Scientific Mapping of Drying with Desiccants: A Bibliometric Investigation

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Abstract

This study conducts a bibliometric analysis of research on drying systems employing desiccants. Results show slow yet steady growth, with publications concentrated in Asian institutions, particularly in China. Keyword analysis highlights core themes such as desiccant dehumidification, heat and mass transfer, and energy efficiency, indicating growing interest in sustainable and cost-effective drying. The study also identifies gaps and opportunities for future research, notably the development of new sorption materials and the integration of energy-recovery strategies. Overall, the findings provide an updated map of the scientific landscape of desiccant-assisted drying.

Keywords: Drying; Desiccant; Dehumidification; Bibliometrics; Mapping.

1 Introduction

Moisture in food products is generally classified as either bound or unbound water. Bound water is associated with the molecular structure of the material, whereas unbound water facilitates biological reactions that may promote microbial proliferation and, consequently, deteriorate product quality. The amount of unbound water can be quantified through the water activity coefficient, defined as the ratio between the partial pressure of water vapor above the product and that of pure water at the same temperature (Dake et al., 2021).

Thermal drying—governed by coupled heat and mass transfer—remains one of the most effective methods for controlling water activity. In addition to agricultural applications, several industrial sectors require controlled low-humidity environments. For instance, in semiconductor and microchip fabrication, excess moisture may cause surface oxidation and contamination, thereby reducing device efficiency and lifespan (Misha et al., 2014).

Thermal drying is widely used to prolong the shelf life of agricultural products by preventing microbial and fungal growth. However, inefficient drying or storage practices often lead to post-harvest losses (Sharma et al., 2009). The process demands substantial energy, typically derived from fossil fuels, solar energy, or biomass. Given that fossil fuels are finite and environmentally harmful, current research emphasizes the use of renewable energy sources (Kumar et al., 2016). Open-sun drying, still commonly used by small-scale farmers, is often

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inefficient: it increases drying time, causes non-uniform moisture removal, lacks temperature control, and exposes the product to contamination, color loss, and nutrient degradation (Khalil et al., 2023).

Solar dryers are generally classified according to the dominant heat-transfer mechanism—natural or forced convection—and by their exposure to solar radiation: direct, indirect, mixed, or hybrid (Fudholi et al., 2010). In indirect systems, a solar collector preheats the air before it enters the drying chamber. In direct systems, a transparent cover allows solar radiation to reach the product. Mixed systems combine both configurations, while hybrid systems incorporate an auxiliary heat source (Ekechukwu et al., 1999).

Desiccant-assisted drying operates at relatively low temperatures, relying on the dehumidification of air through adsorption into a hygroscopic material. This process produces an airstream with reduced humidity and moderate temperature, helping to preserve product quality and lower energy consumption. The preconditioned air—by free or forced convection, or direct solar heating—promotes the evaporation of internal moisture within the material (Kamsah, 2016). Because forced convection enhances moisture removal efficiency, a solar dryer powered by photovoltaic (PV) energy presents an appealing alternative for driving blowers and preheating the air before it enters the drying chamber (Tiwari et al., 2018), particularly in rural regions with limited energy infrastructure. Fossil-fuel dryers, by contrast, involve high operational costs that limit accessibility for small producers (Tiwari et al., 2017).

Nevertheless, solar-only systems may prolong the drying process, especially at night or under cloudy conditions. To overcome this limitation, various hybrid configurations have been developed that store solar energy in sorption materials. Mbacho et al. (2021) designed and evaluated a greenhouse-type solar dryer employing clay and calcium chloride ($CaCl_2$) as desiccants. During nighttime operation, fans powered by PV-charged batteries circulated air through the desiccant chamber for dehumidification before it entered the drying compartment. The system was developed to assist smallholders in tomato preservation.

Therefore, this study aims to provide a comprehensive overview of drying processes using desiccant wheels integrated with solar-thermal and photovoltaic energy. A bibliometric analysis is conducted to organize, identify, and evaluate research trends, thereby clarifying the current state of the art and highlighting potential directions for future studies.

2 Methodology

2.1 Bibliometric research

bibliometrix is an open-source R package for bibliometric analysis. It supports data import from Scopus and Web of Science, computation of standard indicators (e.g., h-index, productivity, and growth), construction of co-citation and collaboration networks, and graphical visualization (Aria and Cuccurullo, 2017).

To analyze keyword co-occurrence and journal co-citation, we adopted degree centrality and betweenness centrality (Carvalho, 2013). Degree centrality counts direct connections and can be separated into in-degree (how often a study is cited) and out-degree (how many references it cites). Betweenness centrality quantifies nodes that act as bridges between otherwise unconnected parts of the network.

For highly cited papers, we computed a corrected impact factor (CIF) that combines the mean number of citations with the journal impact factor from Journal Citation Reports (Carvalho, 2013):

$$\mathrm{CIF} = \mathrm{Mean}(\mathrm{Citations}) \times \left(1 + \mathrm{IF}\right) \tag{1}$$

We also considered the Hirsch index and the h-b index proposed by Banks et al. (2006) to identify promising topics; empirically, $h \approx mn$ with years since the first topic paper, until it eventually stabilizes. The fields analyzed were titles, keywords, and abstracts—useful to estimate research volume in a topic and to reveal “hot” themes (Banks et al., 2006).

2.2 Data collection and processing

The review targets drying systems that employ desiccant wheels and integrate solar-thermal and PV energy. We conducted a quantitative bibliometric analysis to map trends and gaps. Initial keywords were "drying," "desiccant," "dehumidification," and "photovoltaic," later refined iteratively.

The primary search in Scopus used "drying" AND "desiccant" over 1965–2024. Refinements (Engineering, Energy, and Environmental Sciences; English; Article and Conference Paper) yielded 346 records. Adding "photovoltaic" reduced the set to two (2022–2023). Replacing "photovoltaic" with "dehumidification" returned 95 records (1984–2024). A comparable Web of Science search for the latter three terms produced 56 records. After merging in RStudio, we removed 49 duplicates; because most WoS items were also in Scopus, subsequent analyses relied on Scopus only.

3 Results

3.1 Evolution of scientific activity

The Scopus dataset comprises 95 documents published in 57 journals, with a mean of 18 citations per document and a total of 2,149 references. The annual publication growth rate is 1.29% (Table 1), indicating modest expansion over the period considered.

Tabela 1 – Main dataset information

Period	1984–2024
Sources (journals, books, etc.)	57
Documents	95
Annual growth rate	1.29%
Average document age	15.1
Mean citations per document	18.33
References	2,149

Annual output fluctuates (Figure 1), peaking in 2022 with nine articles. No publications were recorded in 1992, 2007, or between 1996 and 1999.

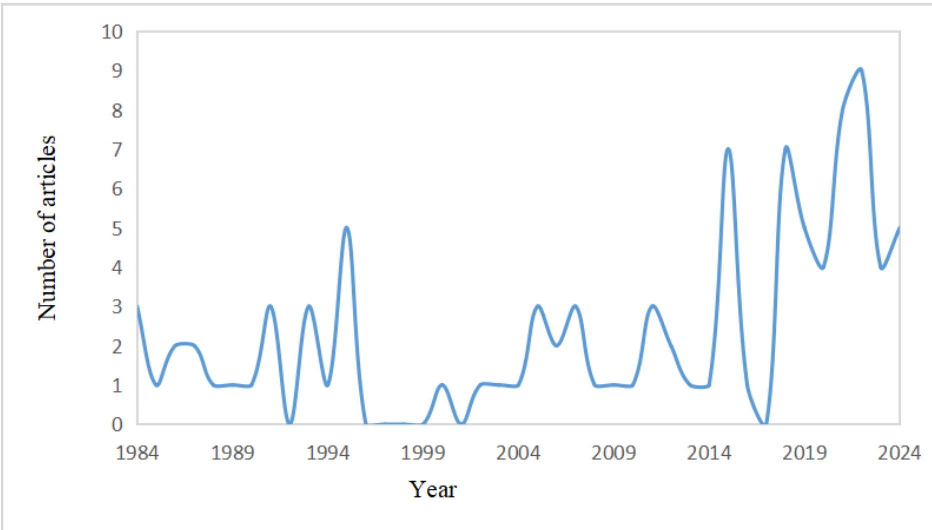

Figura 1 – Annual scientific production

Among the first three papers in 1984, two share the title *SOLAR DEHUMIDIFIED AIR FOR LOW TEMPERATURE DRYING SYSTEMS*; one is a conference paper by P. Gandhidasan (University of the West Indies) in *Proc.*

Fourth Int. Drying Symp., examining low-temperature drying with a liquid desiccant in a packed tower, with solar regeneration and nighttime/cloudy-period storage. Another 1984 paper addresses HVAC dehumidification rather than drying. In total, nine papers focus on desiccant dehumidification for refrigeration/air-conditioning—outside our primary scope but informative for method and technology context.

The mean total citations per year are approximately 1.82 (Figure 2). From 1984 to 1999, before a slight increase in output, the average was 1.11; between 2000 and 2007, average publications rose to 3.06; from 2013 to 2024, mean citations decreased to 2.32. Together, Figures 1 and 2 suggest that peaks in output tend to precede periods of higher citation counts.

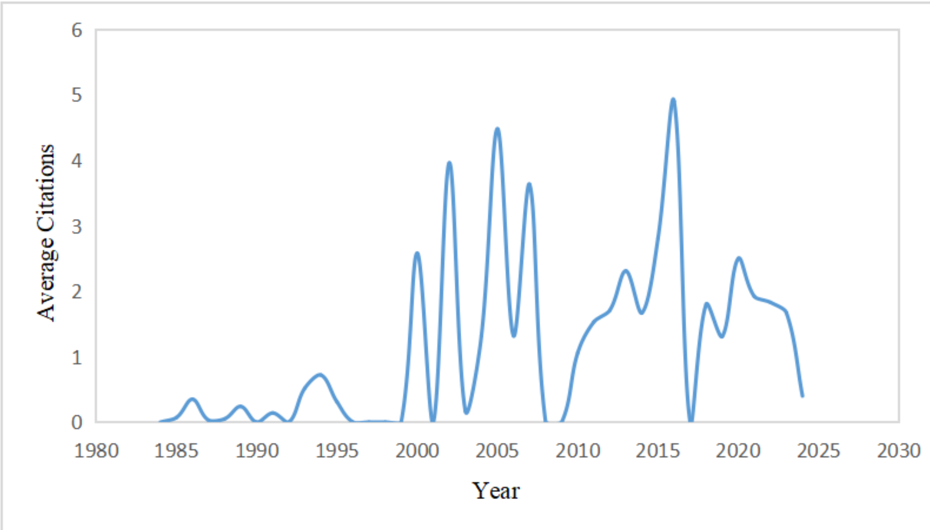

Figura 2 – Mean total citations per year

The most cited paper—*EXPERIMENTAL AND THEORETICAL ANALYSIS OF HEAT AND MASS TRANSFER IN A PACKED COLUMN DEHUMIDIFIER/REGENERATOR WITH LIQUID DESICCANT*—has 185 citations (Giovanni A. Longo; Andrea Gasparella, University of Padova). It investigates chemical air dehumidification/regeneration using hygroscopic saline solutions, demonstrating substantial humidity-ratio reductions suitable for drying and HVAC applications.

3.2 Sources

Source analysis helps identify suitable venues. Figure 3 lists the top ten journals by publication count; *Applied Thermal Engineering* leads with seven articles.

Publication counts alone are insufficient; consistency and cadence also matter. Figure 4 shows cumulative output over time: *ASHRAE Transactions* remained inactive in this topic after 1995 and reappeared only in 2024. The journal with the highest count began contributing in 2006 and has grown steadily since then. *Renewable Energy* appears the most regular in cadence.

High output in a journal does not guarantee the highest citation volume (Figure 5). *Applied Thermal Engineering* ranks fourth by citations, while *International Journal of Refrigeration* leads with 300 citations.

Table 2 reports the corrected impact factor (CIF) for the most cited articles, combining citation means with journal IF. This underscores that citation counts alone may understate relevance when journal visibility is high. Figure 6 orders CIF values in descending order.

3.3 Affiliations

Figure 7 shows relatively close publication counts across institutions. Seven of the listed affiliations are in Asia—five in China—plus one in the Netherlands and one in the United States. Notably, the five most cited

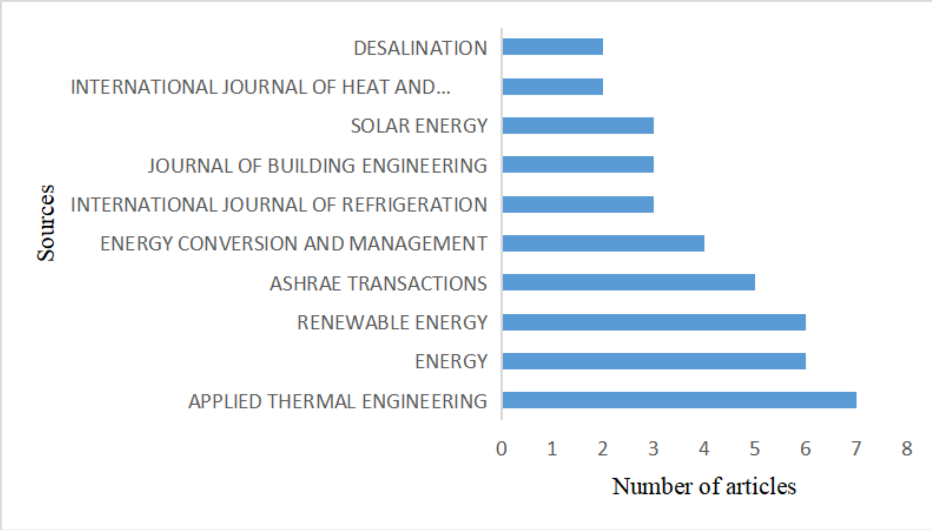

Figura 3 – Most relevant sources

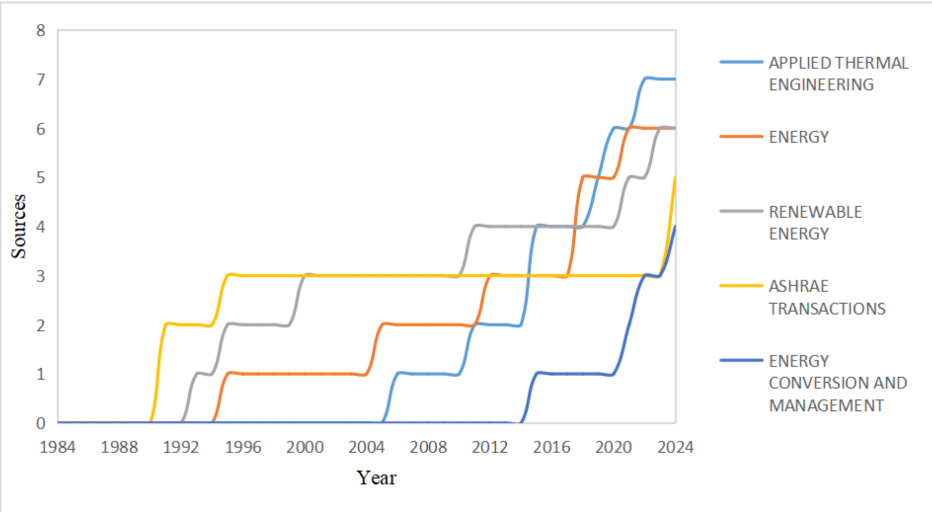

Figura 4 – Cumulative source production over time

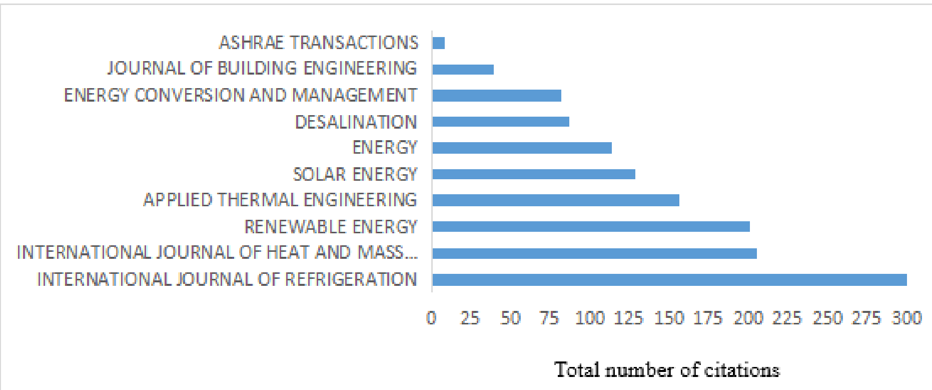

Figura 5 – Citations by source

Tabela 2 – Selected articles and corrected impact factor (CIF)

Authors	Title	Journal	Mean citations	JCR/IF	CIF
Longo GA; Gasparella A	Experimental and theoretical analysis of heat and mass transfer in a packed column dehumidifier/regenerator with liquid desiccant	International Journal of Heat and Mass Transfer	9.25	5.0	55.5
Jain S; Bansal PK	Performance analysis of liquid desiccant dehumidification systems	International Journal of Refrigeration	9.72	3.5	43.74
Al-Farayedhi AA; Gandhidasan P; Al-Mutairi MA	Evaluation of heat and mass transfer coefficients in a gauze-type structured packing air dehumidifier operating with liquid desiccant	International Journal of Refrigeration	4.13	3.5	18.585
Ettouney H	Design and analysis of humidification dehumidification desalination process	Desalination	4.20	8.4	39.48
Thoruwa TFN; Johnstone CM; Grant AD; Smith JE	Novel, low-cost $CaCl_2$-based desiccants for solar crop drying applications	Renewable Energy	2.68	9.0	26.8
Misha S; Mat S; Ruslan MH; Salleh E; Sopian K	Performance of a solar-assisted solid desiccant dryer for kenaf core fiber drying under low solar radiation	Solar Energy	5.60	6.0	39.2
Tu R; Liu X-H; Jiang Y	Lowering the regeneration temperature of a rotary wheel dehumidification system using exergy analysis	Energy Conversion and Management	5.30	9.9	57.77
Elsayed MM; Gari HN; Radhwan AM	Effectiveness of heat and mass transfer in packed beds of liquid desiccant system	Renewable Energy	1.56	9.0	15.6
Misha S; Mat S; Ruslan MH; Salleh E; Sopian K	Performance of a solar-assisted solid desiccant dryer for oil palm fronds drying	Solar Energy	5.44	6.0	38.08
Ramzy KA; Kadoli R; Ashok Babu TP	Improved utilization of desiccant material in packed bed dehumidifier using composite particles	Renewable Energy	3.21	9.0	32.1

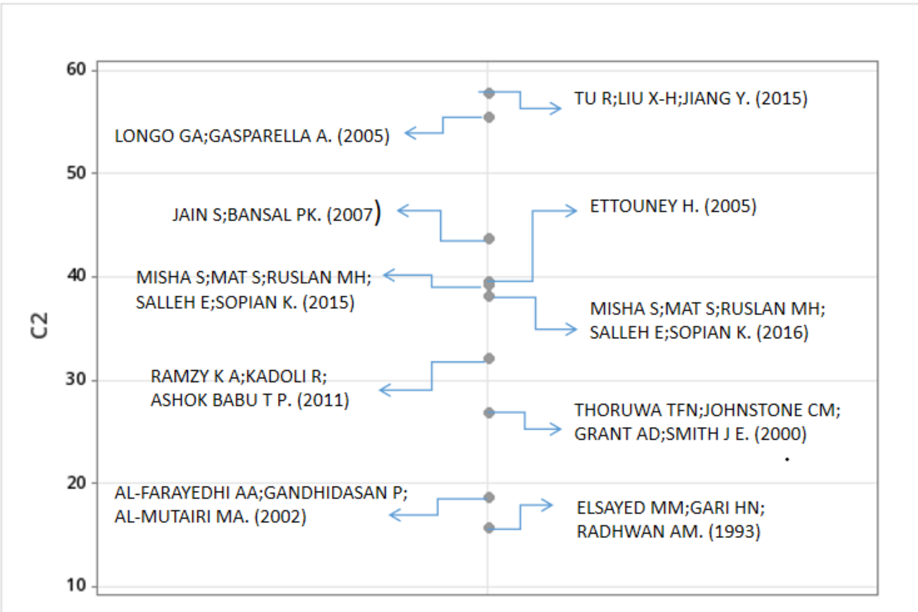

Figura 6 – Corrected impact factor (CIF)

papers do not belong to these top-publishing affiliations.

The five most productive affiliations began contributing only recently: Kyushu University first appeared in 2015, whereas the second-ranked institution began publishing in 2022, with three papers that year and five in 2024. To profile research emphases, we examined the most cited articles from these affiliations (Table 3).

3.4 Collaboration networks

The country co-authorship network (Figure 9) indicates limited collaboration among the four most prolific countries, likely reflecting distinct regional emphases.

The keyword co-occurrence network (Figure 10) reveals three main clusters. The **red** cluster centers on *drying* and *dehumidification*, with *adsorption*, *heat transfer*, and *silica gel* indicating solid-desiccant approaches. The

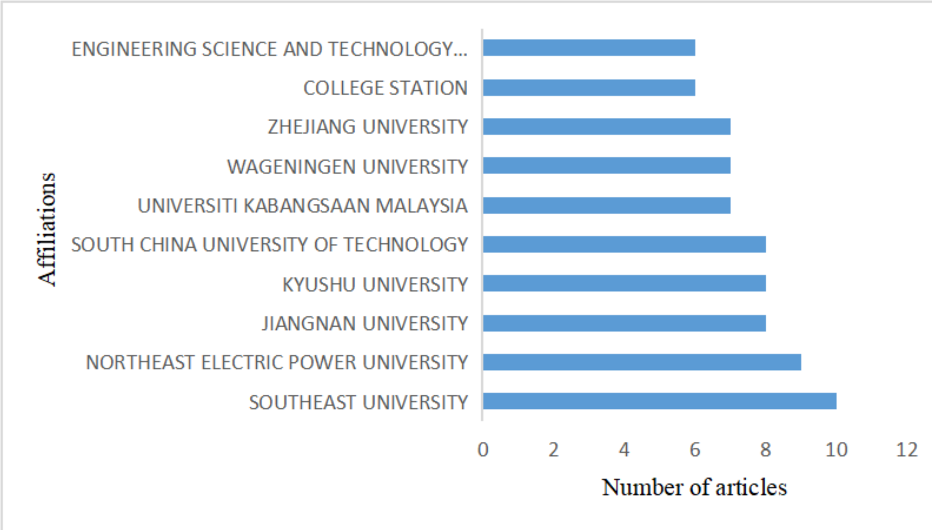

Figura 7 – Most relevant affiliations

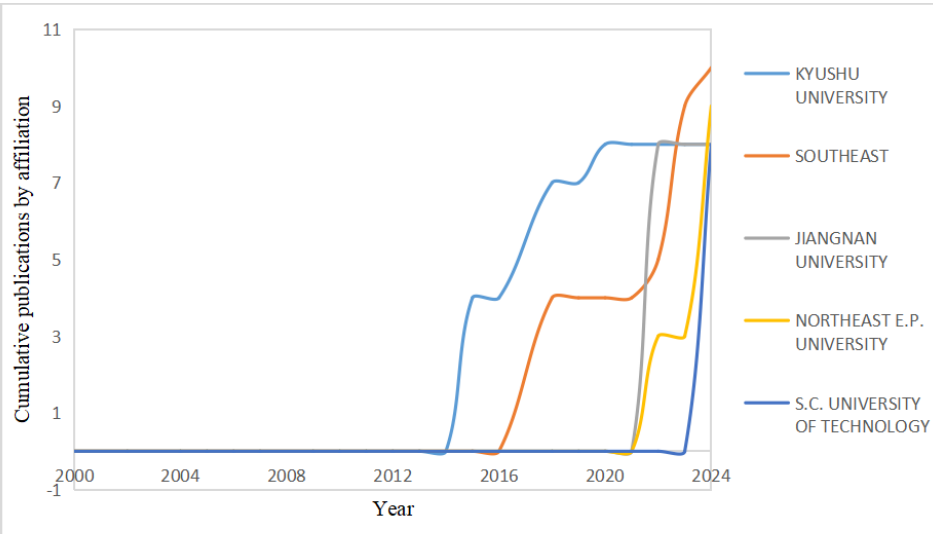

Figura 8 – Affiliations over time

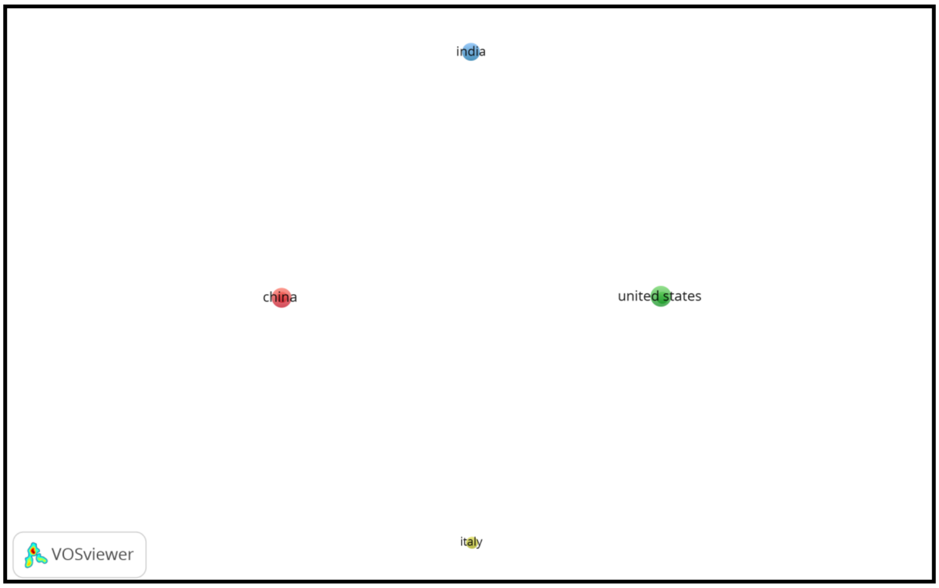

Figura 9 – Country co-authorship network

Tabela 3 – Most cited articles in the top affiliations

Affiliation	Citations	Article titles
Southeast University	14	Experimental and simulated study on a novel compressed air drying system using a liquid desiccant cycle
South China University of Technology	4	A moisture-absorbing cellulose nanofibril-based foam via ambient drying for high-performance dehumidification
Northeast Electric Power University	18	A novel absorption-based enclosed heat pump dryer combining liquid desiccant dehumidification and mechanical vapor recompression: case study and performance evaluation
Kyushu University	16	Steady-state investigation of desiccant drying system for agricultural applications
Jiangnan University	13	Fabrication of hygroscopic photothermal fibroin-based aerogels for dehumidification and solar-driven water harvesting

green cluster emphasizes *humidity control* and *driers (materials)*, with *energy efficiency* and *energy utilization* suggesting process optimization; *wheels* likely refers to desiccant-wheel technologies. The **blue** cluster focuses on *liquid desiccant* and its ties to *air conditioning* and *solar energy*, pointing to HVAC and sustainability applications.

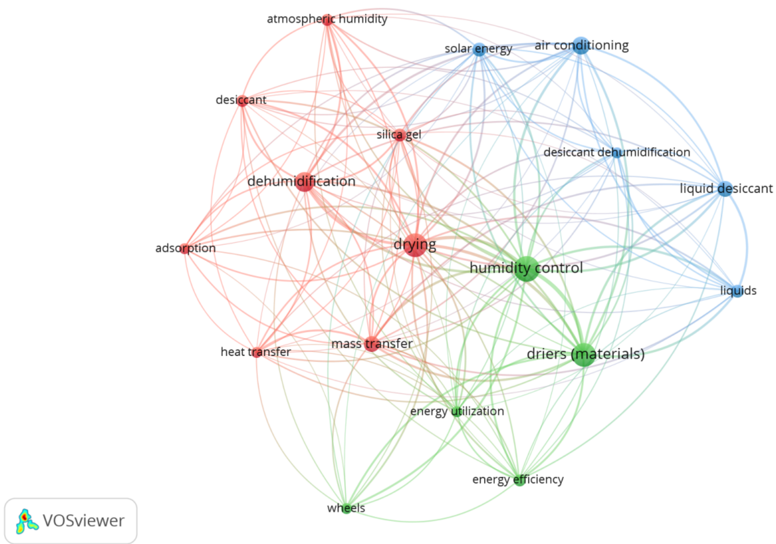

Figura 10 – Keyword network

Table 4 reports centralization and betweenness for the main keywords. Terms such as *dehumidification* and *humidity control* show high centralization, reflecting broad usage and connectivity. *solar energy* and *mass transfer* have high betweenness, acting as bridges among subareas and linking desiccant drying with energy and transport phenomena.

Figure 11 shows the distribution of keywords by the M-index, which helps distinguish established, saturated, and emerging topics. *Dehumidification*, *drying*, and *humidity control* exhibit intermediate M values, indicating well-established areas. By contrast, *liquid desiccant*, *solar energy*, and *energy efficiency* attain higher M values, suggesting emerging, high-impact directions aligned with sustainable, energy-efficient systems. Low M values typically correspond to niche or under-explored themes.

4 Conclusion

This bibliometric review maps research on desiccant-based drying for dehumidification processes. Although annual growth is modest, the field shows clear interest in improving humidity control while reducing energy use. Publication volume concentrates in China and the United States, with Asian universities particularly prolific; however, the most impactful institutions are not necessarily the most productive, underscoring the need to balance quantity and quality.

Tabela 4 – Keyword centralization and intermediation metrics.

Centralization			Intermediation		
#	Term	Value	#	Term	Value
1	adsorption	0.059	17	solar energy	0.618
2	air conditioning	0.136	2	air conditioning	0.618
3	atmospheric humidity	0.069	12	humidity control	0.618
4	dehumidification	0.165	4	dehumidification	0.618
5	desiccant	0.074	7	driers (materials)	0.618
6	desiccant dehumidification	0.071	15	mass transfer	0.618
7	driers (materials)	0.266	11	heat transfer	0.618
8	drying	0.234	8	drying	0.618
9	energy efficiency	0.084	16	silica gel	0.618
10	energy utilization	0.071	9	energy efficiency	0.502
11	heat transfer	0.067	10	energy utilization	0.378
12	humidity control	0.307	5	desiccant	0.289
13	liquid desiccant	0.122	3	atmospheric humidity	0.240
14	liquids	0.105	1	adsorption	0.177
15	mass transfer	0.132	18	wheels	0.057
16	silica gel	0.088	6	desiccant dehumidification	0.049
17	solar energy	0.092	13	liquid desiccant	0.049
18	wheels	0.064	14	liquids	0.049

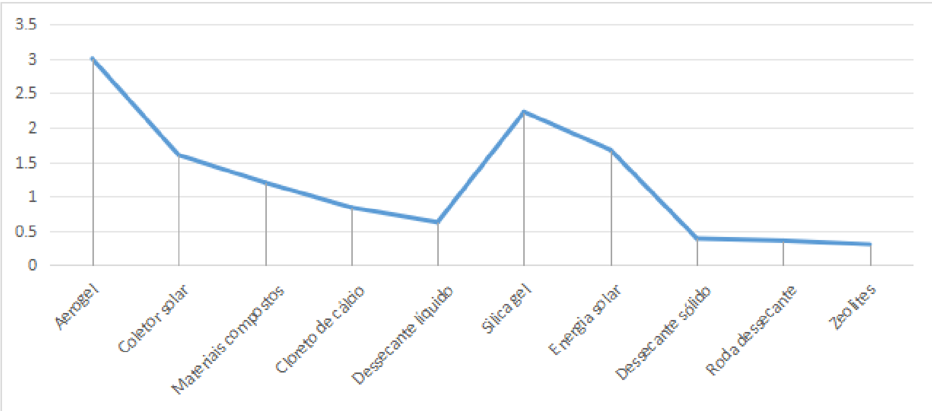

Figura 11 – Most relevant topics (M-index)

Keyword patterns emphasize liquid desiccants, heat and mass transfer, energy efficiency, and applications across industrial and agricultural contexts—consistent with the pursuit of cost-effective, sustainable drying. Promising directions include innovative hygroscopic materials and integration with heat-recovery systems.

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