration and authentication, represented by keywords such as "adulteration," "blending," "authentication," "chemometrics," and "FTIR spectroscopy." These terms indicate that a major intellectual driver of the field is the need to safeguard label claims and ensure market confidence through rapid, reproducible authentication workflows—an emphasis that is consistent with prior comprehensive reviews positioning FTIR-based profiling and multivariate chemometrics as practical solutions for routine VCO quality control and fraud detection [2].

The next thematic grouping clusters terms related to antimicrobial activity, antioxidant capacity, and MCFAs under a broader "nutrition/bioactive activity" orientation. Rather than indicating isolated topics, this co-occurrence pattern suggests that the field commonly frames VCO's functional-food positioning through mechanistic links between its bioactive profile (e.g., phenolics and medium-chain lipids) and biological endpoints such as oxidative stress modulation and host defense—aligning with compositional and bioactivity syntheses that describe VCO as a bioactive-rich oil with multi-target potential [2].

Cluster 3 emphasizes inflammation and functional-food targeting, with prominent terms such as "anti-inflammatory," "functional food," "inflammation," and "medium-chain triglycerides." This structure indicates that "anti-inflammatory" is not treated as a standalone claim but is frequently discussed alongside diet-related metabolic contexts (e.g., obesity and metabolic disorders). The cluster, therefore, reflects a translational trajectory in which VCO is investigated as a dietary intervention whose lipid architecture (medium-chain triglycerides) is hypothesized to influence inflammatory pathways and metabolic outcomes, reinforcing the growing clinical and nutraceutical framing of VCO research.

Cluster 4 connects "cholesterol" with "microencapsulation" and "sensory evaluation," highlighting an important bridge between health-oriented outcomes and formulation science. This co-occurrence implies that, as interest in lipid-profile outcomes increases, researchers simultaneously address the practical constraints of using VCO in real food systems—namely stability, palatability, controlled release, and consumer acceptance. Recent work on VCO microencapsulation (e.g., O/W emulsification and complex coacervation) supports this interpretation by demonstrating how encapsulation strategies can protect sensitive constituents while enabling incorporation into diverse matrices without compromising sensory quality [6].

Cluster 5 discusses extraction and nanoemulsion technology, represented by terms such as "extraction," "nanoemulsion," and "response surface methodology." This cluster signals that processing and delivery innovation has become an emerging and increasingly central theme: studies are not only optimizing extraction conditions to preserve functional compounds, but also engineering nanoemulsified systems to improve dispersibility, stability, and bioavailability. The prominence of nanoemulsion-related keywords is consistent with earlier methodological work on VCO nanoemulsion preparation (e.g., phase inversion temperature approaches) [3] and with more recent application-oriented studies developing VCO nanoemulsion/nanoemulgel systems to enhance techno-biofunctionality [5].

Figure 12 displays research themes and keyword relationships related to VCO.

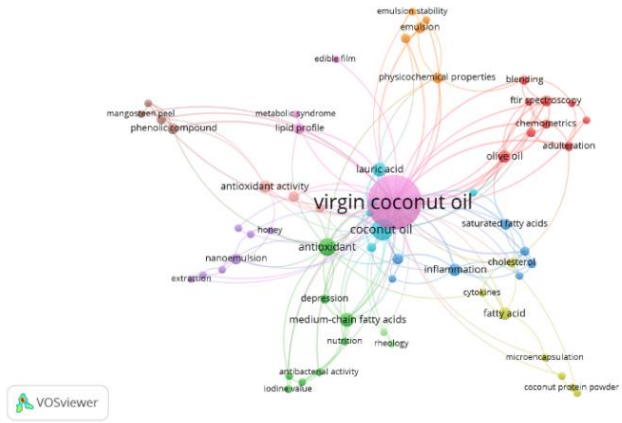

Figure 12. Research themes and keyword relationships related to virgin coconut oil (VCO)

Cluster six includes terms such as "antibacterial," "lactic acid," "monolaurin," and "randomized trial," indicating a consolidated line of inquiry that moves from mechanistic antimicrobial hypotheses (often linked to lauric acid/monolaurin) toward validation in human-relevant designs. This positioning is supported by prior reviews emphasizing lauric acid/monolaurin as key antimicrobial agents in VCO [4, 66], while the appearance of "randomized trial" suggests a gradual shift toward clinical-grade evidence rather than purely in vitro demonstrations—an implication that directly supports calls for more standardized clinical trials in the field.

Emulsion performance and physicochemical functionality are emphasized in cluster 7 through terms such as "emulsion," "food supplement," and "rheological properties." The co-

occurrence pattern indicates that formulation stability and flow behavior are treated as enabling sciences for product translation, particularly when VCO is positioned for functional-food supplementation. This cluster, therefore, complements the nanoemulsion and microencapsulation themes by reflecting downstream formulation requirements needed for scalable products with consistent performance in food systems.

Within this group, studies focus on synergistic fortification—pairing VCO with other bioactive sources (e.g., phenolic-rich co-ingredients) to enhance functionality and broaden application in food, cosmetic, and health domains. The cluster suggests that VCO is increasingly studied not only as a single-ingredient functional oil but also as a carrier or co-formulant within multi-bioactive systems, which aligns with the broader trend of designing composite functional products that target multiple pathways simultaneously.

Cluster nine links "lipid profile" and "metabolic syndrome" with terms such as "edible film," indicating expansion from health-outcome research into sustainable, value-added packaging or delivery formats. This thematic intersection implies that metabolic-health framing is increasingly connected to applied food-material innovations, where VCO is explored as part of functional edible films that can confer both technological and potential bioactive benefits in food preservation and delivery.

Cluster 10 emphasizes "oxidative stress," "polyphenols," and "antioxidant activity," reflecting a mature and still-influential research backbone in which oxidative stress modulation remains a central justification for VCO's functional claims. Importantly, the persistence of this cluster alongside emerging processing themes (nanoemulsion/microencapsulation) suggests a field-level shift from demonstrating antioxidant potential toward improving delivery and stability of antioxidant-related constituents through advanced formulation technologies [3, 5, 6]. Overall, the network structure indicates that VCO research is consolidating around two interacting directions: strengthening biological evidence (antimicrobial, anti-inflammatory, metabolic endpoints) and accelerating translation via authentication, processing optimization, and delivery innovations.

3.14 The co-citation visualization network

The co-citation visualization network reveals the collaborative relationships between countries in producing scientific research on VCO (Figure 13). India emerges as the central hub, playing a pivotal role in global research by establishing strong connections with multiple countries, including the United States, Thailand, and Nigeria. This highlights India's significant contribution to the field, likely driven by its focus on coconut production and the increasing recognition of VCO's functional food properties. The connection with the United States reflects interdisciplinary collaborations, where advanced methodologies such as analytical technologies and clinical studies are integrated with production-focused research led by India. India's link with Nigeria signifies emerging partnerships, indicating a growing interest in VCO's applications in African contexts. Nodes represent countries, with node size corresponding to the volume of research contributions. Lines indicate collaborative links between countries, with line thickness representing the strength of collaboration (frequency of co-authored publications). Colors group countries into clusters based on the intensity of their collaborative relationship.

Figure 13. The network visualization illustrates collaboration relationships between countries in research related to the topic under study

A prominent regional collaboration is evident in Southeast Asia, where Malaysia, Indonesia, and China form a closely linked cluster. Malaysia serves as a key connector in this group, facilitating research exchanges between Indonesia and China. This regional collaboration highlights Southeast Asia's leadership in VCO research, driven by its role as a major coconut-producing region. The strong ties between Malaysia and Indonesia suggest shared interests in optimizing VCO production methods and exploring its nutritional and therapeutic applications. The connection between India and this Southeast Asian cluster signifies substantial inter-regional cooperation, which is essential for advancing the global understanding of VCO's health and functional food benefits.

The United States also appears as an important international partner, establishing links with India and Thailand. This reflects the involvement of Western countries in contributing technical expertise and resources to complement the agricultural and production-driven research occurring in Asia. Meanwhile, Nigeria, although represented as a smaller node, signifies emerging collaborations, hinting at future opportunities to explore VCO's functional food applications in Africa. In conclusion, the co-citation network demonstrates that India and Southeast Asia (Malaysia, Indonesia, and China) are the dominant contributors to VCO research, with India serving as the central hub of international collaboration. The United States plays a key supporting role by providing advanced methodologies, while emerging contributions from Nigeria point toward broader global engagement. This interconnected network reflects the growing international effort to explore VCO's production, quality, and health applications, solidifying its status as a valuable functional food in both regional and global contexts.

3.15 The evolution and future potential of VCO research

The research paradigm of VCO has evolved significantly over time, transitioning from traditional knowledge to a scientifically driven field with global relevance. In its earliest phase, VCO was deeply rooted in cultural and traditional practices, particularly in tropical regions where coconuts are abundant [28]. Communities valued VCO as a natural remedy for common ailments and as a culinary staple, using it for energy, skincare, and general well-being. However, these benefits were largely based on anecdotal evidence and lacked rigorous scientific investigation. During this period, the understanding of VCO's potential was limited to localized

knowledge, and its application was confined to traditional medicine and household use.

In the late 20th century and early 2000s, VCO research entered a new phase focusing on scientific exploration of its nutritional composition and health benefits [72]. Researchers began identifying its bioactive compounds, particularly MCFAs such as lauric acid, capric acid, and caprylic acid, which were found to have antimicrobial, antiviral, and anti-inflammatory properties [8, 66]. Studies also highlighted VCO's antioxidant capacity, attributed to its phenolic compounds [73, 74]. These findings marked the first scientific validation of VCO's potential benefits. However, research during this period was often small-scale and isolated, with limited global recognition. Despite its promising results, VCO was still regarded primarily as a natural product with niche applications, rather than a scientifically validated health supplement.

The mid-2000s saw a paradigm shift as VCO gained recognition as a functional food—products that offer specific health benefits beyond basic nutrition [28, 38]. This phase was characterized by interdisciplinary research involving food science, biochemistry, and medicine, as well as increasing global interest in health-conscious lifestyles. Researchers began exploring VCO's role in addressing metabolic disorders such as diabetes and obesity, its potential to support cardiovascular health by improving lipid profiles, and its ability to enhance immunity [75-77]. The focus also expanded to include the role of VCO in gut health, particularly its effects on the gut microbiome [78, 79]. Bibliometric analyses revealed a growing body of publications, highlighting the increasing collaboration between tropical countries, where VCO is produced, and international research institutions.

In recent years, advancements in VCO research have further solidified its position as a versatile and valuable product. Systematic reviews, meta-analyses, and clinical trials have provided robust evidence for its health claims, including its potential to improve cognitive function, support weight management, and reduce inflammation [80, 81]. Advanced analytical techniques such as genomics, metabolomics, and proteomics have enabled a deeper understanding of VCO's mechanisms of action at the molecular level [82, 83]. Furthermore, the applications of VCO have expanded beyond the food sector. It is now widely used in nutraceuticals, cosmetics, and even renewable energy, reflecting its versatility and growing market demand [68, 84]. Researchers have also begun exploring its potential in innovative areas such as biodegradable materials and pharmaceutical formulations [85-87].

Looking ahead, the future trajectory of VCO research promises exciting opportunities for innovation and impact. Sustainability is expected to become a central theme, with research focusing on eco-friendly production processes, waste utilization, and the development of value-added by-products from VCO manufacturing. For example, coconut shells and husks, which are often discarded as waste, could be repurposed for bioenergy or biodegradable packaging. Advances in personalized healthcare and nutrition may also drive the development of tailored VCO-based products designed for specific health profiles, such as individuals with metabolic disorders or compromised immunity.

Another promising area of future research is the impact of VCO on the gut microbiome. As understanding of the gut's role in overall health grows, VCO's anti-microbial and prebiotic properties could make it a key player in gut health management. Establishing standardized guidelines for VCO production and quality assurance will also be critical to ensuring consistency in health claims and enhancing its global regulatory acceptance. This standardization could help position VCO as a mainstream functional food in international markets.

The integration of digital tools such as artificial intelligence and machine learning may revolutionize the development of VCO-based products. These technologies could be used to predict consumer behavior, optimize product formulations, and identify new applications for VCO. Innovative products such as ready-to-drink beverages, energy bars, and medical foods incorporating VCO are likely to emerge, catering to the growing demand for convenient and health-focused options. Furthermore, interdisciplinary collaborations between food science, biotechnology, and environmental research are expected to expand the scope of VCO's applications, making it a valuable resource across multiple industries.

The research paradigm of VCO has shifted dramatically, from its origins in traditional knowledge to a global, evidence-based field of study. This evolution reflects the growing recognition of VCO's potential as a functional food, supported by scientific advancements and interdisciplinary collaboration. As research continues to explore new frontiers, VCO is poised to play an increasingly significant role in health, sustainability, and innovation, making it a cornerstone of future functional food development.

4. CONCLUSIONS

The field of VCO research has witnessed a remarkable transformation, evolving from traditional anecdotal applications to a globally recognized area of scientific inquiry. This bibliometric analysis highlights key contributors, influential journals, and thematic advancements that have shaped the landscape of VCO research. Publications in this field have shown exponential growth, with the majority produced in the last decade. Regions like Southeast Asia dominate the production and initial exploration, while collaborations with countries such as the USA and Australia have strengthened the global research impact. Despite this growth, the field remains fragmented, with a wide array of authors and institutions contributing without a centralized research network. The intellectual core of VCO research spans several primary areas: its bioactive components, functional food applications, and its integration into industries such as nutraceuticals and cosmetics. Key publications and influential journals, such as the *Journal of Food Science and Technology* and *IOP Conference Series*, have played vital roles in disseminating knowledge. Seminal works have provided foundational understanding, such as the role of MCFAs and antioxidants in promoting health benefits. Recent advancements emphasize the exploration of VCO's effects on gut microbiota, its potential in personalized nutrition, and sustainable production practices. Emerging themes include its use in metabolic health, cognitive support, and skin health, reflecting the broadening scope of applications. This analysis provides an in-depth perspective on the global research landscape of VCO, revealing its challenges and potential growth areas. However, the study is limited by its reliance on specific bibliometric data sources and lacks integration of qualitative assessments from other repositories like PubMed or Web of Science.

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REFERENCES

[1] Mendis, S., Graham, I., Narula, J. (2022). Addressing the global burden of cardiovascular diseases; need for scalable and sustainable frameworks. Glob Heart, 17(1): 48. https://doi.org/10.5334/gh.1139

[2] Arokiasamy, P., Salvi, S., Selvamani, Y. (2021). Global burden of diabetes mellitus. In Handbook of Global Health, pp. 1-44. https://doi.org/10.1007/978-3-030-05325-3_28-2

[3] Vaduganathan, M., Mensah, G.A., Turco, J.V., Fuster, V., Roth, G.A. (2022). The global burden of cardiovascular diseases and risk: A compass for future health. Journal of the American College of Cardiology, 80(25): 2361-2371. https://doi.org/10.1016/j.jacc.2022.11.005

[4] Gul, K., Singh, A.K., Jabeen, R. (2015). Nutraceuticals and functional foods: The foods for the future world. Critical Reviews in Food Science and Nutrition, 56(16): 2617-2627. https://doi.org/10.1080/10408398.2014.903384

[5] Rohman, A., Irnawati, Erwanto, Y., Lukitaningsih, E., Rafi, M., Fadzilah, N.A., Windarsih, A., Sulaiman, A., Zakaria, Z. (2019). Virgin coconut oil: Extraction, physicochemical properties, biological activities and its authentication analysis. Food Reviews International, 37(1): 46-66. https://doi.org/10.1080/87559129.2019.1687515

[6] Montefrio, M.J.F. (2019). Cosmopolitan translations of food and the case of alternative eating in Manila, the Philippines. Agric Hum Values, 37(2): 479-494. https://doi.org/10.1007/s10460-019-10000-z

[7] Hasan, H.M., Leanpolchareanchai, J., Jintapattanakit, A. (2014). Preparation of virgin coconut oil nanoemulsions by phase inversion temperature method. AMR, 1060: 99-102. https://doi.org/10.4028/www.scientific.net/amr.1060.99

[8] Nasir, N.A.M.M., Abllah, Z., Azura Jalaludin, A., Azura Shahdan, I., Hayati Wan Abd Manan, W.N. (2018). Virgin coconut oil and its antimicrobial properties against pathogenic microorganisms: A review. In Proceedings of the International Dental Conference of Sumatera Utara 2017 (IDCSU 2017). https://doi.org/10.2991/idcsu-17.2018.51

[9] Sungpud, C., Panpipat, W., Chaijan, M., Sae Yoon, A. (2020). Techno-biofunctionality of mangostin extract-loaded virgin coconut oil nanoemulsion and nanoemulgel. PLoS ONE, 15(1): e0227979. https://doi.org/10.1371/journal.pone.0227979

[10] Annisa, D.N., Nurhadi, B., Indiarto, R., Saputra, R.A., Mahani. (2023). Characteristics of virgin coconut oil (VCO) microencapsulation using O/W emulsification and complex coacervation methods. International Food Research Journal, 30(6): 1603-1616. https://doi.org/10.47836/ifrj.30.6.22

[11] Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., Lim, W.M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. Journal of Business Research, 133: 285-296. https://doi.org/10.1016/j.jbusres.2021.04.070

[12] Linnenluecke, M.K., Marrone, M., Singh, A.K. (2019). Conducting systematic literature reviews and bibliometric analyses. Australian Journal of Management, 45(2): 175-194. https://doi.org/10.1177/0312896219877678

[13] Aria, M., Cuccurullo, C. (2017). Bibliometrix: An R-tool for comprehensive science mapping analysis. Journal of Informetrics, 11(4): 959-975. https://doi.org/10.1016/j.joi.2017.08.007

[14] Yang, K., Meho, L.I. (2006). Citation analysis: A comparison of Google Scholar, Scopus, and Web of Science. Proceedings of the American Society for Information Science and Technology, 43(1): 1-15. https://doi.org/10.1002/meet.14504301185

[15] Gasparyan, A.Y., Yessirkepov, M., Voronov, A.A., Trukhachev, V.I., Kostyukova, E.I., Gerasimov, A.N., Kitas, G.D. (2016). Specialist bibliographic databases. Journal of Korean Medical Science, 31(5): 660. https://doi.org/10.3346/jkms.2016.31.5.660

[16] Caputo, A., Kargina, M. (2021). A user-friendly method to merge Scopus and Web of Science data during bibliometric analysis. Journal of Marketing Analytics, 10(1): 82-88. https://doi.org/10.1057/s41270-021-00142-7

[17] Pranckutė, R. (2021). Web of Science (WoS) and Scopus: The titans of bibliographic information in today's academic world. Publications, 9(1): 12. https://doi.org/10.3390/publications9010012

[18] Mongeon, P., Paul-Hus, A. (2015). The journal coverage of Web of Science and Scopus: A comparative analysis. Scientometrics, 106(1): 213-228. https://doi.org/10.1007/s11192-015-1765-5

[19] van Nunen, K., Li, J., Reniers, G., Ponnet, K. (2018). Bibliometric analysis of safety culture research. Safety Science, 108: 248-258. https://doi.org/10.1016/j.ssci.2017.08.011

[20] Ng, J.Y., Liu, H., Masood, M., Syed, N., Stephen, D., Ayala, A.P., Sabé, M., Solmi, M., Waltman, L., Haustein, S., Moher, D. (2024). Guidance for the reporting of bibliometric analyses: A scoping review. openRxiv. https://doi.org/10.1101/2024.08.26.24312538

[21] McAllister, J.T., Lennertz, L., Atencio Mojica, Z. (2021). Mapping a discipline: A guide to using VOSviewer for bibliometric and visual analysis. Science & Technology Libraries, 41(3): 319-348. https://doi.org/10.1080/0194262x.2021.1991547

[22] Wong, D. (2018). VOSviewer. Technical Services Quarterly, 35(2): 219-220. https://doi.org/10.1080/07317131.2018.1425352

[23] Martins, J., Gonçalves, R., Branco, F. (2022). A bibliometric analysis and visualization of e-learning adoption using VOSviewer. Universal Access in the Information Society, 23(3): 1177-1191. https://doi.org/10.1007/s10209-022-00953-0

[24] Bukar, U.A., Sayeed, M.S., Razak, S.F.A., Yogarayan, S., Amodu, O.A., Mahmood, R.A.R. (2023). A method for analyzing text using VOSviewer. MethodsX, 11: 102339. https://doi.org/10.1016/j.mex.2023.102339

[25] Sanjeewani, N.A., Sakeena, M.H.F. (2013). Formulation and characterization of virgin coconut oil (VCO) based emulsion. International Journal of Scientific and Research Publications, 3(12): 1-6.
[26] Preeti, Sambhakar, S., Malik, R., Bhatia, S., Al Harrasi, A., Rani, C., Saharan, R., Kumar, S., Geeta, Sehrawat, R. (2023). Nanoemulsion: An emerging novel technology for improving the bioavailability of drugs. Scientifica, 2023: 1-25. https://doi.org/10.1155/2023/6640103
[27] Kulandasamy, T., Rao, S.K., Farzana, W. (2023). Microencapsulation of enzymatically destabilized virgin coconut oil by spray drying technique: Optimization of process parameters, quality assessment and studies on physico-chemical characteristics of microcapsule. Food and Humanity, 1: 650-661. https://doi.org/10.1016/j.foohum.2023.07.003
[28] Marina, A.M., Che Man, Y.B., Amin, I. (2009). Virgin coconut oil: Emerging functional food oil. Trends in Food Science & Technology, 20(10): 481-487. https://doi.org/10.1016/j.tifs.2009.06.003
[29] Marina, A.M., Che man, Y.B., Nazimah, S.A.H., Amin, I. (2009). Antioxidant capacity and phenolic acids of virgin coconut oil. International Journal of Food Sciences and Nutrition, 60(sup2): 114-123. https://doi.org/10.1080/09637480802549127
[30] Khaw, KT., Sharp, S.J., Finikarides, L., Afzal, I., Lentjes, M., Luben, R., Forouhi, N.G. (2018). Randomised trial of coconut oil, olive oil or butter on blood lipids and other cardiovascular risk factors in healthy men and women. BMJ Open, 8(3): e020167. https://doi.org/10.1136/bmjopen-2017-020167
[31] Villarino, B.J., Dy, L.M., Lizada, Ma, C.C. (2007). Descriptive sensory evaluation of virgin coconut oil and refined, bleached and deodorized coconut oil. LWT - Food Science and Technology, 40(2): 193-199. https://doi.org/10.1016/j.lwt.2005.11.007
[32] Shilling, M., Matt, L., Rubin, E., Visitacion, M.P., Haller, N.A., Grey, S.F., Woolverton, C.J. (2013). Antimicrobial effects of virgin coconut oil and its medium-chain fatty acids on clostridium difficile. Journal of Medicinal Food, 16(12): 1079-1085. https://doi.org/10.1089/jmf.2012.0303
[33] Ghani, N.A.A., Channip, A., Chok Hwee Hwa, P., Ja'afar, F., Yasin, H.M., Usman, A. (2018). Physicochemical properties, antioxidant capacities, and metal contents of virgin coconut oil produced by wet and dry processes. Food Science & Nutrition, 6(5): 1298-1306. https://doi.org/10.1002/fsn3.671
[34] Ogbolu, D.O., Oni, A.A., Daini, O.A., Oloko, A.P. (2007). In vitro antimicrobial properties of coconut oil on candida species in Ibadan, Nigeria. Journal of Medicinal Food, 10(2): 384-387. https://doi.org/10.1089/jmf.2006.1209
[35] Rohman, A. (2016). Infrared spectroscopy for quantitative analysis and oil parameters of olive oil and virgin coconut oil: A review. International Journal of Food Properties, 20(7): 1447-1456. https://doi.org/10.1080/10942912.2016.1213742
[36] Illam, S.P., Narayanankutty, A., Raghavamenon, A.C. (2017). Polyphenols of virgin coconut oil prevent pro-oxidant mediated cell death. Toxicology Mechanisms and Methods, 27(6): 442-450. https://doi.org/10.1080/15376516.2017.1320458
[37] Carpiné, D., Dagostin, J.L.A., Bertan, L.C., Mafra, M.R. (2015). Development and characterization of soy protein isolate emulsion-based edible films with added coconut oil for olive oil packaging: Barrier, Mechanical, and thermal properties. Food Bioprocess Technol, 8(8): 1811-1823. https://doi.org/10.1007/s11947-015-1538-4
[38] Srivastava, Y., Semwal, A.D., Sharma, G.K. (2018). Virgin coconut oil as functional oil. In Therapeutic, Probiotic, and Unconventional Foods, pp. 291-301. https://doi.org/10.1016/b978-0-12-814625-5.00015-7
[39] Zeng, Y.Q., He, J.T., Hu, B.Y., Li, W., Deng, J., Lin, Q.L., Fang, Y. (2022). Virgin coconut oil: A comprehensive review of antioxidant activity and mechanisms contributed by phenolic compounds. Critical Reviews in Food Science and Nutrition, 64(4): 1052-1075. https://doi.org/10.1080/10408398.2022.2113361
[40] Rozani, M.A.S., Hamid, H.A.A., Hadzir, N.M., Latif, M.A.M., Som, A.M. (2024). Virgin coconut oil-based emulsion and its benefits: A review. Malaysian Journal of Analytical Sciences, 28(5): 1087-1101.
[41] Prasanna, N.S., Selvakumar, M., Choudhary, N., Raghavarao, K.S.M.S. (2024). Virgin coconut oil: Wet production methods and food applications – A review. Sustainable Food Technology, 2(5): 1391-1408. https://doi.org/10.1039/d4fb00093e
[42] Yeap, S.K., Beh, B.K., Ali, N.M., Yusof, H.M., Ho, W.Y., Koh, S.P., Alitheen, N.B., Long, K. (2014). Antistress and antioxidant effects of virgin coconut oil in vivo. Experimental and Therapeutic Medicine, 9(1): 39-42. https://doi.org/10.3892/etm.2014.2045
[43] Famurewa, A.C., Ejezie, F.E. (2018). Polyphenols isolated from virgin coconut oil attenuate cadmium-induced dyslipidemia and oxidative stress due to their antioxidant properties and potential benefits on cardiovascular risk ratios in rats. Avicenna Journal of Phytomedicine, 8(1): 73.
[44] Famurewa, A.C., Ekeleme-Egedigwe, C.A., Nwali, S.C., Agbo, N.N., Obi, J.N., Ezechukwu, G.C. (2017). Dietary supplementation with virgin coconut oil improves lipid profile and hepatic antioxidant status and has potential benefits on cardiovascular risk indices in normal rats. Journal of Dietary Supplements, 15(3): 330-342. https://doi.org/10.1080/19390211.2017.1346031
[45] Dayrit, F.M., Dimzon, I.K.D., Valde, M.F., Santos, J.E.R., Garrovillas, M.J.M., Villarino, B.J. (2011). Quality characteristics of virgin coconut oil: Comparisons with refined coconut oil. Pure and Applied Chemistry, 83(9): 1789-1799. https://doi.org/10.1351/pac-con-11-04-01
[46] Ahmad, A., Ayub, H. (2022). Fourier transform infrared spectroscopy (FTIR) technique for food analysis and authentication. In Nondestructive Quality Assessment Techniques for Fresh Fruits and Vegetables, pp. 103-142. https://doi.org/10.1007/978-981-19-5422-1_6
[47] Sudhakar, A., Chakraborty, S.K., Mahanti, N.K., Varghese, C. (2021). Advanced techniques in edible oil authentication: A systematic review and critical analysis. Critical Reviews in Food Science and Nutrition, 63(7): 873-901. https://doi.org/10.1080/10408398.2021.1956424
[48] Priya, R.B., Rashmitha, R., Preetham, G.S., Chandrasekar, V., Mohan, R.J., Sinija, V.R., Pandiselvam, R. (2022). Detection of adulteration in coconut oil and virgin coconut oil using advanced analytical techniques: A review. Food Anal. Methods, 15(11): 2917-2930. https://doi.org/10.1007/s12161-022-02342-y

[49] Pandiselvam, R., Kaavya, R., Martinez Monteagudo, S.I., Divya, V., Jain, S., Khanashyam, A.C., Kothakota, A., Prasath, V.A., Ramesh, S.V., Sruthi, N.U., Kumar, M., Manikantan, M.R., Kumar, C.A., Khaneghah, A.M., Cozzolino, D. (2022). Contemporary developments and emerging trends in the application of spectroscopy techniques: A particular reference to coconut (Cocos nucifera L.). Molecules, 27(10): 3250. https://doi.org/10.3390/molecules27103250

[50] Mousa, M.A.A., Wang, Y., Antora, S.A., Al-qurashi, A.D., Ibrahim, O.H.M., He, H.J., Liu, S., Kamruzzaman, M. (2021). An overview of recent advances and applications of FT-IR spectroscopy for quality, authenticity, and adulteration detection in edible oils. Critical Reviews in Food Science and Nutrition, 62(29): 8009-8027. https://doi.org/10.1080/10408398.2021.1922872

[51] Zakaria, Z.A., Somchit, M.N., Mat Jais, A.M., Teh, L.K., Salleh, M.Z., Long, K. (2011). In vivo Antinociceptive and anti-inflammatory activities of dried and fermented processed virgin coconut oil. Medical Principles and Practice, 20(3): 231-236. https://doi.org/10.1159/000323756

[52] Famurewa, A.C., Maduagwuna, E.K., Folawiyo, A.M., Besong, E.E., Eteudo, A.N., Famurewa, O.A., Ejezie, F.E. (2019). Antioxidant, anti-inflammatory, and antiapoptotic effects of virgin coconut oil against antibiotic drug gentamicin-induced nephrotoxicity via the suppression of oxidative stress and modulation of iNOS/NF-κB/caspase-3 signaling pathway in Wistar rats. Journal of Food Biochemistry, 44(1): e13100. https://doi.org/10.1111/jfbc.13100

[53] Satheesh, N. (2015). Review on production and potential applications of virgin coconut oil. Annals: Food Science & Technology, 16(1): 115.

[54] Amit, Jamwal, R., Kumari, S., Dhaulaniya, A.S., Balan, B., Kelly, S., Cannavan, A., Singh, D.K. (2020). Utilizing ATR-FTIR spectroscopy combined with multivariate chemometric modelling for the swift detection of mustard oil adulteration in virgin coconut oil. Vibrational Spectroscopy, 109: 103066. https://doi.org/10.1016/j.vibspec.2020.103066

[55] Mulia, K., Zaenal, M.F., Krisanti, E.A. (2019). Encapsulation of oleoresin from ginger (Zingiber officinale var. Roscoe) in vegetable oils based nanoemulsions: Preparation and characterization for oral delivery formulation. AIP Conference Proceedings, 2096: 030011. https://doi.org/10.1063/1.5096715

[56] Suryani, Sahumena, M.H., Mabilla, S.Y., Ningsih, S.R., Adjeng, A.N.T., Aswan, M., Ruslin, Yamin, Nisa, M. (2020). Preparation and evaluation of physical characteristics of vitamin E nanoemulsion using virgin coconut Oil (VCO) and olive oil as oil phase with variation concentration of tween 80 surfactant. Research Journal of Pharmacy and Technology, 13(7): 3232. https://doi.org/10.5958/0974-360x.2020.00572.7

[57] Azubuike-Osu, S.O., Famurewa, A.C., David, J.C., Abi, I., Ogbu, P.N., Oparaji, C.K., Nwaeze, K.G., Akunna, G.G. (2021). Virgin coconut oil resists arsenic-induced cerebral neurotoxicity and cholesterol imbalance via suppression of oxidative stress, adenosine deaminase and acetylcholinesterase activities in rats. Natural Product Communications, 16(6): 1-8. https://doi.org/10.1177/1934578x211016962

[58] Zhong, X., Tang, J., Jiang, R., Yuan, P., Zhao, Q., Gong, S., Liu, J., Wang, L. (2021). The predictive value of minute ventilation versus carbon dioxide production in pulmonary hypertension associated with left heart disease. Annals of Translational Medicine, 9(4): 351-351. https://doi.org/10.21037/atm-21-366

[59] Iranloye, B., Oludare, G., Olubiyi, M. (2013). Anti-diabetic and antioxidant effects of virgin coconut oil in alloxan induced diabetic male Sprague Dawley rats. Journal of Diabetes Mellitus, 3(4): 221-226. https://doi.org/10.4236/jdm.2013.34034

[60] Zicker, M.C., Silveira, A.L.M., Lacerda, D.R., Rodrigues, D.F., Oliveira, C.T., de Souza Cordeiro, L.M., Lima, L.C.F., Santos, S.H.S., Teixeira, M.M., Ferreira, A.V.M. (2019). Virgin coconut oil is effective to treat metabolic and inflammatory dysfunction induced by high refined carbohydrate-containing diet in mice. The Journal of Nutritional Biochemistry, 63: 117-128. https://doi.org/10.1016/j.jnutbio.2018.08.013

[61] Illam, S.P., Kandiyil, S.P., Narayanankutty, A., Veetil, S.V., Babu, T.D., Uppu, R.M., Raghavamenon, A.C. (2021). Virgin coconut oil complements with its polyphenol components mitigate sodium fluoride toxicityin vitroandin vivo. Drug and Chemical Toxicology, 45(6): 2528-2534. https://doi.org/10.1080/01480545.2021.1962691

[62] Famurewa, A.C., Ejezie, A.J., Ugwu-Ejezie, C.S., Ikekpeazu, E.J., Ejezie, F.E. (2018). Antioxidant and anti-inflammatory mechanisms of polyphenols isolated from virgin coconut oil attenuate cadmium-induced oxidative stress-mediated nephrotoxicity and inflammation in rats. Journal of Applied Biomedicine, 16(4): 281-288. https://doi.org/10.1016/j.jab.2018.02.003

[63] Ngampeerapong, C., Chavasit, V., Durst, R.W. (2018). Bioactive and nutritional compounds in virgin coconut oils. Malaysian Journal of Nutrition, 24(2): 257-267.

[64] Mena, T.P., Sutrisno, Marfu'ah, S. (2020). Antibacterial activity of free fatty acids, potassium soap, and fatty acids methyl esters from VCO (Virgin Coconut Oil). IOP Conference Series: Materials Science and Engineering, 833(1): 012023. https://doi.org/10.1088/1757-899x/833/1/012023

[65] Suryani, S., Sariani, S., Earnestly, F., Marganof, M., Rahmawati, R., Sevindrajuta, S., Mahlia, T.M.I., Fudholi, A. (2020). A comparative study of virgin coconut oil, coconut oil and palm oil in terms of their active ingredients. Processes, 8(4): 402. https://doi.org/10.3390/pr8040402

[66] Nitbani, F.O., Tjitda, P.J.P., Nitti, F., Jumina, J., Detha, A.I.R. (2022). Antimicrobial properties of lauric acid and monolaurin in virgin coconut oil: A review. ChemBioEng Reviews, 9(5): 442-461. https://doi.org/10.1002/cben.202100050

[67] Ngatirah, N., Hidayat, C., Rahayu, E.S., Utami, T. (2022). The role of fat blends in improving the physicochemical properties of palm kernel oil for monolaurin synthesis. Trends in Sciences, 19(11): 4214. https://doi.org/10.48048/tis.2022.4214

[68] Abdalla, S., Aroua, M.K., Gew, L.T. (2024). A comprehensive review of plant-based cosmetic oils (virgin coconut oil, olive oil, argan oil, and jojoba oil): Chemical and biological properties and their cosmeceutical applications. ACS Omega, 9(44): 44019-

44032. https://doi.org/10.1021/acsomega.4c04277
[69] Wachidah Yuiwarti, E.Y., Saraswati, T.R., Kusdiyantini, E. (2018). Effect of VCO and olive oil on HDL, LDL, and cholesterol level of hyperglycemic Rattus Rattus Norvegicus. Journal of Physics: Conference Series, 1025: 012064. https://doi.org/10.1088/1742-6596/1025/1/012064
[70] Kappally, S., Shirwaikar, A., Shirwaikar, A. (2015). Coconut oil–a review of potential applications. Hygeia Journal for Drugs and Medicines, 7(2): 34-41.
[71] Selvi, M.K., Nagalapur, A.N., Vijayaraj, P. (2023). Comparative study to assess the medium-chain triglyceride content in various edible oils for functional food formulation. Medicinal Plants - International Journal of Phytomedicines and Related Industries, 15(4): 794-803. https://doi.org/10.5958/0975-6892.2023.00081.3
[72] Rajamohan, T., Archana, U. (2018). Nutrition and health aspects of coconut. In the Coconut Palm (Cocos nucifera L.) - Research and Development Perspectives, pp. 757-777. https://doi.org/10.1007/978-981-13-2754-4_15
[73] Mulyadi, A.F., Schreiner, M., Dewi, I.A. (2018). Phenolic and volatile compounds, antioxidant activity, and sensory properties of virgin coconut oil: Occurrence and their relationship with quality. AIP Conference Proceedings, 2021: 070020. https://doi.org/10.1063/1.5062818
[74] Zainodin, E.L., Rashidi, N.F., Abdul Mutalib, H., Ishak, B., Ghazali, A.R. (2024). Antioxidant properties of virgin coconut oil and its cytotoxicity towards human keratinocytes. Natural Product Communications, 19(12). https://doi.org/10.1177/1934578x241309739
[75] Araújo de Vasconcelos, M.H., Tavares, R.L., Dutra, M.L. da V., Batista, K.S., D'Oliveira, A.B., Pinheiro, R.O., Pereira, R.A., Lima, M.S., Salvadori, M.G.S.S., de Souza, E.L., Magnani, M., Alves, A.F., Aquino, J.S. (2023). Extra virgin coconut oil (Cocos nucifera L.) intake shows neurobehavioural and intestinal health effects in obesity-induced rats. Food & Function, 14(14): 6455-6469. https://doi.org/10.1039/d3fo00850a
[76] Hima, L., Pratap, U.P., Karrunanithi, S., Ravichandran, K.A., Vasantharekha, R., ThyagaRajan, S. (2019). Virgin coconut oil supplementation in diet modulates immunity mediated through survival signaling pathways in rats. Journal of Complementary and Integrative Medicine, 17(1). https://doi.org/10.1515/jcim-2019-0114
[77] Jeyakumar, S.M., Damayanti, K., Rajkumar Ponday, L., Acharya, V., Koppala, S.R., Putcha, U.K., Nagalla, B., Vajreswari, A. (2023). Assessment of virgin coconut oil in a balanced diet on indicators of cardiovascular health in non-obese volunteers: A human metabolic study. Diabetes & Metabolic Syndrome: Clinical Research & Reviews, 17(9): 102844. https://doi.org/10.1016/j.dsx.2023.102844
[78] Djurasevic, S., Bojic, S., Nikolic, B., Dimkic, I., Todorovic, Z., Djordjevic, J., Mitic-Culafic, D. (2018). Beneficial effect of virgin coconut oil on alloxan-induced diabetes and microbiota composition in rats. Plant Foods Hum Nutr, 73(4): 295-301. https://doi.org/10.1007/s11130-018-0689-7
[79] El-Meidany, W.M.R., Tayel, D.I. (2019). Can virgin coconut oil be the neutraceutical for chronic constipation among autistic children: A case study. Canadian Journal of Clinical Nutrition, 7(1): 26-33. https://doi.org/10.14206/canad.j.clin.nutr.2019.01.03
[80] Fernando, M.G., Silva, R., Fernando, W.M.A.D.B., de Silva, H.A., Wickremasinghe, A.R., Dissanayake, A.S., Sohrabi, H.R., Martins, R.N., Williams, S.S. (2023). Effect of virgin coconut oil supplementation on cognition of individuals with mild-to-moderate alzheimer's disease in Sri Lanka (VCO-AD study): A randomized placebo-controlled trial. Journal of Alzheimer's Disease, 96(3): 1195-1206. https://doi.org/10.3233/jad-230670
[81] Rahman, S.K., Azman, I.N. (2023). Evaluating the effects of virgin coconut oil on lipid profile and inflammatory markers in ACS. Journal of Artificial Intelligence in Medicine, 11: 1-20.
[82] Ramesh, S.V., Sudha, R., Niral, V., Rajesh, M.K. (2022). Enhancing genetic gain in coconut: Conventional, molecular, and genomics-based breeding approaches. Accelerated Plant Breeding, 4: 313-357. https://doi.org/10.1007/978-3-030-81107-5_10
[83] Ignacio, I.F., Miguel, T.S. (2021). Research opportunities on the coconut (Cocos nucifera L.) using new technologies. South African Journal of Botany, 141: 414-420. https://doi.org/10.1016/j.sajb.2021.05.030
[84] Yohannan, A. (2020). Quantitative analysis of fatty acids on biodiesel fuel derived from virgin coconut oil. International Research Journal of Engineering and Technology, 7(5): 7031-7037.
[85] Juliyarsi, I., Melia, S., Novia, D., Nabila, S. (2021). Physical, mechanical, and microstructure properties of whey edible films incorporated with Virgin Coconut Oil (VCO). IOP Conference Series: Earth and Environmental Science, 888(1): 012042. https://doi.org/10.1088/1755-1315/888/1/012042
[86] Carpiné, D., Dagostin, J.L.A., de Andrade, E.F., Bertan, L.C., Mafra, M.R. (2016). Effect of the natural surfactant Yucca schidigera extract on the properties of biodegradable emulsified films produced from soy protein isolate and coconut oil. Industrial Crops and Products, 83: 364-371. https://doi.org/10.1016/j.indcrop.2016.01.014
[87] Tripathi, S., Sahu, U. kumar, Meshram, J., Kumari, R., Tripathi, D.K., Ajazuddin, Alexander, A., Sharma, H., Sahu, G.K. (2018). Formulation and characterization of Virgin Coconut Oil Emulsion (VCOE) for treatment of Alzheimer's disease. Research Journal of Pharmaceutical Dosage Forms and Technology, 10(2): 49. https://doi.org/10.5958/0975-4377.2018.00009.5