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Analysis of Esterification Research in Indonesia for 25 Years using Bibliometric Method

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Abstract

The rapid development in the industrial world today, especially in the chemical industry, increases the need for ester compounds. The development of research and use of ester compounds in the industry will not stop as long as technology is still developing. The ester compound, one of the industrial organic compounds with the highest volume, can be used in various industrial worlds, such as textile, pharmaceutical, and food industries. The esterification process is considered to be the most common and most widely practiced ester synthesis process. Therefore, the purpose of this study was to analyze the esterification process in Indonesia for twenty-five years (1997-2022) using the bibliometric method. Information of bibliometric is extracted from the Scopus database with the keyword "Esterification". The study identifies the most prolific authors and top institutions for journals. Networks linking keywords in esterification studies were mapped to visualize research hotspots using similarity visualization software (VOSviewer). The most significant topics were covered by the journal with a total of 365 publications. Subjects related to the esterification process were determined as the most relevant.

Keywords: Bibliometric Analysis, Esterification Process, VOSviewer

1. Introduction

Currently, the development of the industrial world in Indonesia is growing rapidly, especially in the chemical industry. The need for ester compounds as a result of the esterification process in the chemical industry is also increasing. Esters are the most widely used industrial organic compounds and may be employed in a variety of industrial contexts, including textile, pharmaceutical, food, and even energy industries (fuel). The ester molecule is polar and relatively low molecular mass soluble in water. Esters with low molecular weight tend to be volatile and have a characteristic aroma. On the other hand, when the molecular weight is high, they are colorless and odorless crystalline solids depending on the structure [1].

Esterification is one of the most important processes in the synthesis of organic compounds. Esters are organic substances that can be found either naturally or synthetically [1]. The primary product of esterification are biofuels such as biodiesel [2], solvents such as acetyl acetate and methyl acetate [3], paints and varnishes, medicines, plastics, and coatings [4], and some are used as herbicides and pesticides [5]. Esters are frequently employed in food products as flavoring and preservation ingredients [6], as a significant perfume additive in the soap and cosmetics sector, or in the formulation of personal care product.

Therefore, esterification was analyzed using the bibliometric method in the last five years to provide an overview of the latest research developments in Indonesia. The bibliometric method with the topic of esterification is also assisted by the VOSviewer software with the Scopus database. According to George et al. (2021) and Omoregbe et al. (2020), bibliometric method uses quantitative data analysis to identify publications and research trends in a

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particular research area [7,8]. This analysis uses data to look at the authors' collaborative network, scientific results and contributions, the impact of researchers' work, organizational collaborations and contributions, and country contributions to research. Bibliometric methods must go beyond only reporting the outcomes of performance analysis and scientific mapping produced by scientific databases and software, such as Scopus and Web of Science. In particular, bibliometric methods are not sufficient when describing simply the major contributors and topics [9].

2. Methods

2.1. Bibliometric Method

Analysis of bibliometric is a basic methodology for analyze research in the field of information science. A number of studies offer a thorough bibliometric review of various research areas [10]. This method is a research area that is increasingly receiving attention from the scientific community, especially against the background of the rapid development of computers and the internet [11]. According to Koseoglu et al. (2016), bibliometric method is defined as "quantitative studies of published physical units, or bibliographic units, or surrogates for both" [12]. Other authors view the bibliometric method as a tool that assisted in the analysis, organization, classification, and measurement of the publication pattern of all macro and micro communications along with their authorship using mathematical and statistical calculus, based on intellectual, social, and conceptual structures, and including the themes sought, the method used, and the sample used [13]. The outcomes of the bibliometric study can assist researchers in making better choices about their potential research areas, finding potential academic partners, and choosing the best institution where they can pursue their academic degrees or collaborate on research.

2.2. Data Collection

The Scopus database is used to collect the literature data since it could give pertinent information such as the year, document type, source title, keywords, affiliation, and author. All of this information was selected to search for publication of this study. Scopus database is used to search by keyword ((TITLE (esterification) OR KEY (esterification) AND AFFILCOUNTRY (Indonesia)) AND PUBYEAR > 1996 AND PUBYEAR > 1996) and the year interval ranges from 1997 to 2022. Data collection was conducted on July 31th, 2022. A total of 365 publications were obtained from Indonesia after filtering by relevance and obtaining several types of documents such as articles, conference papers, reviews, book chapters, and short surveys. The captured data is converted to RIS format and analyzed using the VOSviewer software. This software is used to visualize and analyze trends in the form of bibliometric maps. The article data is mapped from the database sources that have been prepared.

3. Results and Discussion

3.1. Publication Trend Analysis

The publication trend for esterification is depicted in Fig. 1. The results showed that the number of annual publications from 1997-2009 was stagnant. However, after 2009 it began to increase gradually. In this case, 2015, 2016, 2018, 2019, 2021, and 2022 experienced a decline in publications in the field. In addition, there were also several years of absence of publication, namely 1997, 1998, 2002, 2003, and 2004. This shows that in early 1997 esterification was not yet known by researchers because at that time Indonesia was experiencing a monetary crisis so that it had a major impact on people's social lives, including the field of education. Meanwhile, 2020 was the record for the largest publication on esterification research (52 documents published). Even that year, the COVID-19 pandemic was rife in Indonesia. However, it did not prevent the researchers from identifying esterification studies. On an annual basis, for the last 25 years, the initial trend (1997-2013) was between 3%, but in the last nine years, the growth increased to 34%. This means that the field of esterification is increasing in several investigations.

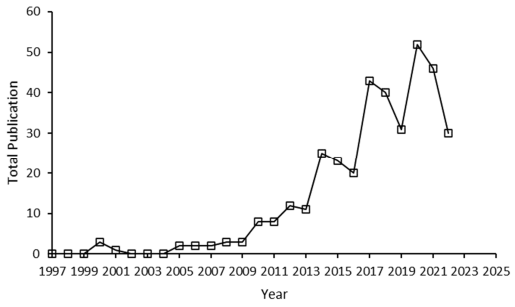

Fig 1. Publication trend per year of esterification

3.2. The Most Productive Source Titles in Esterification Research

In order to get an idea of the sources that assisted with esterification research, we identified the twenty most productive sources of titles in the last twenty-five years (1997-2022). Table 1 shows that the IOP Conference Series Materials Science and Engineering have the highest ranking with a total of 30 publications (19.1%). This was followed by the Aip Conference Proceedings and the Journal of Physics Conference Series, which each had a total of 21 (13.4%) and 14 (8.9%) publications. Among the titles of the first, second and third sources, it has a considerable total of publications with more than 10 publications. While the fourth to twentieth sources have less than 10 total publications.

Table 1:
Top 20 source titles of esterification research

Rank	Source Title	Total Publications
1	IOP Conference Series Materials Science and Engineering	30
2	AIP Conference Proceedings	21
3	Journal of Physics Conference Series	14
4	IOP Conference Series Earth and Environmental Science	9
5	Fuel	7
6	Key Engineering Materials	7
7	Materials Science Forum	7
8	Bioresource Technology	6
9	Indonesian Journal of Chemistry	6
10	Bulletin of Chemical Reaction Engineering Amp Amp Catalysis	5
11	Energy Procedia	5
12	Food Research	5
13	International Journal of Renewable Energy Development	5
14	Journal of Oleo Science	5
15	Matec Web of Conferences	5
16	ARPN Journal of Engineering and Applied Sciences	4
17	Bulletin of Chemical Reaction Engineering Catalysis	4
18	Energy Conversion and Management	4
19	Fuel Processing Technology	4
20	International Journal of Applied Pharmaceutics	4

3.3. The Most Productive Authors in Esterification Research

To get an idea of the most productive authors, we ranked them by total publications on esterification

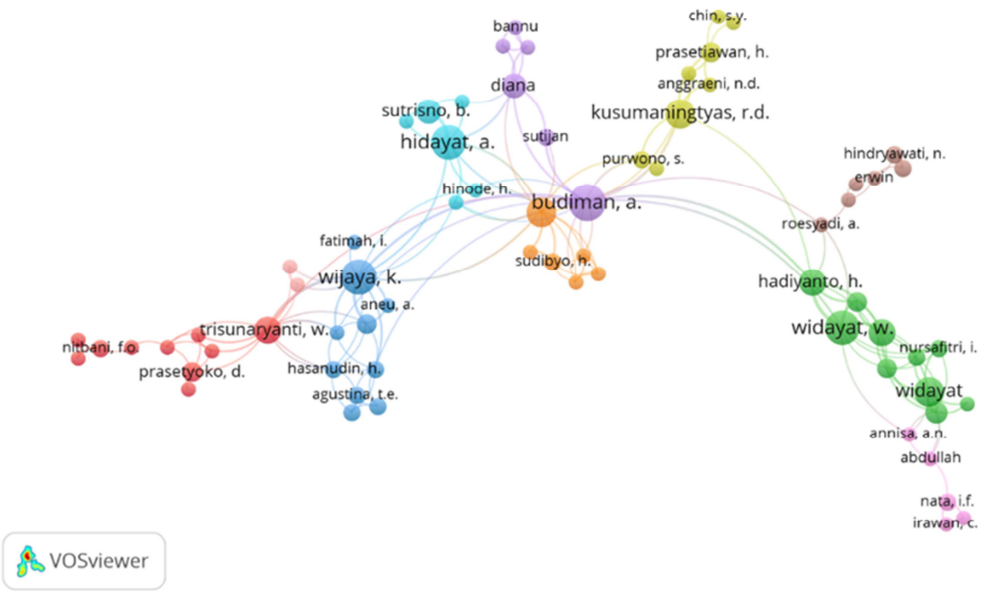

Fig 2. Authors who published research in esterification during 1997-2022

research. According to the result shown in Table 2, the top 10 authors had at least nine articles on esterification research published. It should be noted that the most productive authors are Ju Y.H with a total of 22 publications (16.7%), while Go, A.W., and Silitonga have 16 (12.1%) and 14 (10.6%) publications, respectively. Fig. 2 shows that the authors collaborate on publications together. When authors' colleagues have similar research interests, they are more likely to publish articles together and reference one another's work [14]. For an example, Budiman, Sutijan, and Sawitri conducted a joint study in a journal entitled "Kinetics study of free fatty acid esterification for biodiesel production from palm fatty acid distillate catalyzed by zirconia sulfate". And it is proven by the network between Budiman and Sutijan seen in Fig. 2 (indicated in purple color).

Table 2:
Top 20 most productive authors in esterification research

Rank	Author	Total Publications
1	Ju, Y.H.	22
2	Go, A.W.	16
3	Silitonga, A.S.	14
4	Budiman, A.	13
5	Ismadji, S.	13
6	Wijaya, K.	12
7	Hidayat, A.	11
8	Ong, H.C.	11
9	Widayat, W.	11
10	Mahlia, T.M.I.	9

3.4. The Most Productive Institutions in Indonesia (1997-2022)

A total of 365 publications with the keyword “esterification” have been published in the last twenty-five years. This means that many institutions in Indonesia have contributed to this publication every year. The following shows the top 20 institutions in terms of total publications as seen in the Scopus database. The institution being referred to was the one the author was associated with. Over a period of 25 years (1997-2022), Universitas Gadjah Mada (UGM) became the most productive institution with a total of 55 publications, followed by Institut Teknologi Bandung (ITB) and Institut Teknologi Sepuluh November (ITS) with 35 and 32

publications, respectively (Table 3). Meanwhile, the University of Diponegoro has 28 publications and the University of Indonesia has 27 publications. This shows that the interest of esterification researchers at Universitas Gadjah Mada (UGM), Institut Teknologi Bandung (ITB), and Institut Teknologi Sepuluh November (ITS) is higher than at the University of Indonesia. Although University of Indonesia (UI) is the best university in Indonesia, it is possible that other universities may have a higher interest of this topic.

Table 3:
Top 20 most productive institutions in Indonesia (1997-2022)

Rank	Institution	Total Publications
1	Universitas Gadjah Mada	55
2	Institut Teknologi Bandung	35
3	Institut Teknologi Sepuluh November	32
4	Universitas Diponegoro	28
5	Universitas Indonesia	27
6	National Taiwan University of Science and Technology	25
7	Universitas Islam Indonesia	23
8	Universitas Katolik Widya Mandala Surabaya	22
9	Institut Pertanian Bogor	15
10	Politeknik Negeri Medan	14
11	Universiti Sains Malaysia	13
12	Universiti Malaya	13
13	Universitas Negeri Semarang	13
14	Universitas Syiah Kuala	12
15	Universitas Lampung	11
16	Universiti Tenaga Nasional	10
17	Lembaga Ilmu Pengetahuan Indonesia	9
18	Universitas Sumatera Utara	9
19	University of San Carlos	9
20	Universiti Teknologi Malaysia	8

3.5. Analysis of Term Co-Occurrence Network

3.5.1. Analysis of Keywords

Using keyword analysis, researchers can have a better understanding of the state of current research, upcoming difficulties, and research interests. Table 4 lists the top 20 keywords of this study. The most issues of the research during the last twenty-five years are revealed by these keywords. And here are the top keywords in this research area such as esterification (284), esters (167), biodiesel (146), catalyst (84), fatty acids (77), transesterification (68), methanol (64), article (57), esterification reactions (52), and biodiesel production (46). Table 4 provides a breakdown of each keyword's total link strength.

Table 4:
Top 20 Keywords in Esterification Research (1997-2022) [TP: Total Publication; TLS: Total Link Strength]

Rank	Keyword	TP	TLS
1	Esterification	284	2,311
2	Esters	167	1,717
3	Biodiesel	146	1,474
4	Catalysts	84	982
5	Fatty Acids	77	992
6	Transesterification	68	891
7	Methanol	64	913
8	Article	57	742
9	Esterification Reactions	52	531
10	Biodiesel Production	46	544
11	Catalysis	38	565
12	Palm Oil	37	431
13	Nonhuman	32	403
14	Glycerol	31	271
15	Unclassified Drug	30	378
16	Catalyst Activity	26	243
17	Heterogeneous Catalyst	26	264
18	Vegetable Oils	26	307
19	Catalyst	25	401
20	Molar Ratio	25	302

3.5.2. Analysis of Cluster

VOSviewer software is used for cluster analysis. This produces a co-occurrence keyword knowledge map,

showing emerging trends in esterification research. The size of each node on the map represents how frequently a keyword appears [15]. In bibliometric research, cluster analysis can more accurately identify topics and research material [16]. The analysis of the VOSviewer produced the top six clusters with a total of 190 items. As the number of publications increases every year, the field of esterification research is attracting more researchers all over the world. Cluster analysis suggests that future research should focus on the clusters below viewed from a keyword perspective (Fig 3).

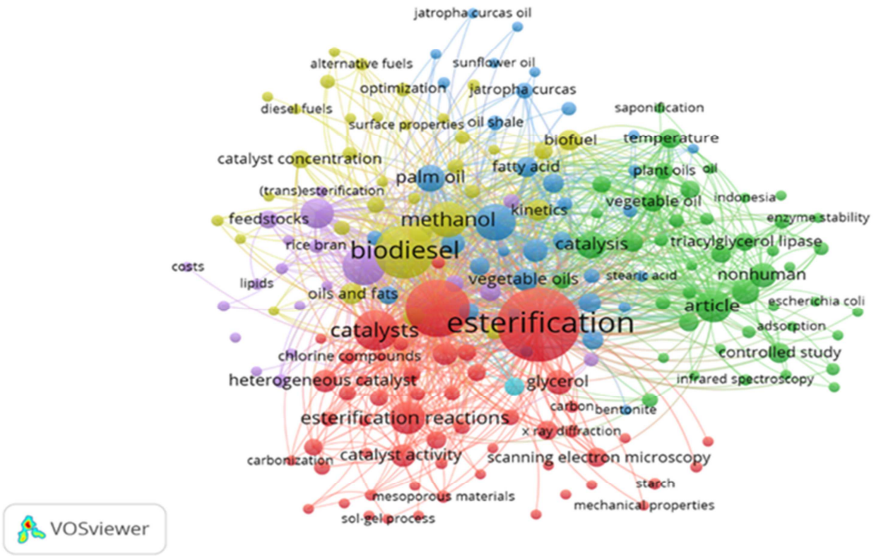

Fig 3. Terms Co-Occurrence Network

Cluster #1. The item with the largest red circle is esterification with a total publication of 284 and a total link strength of 2,311. According to Widaya et al. (2012), the esterification process is a way to produce an ester (RCOOR') by reacting an acid compound and alcohol by removing water in the reaction [17]. Widi et al. (2010) stated that esterification is one of the most important organic reactions in industry, due to its ubiquitous application as an intermediate in the synthesis of chemicals, pharmaceuticals, perfumes, food preservatives, and also as energy such as biofuel and biodiesel [18]. Sondakh et al. (2019) stated that esterification is the optimum process for producing more stable esters from reactive organic acids in bio-oil [19]. The presence of an acid catalyst in a complex mixture of bio-oil and alcohol is the necessary reaction condition for acid esterification in bio-oil.

Cluster #2. The item with the largest green circle is article with a total publication of 57 and a total link strength of 742. Based on the analysis type of document using VOSviewer, it was found that articles were the highest type of document, namely 233 documents (63.84%). In addition, when viewed from the keywords that are often used in esterification research, the word "article" ranks 8th. This shows that researchers are more interested in making it in the form of articles. The hallmark of articles is their brief but meaningful presentation. Article also require very strict rules before being published. Therefore, articles are managed by scientists or researchers who are experts in their fields.

Cluster #3. The item with the largest blue circle is transesterification with a total publication of 68 and a total link strength of 691. It stated that transesterification is a technology that has gained widespread acceptance since 2005. Gerpen (2005) demonstrates that typical base-catalyzed transesterification and acid-catalyzed transesterification reactions can be used to produce triglycerides from free fatty acids in fats and oils [20]. While Leung et al. (2010) reviewed various crude biodiesel purification techniques that might be employed in the industry to minimize free fatty acids in crude oil using transesterification [21]. Generally,

biodiesel (monoalkyl esters) can be produced from different oils (edible or inedible), either by esterification or transesterification reactions with alcohols. Typically, base oils are used in transesterification reactions while acid oils are provided as raw materials for esterification reactions [22].

Cluster #4. The item with the largest yellow circle is biodiesel with a total publication of 146 and a total link strength of 1,474. According to Qadariyah et al (2019), biodiesel has numerous generations. Soybeans and palm oil are examples of the first generation's edible (food) products. Jatropha and nyamplung are two well-known examples of the second generation, which is non-edible biodiesel. A microalga is the third generation [23]. Widayat et al. (2012), stated that biodiesel production can be carried out through an esterification process, namely by converting free fatty acids in rubber seeds into methyl esters [17]. The biodiesel production process using the esterification process requires low levels of free fatty acids (<0.5%). Holilah et al. (2015) used traditional methods to investigate *Rhetalis trisperm* oil, by performing two phases (esterification and transesterification), with an optimal yield of 95.15 percent biodiesel production at 65°C and a reaction period of three hours [24]. According to Ulfah et al. (2019), the ideal conditions for the esterification reaction of used cooking oil with alumina sulfate as a catalyst were a volume ratio of 1.5 methanol/oil, a catalyst/oil proportion of 1 wt%/v, and an hour-long reaction period [25]. The highest biodiesel yield from used cooking oil is 86.67% when produced in two phases, but only 66.67% when produced in one phase. This shows that the esterification optimization process can be carried out for the manufacture of biodiesel in various ways and under different conditions.

Cluster #5. The item with the largest purple circle is fatty acids with a total publication of 77 and a total link strength of 992. Augustia et al. (2018) claim that Palm Fatty Acid Distillate (PFAD), a by-product of the refining of palm oil, comprises 85–95% Free Fatty Acids (FFA) and 5–15% triglycerides [26]. Therefore, PFAD can be used as an inexpensive raw material for biodiesel production through two processes, namely esterification and transesterification. Biodiesel can be synthesized by esterification reaction of Free Fatty Acid (FFA) in Palm Oil Sludge (POS) with alcohol to produce methyl ester and water [27]. According to Kumar et al. (2018), *Jatropha curcas* L. oil with a high oleic acid content is appropriate for producing biodiesel while *Jatropha curcas* L. with linoleic acid as the primary fatty acid is appropriate for use in other industrial applications [28].

Cluster #6. The item with the largest light blue circle is waste cooking oil with a total publication of 17 and a total link strength of 163. The final product's cost will be significantly reduced by using inexpensive oil, such as waste cooking oil [29]. Environmental issues will arise if excessive waste cooking oil is dumped in a landfill or the sewage system. Therefore, a lot of researchers are attempting to employ waste such as leftover cooking oil in the production of biodiesel. However, the high concentration of free fatty acids (FFA) in the oil causes an issue for researchers [30].

4. Conclusions

A bibliometric review of 25 years of esterification research (1997–2022) in Indonesia shows significant growth. It can be seen that starting from 2013 esterification research has increased with the largest record reaching 52 documents published in 2020. Universitas Gadjah Mada occupies the most productive institution in esterification research, which was then followed by Institut Teknologi Bandung and Institut Teknologi Sepuluh November. The similarity visualization software (VOSviewer) reveals the strong collaboration between the most prolific authors and shows that esterification research during 1997-2022 such as esterification, esters, biodiesel, catalysts, and fatty acids is still of interest to the journal. The most prolific author in this study was Ju Y.H with a total of 22 publications (16.7%), followed by Go, A.W. and Silitonga have 16 (12.1%) and 14 (10.6%) publications, respectively. In addition, correspondence with the authors, and institutions is a limitation of this research design. Nonetheless, an examination of the most cited papers shows greater research on an esterification.

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