Health Benefits and Modern Applications of Apple Cider Vinegar: A Four-Decade Review of the Scientific Literature

(Review Article on Bibliometric Investigation of Apple Cider Vinegar)

Dr. Smriti Tripathi* (1st & Correspondence)
Department of Pharmacology, Rameshwaram Institute of Technology and Management, Lucknow, Pin- 227202
Email: smrititripathi2009@gmail.com, ORCID ID: https://orcid.org/0000-0001-9930-5397

***Abstract*—Apple cider vinegar (ACV) is among the most frequently used condiments for its health benefits. ACV studies discovered anti-obesity, anti-bacterial, antifungal, cardiovascular, anti-cancer, and anti-Alzheimer's properties. Thus, ACV research enhances human health in every way. In the present research, we will conduct a bibliometric exploration and analysis of vast quantities of unstructured scientific data. This method enables us to comprehend the evolutionary complexities of the topic when conducting ACV research. The dominant themes of the analysis supported our assertion that ACV has multiple health benefits. This research covered diabetes, oxidative stress, immunomodulation, and antifungal, antimicrobial, and antiviral activities. Based on our findings, we also recommend incorporating bioinformatics, molecular target research, and interdisciplinary cooperation into ACV research. This literature review examines the pharmacological actions and health benefits of ACV. This survey will also enlighten researchers about global ACV research and the areas where they should concentrate their future efforts.**

Keywords—Apple Cider Vinegar; Citation analysis; Bibliographic coupling; Co-authorship analysis; Human health

I. Introduction

The term "Apple Cider Vinegar" (abbreviated "ACV") is a type of vinegar used in many salad dressings, marinades, and sauces. ACV is mildly acidic (5% acetic acid) and made from alcohol, wine, malted barley, and cider [1]. Apple juice and bacteria/yeast ferment to make ACV. Sugar first turns into alcohol, then acid, giving ACV its sour flavor. In a well-balanced diet, moderate ACV consumption has many health benefits. According to study, Apple cider vinegar (ACV) is anti-hyperlipidemia, anti-diabetic, neurodegenerative, antimicrobial, and antibacterial. Polyphenols, flavonoids, and organic acids provide ACV its preventive properties. These components protect human health. ACV research has yielded promising results since its first use in human health, and scientists are working to understand it. ACV's protective effects against different human disorders/diseases have led to the development of many ACV-based products, including tablets, capsules, topical lotions, shampoo, and body wash [2].

ACV research arena is multi-dimensional and interdisciplinary, where the majority of research primarily explores its effect on human health. The existing literature exhibits that ACV has a typically broad level of protective activities for human health [3–9]. ACV's protective abilities result from various natural polyphenolic compounds, especially organic acid found in the ACV [10]. Organic acid found in ACV controls gene expression via the MAPK pathway (Mitogen-activated protein kinase) and regulates lipid levels to improve hepatic metabolism [11–13]. ACV study has yielded encouraging outcomes since its introduction in human health, and experts are working to understand it fully. However, it accelerated ACV research and exponentially increased its informational breadth in recent decades [1]. Hence, researchers must keep abreast of related advancements to ensure adequate knowledge of the areas requiring attention to exploit the maximum benefit from ACV for human health. Unfortunately, it is difficult for researchers and scientists to produce a scoping review based on the vast existing literature. To overcome this, we perform the scientific bibliometric mapping of "Apple Cider Vinegar" in a human health context to analyze the field as a whole and its nuances [14–16].

Bibliometric analysis is a standard and challenging technique, grounded in network analysis methodology, for identifying, developing, and evaluating vast volumes of cluttered scientific data [17]. This method allows us to deconstruct the evolutionary peculiarities of a particular topic while offering light on its emerging areas [18]. Bibliometric mapping gives a bird’s eye view of the domain to analyze how the research has evolved over the years and the interconnectedness within the domain. This report provides precise information regarding ACV research based on a bibliometric analysis of all published articles, reviews, and book chapters. The bibliometric analysis provides significant information about the domain, such as the influential articles, leading authors, their interconnections and other essential information about the field.

ACV research has never been bibliometrically analyzed. This study highlights ACV research's major accomplishments and examines the links between

numerous domain research topics and their health benefits. This analysis seeks to present a holistic view of ACV research to show how researchers' combined efforts have shaped ACV literature to date and where we are and should be heading. This paper clearly highlights ACV's benefits in human health research, making it useful for aspiring ACV researchers. Our findings direct future research as well.

II. Research Methodology

A. Data Mining method

The data for this study has been procured from the "Scopus database," an online collection of research citation databases. Scopus is one of the most expansive collections of research publications from various disciplines. While browsing the database, we conducted an 'advanced search' and ran the search query "Apple Cider Vinegar" OR "Apple Vinegar" using the TITLE-ABS-KEY- search command. Where 'TITLE-ABS-KEY' was the supplied command to search for given keywords in the title, abstract, and keywords of all the documents [3]. In order to retain the study's rigor, we limited ourselves to publications in which "Apple Cider Vinegar" OR "Apple Vinegar" was the primary topic in human health and not a byproduct. We applied advanced qualifiers to the search operation, and the search was targeted to English language documents and published articles from 1975 to December 2022. The last data export from the database was made on 22nd feburary 2023.

The search query returned 372 publications published between 1975 and 2022 related to ACV. This set of papers consists of 336 Research articles, 15 review articles, 14 conference papers, 2 book chapters from 354 journals, 67 countries or territories, and 10421 references. These 372 results were then manually analyzed to ensure contextual and analytical relevancy. Out of the 372 studies, 52 were not focused on ACV research on human health but on other topics, such as aquaculture and murine research study [19–21]. Thus, they were removed from the data set. Consequently, the final 320 studies list was imported from the database for bibliometric analysis. Data was imported in the 'Comma Separated Value' (CSV) format for the analysis.

B. Visualization & Exploration Method

We used Excel and VOSviewer to analyse the data. Vosviewer is Leiden University's network data processing and visualisation tool. Scientific analysis tool VOSviewer builds and displays network data. Citation, Co-Citation, Co-Word, and Co-authorship analyses are part of bibliometric analysis (Figure 1). Our data includes publications, journals, and authors, whose network can be formed using citation, co-citation, co-authorship, and bibliographic coupling relationships. Furthermore, bibliometric analysis can reveal field trends.

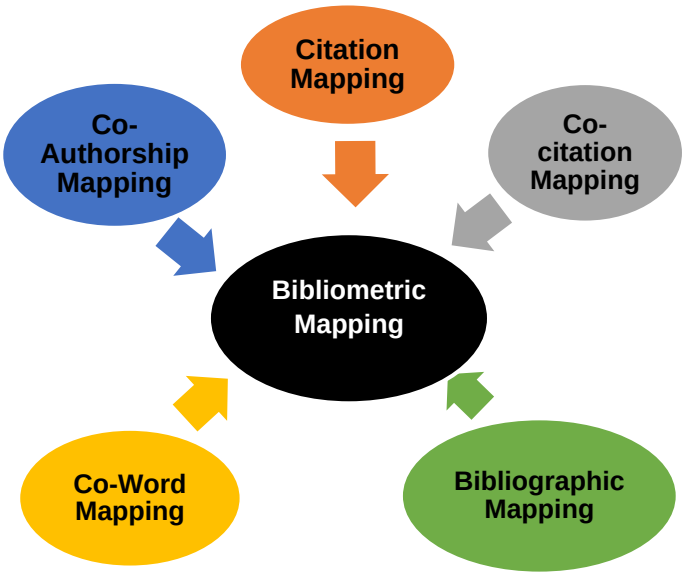

Figure.1. Systemic Representation of Science Mapping (Bibliometric Structure)

III. Results

A. Structured Publication trends

We began the data analysis by focusing on publication trends in the ACV sector. Publication of works that have been subjected to peer review is indicative of the subject's consistent advancement. At the turn of the century, the number of papers published on ACV multiplied, as shown by the trend in Figure 2. The graph's trend line indicates an exponential increase in the upward direction. This supports our argument regarding the growing relevance of ACV research and the researchers' propensity toward ACV. *Driss Ousaaid, Hassan Laaroussi, and Smriti Tripathi* published three papers in 2021. These authors work in human health areas, such as Diabetes research, antioxidants, and Anti-Alzheimer's research [9,22,23]. The recent year 2021 has been the most productive, with 54 articles released. The publication trend analysis provides evidence to claim that ACV research has caught the attention of researchers and area is on the upward slope of development.

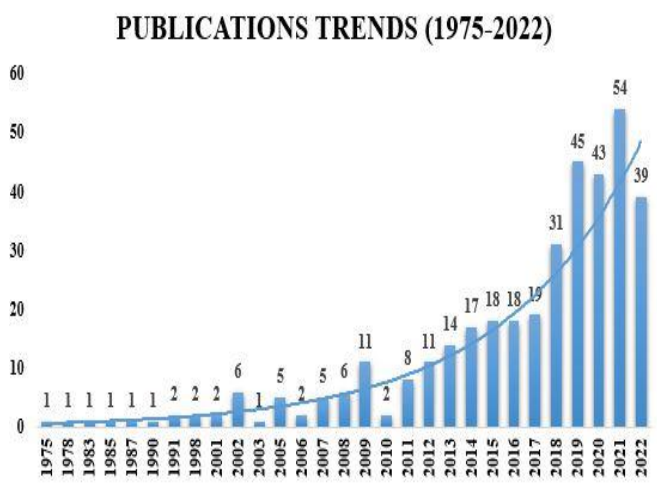

Figure. 2. Year-wise publication trends of published papers. This figure represents the publication trend of published papers between 1975 to 2022.

The graph for year-wise citations of published ACV papers (Figure 3) displays the exponential increase, where 2022 stood at the top with 857 citations. This represents the juggernaut pace of the current publishing trend in the 'ACV' topic and seemingly with a promising future. So from the publishing and citations trend observation, we understand that this area is now in the trend of scientific research. This corroborates our claim regarding the inclination of researchers toward ACV. Hence these pieces of evidence bolster our claims about ACV's potential to deliver critical discoveries in the coming days and a crucial role in human health.

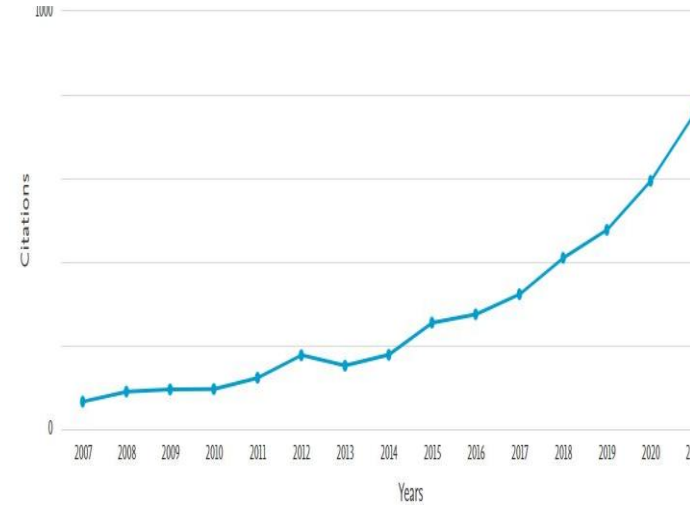

Figure. 3. Year-wise citations of published papers. This figure represents the citations/year by the papers published between 2007 to 2022.

B. Citations Mapping

Citation mapping is the primary technique of empirical analysis that explores the most influential publications in a research field. Citations analysis utilizes the number of citations as the proxy to reflect the quality of the work [24,25]. In the analysis of citations, we map documents (publications), sources (Journals), and countries.

***Cited documents*:** In this analysis, we evaluate published documents' citations and utilize it to identify the domain's influential publications. Identifying the influential works in the area is helpful for newcomers to the area. In the citation analysis, we found that "Risk Factors in Dental Erosion" by Jarvinen v.k. (1991) is the most cited article, with 419 citations [26]. Similarly, Paolino Ninfali got 216 citations in their paper [27] Table 1.

Table 1: Top ten cited ACV publication in citations analysis

Authors	Paper Title	Citations
Jarvinen V.K. (1991)	Risk factors in dental erosion	419
Ninfali P. (2005)	Antioxidant capacity of vegetables, spices and dressings relevant to nutrition	216
Sakanaka S. (2008)	Comparison of antioxidant properties of persimmon vinegar and some other commercial vinegars in radical-scavenging assays and on lipid oxidation in tuna homogenates	87
Theobald A. (1998)	Determination of 5-Hydroxymethylfurfural in Vinegar Samples by HPLC	74
Budak N.H. (2011)	Effects of apple cider vinegars produced with different techniques on blood lipids in high-cholesterol-fed rats	73
Yagnik D. (2018)	Antimicrobial activity of apple cider vinegar against Escherichia coli, Staphylococcus aureus and Candida albicans; downregulating cytokine and microbial protein expression	60
Boffo E.F. (2009)	Classification of Brazilian Apple vinegars according to their 1H NMR spectra by pattern recognition analysis	50
Shishehbor F. (2008)	Apple cider vinegar attenuates lipid profile in normal and diabetic rats	43
Bouazza A. (2016)	Effect of fruit vinegars on liver damage and oxidative stress in high-fat-fed rats	40
Mota A.C. (2015)	Antifungal Activity of Apple Cider Vinegar on Candida Species Involved in Denture Stomatitis	38

In the citation analysis, clusters are formed among publications of different colors like green, red, blue, pink, and yellow in Figure 4. Clusters are colored based on their themes, and articles under the same color represent that they belong to the same themes. The studies in each color cluster are analyzed for their theme identification. All studies found in green clusters were linked with apple vinegar's protective ability for human health, such as antifungal, antibacterial, and antiviral activities.

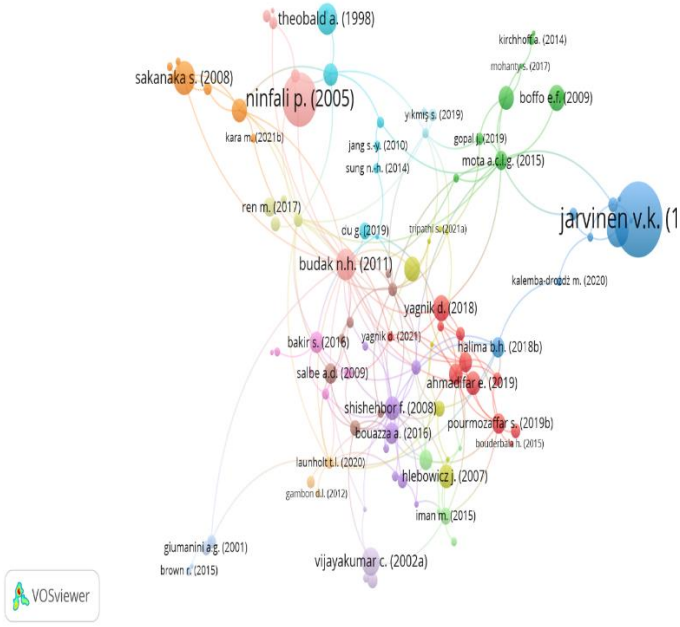

Figure. 4. Citation documents network visualization using VOSviewer

Similarly, pink and red color clusters were associated with various activities of ACV like antioxidants, oxidative stress/diabetes research/metabolic syndrome in animal models. The yellow and blue clusters were linked with various other activities of ACV, like immunomodulatory, drosophila suzukii (Fly), and quantitative aquaculture research. So from this investigation, significant and highly cited work in the ACV research field were identified. Since all the clusters and leading documents in citations belong to research based on ACV's ameliorative ability for human health. It is safe to conclude that major onus in ACV research is exploring its beneficial effects to improve human health.

Cited Sources: Source refers to the publication journals. Sources-based analysis was opted here to show the leading journals publishing ACV works and their clustering based on similarity on the theme of publications. The articles were published in 276 different journals. The selected studies were under the ACV context, so naturally, all the sources belonging to these studies were foods, Agricultural, Biochemistry, Microbiology, Medicine, Dental, and Biological Sciences related journals. "*Environmental Entomology, Journal of Agricultural and Food Chemistry*, *Journal of Economic Entomology, Food Chemistry, Plos one, life science, Scientific Reports, and Nutrition research*" were the leading sources/journals publishing the ACV research [28,29].

In the citations analysis of journals, we found that "*Environmental Entomology*" with 394 citations, and "*Journal of Agricultural and Food Chemistry"* with 204 citations, are among the top journals on the citation list. The citations wise journal list is given below (Table 2). In figure 5, we also found the color clusters that journals within the same cluster had close research interests and the same work domain. We analyzed each cluster to identify the dominant theme of the cluster. The green color cluster, containing journals *Environmental entomology, insects, Plos one, Acta horticulturae,* is found to be associated with the drosophila Suzuki research work, and the journals in this cluster are the leading entomology publishers [30].

Table 2: Leading journals with citations and published articles in ACV field

Journals	Citations	Publications
Environmental Entomology	394	6
Journal of Agricultural and Food Chemistry	204	4
Journal of Economic Entomology	141	5
Food Chemistry	105	3
Journal of Asia-Pacific Entomology	94	2
Plos One	68	3
Scientific Report	64	4
Insects	60	7
Aquaculture	49	6
Life Science Journal	46	3
Nutrition Research	40	2
Journal of Food Science & Technology	25	2

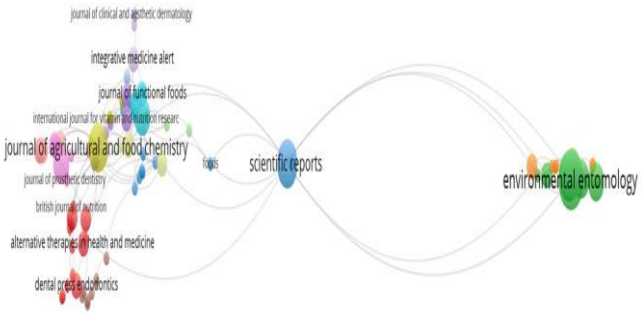

Figure. 5. Citation-based journals on major theme visualization publications using VOSviewer.

Similarly, yellow clusters journals like the *Journal of Agricultural and Food Chemistry, Food Science and Nutrition, British journal of nutrition, Food Chemistry,* and red cluster contain *Alternative therapies in health and medicine* connected with journals publishing majorly on human diseases such as diabetes, anti-inflammatory, antioxidant, antimicrobial research [31–33]. The blue color cluster like *Life science journal, Scientific reports, Foods, Journal of functional foods, Aquaculture research* and the violet cluster contain *Integrative medicine alert, Journal of clinical and aesthetic dermatology* showed the journals publishing life-related research such as Fish culture, dermatitis, hypercholesterinemia and qualitative research work [34–36]. The journal citation mapping highlights essential research domain topics for new researchers. Hence, based on the diverse ranges and subjects of the publications, we found that most ACVs were published in health-related journals that demonstrate the importance of ACVs in enhancing human health.

***Country-wise mapping*:** In the country analysis, we found 67 countries contributed to ACV research publications, 69 papers published in the USA, followed by China with 32 and India with 17 publications. The literature survey study found that the USA is one of the most prolific countries in the domain of "Vinegar research" (Figure 6) [1,37]. In figure 6, the color is based on the time occurrence from 2012 to 2022 from blue to yellow. A list of top countries concerning citation and publication is below in Table 3.

Table 3. Leading countries in the field of ACV publications

Countries	Publications	Citations	Citation/Publication
United State	69	1608	23.30
China	32	185	5.78
Iran	30	400	13.33
Turkey	27	293	10.85
Italy	18	672	37.33
Brazil	18	360	20
India	17	115	6.76
Japan	13	225	17.30
Canada	11	210	19.09
South Korea	10	41	4.1
Iraq	8	15	1.87
Germany	7	205	29.28
Australia	7	176	25.14
Finland	5	444	88.8

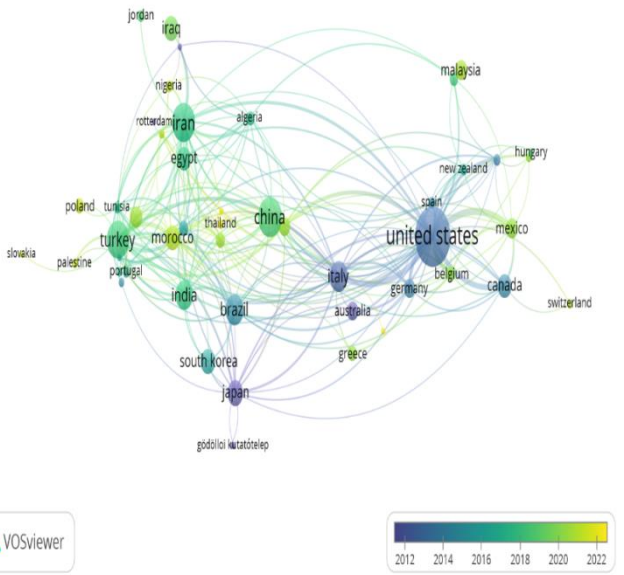

Figure. 6. Leading country publications on major theme visualization using VOSviewer

The United States has higher citations and publications than other countries. We use the citation/publication average ratio as the proxy variable for the quality of work. We found that Finland and Italy got the highest average ratio, explaining that both countries produced high-quality publications in the ACV fields. The results also showed that developing countries like Iraq, South Korea, China and India are not dynamically producing research in the ACV field. Based on the country-wise mapping, we recommend that developed countries like the USA, Italy, and Japan; and developing countries like India, Iran, and Brazil must come together and collaborate to work on ACV in health care.

C. Bibliographic Coupling

This study is based on the relationship between two publications that share references and have similar subjects. The bibliographic coupling strength increases in proportion to the number of shared references. A bibliographic coupling connects bibliographies of two publications if both quote one or more common documents. This analysis is conducted using clusters based on the referencing publications found in ACV publications. By investigating the associations among citing publications, we understand the current development of themes in a research field (Figure 7) [25,38].

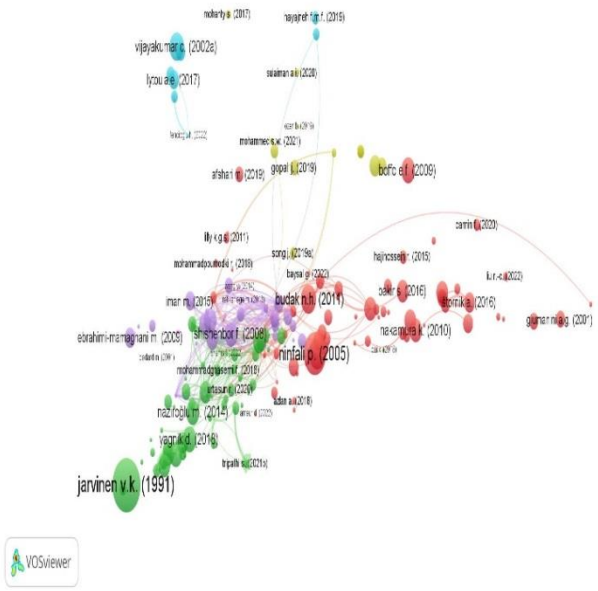

Figure. 7. Bibliographic Coupling based on the citing publications on major theme visualization using VOSviewer

In Figure 7, there are three main color clusters found. The red cluster documents follow the conjoint references list and are linked with human health-related activities such as antidiabetic, anti-oxidant and anti-inflammatory activities. Similarly, green cluster documents follow a similar reference list and are linked with dental research, antimicrobial research, and metabolic syndrome research activities [3,39,40]. The purple cluster is targeted at Diabetes research activities [41,42]. Here we can see that all the leading clusters belong to the research domain of ACV's protection abilities, eventually improving the human health.

D. Co-Citation mapping

The co-citation mapping method establishes a subject similarity between two documents. In a co-citation mapping, two articles are connected if they appear in the same ACV article's reference list. Similar to the bibliometric coupling study, this approach examines document citational links. The greater the number of co-citations between two papers, the greater their co-citation strength and the likelihood of semantic relationship. Hence, a network of links between the objects has developed (Fahimnia *et al.*, 2015; Surwase *et al.*, 2011). Co-citation analysis of the cited references is performed to identify the most influential works from other domains responsible for developing the ACV domain research as the foundation base.

320 articles for ACV research showed a total of 13299 references. Out of these 13299 references, 78 references have been cited at least 3 times within the parent data set of 320 papers. A co-citation analysis-based table list is shown below (Table 4). Analyzing Table 4, we find several works from different topics contributing to ACV research. The cited publications are associated with Drosophila suzukii from a different perspective. In figure 8, each color represents a thematic cluster. The blue and green cluster references are from the research domain of ethanol, acetic acid, blueberry, blackberries, cherries, grapes, raspberries, and strawberries; and are used to understand the behavioral responses of Drosophila suzukii [25,44,45]. In this investigation we identified that Drosophila Suzuki (Vinegar fly) is a suitable research model for circadian rhythm, locomotor behavior, and neuronal activity for the ripening of fruits. Thus, fly model has played major role in exploration of benefit of ACV for human health.

Table 4: Leading cited references in co-citation analysis of ACV articles

Cited References	Paper title	Citations
Landolt,p.j., adams,t., rogg,h., 2012	Trapping spotted wing drosophila, *Drosophila suzukii* (Matsumura)(Diptera: Drosophilidae), with combinations of vinegar and wine, and acetic acid and ethanol.	6
Dalton, d.t., walton, v.m., shearer, p.w., walsh, d.b., 2011	Laboratory survival of *Drosophila suzukii* under simulated winter conditions of the Pacific Northwest and seasonal field trapping in five primary regions of small and stone fruit production in the United States	6
Hauser, m., 2011	A historic account of the invasion of *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae) in the continental United States, with remarks on their identification	5
Iglesias, l.e., nyoike, t.w., liburd, o.e., 2014	Effect of Trap Design, Bait Type, and Age on Captures of *Drosophila suzukii* (Diptera: Drosophilidae) in Berry Crops	5
Abraham, j., zhang, a., angeli,s., abubeker, s., 2015	Behavioral and Antennal Responses of *Drosophila suzukii* (Diptera: Drosophilidae) to Volatiles From Fruit Extracts	4
Lee, j.c., bruck, d.j., curry, h., edwards,d., 2011	The susceptibility of small fruits and cherries to the spotted-wing drosophila, *Drosophila suzukii*	4

Lee, j.c., bruck, d.j., dreves, a.j., ioriatti, c.,2011	In Focus: Spotted wing drosophila, *Drosophila suzukii*, across perspectives	4
Cha, d.h., adams, t., rogg, h., landolt, p.j., 2012	Identification and Field Evaluation of Fermentation Volatiles from Wine and Vinegar that Mediate Attraction of Spotted Wing Drosophila, *Drosophila suzukii*	4
Lee, j.c., burrack, h.j., barrantes, l.d., 2012	Evaluation of Monitoring Traps for *Drosophila suzukii* (Diptera: Drosophilidae) in North America	4

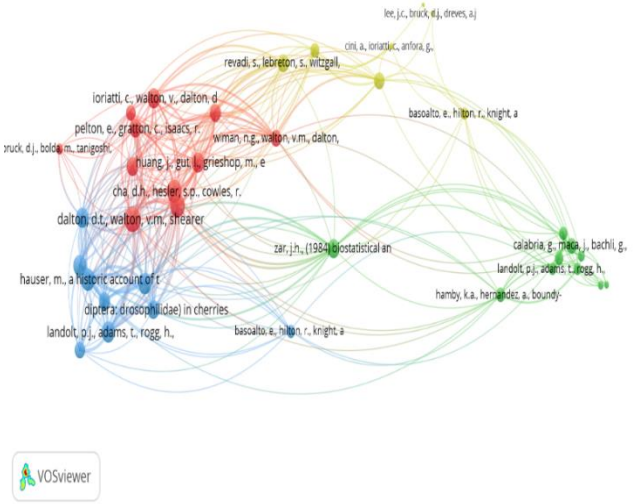

Figure. 8. Co-citations study of cited references on major theme visualization using VOSviewer

E. Co-Word Mapping

This analysis results from the “Keywords” analysis [46]. A keyword analysis is a valuable method to gain insight into the subdomains within the area and associated discipline along the field being analyzed. Keywords are known as the mirror of a study that can help to understand the research trends in that subject area [47]. The type of investigation for co-word analysis is “keywords,” which examine the actual content of the publication itself.

For the Keyword analysis, we have analyzed using “all keywords”. A total of 3226 keywords were found. Only those keywords were selected for the network analysis, which occurred at least 5 times (227 keywords) (Figure 9). “Acetic acid” was the most frequent term for obvious reasons, as Acetic acid is the major element in ACV sub-components. In figure 9, each node in a network represents an entity, and the node's size indicates the occurrence of the keyword. The bigger the node, the greater the occurrence of the keyword. The link between the nodes represents the co-occurrence between the keyword.

We can see 4 significant clusters of keywords of different colors from the all keyword analysis. The red and blue one consists of the main words, mostly centered on Apple Cider Vinegar/Vinegar related to Diabetic research, such as fruit vinegar, apple, apple juice, antioxidant activity, organic acid, ethanol and diabetes mellitus. The yellow cluster words like drosophila suzukii, population dynamics, and animals seem to belong to the Drosophila research. Similarly, green and purple cluster words oxidative stress, streptozotocin, honey bee, seem to be associated with the studies on antimicrobial, antibacterial, quantitative analysis, oxidative stress/metabolic syndrome and diet research models (Figure 9). Thus, health-related ACV research articles exploring the protective abilities of ACV, based on human and animal models, make up the major division of the ACV research. This co-word analysis is essential for new researchers to identify the research distribution of the area for further new research activities.

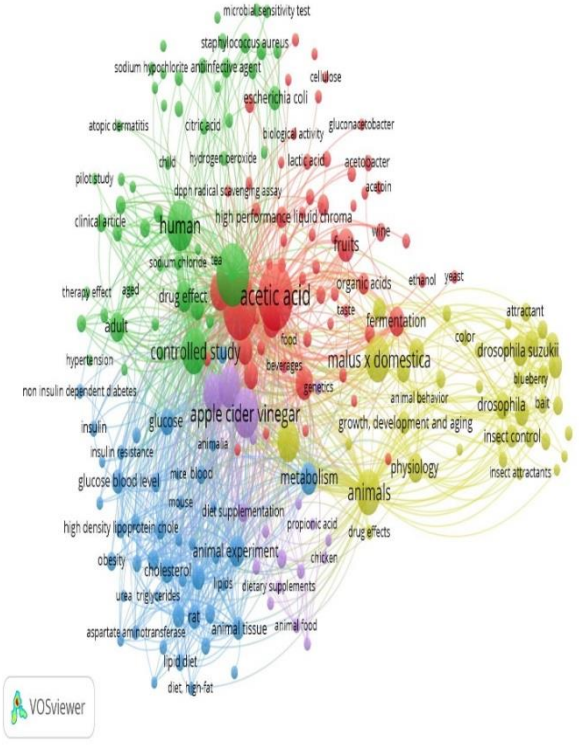

Figure. 9. Co-occurrence of Major keywords based on the publications on major theme visualization using VOSviewer.

F. Co-Authorship Mapping

Co-authorship analysis examines the collaborations between researchers in a particular subject. Hence, co-authorship analysis is a formal method of writers'

intellectual cooperation. Eventually, 1458 writers contributed to the 320 reviewed publications.

Out of these, 165 authors had a minimum of 2 documents published. For every topic in the research area, only a handful of authors are primarily visible when analyzing the work and are responsible for developing the topic [17]. ***Driss Ousaaid, Hassan laaroussi (8 studies each), Smriti Tripathi (6 studies each), Janja trček*** **and** ***Nilgün H Budak (4 studies each)*** are the most prolific researchers in the field of vinegar study, specially ACV. However, the same does not go for other authors on the list. Co-authorship analysis for ACV also shows that these researchers primarily work separately on the topic, and the area lacks cooperation among leading researchers. This may be one of the main reasons that this topic is yet to see the growth stage.

In the co-authorship network analysis, each node represents an entity of authors, and the link within the nodes represents the co-occurrence between the authors (i.e., papers that co-occur or occur together). In Figure 10, the color is based on the occurrence from 2014 to 2022, from blue to yellow. As we can see, most clusters are of the same colors. It also represents no interaction between previous and new researchers in the area.

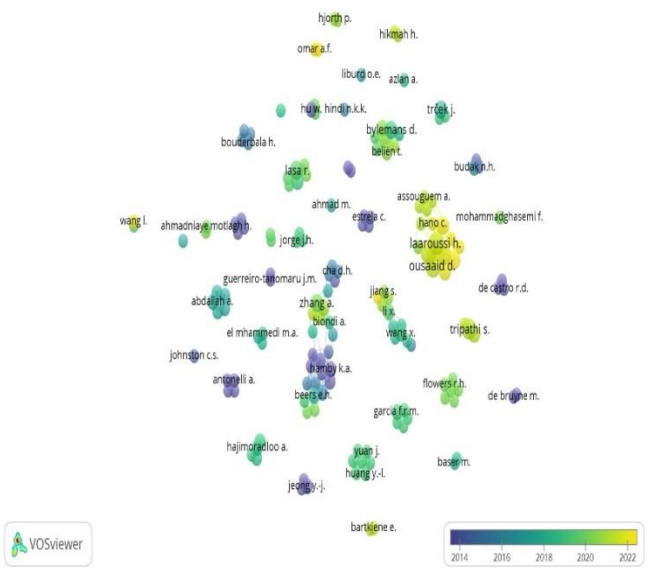

Figure. 10. Visualization of research networks of authors with a minimum of 2 papers on Apple Cider Vinegar (2014–2022). Authors in the same cluster had close research interests

IV. Discussion

Bibliometric mapping will be used to visualize ACV research data in this project. Bibliometric analysis is used in social science and other academic fields to analyses vast amounts of data on mature themes. This methodology is applied to medicine and human health by evaluating ACV research data from over four decades. This method allows methodical investigation of huge unstructured data. ACV should be consumed moderately to maximize long-term health benefits and minimize side effects. ACV's health advantages are well understood due to earlier studies.

The information was extracted and imported from the "Scopus" database. Journals of pharmacy and pharmacology are well-represented and influential in Scopus. A global scholarly literature database helps scholars identify knowledge gaps and inspire new study ideas [49]. This report compiles and simplifies the ACV region's growth. This bibliometric study covers ACV research domain trends. 320 ACV research publications from 48 years are addressed, quoted, and exhibited for clarity. Figure 2 depicts the number of articles published during the nearly half a century of the ACV domain. According to Scopus, ACV was introduced in 1975 in a publication titled "Occurrence of L-sorbose in apple-cider vinegar". Since then, publication trends and reader interest in ACV materials have expanded rapidly. ACV article publication peaked in 2021. This suggests that ACV is a prominent research domain.

Citation analysis (Figure 4) revealed color clusters, indicating similar research interests and work domains. Immunomodulatory, oxidative stress, diabetes research, Drosophila Suzuki and antioxidants, and antibacterial research comprise ACV research [3, 32, 40, 17, 41, 42]. We discovered no molecular or exploratory investigations on ACV's protective effects. In the citation analysis, we examined ACV research's most influential journals. Environmental entomology, Journal of economic entomology, Journal of Agricultural and Food Chemistry, scientific report, Food chemistry, and Plos one are active and high-impact factor journals (Figure 5) [40]. Here, we can cluster leading journals publishing ACV work into entomology, food, health, and herbal medicine journals. ACV research began in the USA, and Finland, Germany, and Italy have strong citation per publication ratios (Figure 6). According to the major keyword analysis, acetic acid, vinegar, human, and ACV were the most common and relevant terms across the studies (Figure 9).

ACV's work is linked to the Drosophila suzukii fly model for health research, according to co-citation analysis. Drosophila suzukii papers dominated co-citation clusters, indicating the fly model's involvement in proving the ACV's health benefits [28,30,44,45]. Table 5 (supplementary file) shows the cluster themes from many Mappings that show how much the ACV researches human health [2,44,45]. Author analysis revealed the top domain researchers (Figure 10). Although work in this area has been increasing daily, there is no collaboration between researchers, so the analysis results call for more collaboration among ACV researchers. Many researchers are studying ACV's anti-diabetic, oxidative stress, and Alzheimer's effects.

Despite the researcher's best efforts, every methodology contains limits that may be addressed in future study. Our work too. Our investigation is limited by using only the "Scopus database" to cover all ACV-

related health therapies. This quantitative analysis did not reveal non-numerically dependent factors like article quality [59]. This analysis helps researchers identify ACV research areas [4,28].

ACV's applications in immunomodulation, neurological disorders like Parkinson's and Alzheimer's, and cardiovascular disease, which pose the greatest risk to humans, require more research. We need the finest alternative models to produce a disease condition that could kill humans. Our study suggests the best disease induction models, such as Drosophila suzukii and rodents (rats and mice). Thus, future researchers should use fly and rodent models to examine the ACV's protective effects against immunomodulatory and neurological disorders in humans. Bibliometric analysis helps interpret field research. Without holistic information, understanding the domain could be like blind people describing an elephant as the area they can reach. Different viewpoints may cause unnecessary strife. This study's findings and recommendations should help future ACV researchers make better health research decisions.

Conclusion

The statistics showed that ACV research is promising and growing. Antioxidant, antidiabetic, anti-inflammatory, and biomarker-lowering properties of ACV were prominent themes in ACV study. This shows that an apple and a spoonful of ACV a day may also prevent illness. We found ACV research subdomains and gaps. This study found gaps in bioinformatics, molecular target investigations, and researcher cooperation. We suggest institutes provide a researcher networking platform to address these issues. For instance, ACV research seminars on human health may focus on understudied regions and allow ACV researchers to collaborate. According to publishing trend research, the ACV field in human health has unexplored potential. Thus, we encourage current scholars to welcome, support, and mentor future scholars to fully explore ACV's health benefits.

Conflict of interest

The authors conclude that they have not found any problematic financial or personal associations that could have influenced the study presented in this publication.

Funding

Not applicable

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