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Bibliometric analysis of research trends on rotary dryers using the VOSviewer application base on the Scopus database

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ABSTRACT

Bibliometric analysis is a crucial way to understand trends and progress in a field of research. Using the VOSviewer application for bibliometric analysis becomes an effective tool to demonstrate research patterns, networking, and research focus. This study explains the analysis of scientific publications related to rotary dryers using the VOSviewer application. This study aims to find trends through analyzing bibliometric data on rotary dryer research for 10 years (2014–2023). Data was collected from the Scopus database. The method used is descriptive causality, using VOSviewer to visualize relationships between keywords, authors, institutions, countries, and network collaborations between authors. The study showed 1,356 articles relevant to rotary dryers between 2014 and 2023. After elimination by document type (article, conference paper, review, and conference review) and language type (English), 465 articles were obtained. The bibliometric analysis results show changes in research trends, from performance studies to the study of the use of energy resources in rotary dryers and their integration with intelligent systems. There are five keyword clusters, with primary keywords in each cluster. The number of articles on the topic of rotary dryers has increased from year to year, with China being the country with the most publications and citations. Still, the number of links and strength of the author's relationship with other countries in carrying out joint publications remain relatively low. The results of this bibliometric analysis provide a helpful overview of research progress and prospects with the topic of rotary dryers and help the authors plan further research.

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INTRODUCTION

Drying is the process of removing water content from a material using various techniques with the main aim of maintaining the quality and durability of the material by reducing the water content until it reaches the desired level. There are various drying methods to dry materials such as agricultural products, such as artificial mechanical, sun drying, and solar power drying (Mihret et al. 2023). A rotary dryer is a mechanical dryer used in the drying process of agricultural products. The drying process using a rotary dryer is very complex, not only the drying phenomenon but also the development of the dried material in the cylinder during drying(Wang et al. 2015).

The use of tools and machines in the product or material drying process has developed over time. The drying machine has been designed to achieve optimum conditions. The engineering of the dryer that has developed is the rotary type of dryer. The use of simple technology up to modern technology can be found in the rotary type of dryer. The use of energy sources in the drying process using rotary-type drying is included in the engineering applied. Drying machines using more than one energy source (hybrid energy) is one of the steps chosen to maximize energy use.

VOSviewer is a data analysis and visualization software that can be used to analyze and visualize scientific networks, such as collaboration between researchers, research topics, or keywords that often appear in scientific publications. (van Eck and Waltman 2010). VOSviewer can read the datasets from various online journal sites including Scopus, Google Scholar, Web of Science, Deminsion, and Pubmed. The databases read by the VOS Viewer can display maps in a variety of different ways depending on each emphasized aspect. (Mustafa and Erbay 2020) This study aims to determine rotary dryer research trends through bibliometric data analysis using the VOSviewer application, with Scopus as the dataset source.

METHODS

The articles used in the bibliometric analysis of these rotary dryers come from the Scopus database. The journals indexed in the Scopus are considered high quality and relevant in various disciplines (Klapka and Slabý 2020). Scopus is also one of the most renowned and internationally recognized bibliometric databases. This study was carried out in several stages (1). Data collection: data can be quotations, references, or other relevant bibliometric data, and the data must be in the VOSviewer format (2). Importing data to VOS Viewer, (3). Data processing, (4). Data interpretation.

Data collection

The data collection was carried out online using the Scopus database on April 1, 2024, with the keyword "Rotary dryer". The query array used for the search is TITLE-ABS-KEY (rotary AND dryer) AND PUBYEAR > 2013 AND PUBLYEAR < 2024 AND (EXCLUDE (DOCTYPE, "dp") OR EXCLUDED (DocType, "bk") OR excluded (DECTYP, "ch")) AND (LIMIT-TO (LANGUAGE, "English")). This search resulted in 1,356 articles. For the accuracy of the data used, a filter was carried out on the articles that were found: the year of the article used from 2014 – 2023, the type of document used is limited to articles and conference papers in English. Articles that are not written in English cannot be included in comparative analysis of countries or research institutions, because the majority of researchers cannot read articles that are not in English, and non-English articles receive fewer citations on average than articles in English (van Raan et al. 2011). Filter results obtained 465 articles relevant to the topic of rotary dryers. Article data is then exported in CSV file format.

Importing data to VOSviewer

Data already exported from the Scopus database is then imported into the VOSviewer application. The choice of data type must be appropriate because VOSviewer supports various types of data (Zupic and Čater 2015). VOS viewer has the option to import data from different sources. If the data is from Scopus, select the option for importing data from Scopus.

Data processing

Data processing uses VOSviewer version 1.6.20 which will produce analysis or visualization according to the instructions provided. Visualization can be determined based on groups or clusters formed in bibliometric data. Clusters in this context can include groups of researchers who often collaborate, groups of

keywords that often appear together in articles, or groups of articles that are frequently cited.

Data interpretation

Network visualization analysis or other analysis results resulting from data processing are part of the interpretation in VOSviewer. Identify elements in data such as keywords, authors, quotations, and countries and the relationship between them represented by points and edges (lines). Identification of groups or clusters can be research collaboration, frequently occurring keyword groups, or frequently mentioned articles (Hudha et al. 2020). The final step is to find trends, changes or trends as well as other interesting findings from rotating dryer research.

Table 1 The number of articles and citations about rotary dryers based on the source

No	Sources	N	Title with higest citations	C	Y
1	Drying Technology	39	Advances in the Application of a Rotary dryer for Drying of Agricultural Products: A Review (Delele et al. 2015)	62	2015
2	Applied Thermal Engineering	19	Performance prediction of the rotary solid desiccant dehumidifier in hybrid air-conditioning system using artificial neural network (Jani et al. 2016)	65	2016
3	IOP Conference Series Earth and Environmental Science	15	Numerical simulation of the flow of agricultural seeds inside a rotary drum dryer by DEM (Wangchai 2019)	2	2019
4	AIP Conference Proceedings	12	The application of mathematical model drying of galangal (*Alpiniagalanga* L.) using hybrid dryer equipment with rotary type of rack (Mahardian et al. 2019)	2	2019
5	IOP Conference Series Materials Science and Engineering	11	Control Systems of Rubber Dryer Machinery Components Using Programmable Logic Control (PLC) (Hendra et al. 2018)	4	2018
6	Powder Technology	11	A novel rotary dryer for drying fertilizer: Comparison of performance with conventional configurations (Silvério et al. 2015)	36	2015
7	Energies	7	Wood chip drying through the using of a mobile rotary dryer (Del Giudice et al. 2019)	29	2019
8	Energy	6	Energy and exergy performance analysis of a marine rotary desiccant air-conditioning system based on the orthogonal experiment (Zhu and Chen 2014)	51	2015
9	International Journal of Refrigeration	6	Experimental evaluation of the dehumidification performance of a metal-organic framework desiccant wheel (Liu et al. 2022)	19	2022
10	Energy Procedia	5	Performance Evaluation of Solid Desiccant Wheel Regenerated by Waste Heat or Renewable Energy (Goodarzia et al. 2017)	33	2017
11	Industrial and Engineering Chemistry Research	5	In Situ Synthesis and Performance of Aluminum Fumarate Metal-Organic Framework Monolithic Adsorbent for Water Adsorption (Tan et al. 2019)	17	2019
12	Journal of Food Process Engineering	5	Impacts of hybrid (convective-infrared-rotary drum) drying on the quality attributes of green pea (Kaveh and Abbaspour-Gilandeh 2020)	28	2020
13	Journal of Physics Conference Series	5	CFD Analysis of Temperature Drying Chamber at Rotary dryer with Combined Energy (Rindang et al. 2019)	2	2019

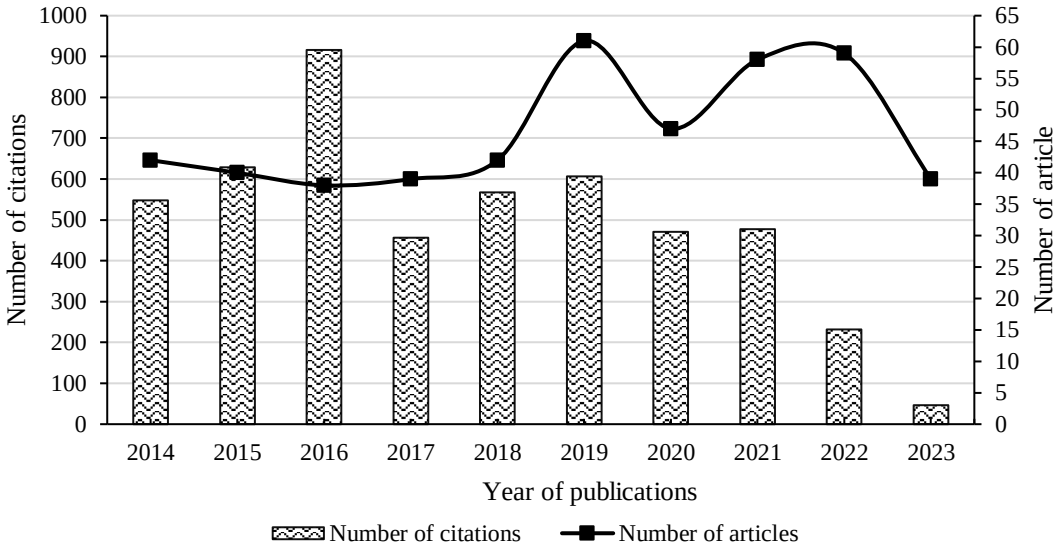

Figure 1 Number of articles and citations relevant to the topic of rotary dryers from 2014 – 2023

RESULTS AND DISCUSSION

Results of data collection and research developments

Based on data searches for articles related to rotary dryers in the Scopus database published from 2014 – 2023 with a minimum number of articles of 5 in each journal, 13 journals/conferences were obtained, as shown in Table 1. The article titles/topics with the average number of cited the most are about the performance or work demonstration of a rotary dryer (article titles no. 2, 8, 6, 10). The research on rotary dryers entering 2020 trends leads to the use of hybrid energy sources on rotary dryers and their integration with intelligent systems.

The evolution of this trend is in line with the development of information and communication technology called the 4.0 era (Chen et al. 2020). Another factor that has also contributed to the development of the trend of research on rotary dryers is the COVID-19 pandemic, which has accelerated the adoption of technology in all its aspects (Sharma and Singh 2023), including in the rotary drier. Devices such as rotary dryers equipped with intelligent systems are more desirable because of improve operational efficiency and reduce human involvement.

The trend in the number of articles on the topic of rotary dryers in the last ten years has increased (Figure 1). Meanwhile, the number of citations to articles tends to decrease each year. The average number of articles relevant to the topic of rotary dryers is 46.5 articles per year with an average citation of 495.2 citations per year and 10.6 citations per article title. In 2016, the number of research articles on rotary dryers was below the annual average number of publications, but the number of article citations far exceeded the annual average citation, namely 916 citations.

Based on the graph in Figure 1, it can be seen that research in the 2014 - 2018 time period with a trend towards the topic of rotary dryer performance had a total of 623.6 citations, which is above the average citation per year. In the 2019 - 2023 research with a trend towards topics regarding the application of intelligent and hybrid energy systems in rotary dryers which has several citations of 366.8 which is smaller than the average citations per year. This condition is caused by the topic of intelligent systems and hybrid energy in a rotary dryer is a relatively new subject that requires more time to gain recognition and accumulate a significant number of citations, and the transition in research focus, where newer topics tend to have a more limited audience.

Visualization using VOSviewer

Keyword Network Analysis

The purpose of the co-occurrence analysis is to find out the relationship between the group of topics formed by the keyword and how often the keyword appears together (Kusuma and Masithoh, 2023). Keywords are analyzed using a thesaurus for keywords that have synonyms and repetitions

with the occurrence of keyword restricted at least five times then obtained 230 of 4.198.

In Figure 2, the size of the nodes shows the frequency of occurrence of keywords on the rotary dryer topic. Keywords that appear frequently will have larger node sizes. The strength of the link presented by the thickness of the line indicates the strength of the relationship between elements (keywords, authors, topics). Thicker lines indicate stronger relationships between the elements. The different colours of nodes in the VOSviewer visualization show clusters or groups of closely related elements in the network. Clustering in VOSviewer aims to identify structures or patterns in the network that help map related concepts or topics.

The keyword that often appears in the rotary dryer topic is dryer (equipment) which appears 155 times. There are 5 clusters based on keywords in the data that has been analyzed. Cluster 1 is red, cluster 2 is green, cluster 3 is blue, cluster 4 is yellow and cluster 5 is purple. Keywords in each cluster can be seen in Table 2.

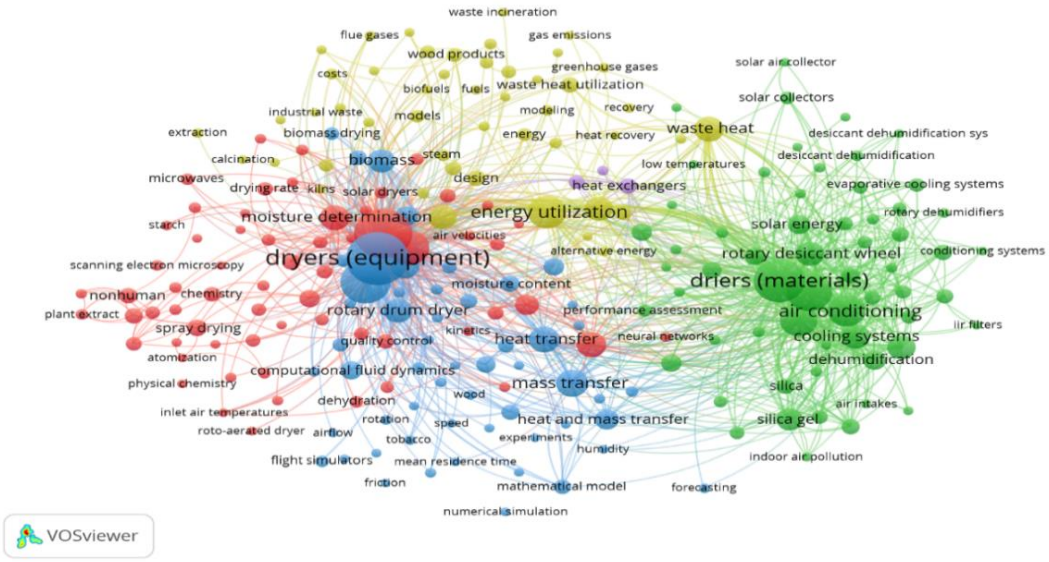

Figure 2 VOSviewer network visualization based on keyword occurrences

Table 2 Keywords for each cluster

Number	Cluster	Keywords
1	Cluster 1 (red), 63 keywords	agriculture (11), air (35), air temperature (8), air velocities (6), animal (7), antioxidant (13), antioxidant (23), atomization (5), bioactive compounds (6), chemistry (12), color (8), comparative study (7), controlled study (9), dehydration (8), desiccation (9), diffusion (5), drops (7), drying (135), drying chambers (6), drying characteristics (5), drying methods (5), drying performance (6), drying rate (10), drying temperature (13), drying time (9), evaporation (11), final moisture content (6), fluidized beds (11), fruits (9), high moisture contents (6), infrared drying (9), infrared radiation (5), initial moisture content (7), inlet air temperatures (5), kinetics (6), machinery (5), microwaves (8), moisture (68), moisture determination (35), neural networks (6), nonhuman (13), particle size (18), particle size analysis (6), physical chemistry (5), plant extract (7), plants (botany) (7), powder (10), priority journal (5), procedures (7), product design (6), quality control (12), rotary evaporators (5), roto-aerated dryer (5), scanning electron microscopy (7), solar dryers (8), specific energy consumption (9), spray drying (15), spray nozzles (5), starch (6), surface properties (5), sustainable development (8), unclassified drug (6), water (7).
2	Cluster 2 (green), 60 keywords	Adsorption (14), air conditioning (5), air intakes (5), air quality (10), coefficient of performance (11), conditioning systems (5), cooling (18), cooling systems (33), dehumidification (22), dehumidification performance

Number	Cluster	Keywords
		(9), dehumidification system (10), desiccant air-conditioning systems (11), desiccant cooling (8), desiccant cooling systems (10), desiccant dehumidification (7), desiccant dehumidification systems (7), desiccant dehumidifier (9), desiccant wheel (32), digital storage (5), driers (materials) (105), energy conservation (15), evaporative cooling systems (10), exergy (18), exergy analysis (7), exergy destructions (5), exergy efficiencies (5), experimental investigations (6), gas adsorption (6), heat pump systems (7), humidity control (82), hybrid systems (6), iir filters (5), indoor air pollution (5), liquid desiccant (6), liquids (6), low temperatures (5), moisture removal (7), performance (18), performance assessment (9), pumps (5), refrigeration (12), regeneration (7), regeneration temperature (14), rotary dehumidifiers (6), rotary desiccant wheel (32), rotary wheels (6), silica (13), silica gel (27), silica gel desiccant wheels (5), solar air collector (5), solar collectors (9), solar energy (21), solar heating (5), solid desiccants (5), temperature and humidities (8), thermal energy (5), thermoelectric equipment (12), ventilation (9), water vapor (6), wheels (58).
3	Cluster 3 (blue), 55 keywords	%moisture (5), airflow (5), biomass (31), biomass drying (9), chemical industry (7), computational fluid dynamics (20), computer simulation (6), cylinders (shapes) (5), desorption (7), different operating conditions (5), discrete element method (5), drums (7), dryer (34), dryers (equipment) (155), drying efficiency (7), drying process (21), energy consumption (18), environmental technology (6), equipment (5), experimental conditions (5), experimental study (6), experiments (5), fertilizers (6), finite difference method (5), flight simulators (8), flow rate (10), forecasting (6), friction (5), heat and mass transfer (23), heat transfer (39), heating (12), humidity (5), mass transfer (42), mathematical model (12), mathematical modeling (5), mean residence time (5), moisture content (15), numerical simulation (5), operating parameters (6), optimization (14), pelletizing (60), processes (9), regression analysis (7), residence time (9), residence time distribution (5), rotary drum dryer (32), rotary dryer (98), rotary kilns (5), rotation (6), rotational speed (11), simulation (15), speed (5), tobacco (6), velocity (5), wood (6).
4	Cluser 4 (yellow), 48 keywords	alternative energy (6), biofuels (5), calcination (5), carbon dioxide (7), coal (9), coal combustion (5), combustion (7), computer software (6), costs (7), design (14), drying systems (6), economic analysis (5), energy (9), energy efficiency (32), energy saving (5), energy utilization (60), environmental impact (5), extraction (6), flue gases (6), forestry (6), fossil fuels (5), fuels (6), gas emissions (5), gases (5), gasification (6), greenhouse gases (6), heat recovery (5), industrial waste (5), investments (7), kilns (5), lime (5), modeling (7), models (9), numerical model (5), operating condition (10), recovery (6), renewable energy (12), sensitivity analysis (9), steam (8), sugar cane (5), superheated steam (5), temperature (32), waste heat (36), waste heat utilization (13), waste incineration (5), wastewater treatment (6), wood chip (5), wood products (11).
5	Cluster 5 (purple), 3 keywords	efficiency (10), heat exchangers (13), rotary heat exchangers (6).

Cluster 1 on the rotary dryer topic mainly contains keywords related to technology in the drying process such as roto-aerated dryers, solar dryers, spray drying, infrared drying, and rotary evaporators. Cluster 2 main keywords relate to components and systems in the drying process such as driers (materials), pumps, silica gel, solar air collector, solar energy, ventilation, conditioning systems, cooling systems, dehumidification systems, desiccant cooling systems, evaporative cooling systems, heat pump systems, hybrid systems. Cluster 3 contains keywords related to the application of computational technology to the drying process, such as computer simulation, computational fluid dynamics, flight simulators, mathematical models, and mathematical modeling.

Cluster 4 contains keywords related to alternative energy in drying and waste (heat and gas) such as alternative energy, biofuels, coal combustion, energy utilization, flue gases, fossil fuels, renewable energy, environmental impact, gas emissions, industrial waste, waste heat, waste heat utilization, waste incineration, wastewater treatment. Cluster 5 consists of keywords related to devices that transmit heat such as heat exchangers, rotary heat exchangers, and efficiency.

The yellow node as shown in Figure 3 is a trend in the direction of research development of rotating dryers based on keywords in recent years leading to alternative energy and waste (heat and gas) such as gas emissions, waste incineration, renewable energy, solar water collector, solar heating and specific energy consumption.

The density visualization on the VOSviewer shows how the elements are concentrated in a particular area of the network. As shown in Figure 4, dark yellow and wider circles and compact keywords show that research on the topic of rotary dryers with this keyword is becoming popular. Table 3 shows the ten keywords with the highest frequency of occurrence and strength of relation. Link strength on VOSviewer indicates the strength or entity of the relationship between two connected elements in network analysis. The aim is to show how strong or close the relationship between these elements (keywords) is on the topic of the rotary dryer.

Table 3 Keywords with the highest occurrence and link strength

No	Keywords	*Occurrences*	*Strenght*
1	dryers (equipment)	155	987
2	drying	135	950
3	driers (materials)	105	1006
4	rotary dryer	98	601
5	humidity control	82	844
6	moisture	68	611
7	energy utilization	60	548
8	air conditioning	58	605
9	wheels	58	567
10	mass transfer	42	385

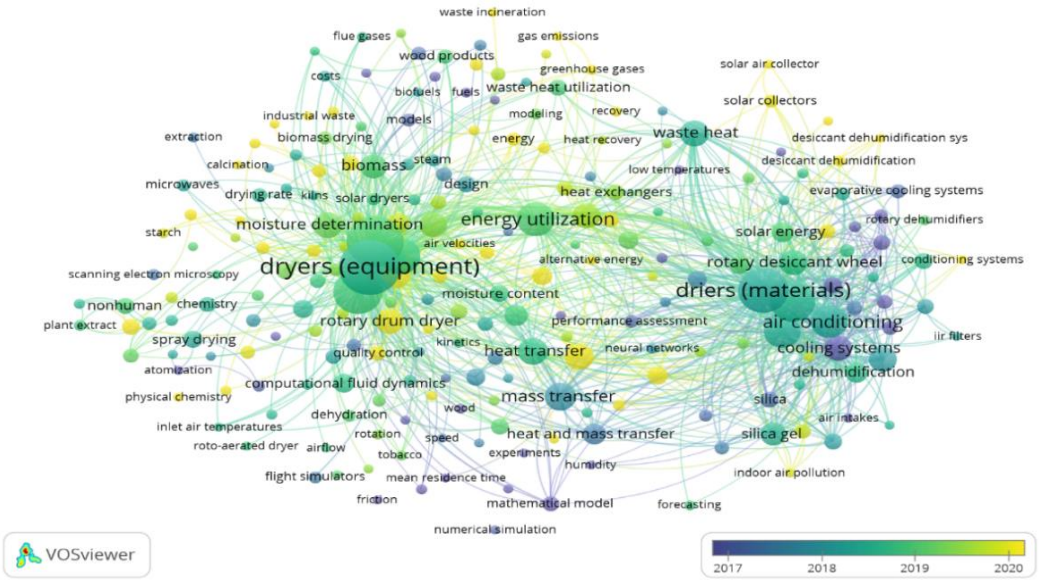

Figure 3 Overlay visualization of keywords on the rotary dryer topic

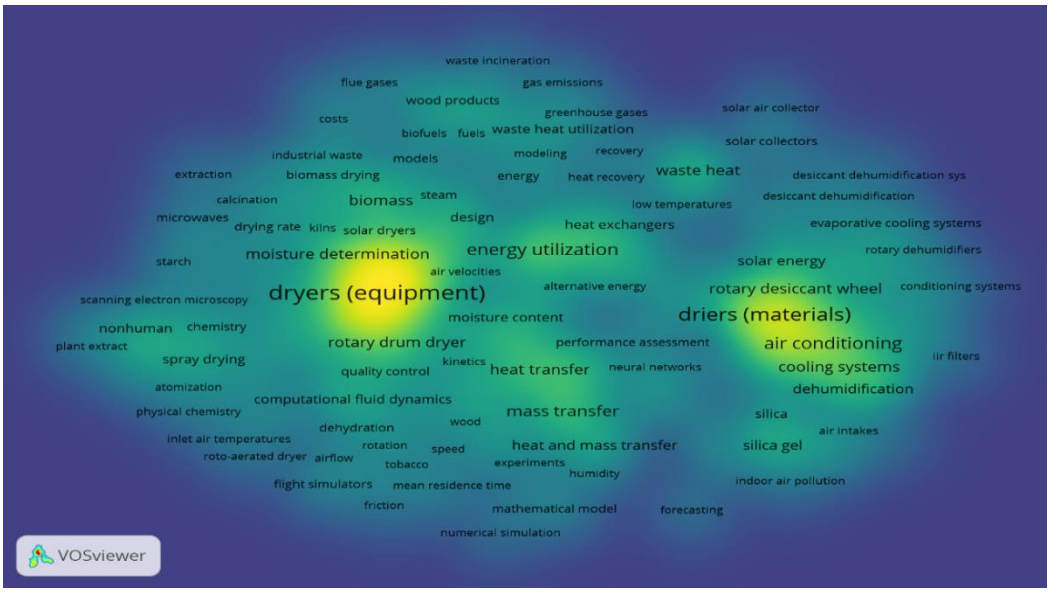

Figure 4 Visualization of keyword density on the rotary dryer topic

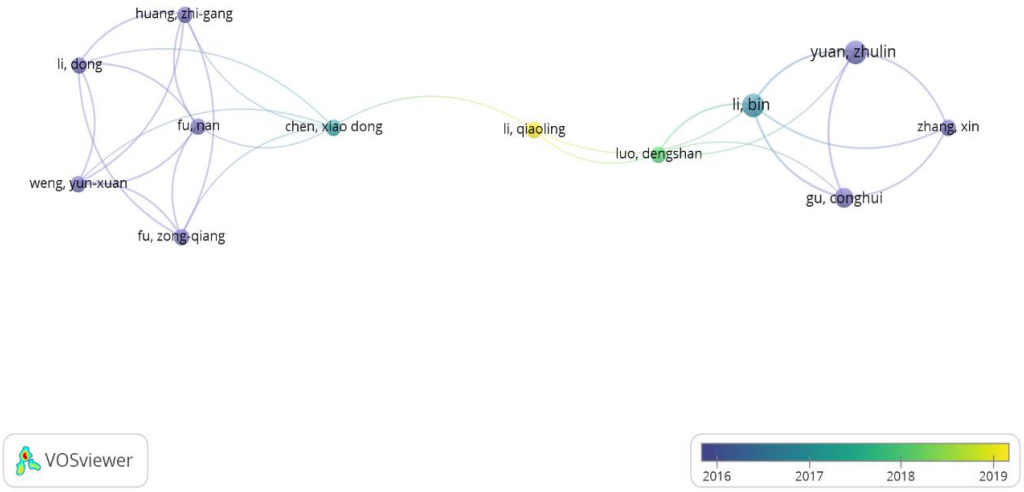

Figure 5 Overlay visualization of author and co-authorship on the rotary dryer topic

Authors and co-authorship network analysis

The author and co-authorship analysis aims to understand collaboration patterns between researchers who are researching the topic of rotary dryers. It's useful to find a collaboration network between authors, map their relationships, and study patterns of cooperation among authors. Each node in this network serves as a representation of the author in his writing connection. Of the 1,554 authors in the data analysis, 202 authors are collaborating on at least two different documents. Figure 5 shows a co-authorship network formed by the connections of 12 authors.

A network analysis of author and co-authorship in time dimensions shows information about the authors who wrote together in a given year. In this case, the relationship between authors can be classified as their annual relationship. Based on Figure 5 Chen, xiao Dong is the writer who has the most connections with other writers. Meanwhile, the latest publication on the topic of rotating dryers based on a network analysis of authors and co-authorship marked with yellow is Li, Qiaoling.

Network analysis of the most productive countries

Based on the data that has been analyzed as shown in Table 4 and Figure 6, the United States is the country that has published the earliest on the topic of rotary dryers shown with purple nodes

with 30 numbers of articles. The number of United States articles is lower than that of China, but the link and total link strength that refers to the number of inter-country links and the strength/intensity of the relationship is still low. The United States publishes jointly with nine countries: China, Brazil, India, Australia, Thailand, Colombia, Canada, Pakistan, and Poland, while the Chinese publish with five countries: Australia, Brazil, Canada, Japan, and the United States.

From Table 4, China, India, Brazil, Indonesia and the USA are the five countries with the highest number of articles on rotary dryer. This is supported by several factors: these countries have dominant industries that use rotary dryers, such as mining, mineral processing, and chemical manufacturing. The availability of resources, such as Indonesia and Brazil's extensive access to raw materials (biomass and agricultural products). Investment in technology, the USA leading in technological innovation, while India and China focus on energy-efficient technologies. Lastly government policy support. (Bali 2024)

Iran is a country that is relatively new in publishing the topic of rotary dryers as seen from the yellow nodes but the number of citations per article is high. Keywords that often appear in articles published in Iran are energy utilization (10), energy consumption (5), specific energy consumption (5), exergy (4), and solar energy (3). The research trend carried out by Iran based on the keywords that emerged was on energy use in rotary dryers including the type of energy used (hybrid) and energy efficiency in the process. China, which appeared in the middle (2018) in rotary dryer topic research, has the highest number of articles and several citations. However, the number of relationships and the strength of relationships with other countries in carrying out joint publications is still relatively low.

Table 4 Top 10 countries with a number of articles on the topic of rotary dryers

Rank	Country	NA	Percentage	NC	NCA
1	China	84	15,8	1054	12,5
2	India	46	8,7	500	10,9
3	Brazil	44	8,3	527	12
4	Indonesia	31	5,8	102	3,3
5	United states	30	5,6	433	14,4
6	Iran	23	4,3	409	17,8
7	Australia	21	4,0	382	18,2
8	Thailand	20	3,8	57	2,9
9	Germany	19	3,6	225	11,8
10	Canada	17	3,2	236	13,9

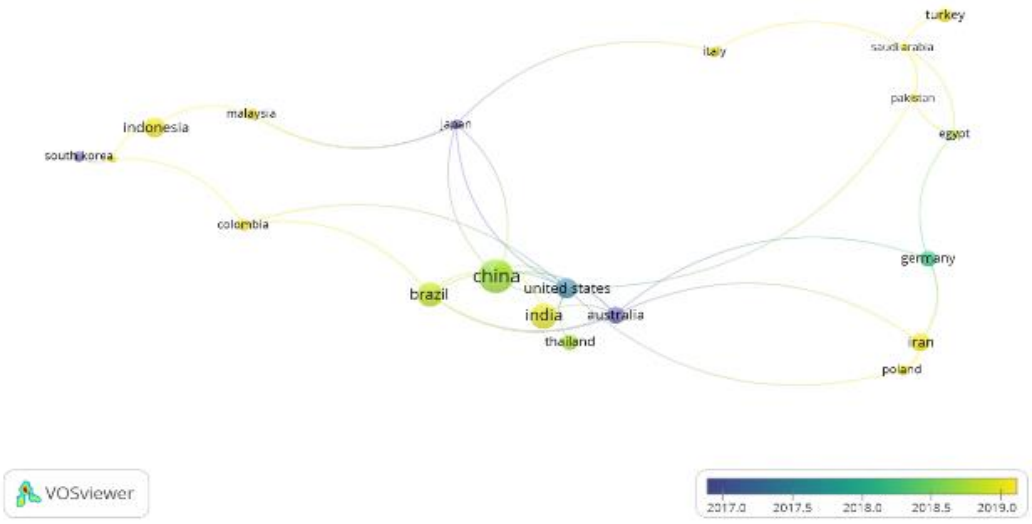

Figure 6 Overlay visualization of countries on the rotary dryer topic

CONCLUSION

This bibliometric analysis provides an overview of the progress and prospects of research on the rotary dryers topic. The number of articles starting in 2017 tends to increase, but the number of citations has a changing pattern. There is a change in research trends from performance studies to the use of hybrid energy sources in rotary dryers and their integration with intelligent systems. Five keyword clusters are formed consisting of cluster 1 with keywords related to technology in the drying process, cluster 2 with keywords related to components and systems in the drying process, cluster 3 contains keywords related to the application of computational technology to the process of drying, Cluster 4 with keywords related to alternative energy in drying and waste (heat and gas), cluster 5 consists of keywords related to devices in the heat flow.

Thereare 202authors are collaborating on at least two different documents, and only 12 authors are connected. Chen, Xiao Dong from China is the author with the most connections to another author. The development of research on rotary dryers in China is very rapid, marked by the greatest number of articles and citations.

Based on this bibliometric analysis, the authors opinion that future research trends on rotary dryers will focus on energy efficiency (hybrid energy) and the implementation of smart control system.

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