BRAZILIAN JOURNAL OF FOOD TECHNOLOGY

ISSN 1981-6723
Online version

ORIGINAL ARTICLE

Bibliometric study of volatile compounds in commercial fruits of the *Solanaceae* family

Estudo bibliométrico de compostos voláteis em frutos comerciais da família Solanaceae

Andres Mauricio Baena-Pedroza[1]*, Lina María Londoño-Giraldo[2], Eduardo Javid Corpas-Iguaran[3], Gonzalo Taborda-Ocampo[1]

[1]Universidad de Caldas, Chemistry Department, Manizales - Colombia
[2]Universidad Libre, Microbiology Department, Pereira - Colombia
[3]Universidad Católica, Bacteriology Department, Manizales - Colombia

***Corresponding Author:** Andres Mauricio Baena-Pedroza, Universidad de Caldas, Laboratorio de Investigación en Química Analítica (E210), Grupo de Investigación en Cromatografía y Técnicas Afines (GICTA), Cll 65 #26-10, Manizales/Caldas - Colombia, e-mail: andbaenap@gmail.com.

Cite as: Baena-Pedroza, A. M., Londoño-Giraldo, L. M., Corpas-Iguaran, E. J., & Taborda-Ocampo, G. (2021). Bibliometric study of volatile compounds in commercial fruits of the *Solanaceae* family. *Brazilian Journal of Food Technology*, *24*, e2020132. https://doi.org/10.1590/1981-6723.13220

Abstract

Bibliometric analysis is a discipline that allows us to identify knowledge trends, assesses scientific activity and the impact of research through its volume, evolution, visibility, and structure. The present study aimed to carry out a bibliometric study of scientific research that contributes to the knowledge of Volatile Organic Compounds (VOCs) of edible and commercial fruits of *Solanaceae* family. The research consisted of extracting the information from papers in the *Web of Science* database. We analyzed and performed the production, visibility, and impact of these papers, also relationships and collaboration between authors using BibExcel and VOSviewer software. As a result, 178 documents were obtained from 2001 to 2017. Tomato is the fruit with the largest number of related articles that are focused on studying compounds responsible for taste, aroma, and biotic and abiotic relationships, as well as studies for identification of the genes responsible for these organoleptic and ecological traits. Papers analyzed are related to the research studies of 491 authors from 239 different organizations distributed in 45 countries. This bibliometric study allowed to identify trends in the knowledge in VOCs with respect to *Solanaceae* fruits, as well as recognizing the location of the scientific material in this field.

Keywords: Bibexcel; Metabolomics, *Solanaceae*, *Solanum lycopersicum,* Volatile compounds, publications.

Resumo

A Bibliometria é uma disciplina que nos permite identificar tendências do conhecimento, avaliar a atividade científica e o impacto da pesquisa por meio de seu volume, evolução, visibilidade e estrutura. O presente estudo teve o objetivo de realizar uma análise bibliométrica das pesquisas científicas que contribuem com o conhecimento de compostos orgânicos voláteis de frutos comestíveis e comerciais da família *Solanaceae*. A pesquisa consistiu em extrair a informação dos trabalhos no banco de dados Web of Science. Analisamos a produção, a visibilidade e o impacto desses artigos, os relacionamentos e a colaboração entre autores, usando os programas BibExcel e VOSviewer. Como resultado, 178 documentos foram obtidos entre 2001 e 2017. O tomate é a fruta com o maior

número de artigos relacionados que se concentram no estudo de compostos responsáveis pelo sabor, aroma e relações bióticas e abióticas. Ademais, há estudos para identificar os genes responsáveis pelas propriedades organolépticos e ecológicos. Os artigos analisados são o produto do desenvolvimento das pesquisas de 491 autores e de 239 organizações diferentes distribuídas em 45 países. Este estudo bibliométrico permitiu identificar tendências sobre o conhecimento dos compostos orgânicos voláteis em frutos de *Solanaceae*, para reconhecer a localização do material científico nessa área.

Palavras-chave: Bibexcel; Metabolômica; *Solanaceae*; *Solanum lycopersicum*; Compostos voláteis.

1 Introduction

Analysis of scientific publications is the fundamental basis of serious research studies, seeing that it allows knowing the precedents of a formal investigation (Patrón et al., 2014). In addition, this analysis allows extracting the perceptions of the intellectual and social structures of a specific field of study (Damar et al., 2018). Bibliometric analysis is cataloged as a subdiscipline of scientometrics that reports the results of the research process (i.e. volume, evolution, visibility and, structure), which allows assessing the scientific activity and the impact of research as well as the source (Escorcia & Poutou, 2009).

Bibliometrics investigate the nature and the development of a discipline by using statistical computational analysis (González de Dios et al., 1997), based on the information in bibliographic material that measures scientific productivity (Recio et al, 2017). A bibliometric analysis identifies groups and fields of excellence such as thematic associations, interdisciplinarity, emerging disciplines and collaboration networks (Sánchez, 2014).

Plants are characterized by high biodiversity and their importance for the sustainability of ecosystems, providing several products and services (i.e. largest carbon reserve, the base of the trophic pyramid and, those responsible for carrying out the gas exchange in aquatic and terrestrial environments) (Corlett, 2016). There are around of 250,000 species of flowering plants, and of these only 150 species are cultivated, 12 of these species provide 75% of the world's food production system dominated by cereals (Samuels, 2015).

Therefore, to promote food security, it is necessary that research efforts should be focused on plants with global food importance, especially to those plants that belong to Solanaceae family, i.e., a complex family of angiosperms (105 genera and 2030 species) (Fadl Almoulah et al., 2017; Lim, 2013). South America has the greatest diversity of Solanaceae species. The family also is represented in each continent due to agricultural propagation (Samuels, 2015). The family has ornamental (Lim, 2013), food (i.e. tomato, chili, eggplant, *lulo*, potato, and, tree tomato) and harmful species (i.e. tobacco, *toloache*, mandragora, henbane and belladonna) (Towell, 2001).

Several secondary metabolites have been reported in Solanaceae family, such as phytoalexins (responsible for the allelopathic effects in potatoes, tomatoes, chili, tobacco and eggplant) (Mushtaq & Siddiqui, 2018). In addition, it has been reported that VOCs in this family is playing an important role for defense against pests, predation of herbivores and, microbial and fungal pathogens (Iijima, 2014; Yang et al., 2013). In *lulo,* it could be detected high contents of 6-carbon compounds, also known as Volatile Green Leaves (VGL) which has been associated to aroma (Corpas et al., 2016). In tomato, amino acid, lipids and, carotenoids derived volatile are responsible for characteristic flavor components (Dávila-Aviña et al., 2011).

Fruits and vegetables of Solanaceae family play an important role in providing dietary diversity, food security, nutrition and income generation in different regions of the world (Adu et al., 2018). This article aimed to perform a bibliometric study of the scientific papers developed in fruits of edible species of Solanaceae family related to their VOCs profile. All issues highlighted above are linked to the approaches of the current research, as well as their dynamics of science production, organizations and researchers that could develop relevant knowledge for this family.

2 Materials and methods

2.1 Type of study

The present bibliometric study included a descriptive analysis of papers found in the main collection of the *Web of Science* database associated to VOCs commercial fruits from Solanaceae family. The advanced search was carried out on April 9, 2018 and included the documents published from 2001 to 2017.

2.2 Creation of the search algorithm

Search algorithm creation included the scientific and common names of fruits such as cherry tomato, tree tomato, common tomato, cape gooseberry, *lulo*, paprika, eggplant, *dulcamara*, goji berries and different types of chili peppers, to which it has been previously added the words "*volatile AND*". Each conjugation of keywords was entered independently in a search field, and in turn, all were connected by the Boolean operator "OR" that allowed including all correlated studies in the search performed. The change in the number of documents found after the introduction of each new keyword to the search algorithm was analyzed. Finally, a short, complete, and precise text was obtained to fulfill the proposed objective.

The search algorithm used was the following:

((((((((((((((Title: (volatile * AND tomato) OR Title: (volatile * AND "Solanum lycopersicum")) OR Title: (volatile * AND "Solanum quintozenes")) OR Title: (volatile * AND Eggplant)) OR Title: (volatile * AND "Chili pepper")) OR Title: (volatile * AND "Capsicum annuum")) OR Title: (volatile * AND "Capsicum baccate")) OR Title: (volatile * AND "Capsicum Chinese")) OR Title: (volatile * AND "Capsicum frutescent")) OR Title: (volatile * AND "Bell pepper")) OR Title: (volatile * AND aucuba)) OR Title: (volatile * AND "Physalis peruviana")) OR Title: (volatile * AND "Cape gooseberry")) OR Title: (volatile * AND "Solanum betake")) OR Title: (volatile * AND "Solanum nigrum")) OR Title: (volatile * AND "Lyceum barbarum")) OR Title: (volatile * AND "Lyceum ruthenium")) OR Title: (volatile * AND goji))

2.3 Debugging and obtaining the data matrix

Debugging data was performed using three criteria as following: documents that did not correspond to the topic of interest that had to be evaluated; documents that were classified as "*Meeting abstract*" and; documents consisted of corrections regarding scientific articles that had already considered in the main search. The application of these criteria allowed avoiding errors in the processing data associated with documents without citations or without relevant information for the bibliometric study.

2.4 Analysis of data

The groups made in this bibliographic study consisted of extracting the number of publications, type of documents, country, authors, journals, number of citations, organizations, and the year of publication. To analyze the bibliographic information, the BibExcel program (Persson et al., 2019) was used. Frequencies of each of the terms were analyzed, and data and vector matrices were constructed to represent each analysis performed (Pichuante, 2016). Results obtained were transferred to the Microsoft Excel 2016® to perform the respective bibliometric analyzes and the corresponding graphs.

Additionally, three bibliometric indicators were taken into account as following: (1) production indicators (i.e. groups publications according to type of document, author, country, organization or institution, magazine and year); (2) visibility and impact indicators (i.e. H-index, institutions and countries); (3) relationship and collaboration indicators (i.e. co-occurrences of keywords and co-authorships between authors and countries) (Alonso et al., 2016). These indicators were carried out with the VOSviewer software (van Eck & Waltman, 2010).

3 Results and discussion

The search algorithm showed 190 documents registered in the *Web of Science* database. However, 12 of them were excluded from the analysis (in which four documents did not correspond to the subject; three papers consisted of duplicated information, and five documents contained meeting abstract). A final number of 178 documents were used in the present bibliometric study.

The frequency analysis by type of document allowed to show that the 178 results obtained in *Web of Science* database could be distributed in 174 scientific articles, three subject reviews and one book chapter, which have been published from 2001 to 2017 (Figure 1). The aforementioned results indicated that the scientific productivity and importance research of VOCs fruits in Solanaceae family is increasing. Papers published from 2004 to 2006, and in 2009 are those that had the greatest scientific relevance, owing to the highest number of citations (Figure 1). These studies are associated with tomato fruits, being focused on the analysis of VOCs responsible for flavor (Tieman et al., 2006a) and on VOCs produced in response to biotic and abiotic stimuli (Ament et al., 2004; Bleeker et al., 2009; Farag & Paré, 2002). In addition, genomic studies on tomato fruit were also carried out and focused on the identification of genes and locus associated with VOCs of flavor (Lewinsohn et al., 2005; Mathieu et al., 2009; Simkin et al., 2004; Tieman et al., 2006b; Zanor et al., 2009). The paper with the highest number of citations is entitled "*A novel approach for nontargeted data analysis for metabolomics Large-scale profiling of tomato fruit volatiles",* published in 2005 in *Plant Physiology* journal (Tikunov et al., 2005), considered a pioneer document in the implementation of arguments and metabolomic tools in the study of tomato.

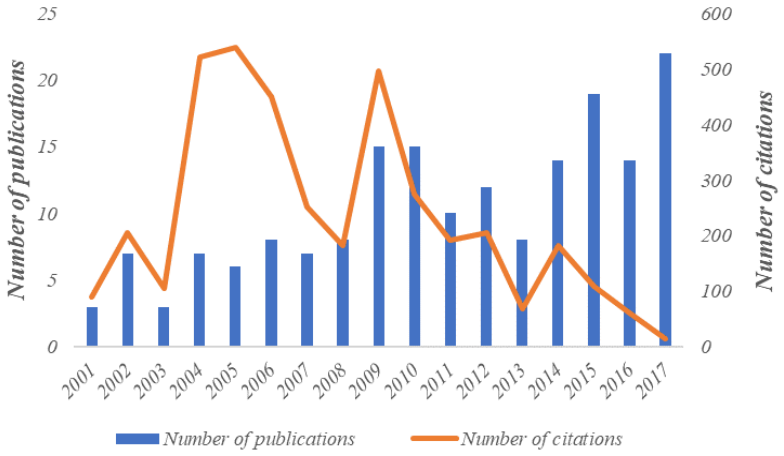

Figure 1. Number of publications and citations distributed per year.

The analysis of the publications by countries from 2001 to 2017 showed that 45 countries have contributed to the research of VOCs of cultivated species of Solanaceae family. The ten countries with the highest number of publications (Figure 2A) were as following: The United States of America (USA) with 46 publications in 15 years; followed by China (34 publications in 10 years); Italy (19 publications in nine years); Spain (18 publications in 13 years); the Netherlands (17 publications in 10 years); Mexico (11 publications in 7 years); Brazil, France, United Kingdom (seven publications in 6 years) and; Canada (six publications in 3 years). When correlating this data with co-authorships between countries, it has been shown that the USA is the country with the largest number of development and collaborative studies (Figure 2B). The USA has established research relationship between China, Canada, Germany, Brazil, England, Japan, France, and the Netherlands.

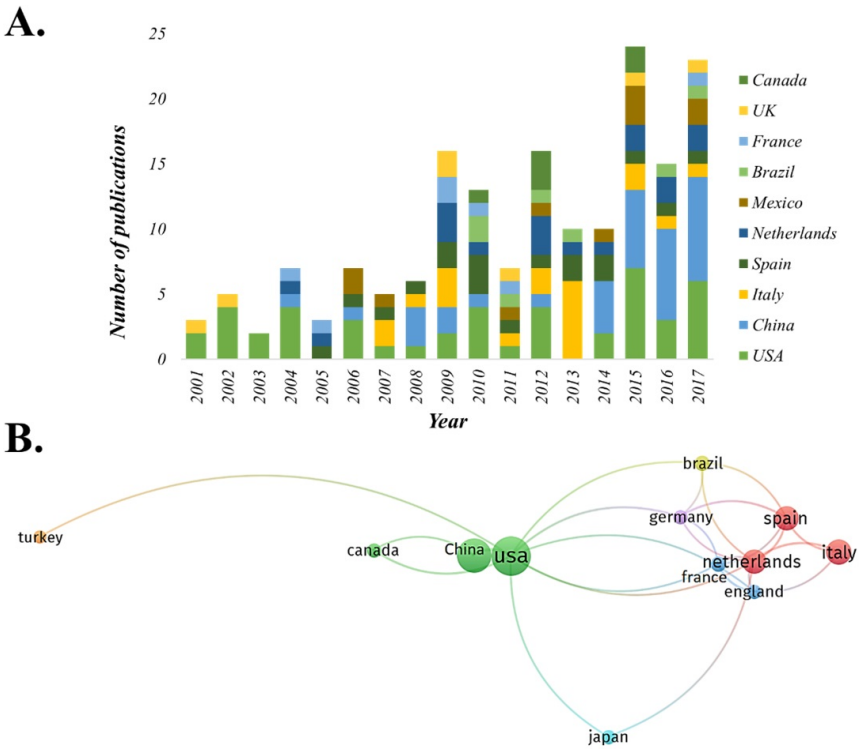

Figure 2. List of Solanaceae publications between countries. (**A**) Number of publications per year concerning the 10 most published countries; (**B**) Co-authorships between countries.

The analysis of the number of publications of authors reflected that the scientific publications developed in 17 years were associated with the research production of 491 researchers (Figure 3). Notwithstanding, 12 authors had at least four or more publications. The most cited authors in the aforementioned field in order of relevance were as following: Baldwin EA (13 publications); Klee HJ (11 publications); Bai JH (8 publications); Bovy AG (six publications); Barriger S and, Chen KS (five publications); Granell A, Pine J, Iodice L and, Plotto (four publications). The years with the highest productivity of those authors were identified in 2007, 2009 and 2015.

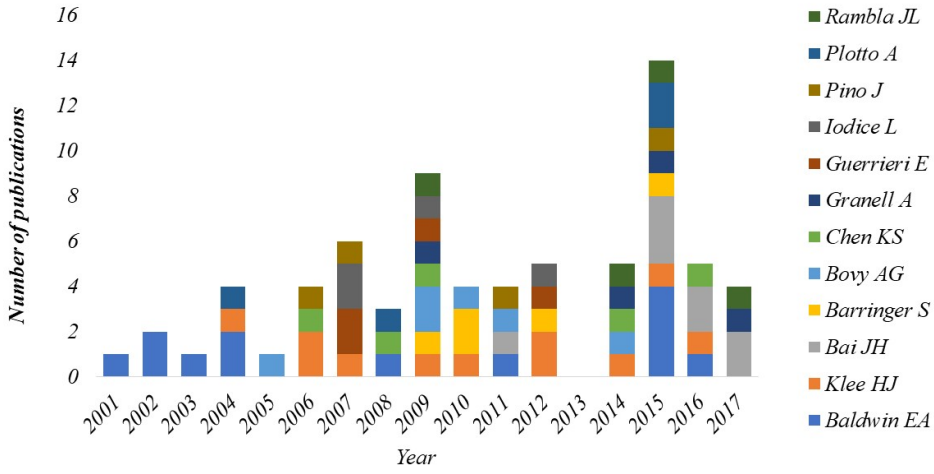

Figure 3. Number of publications per year and per author.

The analysis of the number of papers by journal showed that the documents registered in the *Web of Science* database were published in 92 scientific journals and specialized books. In addition, 37% of the studies were published in the top 10 journals and most of them published in this field of research (Figure 4A). The journal with the highest number of publications was the *Journal of Agricultural and Food Chemistry* consisting of 13 published articles. However, 77% of these studies were focused on the analysis of tomato *(Solanum lycopersicum)* and aimed at determining VOCs responsible for flavor using techniques such as liquid-liquid microextraction (LLME) (Aubert et al., 2005), Porapak Q (PQM) and Simultaneous Distillation-Extraction (SDE) (Maneerat et al., 2002), the effect of carotenoids on VOCs formation (Lewinsohn et al., 2005), influence of the application of electric fields in tomato flavor (Vallverdú-Queralt et al., 2013) and temperature in VOCs lipid derivatives (Xu & Barringer, 2009). On the other hand, 23% of them carried out research in chili (*Capsicum annuum*) by evaluating changes in metabolism when is inoculated with *Rhizobium* (Silva et al., 2014), as well as the determination and identification of sulfur compounds (Naef et al, 2008; Starkenmann & Niclass, 2011). The journals with more publications were associated to *Food Chemistry* and *Journal of Food Science* consisting of nine articles; their publications were related to the cherry tomato and different types of pepper, *pimento*, and cape gooseberry species. With respect to the *Journal of Experimental Botany*, seven articles on tomato were indicated. Finally, *Journal of Chemical Ecology*, *Journal of the Science of Food and Agriculture*, *Phytochemistry*, *Postharvest Biology and Technology, Food Research International and Plant Physiology* have reported five articles per journal. The correlation analysis by citations between journals (Figure 4B) has shown that the aforementioned journals were correlated to each other, since the products published by them were used as a basis to support and distinguish investigations on fruits of Solanaceae family, favoring the visibility of these scientific investigations and promoting the development of this field of knowledge.

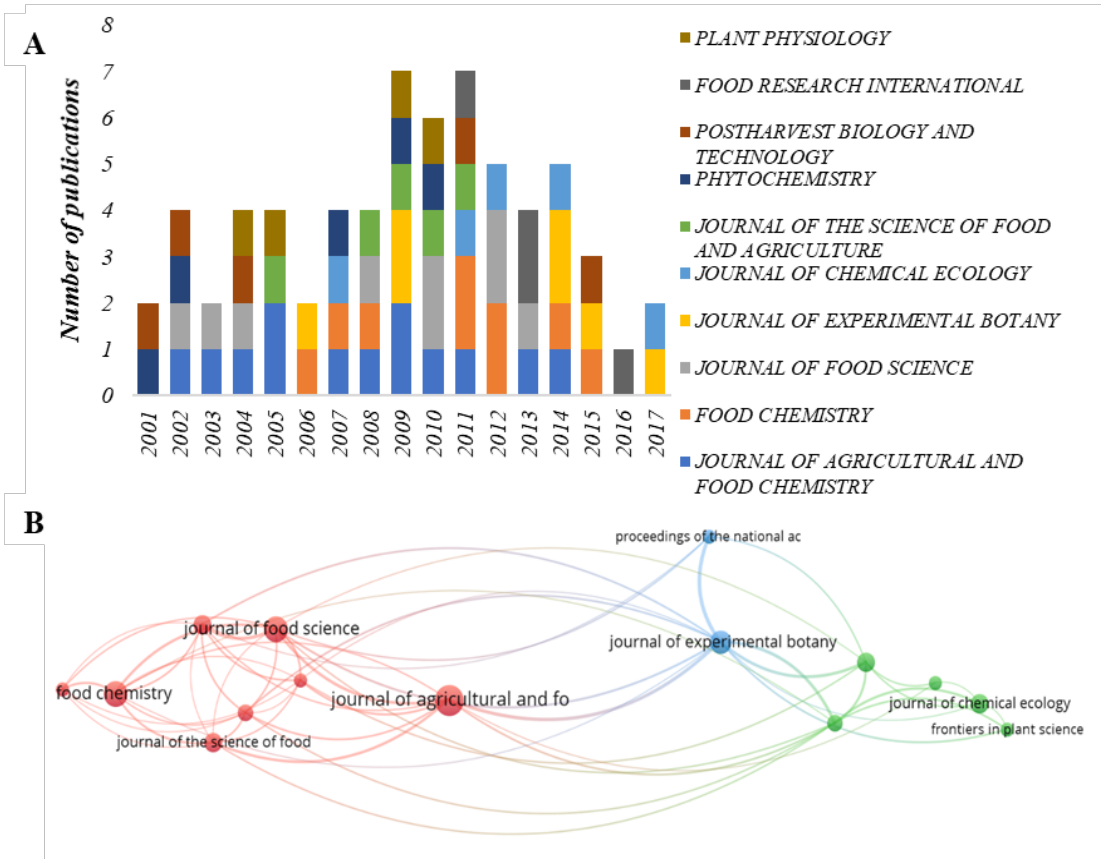

Figure 4. List of journals associated with the publication in *Solanaceae family*. (**A**) Number of publications per year according to the journal; (**B**) Network diagram of the correlation between citations and the scientific journal.

The analysis of the publications evaluated showed that 239 organizations between universities and institutions were responsible for looking into the production of fruits of the family Solanaceae. It could be noted that 88 of 178 articles were resulted from studies of organizations that consisted of five or more associated research and investigations, most of them being published in 2015 (Figure 5). On the other hand, the USA-Department of Agriculture (USDA) has published a volume of 21 papers, the University of Florida (USA) with 18 publications, the Wageningen University of the Netherlands with 12 publications, Nanjing University of Agriculture of China with nine publications, the Polytechnic University of Valencia of Spain with six publications and the CNR Institute of Italy, the Ohio State University of USA and the University of Bologna of Italy each one consisting of five publications.

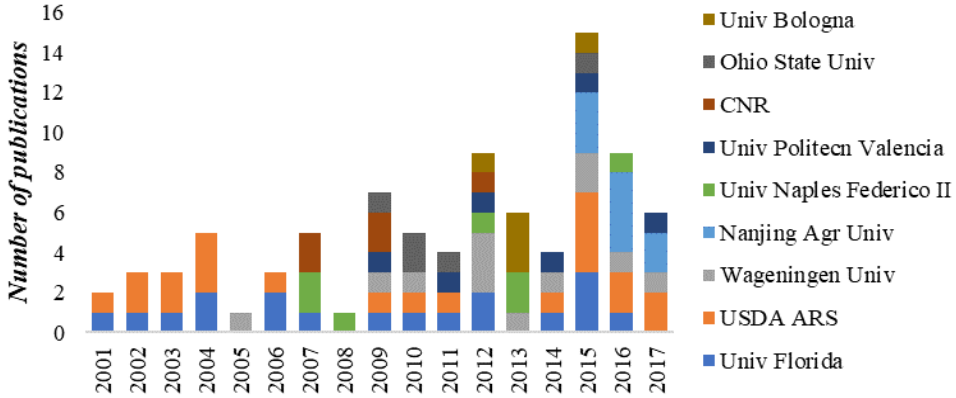

Figure 5. Number of publications per year according to the organization.

The H-index analysis by author (Figure 6A) showed that the authors who published more, had an almost direct relationship with the value of the H-index obtained, which has shown that their studies were relevant in this field evaluation, and that they may be responsible for discussing or distinguishing the new proposals that were being developed. Taking into account the aforementioned subjects, if the H-indexes by countries are evaluated (Figure 6B), it will be possible to appreciate that in the case of the USA presents an H-Index of 20, they may be referred to the studies associated with E. Baldwin researcher of USDA and H. J. Klee of the University of Florida. The other countries like UK, Germany, France, Brazil, and Canada, showed that the studies they have published had more relevance and quality, since the H-index was proportional to the number of citations.

The analysis of co-occurrences by keywords (Figure 7) showed that the 178 publications selected in the analysis were associated with 1200 keywords, however, only 162 have shown correlations between them. The foregoing evidence over 17 years of research have been highlighted this bibliometric analysis of commercial Solanaceae species, in which the mainly fruit studied in this field of interest was the tomato (*Solanum lycopersicum*). In this field of knowledge, some studies have been developed and associated with the determination of the volatile composition from fruits using Gas Chromatography (GS) and extraction techniques such as Solid Phase Micro-Extraction (SPME), which was intended to extract and pre-concentrate volatile compounds in a single stage without using solvents, i.e., being reusable and portable (Piri-Moghadam et al., 2016). This technique has also been implemented for *in situ* explorations to assist in evaluations of biological and environmental processes. This type of research is associated with the identification of VOCs responsible for aromas and flavors, and those VOCs with lipid or carotenoid derivatives and changes in the metabolic composition due to the action of biotic or abiotic factors in addition to natural mechanisms of resistance to pests. The main reason that tomato is the most studied fruit is associated with its research model for the evaluation of ripening processes in climacteric fruits, in addition to being the most commercialized vegetable in the world (Tieman et al., 2006a), then capturing general interest.

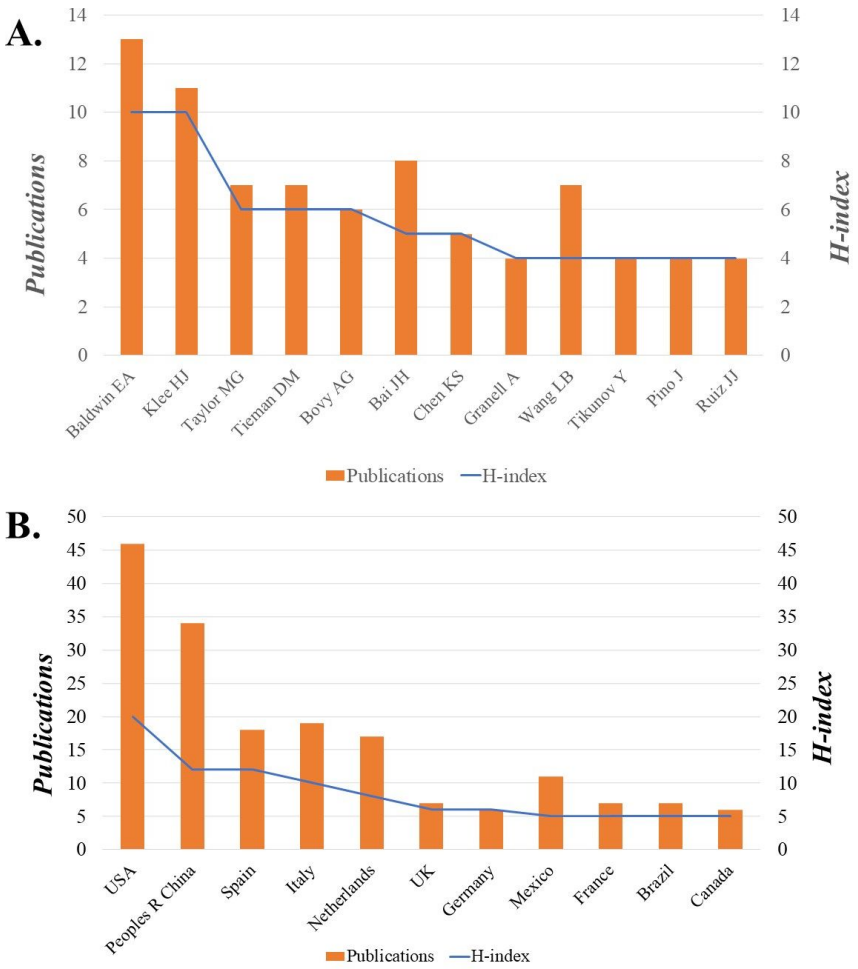

Figure 6. Index-H of publications in the field of Solanaceae fruit trees. (A) By authors; (B) By country.

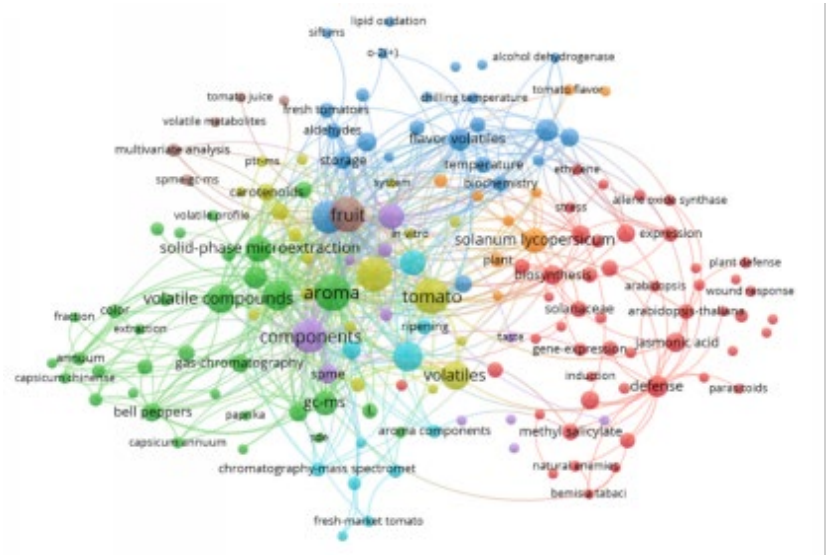

Figure 7. Co-occurrence analysis by keywords.

4 Conclusions

Bibliometric analysis is a research technique that can be applied to multiple fields of science, being able to identify trends in metabolomic knowledge, enrich the literature review and guide researchers to develop

innovative scientific proposals that can fill knowledge gaps. These different aspects were able to identify in this bibliometric study, the dynamics of VOCs in fruit and food species of the family Solanaceae. It was demonstrated that for the application of search algorithm in the *Web of Science* database, it could be noted that 178 documents were divided into 174 scientific articles, three topic reviews and one book chapter, furthermore, these documents have been published increasingly from 2001 to 2017. With respect to research efforts by 491 authors from 239 different organizations distributed in 45 countries, it could be pointed out that the majority of articles in this field of knowledge have been published in the *Journal of Agricultural and Food Chemistry, Journal of Food Science* and *Food Chemistry.* At the same time, the greatest exponents in the Solanaceae study were related to Baldwin EA and Klee HJ. i.e., researchers from the Department of Agriculture and the University of Florida in the USA. This bibliometric study allowed identifying the trends on the current state of knowledge in the field of VOCs associated with fruits of Solanaceae family, as well as recognizing the location of the scientific material in this field, changing trends related to the subject and niches that should be occupied in future research. In this way, the panorama focused on the metabolomic knowledge of species of Solanaceae of local or regional interest has been drawn up with the intention of maintaining and fostering the great diversity of Solanaceae family.

Acknowledgements

The authors express their acknowledgment to the Department of Science and Technology of Colombia COLCIENCIAS. A. Baena under the call 775 of *Jóvenes Investigadores e Innovadores por la Paz* 2017 and L. Londoño under the call 727 of 2015 of national doctoral programs.

References

Adu, M., Asare, P., Yawson, D., Nyarko, M., & Osei-Agyeman, K. (2018). Agronomic bioforti fi cation of selected underutilised solanaceae vegetables for improved dietary intake of potassium (K) in Ghana. *Heliyon*, *4*(8), e00750. PMid:30167498. http://dx.doi.org/10.1016/j.heliyon.2018.e00750

Alonso, A., Tannuri, E., Cabrini, M., Pandiella, A., & Benavent, R. (2016). Un análisis bibliométrico en el área de la Medicina: colaboración científica entre Brasil y España (2002-2011). *Investigación Bibliotecológica*, *30*(69), 205-229. http://dx.doi.org/10.1016/j.ibbai.2016.04.018

Ament, K., Kant, M., Sabelis, M., Haring, M., & Schuurink, R. (2004). Jasmonic acid is a key regulator of spider mite-induced volatile terpenoid and methyl salicylate emission in tomato. *Plant Physiology*, *135*(4), 2025-2037. PMid:15310835. http://dx.doi.org/10.1104/pp.104.048694

Aubert, C., Baumann, S., & Arguel, H. (2005). Optimization of the analysis of flavor volatile compounds by liquid-liquid microextraction (LLME). Application to the aroma analysis of melons, peaches, grapes, strawberries, and tomatoes. *Journal of Agricultural and Food Chemistry*, *53*(23), 8881-8895. PMid:16277379. http://dx.doi.org/10.1021/jf0510541

Bleeker, P., Diergaarde, P., Ament, K., Guerra, J., Weidner, M., Schutz, S., de Both, M. T., Haring, M. A., & Schuurink, R. C. (2009). The role of specific tomato volatiles in tomato-whitefly interaction. *Plant Physiology*, *151*(2), 925-935. PMid:19692533. http://dx.doi.org/10.1104/pp.109.142661

Corlett, R. T. (2016). Plant diversity in a changing world: Status, trends, and conservation needs. *Plant Diversity*, *38*(1), 10-16. PMid:30159445. http://dx.doi.org/10.1016/j.pld.2016.01.001

Corpas, E., Taborda, G., Alzate, O. T., & Ortiz, A. (2016). Compuestos volátiles de la fracción volátil en pulpa de lulo (S. Quitoense L.) Bajo diferentes condiciones de almacenamiento. *Vitae*, *23*(March), S831-S835.

Damar, H.T., Bilik, O., Ozdagoglu, G., Ozdagoglu, A., & Damar, M. (2018). Scientometric overview of nursing research on pain management. *Revista Latino-Americana de Enfermagem*, *26*, e3051. PMid:30183876. http://dx.doi.org/10.1590/1518-8345.2581.3051

Dávila-Aviña, J. E. J., González-Aguilar, G. A., Ayala-Zavala, J. F., Sepúlveda, D. R., & Olivas, G. I. (2011). Compuestos volátiles responsables del sabor del tomate. *Revista Fitotecnia Mexicana*, *34*(2), 133-143. http://dx.doi.org/10.35196/rfm.2011.2.133

Escorcia, T., & Poutou, R. (2009). Análisis bibliométrico de los artículos originales publicados en la revista Universitas Scientiarum (1987-2007). *Universitas Scientiarum*, *13*(3), 236-244.

Fadl Almoulah, N., Voynikov, Y., Gevrenova, R., Schohn, H., Tzanova, T., Yagi, S., Thomas, J., Mignard, B., Ahmed, A. A. A., El Siddig, M. A., Spina, R., & Laurain-Mattar, D. (2017). Antibacterial, antiproliferative and antioxidant activity of leaf extracts of selected Solanaceae species. *South African Journal of Botany*, *112*, 368-374. http://dx.doi.org/10.1016/j.sajb.2017.06.016

Farag, M. A., & Paré, P. (2002). C6-green leaf volatiles trigger local and systemic VOC emissions in tomato. *Phytochemistry*, *61*(5), 545-554. PMid:12409021. http://dx.doi.org/10.1016/S0031-9422(02)00240-6

González de Dios, J., Moya, M., & Mateos Hernández, M. A. (1997). Indicadores bibliométricos : características y limitaciones en el análisis de la actividad científica Justificación de la evaluación científica. *Anales Espanoles de Pediatria*, *47*(3), 235-244. PMid:9499274.

Iijima, Y. (2014). Recent advances in the application of metabolomics to Studies of Biogenic Volatile Organic Compounds (BVOC) produced by plant. *Metabolites*, *4*(3), 699-721. PMid:25257996. http://dx.doi.org/10.3390/metabo4030699

Lewinsohn, E., Sitrit, Y., Bar, E., Azulay, Y., Meir, A., Zamir, D., & Tadmor, Y. (2005). Carotenoid pigmentation affects the volatile composition of tomato and watermelon fruits, as revealed by comparative genetic analyses. *Journal of Agricultural and Food Chemistry*, *53*(8), 3142-3148. PMid:15826071. http://dx.doi.org/10.1021/jf047927t

Lim, T. (2013). *Edible medical and non-medicibal plants* (Vol. 6). USA: Springer Berlin Heidelberg. https://doi.org/10.1007/978-94-007-5628-1

Maneerat, C., Hayata, Y., Kozuka, H., Sakamoto, K., & Osajima, Y. (2002). Application of the porapak Q column extraction method for tomato flavor volatile analysis. *Journal of Agricultural and Food Chemistry*, *50*(12), 3401-3404. PMid:12033802. http://dx.doi.org/10.1021/jf011626r

Mathieu, S., Cin, V., Fei, Z., Li, H., Bliss, P., Taylor, M., Klee, H. J., & Tieman, D. M. (2009). Flavour compounds in tomato fruits: identification of loci and potential pathways affecting volatile composition. *Journal of Experimental Botany*, *60*(1), 325-337. PMid:19088332. http://dx.doi.org/10.1093/jxb/ern294

Mushtaq, W., & Siddiqui, M. (2018). Allelopathic Solanaceae plants. *Journal of Plant Protection Research*, *58*(1), 1-7. http://dx.doi.org/10.24425/119113

Naef, R., Velluz, A., & Jaquier, A. (2008). New volatile sulfur-containing constituents in a simultaneous distillation-extraction extract of red bell peppers (Capsicum annuum). *Journal of Agricultural and Food Chemistry*, *56*(2), 517-527. PMid:18163560. http://dx.doi.org/10.1021/jf072493y

Patrón, C., López, J., Piovesan, S., & Bettina, D. (2014). Análisis bibliométrico de la producción científica de la revista Odontoestomatología. *Odontoestomatologia*, *16*(23), 34-43.

Persson, O., Danell, R., & Schneider, J. W. (2019). How to use Bibexcel for various types of bibliometric analysis. In F. Åström, R. Danell, B. Larsen & J. Schneider (Eds.), *Celebrating Scholarly Communication Studies: A Festschrift for Olle Persson at His 60th Birthday* (pp. 9-24). Leuven, Belgium: International Society for Scientometrics and Informetrics.

Pichuante, C. (2016). *Visualización de grafos de co-autoría y de conocimiento basado en publicaciones científicas, implentada en VOSviewer.* Chile: Pontificia Universidad Católica de Chile.

Piri-Moghadam, H., Ahmadi, F., & Pawliszyn, J. (2016). A critical review of solid phase microextraction for analysis of water samples. *Trends in Analytical Chemistry*, *85*, 133-143. http://dx.doi.org/10.1016/j.trac.2016.05.029

Recio, M., Yepes, N., & Moreno, F. (2017). Análisis bibliométrico de las publicaciones sobre síndrome metabólico en dos revistas biomédicas colombianas de alto impacto. *Salutem Scientia Spiritu*, *3*(1), 12-21.

Samuels, J. (2015). Biodiversity of food species of the Solanaceae family: a preliminary taxonomic inventory of subfamily Solanoideae. *Resources*, *4*(2), 277-322. http://dx.doi.org/10.3390/resources4020277

Sánchez, J. (2014). *Análisis bibliométrico para la determinación del estado actual de la producción científica de los autores de la faculta de estudios a distancia de la Universidad Militar Nueva Granada en la Revista Academica y Virtualidad.* Granada: Universidad Militar Nueva Granada.

Silva, L. R., Azevedo, J., Pereira, M. J., Carro, L., Velazquez, E., Peix, A., Valentão, P., & Andrade, P. B. (2014). Inoculation of the Nonlegume Capsicum annuum (L.) with Rhizobium Strains. 2. Changes in sterols, triterpenes, fatty acids, and volatile compounds. *Journal of Agricultural and Food Chemistry*, *62*(3), 565-573. PMid:24405510. http://dx.doi.org/10.1021/jf4046655

Simkin, A.J., Schwartz, S., Auldridge, M., Taylor, M., & Klee, H. (2004). The tomato carotenoid cleavage dioxygenase 1 genes contribute to the formation of the flavor volatiles β-ionone, pseudoionone, and geranylacetone. *The Plant Journal*, *40*(6), 882-892. PMid:15584954. http://dx.doi.org/10.1111/j.1365-313X.2004.02263.x

Starkenmann, C., & Niclass, Y. (2011). New Cysteine-S-Conjugate Precursors of Volatile Sulfur Compounds in Bell Peppers (Capsicum annuum L. Cultivar). *Journal of Agricultural and Food Chemistry*, *59*(7), 3358-3365. PMid:21375341. http://dx.doi.org/10.1021/jf1042322

Tieman, D., Taylor, M., Schauer, N., Fernie, A., Hanson, A., & Klee, H. (2006a). Tomato aromatic amino acid decarboxylases participate in synthesis of the flavor volatiles 2-phenylethanol and 2-phenylacetaldehyde. *Proceedings of the National Academy of Sciences of the United States of America*, *103*(21), 8287-8292. PMid:16698923. http://dx.doi.org/10.1073/pnas.0602469103

Tieman, D. M., Zeigler, M., Schmelz, E. A., Taylor, M. G., Bliss, P., Kirst, M., & Klee, H. J. (2006b). Identification of loci affecting flavour volatile emissions in tomato fruits. *Journal of Experimental Botany*, *57*(4), 887-896. PMid:16473892. http://dx.doi.org/10.1093/jxb/erj074

Tikunov, Y., Lommen, A., de Vos, C. H., Verhoeven, H. A., Bino, R. J., Hall, R. D., & Bovy, A. G. (2005). A novel approach for nontargeted data analysis for metabolomics. Large-scale profiling of tomato fruit volatiles. *Plant Physiology*, *139*(3), 1125-1137. PMid:16286451. http://dx.doi.org/10.1104/pp.105.068130

Towell, J. (2001). Una semblanza de las solanaceae. *Etnobiología*, *1*(1), 17-23.

Vallverdú-Queralt, A., Bendini, A., Barbieri, S., Di Lecce, G., Martin-Belloso, O., & Toschi, T. G. (2013). Volatile profile and sensory evaluation of tomato juices treated with pulsed electric fields. *Journal of Agricultural and Food Chemistry*, *61*(8), 1977-1984. PMid:23373424. http://dx.doi.org/10.1021/jf3051126

van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, *84*(2), 523-538. PMid:20585380. http://dx.doi.org/10.1007/s11192-009-0146-3

Xu, Y., & Barringer, S. (2009). Effect of temperature on lipid-related volatile production in tomato puree. *Journal of Agricultural and Food Chemistry*, *57*(19), 9108-9113. PMid:19743856. http://dx.doi.org/10.1021/jf902192r

Yang, C., Wang, J., & Li, D. (2013). Microextraction techniques for the determination of volatile and semivolatile organic compounds from plants: a review. *Analytica Chimica Acta*, *799*, 8-22. PMid:24091369. http://dx.doi.org/10.1016/j.aca.2013.07.069

Zanor, M. I., Rambla, J., Chaïb, J., Steppa, A., Medina, A., Granell, A., Fernie, A. R., & Causse, M. (2009). Metabolic characterization of loci affecting sensory attributes in tomato allows an assessment of the influence of the levels of primary metabolites and volatile organic contents. *Journal of Experimental Botany*, *60*(7), 2139-2154. PMid:19346240. http://dx.doi.org/10.1093/jxb/erp086

Funding: None.

Received: June 02, 2020; Accepted: Oct. 29, 2020