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Bibliometric Mapping Analysis of Nanocrystalline Starch in Food Packaging Application using VOSviewer

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Abstract. Biodegradable materials needed to reduce packaging waste and extend food shelf life. Starch nanomaterials are one of the promising alternatives as environmentally friendly sustainable food packaging for single-use products. This study was to conduct a bibliometric analysis of starch nanocrystal research in food packaging applications using mapping analysis on VOSviewer software. Data was obtained from Google Scholar search which is integrated with Publish or Perish as a reference application. The data search was based on the keywords "nanocrystalline, starch, food, packaging, chemistry". The results showed that there were 1000 articles that met the research keyword criteria with visualization showing 269 items and 10706 links divided into 8 clusters. The results of the analysis show that the number of research publications from 2012 to 2022 has increased every year until 2021. However, in 2022 the number of articles published decreased quite dramatically. This research is expected to help further researchers and be a consideration in deciding the research topic.
Keywords: bibliometric, nanocrystalline starch, food packaging, VOSviewer

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1. Introduction

Application of nanotechnology in food packaging aims to improve the characteristics of food packaging materials, such as strength, antimicrobial properties, and stability to temperature **[1]**. Most of the materials used for food packaging are non-biodegradable resulting in waste that has the potential to become serious global problem. In reducing packaging waste and extending food shelf life, biomaterials are needed to develop edible and biodegradable films/coatings. Biopolymers such as starch-based materials are a promising alternative for a good environmental health as sustainable food packaging for single-use products **[2]**.

Over the years, starch nanomaterials is a concern due to their heteropolymer structure that can be used in various applications **[3]**. Starch as nanoparticles has a high binding strength so that it can be applied as a reinforcement or filler for synthetic or plastic polymers **[4] [5]**. Many researches have been

studied about application of starch nanomaterials in the food sector as food packaging materials. Starch nanocrystals used as food packaging that can decompose naturally **[6]**. Furthermore, reported that green sago starch nanocrystals can be used as reinforcement, barrier capacity, and good hydrophobicity for food packaging **[7]**. In addition, rice starch layers containing nanocrystalline were reported as good candidates for food packaging **[8]**. The use of starch nanoparticles as nanofiller for the synthesis of nanocomposite films has been extensively studied recently **[9] [10] [11] [12] [13]**. The scientific study of starch nanoparticles to improve packaging quality is a very promising field. Application of starch nanocrystals as industrial packaging continues to look for innovative solutions to create an efficient and sustainable system. Starch nanoparticles have become the focus of an increasing number of scientific papers with the aim of developing bio composite by combining starch nanoparticles with different biopolymer matric.

Before conducting further studies, it is necessary to analyze interesting and relevant topics to be discussed in developing starch nanocrystals as industrial packaging. The future food industry plays an important role in finding new starch sources, modifying processes, mechanical properties, functional properties, improving the performance of starch-based materials by mixing with other biopolymers, as well as the use of micro and nano-sized reinforcement. One way to do this is through bibliometric analysis.

Therefore, this study aims to mapping bibliometric analysis of nanocrystalline starch in food packaging in the VOSviewer application with the Google Scholar database integrated into the Publish or Perish application. The results of this study are expected to help further researchers in deciding research topics, especially those related to the development of food packaging with starch nanocrystals.

2. Methods

Data in this study were obtained from articles that published in journals indexed by Google Scholar. Google Scholar is a publication search engine that can be accessed freely and some of its features support the search for published research results. Google Scholar is integrated with Publish or Perish to calculate citations and some related information as well as a reference manager application to get research data by searching *Google Scholar Search*. Publish or Perish software used by entering keywords, publication type, and year of publication. Search article data with the keywords "*nanocrystalline, starch, food, packaging, chemistry*" in the 2012-2022 range. The data obtained is saved as a result in *.ris and *csv formats. Furthermore, the visualization and analysis of the trend of the mapping bibliometric was carried out using the VOSviewer software. The data obtained are mapped into three forms of visualization including, network visualization, density visualization, and overlay visualization.

3. Results and Discussion

3.1. Publication data search results

Based on the results of collected by publication data based on the Google Scholar through the Publish or Perish reference manager application, 1000 articles were obtained that met the research keyword criteria. Search results in *csv file format display metadata including number of citations, author, title, year, journal name, publisher, rating, article links, and related URLs. Based on the data displayed by Publish or Perish (see Figure 1), the total number of citations for all articles is 34483 with the number of citations per year 3448.30, citations per article 34.48, and authors per article 4.01. The impact and productivity of published articles is measured by the h-index value of 94 with hI,annual (per year) 4.3; g-index 141; hI, norm 43; and hA-index 39. Table 1 shows the 50 relevant articles with the highest number of citations

Results	Help
Publication years:	2012-2022
Citation years:	10 (2012-2022)
Papers:	1000
Citations:	34483
Cites/year:	3448.30
Cites/paper:	34.48
Authors/paper:	4.01
h-index:	94
g-index:	141
hI,norm:	43
hI,annual:	4.30
hA-index:	39

Figure 1. Results of article search data obtained from the Publish or Perish reference manager

Table 1. Relevant published data regarding starch nanocrystals in food packaging applications

No	Authors	Title	Year	Cites
1	B Hassan, SAS Chatha, AI Hussain, KM Zia…	Recent advances on polysaccharides, lipids and protein based edible films and coatings: A review	2018	573
2	D Trache, MH Hussin, CTH Chuin, S Sabar…	Microcrystalline cellulose: Isolation, characterization and bio-composites application—A review	2016	435
3	H Wang, J Qian, F Ding	Emerging chitosan-based films for food packaging applications	2018	424
4	X He, HM Hwang	Nanotechnology in food science: Functionality, applicability, and safety assessment	2016	384
5	F Garavand, M Rouhi, SH Razavi, I Cacciotti…	Improving the integrity of natural biopolymer films used in food packaging by crosslinking approach: A review	2017	322
6	MP Arrieta, J López, A Hernández, E Rayón	Ternary PLA–PHB–Limonene blends intended for biodegradable food packaging applications	2014	319
7	S Ranjan, N Dasgupta, AR Chakraborty…	Nanoscience and nanotechnologies in food industries: opportunities and research trends	2014	261
8	I Majid, GA Nayik, SM Dar, V Nanda	Novel food packaging technologies: Innovations and future prospective	2018	222

9	N Duran, PD Marcato	Nanobiotechnology perspectives. Role of nanotechnology in the food industry: a review	2015	217
10	YI Cornejo-Ramírez, O Martínez-Cruz…	The structural characteristics of starches and their functional properties	2018	205
11	J Wróblewska-Krepsztul, T Rydzkowski…	Recent progress in biodegradable polymers and nanocomposite-based packaging materials for sustainable environment	2018	185
12	B Khan, M Bilal Khan Niazi, G Samin…	Thermoplastic starch: A possible biodegradable food packaging material—A review	2017	177
13	M Atef, M Rezaei, R Behrooz	Preparation and characterization agar-based nanocomposite film reinforced by nanocrystalline cellulose	2014	149
14	H Tian, J Yan, AV Rajulu, A Xiang, X Luo	Fabrication and properties of polyvinyl alcohol/starch blend films: Effect of composition and humidity	2017	142
15	A Ali, Y Chen, H Liu, L Yu, Z Baloch, S Khalid…	Starch-based antimicrobial films functionalized by pomegranate peel	2019	138
16	AM Salaberria, J Labidi, SCM Fernandes	Chitin nanocrystals and nanofibers as nano-sized fillers into thermoplastic starch-based biocomposites processed by melt-mixing	2014	130
17	AI Cano, M Cháfer, A Chiralt…	Physical and microstructural properties of biodegradable films based on pea starch and PVA	2015	123
18	K Ramachandraiah, SG Han…	Nanotechnology in meat processing and packaging: potential applications—a review	2015	120
19	E Ogunsona, E Ojogbo, T Mekonnen	Advanced material applications of starch and its derivatives	2018	113

20	J Muller, C González-Martínez, A Chiralt	Poly (lactic) acid (PLA) and starch bilayer films, containing cinnamaldehyde, obtained by compression moulding	2017	110
21	KK Dash, NA Ali, D Das, D Mohanta	Thorough evaluation of sweet potato starch and lemon-waste pectin based-edible films with nano-titania inclusions for food packaging applications	2019	106
22	N Bumbudsanpharoke, J Choi…	Applications of nanomaterials in food packaging	2015	106
23	K Piyada, S Waranyou, W Thawien	Mechanical, thermal and structural properties of rice starch films reinforced with rice starch nanocrystals	2013	105
24	M Fazeli, M Keley, E Biazar	Preparation and characterization of starch-based composite films reinforced by cellulose nanofibers	2018	104
25	S Tabasum, M Younas, MA Zaeem, I Majeed…	A review on blending of corn starch with natural and synthetic polymers, and inorganic nanoparticles with mathematical modeling	2019	104
26	R Jumaidin, SM Sapuan, M Jawaid, MR Ishak…	Characteristics of thermoplastic sugar palm Starch/Agar blend: Thermal, tensile, and physical properties	2016	103
27	JBA Da Silva, FV Pereira, JI Druzian	Cassava starch-based films plasticized with sucrose and inverted sugar and reinforced with cellulose nanocrystals	2012	97
28	L Dai, J Zhang, F Cheng	Effects of starches from different botanical sources and modification methods on physicochemical properties of starch-based edible films	2019	97
29	A Bratovčić, A Odobašić, S Ćatić…	Application of polymer nanocomposite materials in food packaging	2015	94

30	S Ali Akbari Ghavimi, MH Ebrahimzadeh…	Polycaprolactone/starch composite: Fabrication, structure, properties, and applications	2015	90
31	E Šárka, V Dvořáček	New processing and applications of waxy starch (a review)	2017	85
32	A Chávez-Salazar, LA Bello-Pérez…	Isolation and partial characterization of starch from banana cultivars grown in Colombia	2017	82
33	J Jeevahan, M Chandrasekaran	Nanoedible films for food packaging: A review	2019	81
34	SJ Wesley, P Raja, AAS Raj…	Review on-nanotechnology applications in food packaging and safety	2014	79
35	LM Fonseca, CE dos Santos Cruxen, GP Bruni…	Development of antimicrobial and antioxidant electrospun soluble potato starch nanofibers loaded with carvacrol	2019	73
36	P Shao, H Zhang, B Niu, W Jin	Physical stabilities of taro starch nanoparticles stabilized Pickering emulsions and the potential application of encapsulated tea polyphenols	2018	68
37	P Chaudhary, F Fatima, A Kumar	Relevance of nanomaterials in food packaging and its advanced future prospects	2020	67
38	JHR Llanos, CC Tadini	Preparation and characterization of bio-nanocomposite films based on cassava starch or chitosan, reinforced with montmorillonite or bamboo nanofibers	2018	65
39	E Fortunati, A Mazzaglia…	Sustainable control strategies for plant protection and food packaging sectors by natural substances and novel nanotechnological approaches	2019	65
40	M Cheng, J Wang, R Zhang, R Kong, W Lu…	Characterization and application of the microencapsulated carvacrol/sodium alginate films as food packaging materials	2019	59

41	V Goudarzi, I Shahabi-Ghahfarrokhi	Photo-producible and photo-degradable starch/TiO2 bionanocomposite as a food packaging material: Development and characterization	2018	57
42	A Mukurumbira, M Mariano, A Dufresne…	Microstructure, thermal properties and crystallinity of amadumbe starch nanocrystals	2017	55
43	H Molavi, S Behfar, MA Shariati, M Kaviani…	A review on biodegradable starch based film	2021	55
44	P Jariyasakoolroj, P Leelaphiwat…	Advances in research and development of bioplastic for food packaging	2020	54
45	N Devi, J Dutta	Development and in vitro characterization of chitosan/starch/halloysite nanotubes ternary nanocomposite films	2019	48
46	ML Sanyang, SM Sapuan, M Jawaid…	Effect of plasticizer type and concentration on dynamic mechanical properties of sugar palm starch–based films	2015	46
47	M Guimarães, VR Botaro, KM Novack…	High moisture strength of cassava starch/polyvinyl alcohol-compatible blends for the packaging and agricultural sectors	2015	42
48	A Azfaralariff, FF Fazial, RS Sontanosamy…	Food-grade particle stabilized pickering emulsion using modified sago (Metroxylon sagu) starch nanocrystal	2020	41
49	K Gonzalez, L Iturriaga, A Gonzalez, A Eceiza…	Improving mechanical and barrier properties of thermoplastic starch and polysaccharide nanocrystals nanocomposites	2020	37
50	A Plucinski, Z Lyu, BVKJ Schmidt	Polysaccharide nanoparticles: from fabrication to applications	2021	33

3.2. Research development of nanocrystalline starch in food packaging application

Based on research data from Publish or Perish, an analysis of the development of starch nanocrystal research in food packaging applications from 2012 to 2022 is summarized in **Table 2**.

Table 2. Research developments of starch nanocrystals in food packaging

Year	Number of Publication
2012	13
2013	26
2014	32
2015	38
2016	43
2017	60
2018	108
2019	129
2020	172
2021	219
2022	156
Average	**90.55**

The relationship between the number of articles published in each year is depicted by a curve (see Figure 2). The data shows the development of research from year to year, it can be seen that the number of related research publications has increased every year until 2021. From 2012 to 2017, the increase in the number of publications that occurred did not differ significantly, as shown by a gentle curve. Then, the curve rose sharply from 2017 to 2018 showing a significant increase from 60 to 108 published articles. The same thing happened in 2019-2021 with an increase of 90 articles from the previous total. However, in 2022 the number of articles published decreased quite dramatically from 219 to 156 articles.

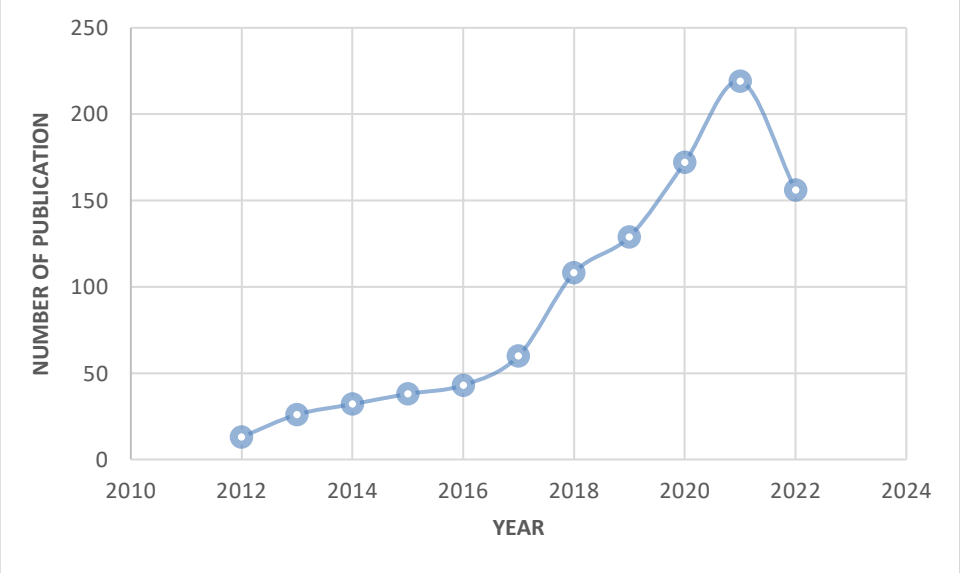

Figure 2 Development of publication of articles on starch nanocrystal research in food packaging application

3.3. Visualization nanocrystalline starch topic area using VOSviewer

VOSviewer displays a bibliometric map that interprets a relationship. VOSviewer software has several characteristics including, it can map various types of bibliometric analysis, supports several bibliographic databases, limits the analysis of small to medium amounts of data in a certain time. This mapping is a function of text processing using layout and cluster techniques with visualization features [11]. The results of the visualization of research mapping related to starch nanocrystals in food packaging applications show 269 items with a total of 10706 links which are divided into 8 clusters, namely:

a. Cluster 1 consists of 48 items including, antimicrobial agent, antimicrobial film, antimicrobial property, bio, biodegradable packaging, biodegradable polymer, biomedical application, bio nanocomposite film, bioplastic, cellulose nanofiber, chemistry, chitin, chitin nanocrystal, chitosan, cnc, cnf, cross, derivative, environment, form, investigation, matrix, mechanical property, nanocellulose, nanocomposite, nanocrystal, nanofiber, nanomaterial, ncc, opportunity, optical property, overview, paper, pbat, polylactic acid, process, prospect, recent advance, recent progress, review, state, thermoplastic starch, treatment, type, wvp, zinc oxide, zinc oxide nanoparticle
b. Cluster 2 consists of 46 items including, acid hydrolysis, advance, approach, bacterial cellulose nanocrystal, banana starch, biodegradable packaging material, chemical characteristic, chemical method, chemical modification, citric acid, comparison, emulsion, esterification, filler, functional property, gelatin, granule, green chemistry, hydrolysis, hydroxyl group, microcrystalline cellulose, microstructure, modification, native starch, packaging, physical, physicochemical property, plastic, plasticizer, product, properties, reagent, rice starch, size, snc, solution, starch, starch granule, starch nanocrystal, starch nanoparticle, structure, surface, surface modification, synthesis, utilization, water.
c. Cluster 3 consists of 44 items including, ability, acid, active film, agent, antioxidant property, behavior, biodegradable material, bio nanocomposite, case, cassava, cellulose nanocrystal, cellulose nanocrystals, characterization, chemical change, chemical structure, chemical treatment, chitosan film, cncs, corn, corn starch, crystallinity, drug delivery, effect, enhancement, fabrication, fermentation, fiber, field, ftir, isolation, lactic acid, morphology, oil, polyvinyl alcohol, potato, potato starch, potential, processing, raw material, rice, study, sugar, sugarcane bagasse, tensile
d. Cluster 4 consists of 39 items including active food packaging, active packaging, anthocyanin, biodegradable film, cationic starch, chemical bound, chemical crosslinking, chemical interaction, component, curcumin, development, edible film, essential oil, evaluation, ectuction, film, food additive, food packaging, food packaging film, impact, improvement, morphological property, nanocomposite film, natural polymer, packaging application, pea starch, pectin, polysaccharide, potential application, potential use, preparation, property, protein, pva, quality, researcher, safety, stability, vinyl alcohol.
e. Cluster 5 consists of 32 items including, antimicrobial activity, arenga pinata, bio nanocomposite, biodegradability, biodegradation, cellulose, characteristics, chemical reaction, chemical similarity, compatibility, composite, comprehensive review, degradation, fibre, food packaging application, food packaging material, food product, nanocrystalline, nanocrystalline cellulose, packaging film, physical property, physicochemical property, polymer, reinforcement, shelf life, starch film, sugar palm, sugar palm starch, synthetic polymer, tio, water barrier property
f. Cluster 6 consists of 29 items including addition, advantage, analytical grade, antibacterial activity, application, barrier property, biopolymer, cassava starch, cellulose nanofibril, chemical, chemical reagent, coating, fact, food, food packaging industry, low cost, mechanical, mechanical treatment, nanofiller, nanoparticle, optimization, packaging industry, performance, production, source, starch matrix, storage, textile, vaue
g. Cluster 7 consists of 23 items including, alternative, bacterial cellulose, bio composite, chemical resistance, combination, composite film, content, food chemistry, food industry, glycerol, hemicellulose, hydrophobicity, interaction, lignin, nanotechnology, packaging material, rice starch

nanocrystal, silver nanoparticle, soy protein, strength, structural property, surface chemistry, thermal stability.

h. Cluster 8 consists of 9 items including agriculture, chemical composition, chemical property, extraction, formation, influence, medicine, morphological, thermal property.

Each visualized cluster shows the relationship between one term and another. The size of the letters and circles correlated positively with the occurrence of keywords and abstracts of related articles. That is, the size of the circle is determined by the frequency of its occurrence, the more it appears, the larger the size and letters visualized [12]. Bibliometric mapping in VOSviewer is displayed in three different visualizations, network visualization (**Figure 3**) shows the relationship between terms in the topic of nanocrystalline starch in food packaging which is connected by various lines to form a network. This visualization depicts clusters from each research area studied, such as starch nanocrystals in cluster 2 with 120 occurrences, 193 links and a total link strength of 819. Starch nanocrystals are associated with food packaging terms, nanocomposite films, and biodegradable films in cluster 4. Density visualization (**Figure 4**) shows that the brighter the yellow color, the larger the size of the term circle. That is, a lot of research involving the term has been done. On the other hand, when the color fades and resembles a background color, it shows that there is little research on the term [13]. The results of density visualization show that studies on starch, food packaging, and films have a high number of studies

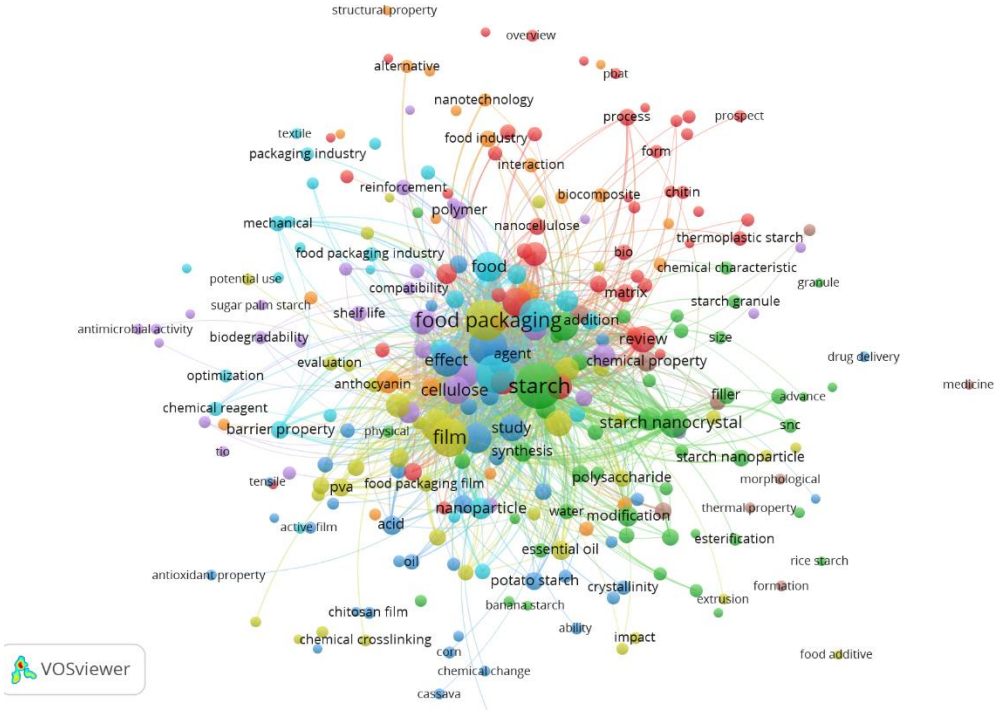

Figure 3 Network visualization with keywords nanocrystal, starch, food, packaging, chemistry in VOSviewer

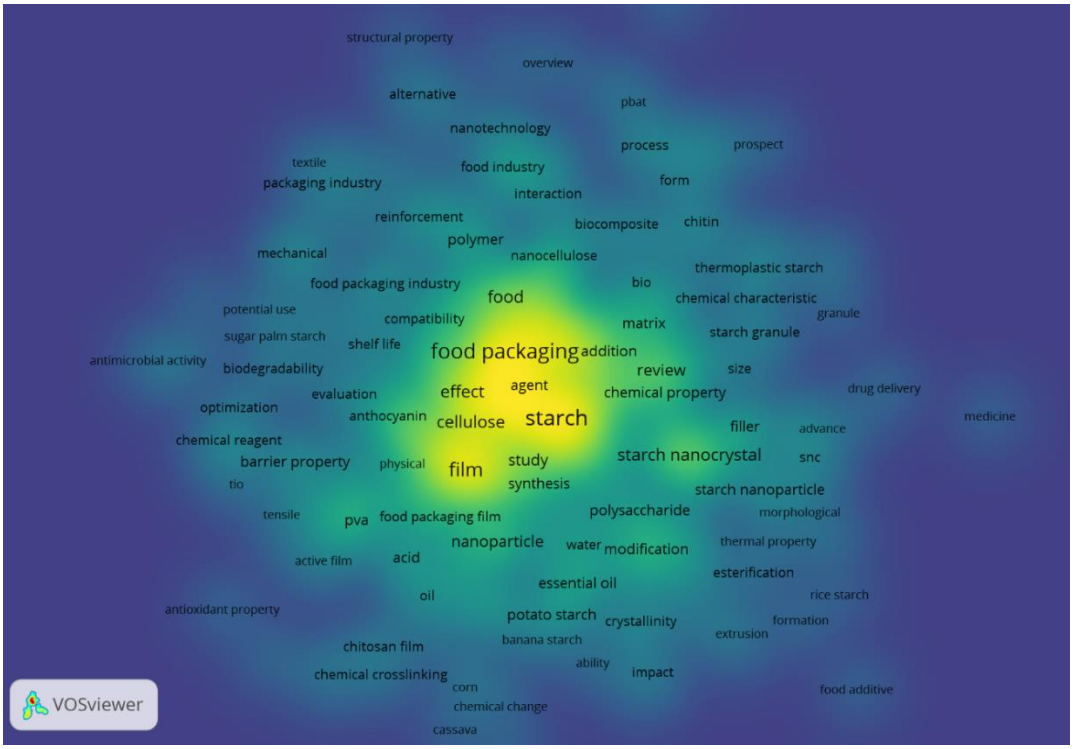

Figure 4 Network visualization with keywords nanocrystal, starch, food, packaging, chemistry in VOSviewer

4. Conclusion

This study aims to analyze bibliometric mapping related to starch nanocrystal research in food packaging applications using VOSviewer. The article data to be analyzed is obtained from the Publish or Perish reference manager application with the Google Scholar database. The data obtained relates to the keywords "nanocrystalline, starch, food, packaging, chemistry" in the year 2012-2022 with a total of 1000 articles relevant to 269 items and 10706 links divided into 8 clusters. The results showed that the number of related research publications increased every year until 2021. From 2012 to 2017, the increase in the number of publications did not differ significantly. A significant increase occurred in 2017 to 2018. Recently, in 2019 to 2021 there was a significant increase. However, in 2022 the number of articles published decreased quite dramatically. The results of the analysis show that research on starch nanocrystals in food packaging applications still has the potential to increase publications this year and the following year.

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