**BIBLIOMETRIC ANALYSIS OF CORN NIXTAMALIZATION USING VOSVIEWER**

**Lady Shernalyn P. Cadavero1, Clarissa B. Juanico2, Aldrin P. Bonto1\***

*1Chemistry Department, De La Salle University, 2410 Taft, Avenue, Manila 0922, Philippines*

*2Institute of Human Nutrition and Food, College of Human Ecology, University of the Philippines Los Baños, College, Laguna, Philippines*

*Corresponding author: \*aldrin.bonto@dlsu.edu.ph*

|  |  |  |
| --- | --- | --- |
| **Article history:**  Complete by editor |  | **ABSTRACT**  Corn is one of the essential crops for food around the globe, accounting for at least 30% of food calories in developing countries. Among the various postharvest processing of maize, nixtamalization (treating maize with lime solution) significantly impacts flavor and aroma, improving textural properties, increasing nutritional values and reducing nutritional values and reducing mycotoxins. Due to these advantageous effects, research publications on maize nixtamalization increased in the last decade. Based on the Scopus database, this bibliometric analysis aimed to give an overview of the research activities on corn nixtamalization from 2010 to 2013. Moreover, bibliometric data were analyzed using VOSviewer 1.6.19 for annual publication trends, countries, organizations, contributing authors, journals, sources, and keywords. With 364 documents retrieved from Scopus search query and processed using VOSviewer, the most productive categories were the following: Mexico (country), 2020 and 2022 (year), Centro de Biotecnología FEMSA (institution), Benjamin Ramírez-Wong of Universidad de Sonora (author), Maize: A Paramount Staple Crop in  the Context of Global Nutrition by Nuss & Tanumihardjo (2010) (publication), and Journal of Cereal Science (journal). Hence, this bibliometric analysis may help cereal researchers to consider utilizing nixtamalization as a postharvest process in improving their local maize varieties or other cereal crops. |
| **Keywords:**  *Corn*  *Zea mays*  *Nixtamalization*  *Lime-cooking*  *Bibliometric analysis* |

**1. Introduction**

*Zea mays L.*, known as corn or maize, is the world's vital annual cereal crop that sources carbohydrates, fats, protein, dietary fiber, vitamins, and health-related phytochemical compounds (Rouf Shah *et al.*, 2016). Corn is classified by its color and kernel configuration—yellow, white, dent, or flint—and includes regular food-grade yellow and white corn, specialty corn like quality protein maize (QPM), waxy, high-amylose, high-oil, blue, popcorn, sweet maize, and Cuzco corn (Rooney & Serna-Saldivar, 2015). As one of the oldest cultivated grains, corn is one of the most productive crop species, with a global average yield of more than eight tons per hectare, and it can be processed in food and industrial products (Langemeier & Zhou, 2022).

In Mexico and Central America, where corn is considered an essential staple, a central technique for processing corn into food products is utilized to ensure that the nutritional content of the corn is sufficient to sustain the dietary needs of its people (Palacios-Pola *et al.*, 2022). This technique is known as nixtamalization, derived from the Nahuatl word "nixtamal," a lime-treated maize prepared as a dough (Trejo-Gonzalez *et al.*, 1982). Nixtamalization is an ancient food processing method by the indigenous Mesoamerican civilizations from 1200 to 500 BC and is still applied in the modern world. It represents the alkaline cooking of corn kernels that are widely used in Mesoamerica (Serna-Saldivar, 2021).

Nixtamalization is a process in which corn is boiled in water containing lime, steeped overnight, and then washed and ground into corn masa. The masa is then molded into tortillas, and/or baked or dried, and then ground to create dry masa flour. Maize tortillas made from traditional masa harina or "dough flour" are the oldest variety of tortillas, the most studied maize food from the preparation process to the determination of its dietary properties (Menchaca-Armenta *et al.*, 2023). Tortillas are made by cooking whole maize in calcium hydroxide-containing water, steeping to anneal the starch granules, removing the excess cooking liquor called nejayote, washing the kernel, and grinding to masa (Chaidez-Laguna *et al.*, 2016). This process necessitates the use of an alkaline or lime solution to weaken the cell walls, allowing the removal of the pericarp and the solubilization of cell walls in the peripheral endosperm, causing swelling and reorganization of starch granules at temperatures above glass transition but below gelatinization, allowing the modification of the physical properties of starch and protein (Carrera *et al.*, 2015). As a result, nixtamalization improves the nutritional value, calcium and iron bioavailability, and physicochemical, thermal, and rheological properties of nixtamal, reduces mycotoxin, and produces a significant amount of resistant starch, which promotes health due to its prebiotic effects (Hernandez *et al.*, 2022; Serna-Saldivar, 2021). Additionally, it increased the calcium intake after shifting to lime in cooking corn (Bressani *et al.*, 1990; Maya-Cortés *et al.*, 2010). The effects of nixtamalization on corn prompted other countries to explore its impact on their local corn varieties and utilize it as an ingredient in varying food products. Studies also showed that corn kernels' protein, fiber, and mineral content improved after nixtamalization (De Leon *et al.*, 2022; Sunico *et al.*, 2021). Nixtamalized corn in varying forms, such as flour, grits, and milk, was also incorporated as an ingredient in food products such as loaf bread (De Leon *et al.*, 2022), salted bread (Sunico *et al.*, 2021), rice corn blend (Hernandez *et al.*, 2022), and fermented beverage (Ramos *et al.*, 2022). Results showed that the products had higher nutritional content than their control counterparts and were also acceptable to their consumers regarding their sensory characteristics and general acceptability. This indicates that corn nixtamalization can be used as an intervention to produce food products with improved nutritional value.

Corn nixtamalization is widely investigated in the academe and food industry. Exploring this method with other corn varieties is a good strategy for introducing new commodities globally. Despite the comprehensive reviews regarding nixtamalized corn (Santiago-Ramos *et al.*, 2018; Serna-Saldivar, 2021), there is still a lack of bibliometric analysis of scientific works published on this topic. Only a few bibliometric mapping analyses on corn have been done (BaoZhong & Jie, 2020; Feng *et al.*, 2022; Montoya *et al.*, 2020), but they are not specific to corn nixtamalization. Bibliometric methods utilize analysis and knowledge mapping to quantify literature evaluation which sorts of citations, authorships, keywords, and methodology (Fasogbon & Adebo, 2022). Hence, this study aims to use the bibliometric method to collect documents related to corn nixtamalization from the Scopus database, then analyze the bibliometric indicators such as citation count for categories such as countries, organizations, authors, journals, sources, and co-occurrence of keywords using the VOSviewer application.

**2. Materials and methods**

**2.1. Data Source and Type of Study**

This study used bibliometric analysis retrieved from the Scopus database from 2010 to 2023, with the date of access on January 28, 2023. A total of 364 documents were obtained using search parameters Boolean syntax (TITLE-ABS-KEY ("nixtamaliz\*") AND TITLE-ABS-KEY ("corn" OR "maize")). The data was exported in CSV format and imported to VOSviewer (version 1.6.19) to create a bibliometric map. Scopus database has been superior to PubMed and Web of Science in sorting data. Scopus is one of the largest bibliographic data sources that provide scientometric indicators to evaluate the citation count and performance of the researchers (Pranckutė, 2021). It has various functions, including an advanced search function for complex search queries and bibliometric data to track citations of articles published in scientific journal sources (Sweileh, 2020). In addition, all source-type documents and language are considered. Obtained data are tabulated, and the representations are applied through tables and graphs using Microsoft Excel 365 program.

In VOSviewer, a bibliographic map only contains one type of item where items are considered an object of interest, such as countries, organizations, authors, documents, and sources connected by only one type of link. Nodes are sometimes used instead of an item in other software tools. A set of items is called a cluster, while a set of items with links is called a network. Items contain weight and score attributes; therefore, a higher weight is more critical than a lower weight used in network and density visualization. On the other hand, score attributes are only applicable in overlay visualization. Links and total link strength (TLS) are two standard weight attributes. Links are the number of links on an item with other items, while TLS is the total strength of the links of an item with other items (Jan van Eck & Waltman, 2019).

**2.2. Bibliometric Analysis and Indicators**

VOSviewer was used to organize and classify bibliometric indicators based on citation and co-occurrence of keywords through network visualization. VOSviewer with the following steps includes selecting the data source, type of analysis, and choosing threshold. Classification of bibliometric information is based on indicators of productivity which refer to the frequency of the researcher's publication, visibility which is based on the influence of the author's publication measured based on the number of citations, and collaboration which is based on joint authorship and citations (Montoya *et al.*, 2020). The indicator used in this review paper is a production indicator based on the number of publications regarding the countries, organizations, authors, documents, journal sources, and the co-occurrence of keywords. Bibliometric analysis is done to summarize large quantities of bibliometric data, and the science mapping technique includes citation analysis, co-citation analysis, bibliometric coupling, co-word analysis, and co-authorship analysis. Citation analysis is used in this paper, where it is a basic technique for bibliometric mapping to reflect the collaboration between publications when one document cites the other. It can also visualize the most impactful and collaborative publication in a research field (Donthu *et al.*, 2021).

**3. Results and discussions**

**3.1. Yearly Publication Output on corn nixtamalization**

The quantity of articles published yearly gives a reliable estimate of the research trend in a particular study area. The trend in the number of publications can provide insight into the likely research trend soon. The research productivity on corn nixtamalization from 2010 to 2023 was shown in Figure 1 by plotting the number of documents and cumulative documents on a year-over-year basis. Annually, the average published article is 26 papers. There was a fluctuation in publications per year; however, evidence of a growing publication trend about nixtamalized corn after 2012, with more published articles from 2013-2019 and a peak in published 41 documents in 2020.

Figure 1 also shows that researchers are increasing pay attention to corn nixtamalization; even though the COVID-19 pandemic and lockdown occurred during 2020-2022, relatively higher papers were still published compared to previous years, indicating innovative progress in answering gaps in this research field. Beyond the year 2020, the increased number of published journals on corn nixtamalization used it as a strategy for (1) micronutrient fortification, which improves the nutritional attributes of corn, and (2) mycotoxins removal for preventing food contamination and improving food safety.

**3.2. Collaboration analysis per country**

There are 41 contributing to the top papers in this study, and determining the country's origin shows collaborative efforts between them in producing and promoting novel information and research potential. Table 1 shows the highest 15 countries with at least three documents published, highlighting Mexico with 265 papers, followed by the United States (57), Indonesia (17), then Spain (13). Eleven countries published articles from 3 to 6, whereas 26 countries published only 1 to 2. By adding the contributions from each country, the total number of publications is 427, which is relatively higher than 364, suggesting that there has been collaborative work between those 41 countries. Notably, out of 41 countries, six countries are included in the 15 nominal GDP ranks, indicating that the economically developed countries identify the development of corn processing using nixtamalization. Mexico received the most significant citations from 265 published journals, followed by the United States and Spain. However, the highest average citations per document were from Brazil (43.33), followed by France (34.25), then the Czech Republic (29.00) due to collaborative works in using nixtamalization as an intervention for mycotoxin removal.

Figure 2 indicates that Mexico has been more collaborative in the other 14 countries except for Brazil, while the United States has been collaborative in other countries besides Indonesia. As supported by the total link strength (TLS) shown in Table 1, Mexico was superior in collaborative research with a TLS of 237, followed by the United States with 152. At the same time, Indonesia and Brazil had the least score of 1 and 5, respectively. TLS shows connectivity between items and contains weight properties regarding citations, occurrences, and documents (Zaib *et al.*, 2022).

**3.3 Collaboration analysis per organization**

Table 2 shows the top 4 organizations identified out of 1010 that meet at least four documents. Three out of the four organizations are from Mexico - (1) Centro de Biotecnología FEMSA, Escuela de Ingeniería y Ciencias, Tecnologico de Monterrey, (2) Ceprobi, Instituto Politécnico Nacional and Departamento de Biotecnología, (3) Departamento de Biotecnología, Universidad Autónoma Metropolitana- iztapalapa, having an average citation of each document of 13.14, 9.00, and 7.33, respectively. These three Mexican organizations dominated the Research Centre for Chemistry Indonesian Institute of Sciences, with average citations of 0.67 only. No TLS indicated in these citation-organization cooperation networks, which all them were separated into clusters, meaning none of their published documents have collaborated.

**3.4 Citation-author relationship**

The construction of mapping of networks through VOSviewer provides a visual relationship to study the activity of an author and their interconnectivity with another researcher. Of 1157 authors obtained, 23 meet the criteria of publishing at least eight research papers regarding corn nixtamalization, shown in Table 4. Ramírez-Wong, B. and Serna-Saldivar, S.O. both published 21 research articles, followed by Santiago-Ramos, D. (16), Gaytán-Martínez, M. (15) and Torres-Chávez, P.I. (15) who are also the prominent groups in the field of research. However, Reyes-Moreno, C. received the highest average citation per document that is 27.33, followed by Milán-Carrillo, J. (27.22), Gutiérrez-Uribe, J.A. (26.82) and Rodríguez-García, M.E. (26.00). All 21 authors show strong collaboration based on their TLS specifically Santiago-Ramos, D. (198), Ramírez-Wong, B. (185), Escalante-Aburto, A. (170) and Torres-Chávez, P.I. (155).

The results of visualization of research mapping related to corn nixtamalization show 23 items with a total of 1157 authors with at least eight published documents divided into 5 clusters. The most extensive connected items or strong collaborative researchers consist of 21 authors in Clusters 1 to 4 (Figure 3), and non-connected items consist of 2 authors in Cluster 5. It was also supported by the TLS of 10 for both Maryati, Y. and Susilowati, A., shown in Table 3. Interestingly, although Maryati, Y. (12) and Susilowati, A. (13) were closed due to the number of their published journals but did not collaborate or with any other research group.

**3.5 Documents and citation analysis**

The citation-document network mapping analysis provides information on the quality of the published journal based on the higher citation, which suggests that the paper has been frequently cited. In this bibliometric analysis, documents with at least 40 times cited were selected, as shown in Table 4. The top cited document was "Maize: A Paramount Staple Crop in the Context of Global Nutrition" by Nuss & Tanumihardjo (2010), which reviews maize as the main staple crop in the context of global nutrition, having 338 citations. Then followed by the research article of Flores-Morales *et al.* (2012), which is about the structural changes in the retrograded starch of maize tortillas as determined by various spectroscopic techniques (with 248 citations). A review by Neme & Mohammed (2017) is the third most cited article (170 citations), which focuses on the occurrence of mycotoxins in grains and the role of postharvest management as a mitigation strategy. These three publications focus on corn functions and consumption safety rather than nixtamalization. None of these three top-cited journals had been cited by a selected group of 17 documents, as shown in Figure 4. There are two distinct highly interconnected clusters (red and blue nodes) wherein the first group, the document from Nuss & Tanumihardjo, 2010 was the most cited publication with 338 citations, followed by Gwirtz & Nieves Garcia-Casal, 2014 (143 citations) and in the second group it was Mora-Rochin *et al.*, 2010 (143 citations). Flores-Morales *et al.*, 2012 and Neme & Mohammed, 2017 citations of 248 and 170, respectively, are not interconnected with other publications. Gwirtz & Nieves Garcia-Casal's 2014 study is about the processing of maize flour and corn meal food products. Mora-Rochin *et al.*, 2010 was the phenolic content and antioxidant activity of tortillas produced from pigmented maize processed by conventional nixtamalization or extrusion cooking. This can be concluded that the publications of Nuss & Tanumihardjo, 2010, Gwirtz & Nieves Garcia-Casal, 2014 and Mora-Rochin *et al.*, 2010 had a significant impact on the research involving corn nixtamal.

**3.6 Most productive journal sources in corn nixtamalization**

The citation-sources relationship obtained from bibliometric mapping analysis by VOSviewer indicates the importance of where the author prefers to publish their results related to corn nixtamalization. The top journals are the following: Journal of Cereal Science (26), Cereal Chemistry (17), CyTA - Journal of Food (16), and Food Chemistry (13) which received 482, 123, 207, and 203 citations, respectively.

In terms of average citations per document, the top four journal sources were Food Control (42.20), Journal of Food Engineering (29.57), LWT - Food Science and Technology (21.08), and Plant Foods for Human Nutrition (18.92) with impact factor (2021) of 6.652, 6.203, 6.056 and 4.124, respectively, indicating the impactful articles being published had high-quality research work. Figure 5 shows the results of visualization of research mapping related to corn nixtamalization, offering 19 items with a total of 146 sources and 7 clusters with at least five documents. The largest set of connected items consists of 17 journal sources included in clusters 1 to 5 and 2 sources not being collaborative included in clusters 6 (AIP Conference Proceedings) and 7 (IOP Conference Series: Materials Science and Engineering). This was supported by information in Table 5 that AIP Conference Proceedings and IOP Conference Series: Materials Science and Engineering had 0 or no TLS.

**3.7 Network visualization of corn nixtamalization based on keywords.**

Identifying co-occurrence-all keywords relationship between terms in the topic of corn nixtamalization is selected for the network visualization map shown in Figure 10. Determining the top ten highest occurrences of keywords are nixtamalization (142), zea mays (116), maize (101), article (44), chemistry (42), starch (40), food handling (34), flour (31), tortillas (30) and calcium (28) with strong TLS with each word as shown in Figure 6. Red, violet, and blue nodes that contained the most occurrences keywords are nixtamalization, *Zea mays*, and maize, respectively, suggesting a strong correlation with other nodes. Violet nodes also include food handling; in blue, nodes are articles and tortillas; in yellow, it is chemistry; in green, nodes include starch, flour, and calcium.

The results of visualization of research mapping related to corn nixtamalization show 166 items with a total of 2423 linked keywords which are divided into 7 clusters, namely:

1. Cluster 1 consists of 48 items, including alkalinity, amino acids, antioxidant

activities, arabinoxylans, carbohydrates, carotenoids, chemical compositions, corn, dietary fiber, dietary fibers, effluents, extrusion, extrusion process, food products, functional properties, glycemic index, grain (agricultural product), hydrated lime, lime, lime-cooking, linoleic acid, maize (zea mays l.), maize flour, mixtures, moisture, nejayote, nixtamalization, nixtamalized corn flours, nutrition, particle size, particle size analysis, phenolic compounds, pigments, plants (botany), proteins, reducing sugars, resistant starch, rheological property, sensory analysis, sugars, textural properties, texture, textures, tortilla, tortilla chips, water absorption, water absorption capacity, and water absorption index.

1. Cluster 2 consists of 31 items including amylose, amylose-lipid complex, analysis, calcium, calcium absorption, calcium carbonate, calcium hydroxide, controlled study, corn flour, flow kinetics, food processing, fourier transform infrared, gelatinization, gelatinization temperature, gelation, germination, hydrolysis, pasting property, pericarp, physical chemistry, physical parameters, physicochemical property, procedures, rheology, scanning electron microscopy, solubility, starch, viscoelasticity, viscosity, x-ray diffraction, x-ray and diffraction.
2. Cluster 3 consists of 26 items, including aflatoxin b1, aflatoxins, alkaline cooking, animal, animals, article, chemical analysis, cooking, food contamination, fumonisin, fumonisin b1, fumonisins, genetics, human, maize, metabolism, Mexico, microbiology, mycotoxin, mycotoxins, nixtamal, nonhuman, priority journal, review, tortillas, and unclassified drug.
3. Cluster 4 consists of 21 items, including anthocyanin, anthocyanins, antioxidant, antioxidant activity, antioxidant capacity, antioxidants, bioactive compounds, chemistry, corn tortilla, corn tortillas, ecological nixtamalization, ferulic acid, food, genotype, heating, ohmic heating, phenol derivative, phenolics, phenols, phytochemical, and zea mays l.
4. Cluster 5 consists of 17 items, including bread, calcium compounds, calcium derivative, calcium oxide, color, cooking time, food handling, hardness, hydrogen-ion concentration, methodology, nixtamalized maize flour, ph, plant seed, seeds, tetragastris balsamifera, water, and zea mays.
5. Cluster 6 consists of 14 items, including diet supplementation, dough, flour, food technology, food fortified, fortified food, humans, iron, nutritional value, physicochemical properties, protein quality, quality protein maize, wheat, and zinc.
6. Cluster 7 consists of 9 items, including blue corn, fermentation, isolation and purification, lactic acid bacteria, masa, optimization, pozol, snacks, and temperature.

**4. Conclusions**

In this review paper, bibliometric mapping analysis is discussed with a focus on citations and co-occurrence. The research concludes that VOSviewer is a valuable tool for examining bibliometric data sourced from Scopus. The study, which analyzes 364 publications, indicates a rise in corn nixtamalization research between 2013 and 2019, with the most prolific year being 2020, despite the pandemic. Mexico, the United States, Spain, and Indonesia are the most collaborative countries due to their cultural reliance on corn as a staple food, used in various forms such as tortillas, sweeteners, corn meals, and snacks. The study reveals that the top organizations have no collaborations based on TLS, primarily located in Mexico. The most productive authors are Benjamin Ramírez-Wong, Sergio O. Serna-Saldivar, and David Santiago-Ramos, while the most cited publications are from Nuss & Tanumihardjo (2010), Flores-Morales *et al.* (2012), and Neme & Mohammed (2017), with either 0 or 1 links found in various clusters. The preferred journal sources are Journal of Cereal Science, Cereal Chemistry, and CyTA - Journal of Food, with the most frequently occurring keywords being nixtamalization, corn, and maize.

**5. References**

BaoZhong, Y., Jie, S. (2020). Mapping the scientific research on maize or corn: a bibliometric analysis of top papers during 2008-2018. *Maydica*, 65(2).

Bressani, R., Benavides, V., Acevedo, E., Ortiz, M. A. (1990). Changes in Selected Nutrient Contents and in Protein Quality of Common and Quality-Protein Maize During Rural Tortilla Preparation. *Cereal Chemistry*, 67(6), 515–518.

Carrera, Y., Utrilla-Coello, R., Bello-Pérez, A., Alvarez-Ramirez, J., Vernon-Carter, E. J. (2015). In vitro digestibility, crystallinity, rheological, thermal, particle size and morphological characteristics of pinole, a traditional energy food obtained from toasted ground maize. *Carbohydrate Polymers*, 123, 246–255.

Chaidez-Laguna, L. D., Torres-Chavez, P., Ramírez-Wong, B., Marquez-Ríos, E., Islas-Rubio, A. R., Carvajal-Millan, E. (2016). Corn proteins solubility changes during extrusion and traditional nixtamalization for tortilla processing: A study using size exclusion chromatography. *Journal of Cereal Science*, 69, 351–357.

De Leon, D. C. A., Bonto, A. P., Tuaño, A. P. P., Juanico, C. B. (2022). Nutrient composition, starch microstructure and thermal properties, and in vitro availability of selected minerals of nixtamalized Philippine quality protein maize variety IPB Var 6 and the production of healthy loaf bread using nixtamalized corn–wheat flour blends. *Journal of Food Processing and Preservation*, 46(9), e16665.

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, 133, 285–296.

Fasogbon, B. M., Adebo, O. A. (2022). A bibliometric analysis of 3D food printing research: A global and African perspective. *Future Foods*, 6, 100175.

Feng, L., Tang, H., Pu, T., Chen, G., Liang, B., Yang, W., Wang, X. (2022). Maize–soybean intercropping: A bibliometric analysis of 30 years of research publications. *Agronomy Journal*, 114(6), 3377–3388.

Flores-Morales, A., Jiménez-Estrada, M., Mora-Escobedo, R. (2012). Determination of the structural changes by FT-IR, Raman, and CP/MAS 13C NMR spectroscopy on retrograded starch of maize tortillas. *Carbohydrate Polymers*, 87(1), 61–68.

Gwirtz, J. A., Nieves Garcia-Casal, M. (2014). Processing maize flour and corn meal food products. In J. P. PenaRosas, M. N. GarciaCasal, & H. Pachon (Eds.), Technical Considerations for Maize Flour And Corn Meal Fortification In Public Health (Vol. 1312, pp. 66–75). Blackwell Science Publ.

Hernandez, J. A., Tuaño, A. P. P., Juanico, C. B. (2022). Development and characterization of the nutritional profile and microbial safety of rice-nixtamalized corn grits blends as potential alternative staple for household consumption. *Future Foods*, 5, 100127.

Jan van Eck, N., & Waltman, L. (2019). VOSviewer Manual. In University of Leiden. https://www.vosviewer.com/documentation/Manual\_VOSviewer\_1.6.13.pdf

Langemeier, M., Zhou, L. (2022). International Benchmarks for Corn Production. *Farmdoc Daily*, 12(29). https://farmdocdaily.illinois.edu/2022/03/international-benchmarks-for-corn-production-6.html

Maya-Cortés, D. C., Figueroa Cárdenas, J. D. D., Garnica-Romo, M. G., Cuevas-Villanueva, R. A., Cortés-Martínez, R., Véles-Medina, J. J., Martínez-Flores, H. E. (2010). Whole-grain corn tortilla prepared using an ecological nixtamalisation process and its impact on the nutritional value. *International Journal of Food Science & Technology*, 45(1), 23–28.

Menchaca-Armenta, M., José Frutos, M., Ramírez-Wong, B., Valero-Cases, E., Muelas-Domingo, R., Quintero-Ramos, A., Isabel Torres-Chávez, P., Carbonell-Barrachina, Á. A., Irene Ledesma-Osuna, A., Nydia Campas-Baypoli, O. (2023). Changes in phytochemical content, bioaccesibility and antioxidant capacity of corn tortillas during simulated in vitro gastrointestinal digestion. *Food Chemistry*, 405, 134223.

Montoya, L. E. H., Iguarán, E. J. C., Ríos, K. C. (2020). Shelf life in dough and corn-derived products: Bibliometric study. *Brazilian Journal of Food Technology*, 23.

Mora-Rochin, S., Gutierrez-Uribe, J. A., Serna-Saldivar, S. O., Sanchez-Pena, P., Reyes-Moreno, C., Milan-Carrillo, J. (2010). Phenolic content and antioxidant activity of tortillas produced from pigmented maize processed by conventional nixtamalization or extrusion cooking. *Journal Of Cereal Science*, 52(3), 502–508.

Neme, K., Mohammed, A. (2017). Mycotoxin occurrence in grains and the role of postharvest management as a mitigation strategies. A review. *Food Control*, 78, 412–425.

Nuss, E. T., Tanumihardjo, S. A. (2010). Maize: A Paramount Staple Crop in the Context of Global Nutrition. *Comprehensive Reviews in Food Science and Food Safety*, 9(4), 417–436.

Palacios-Pola, G., Perales, H., Estrada Lugo, E. I. J., Figueroa-Cárdenas, J. de D. (2022). Nixtamal techniques for different maize races prepared as tortillas and tostadas by women of Chiapas, Mexico. *Journal of Ethnic Foods*, 9(1), 1–10.

Pranckutė, R. (2021). Web of Science (WoS) and Scopus: The Titans of Bibliographic Information in Today's Academic World. Publications 2021, Vol. 9, Page 12, 9(1), 12.

Ramos, P. I. K., Tuaño, A. P. P., Juanico, C. B. (2022). Microbial quality, safety, sensory acceptability, and proximate composition of a fermented nixtamalized maize (Zea mays L.) beverage. *Journal of Cereal Science*, 107.

Rooney, L. W., & Serna-Saldivar, S. O. (2015). Food-Grade Corn Quality for Lime-Cooked Tortillas and Snacks. Tortillas: Wheat Flour and Corn Products. L.W. Rooney, S.O. Serna-Saldivar (Ed.) Tortillas, AACC International Press (pp 227–246). (Chapter 12)

Rouf Shah, T., Prasad, K., Kumar, P. (2016). Maize—A potential source of human nutrition and health: A review. *Cogent Food & Agriculture*, 2(1), 1166995

Santiago-Ramos, D., de Dios Figueroa-Cardenas, J., Maria Mariscal-Moreno, R., Escalante-Aburto, A., Ponce-Garcia, N., Juan Veles-Medina, J. (2018). Physical and chemical changes undergone by pericarp and endosperm during corn nixtamalization-A review. *Journal of Cereal Science*, 81, 108–117.

Serna-Saldivar, S. O. (2021). Understanding the functionality and manufacturing of nixtamalized maize products. *Journal of Cereal Science*, 99, 103205.

Sunico, D. J. A., Rodriguez, F. M., Tuaño, A. P. P., Mopera, L. E., Atienza, L. M., Juanico, C. B. (2021). Physicochemical and Nutritional Properties of Nixtamalized Quality Protein Maize Flour and its Potential as Substitute in Philippine Salt Bread*. Chiang Mai University Journal of Natural Sciences*, 20(2), 1–15.

Sweileh, W. M. (2020). Bibliometric analysis of peer-reviewed literature on food security in the context of climate change from 1980 to 2019. *Agriculture and Food Security*, 9(1), 1–15.

Trejo-Gonzalez, A., Feria-Morales, A., Wild-Altamirano, C. (1982). The Role of Lime in the Alkaline Treatment of Corn for Tortilla Preparation. In R. E. Feeney J. R. Whitaker (Eds.), Advances in Chemistry (Vol. 198, pp. 245–263). American Chemical Society.

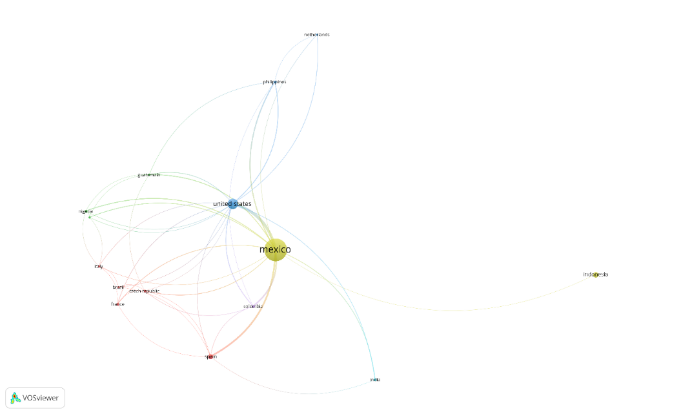
Zaib, G., Cui, H., Hu, X. (2022). Global network mapping research landscape and trends of the endogenous retroviruses: a look through bibliometric analysis. *Rendiconti Lincei*, 33(3), 663–672.

Figures and Tables

Chart, line chart

Description automatically generated

**Figure 1.** Cumulative publications of documents on a year-on-year basis from 2010



**Figure 2.** Citation-country cooperation network on corn nixtamalization

Chart, diagram

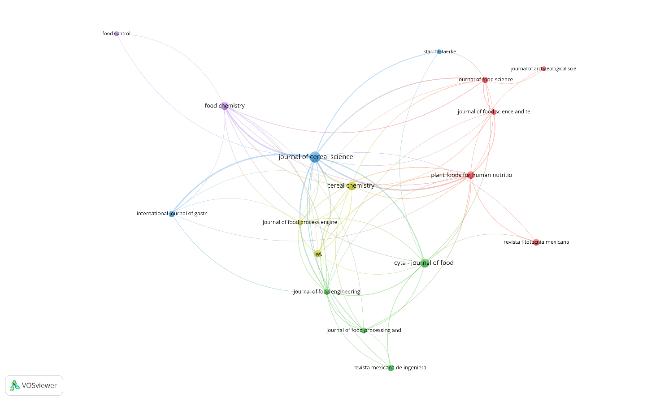
Description automatically generated

**Figure 3.** Citation-author cooperation network on corn nixtamalization

Chart

Description automatically generated

**Figure 4.** Citation-document cooperation network on corn nixtamalization



**Figure 5.** Citation-sources cooperation network on corn nixtamalization

Chart

Description automatically generated with medium confidence

**Figure 6.** Co-occurrence-keywords cooperation network visualization with five as the minimum number of occurrences of a keyword

**Table 1.** The top 15 countries with at least three published documents in corn nixtamalization.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **#** | **Country** | **Quantity** | **Percentage (%)** | **Citation** | **Average citations per document** | **Nominal GDP Rank** | **Total link strength** |
| 1 | Mexico | 265 | 62.06 | 3145 | 11.87 | 15 | 237 |
| 2 | United States | 57 | 13.35 | 1344 | 23.58 | 1 | 152 |
| 3 | Indonesia | 17 | 3.98 | 19 | 1.12 | 17 | 1 |
| 4 | Spain | 13 | 3.04 | 152 | 11.69 | 16 | 46 |
| 5 | India | 6 | 1.41 | 10 | 1.67 | 5 | 11 |
| 6 | Nigeria | 5 | 1.17 | 29 | 5.80 | 31 | 15 |
| 7 | Colombia | 4 | 0.94 | 53 | 13.25 | 44 | 38 |
| 8 | Czech Republic | 4 | 0.94 | 116 | 29.00 | 47 | 12 |
| 9 | France | 4 | 0.94 | 137 | 34.25 | 7 | 11 |
| 10 | Philippines | 4 | 0.94 | 8 | 2.00 | 40 | 29 |
| 11 | Brazil | 3 | 0.70 | 130 | 43.33 | 12 | 5 |
| 12 | Guatemala | 3 | 0.70 | 80 | 26.67 | 70 | 18 |
| 13 | Italy | 3 | 0.70 | 73 | 24.33 | 10 | 8 |
| 14 | Netherlands | 3 | 0.70 | 30 | 10.00 | 19 | 7 |
| 15 | South Africa | 3 | 0.70 | 12 | 4.00 | 39 | 12 |
| 16 | Other 26 countries | 33 | 7.73 | 696 | 21.09 | - | - |

### **Table 2.** Top organizations that published at least three documents

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **#** | **Organization** | **Country** | **Documents** | **Citations** | **Average citations per document** |
| 1 | Centro de Biotecnología FEMSA, Escuela de Ingeniería y Ciencias, Tecnologico de Monterrey | Mexico | 7 | 92 | 13.14 |
| 2 | Ceprobi, Instituto Politécnico Nacional | Mexico | 3 | 27 | 9.00 |
| 3 | Departamento de Biotecnología, Universidad Autónoma Metropolitana-iztapalapa | Mexico | 3 | 22 | 7.33 |
| 4 | Research Centre for Chemistry, Indonesian Institute of Sciences | Indonesia | 3 | 2 | 0.67 |

### **Table 3.** Most productive authors that published more than 8 documents

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **#** | **Author** | **Documents** | **Citations** | **Average citations per document** | **Total link strength** |
| 1 | Ramírez-Wong, B. | 21 | 174 | 8.29 | 185 |
| 2 | Serna-Saldivar, S.O. | 21 | 366 | 17.43 | 120 |
| 3 | Santiago-Ramos, D. | 16 | 247 | 15.44 | 198 |
| 4 | Gaytán-Martínez, M. | 15 | 221 | 14.73 | 79 |
| 5 | Torres-Chávez, P.I. | 15 | 154 | 10.27 | 155 |
| 6 | Quintero-Ramos, A. | 13 | 140 | 10.77 | 118 |
| 7 | Susilowati, A. | 13 | 17 | 1.31 | 10 |
| 8 | Figueroa-Cárdenas, J.D.D. | 12 | 186 | 15.50 | 152 |
| 9 | Maryati, Y. | 12 | 17 | 1.42 | 10 |
| 10 | Alvarez-Ramirez, J. | 11 | 132 | 12.00 | 41 |
| 11 | Gutiérrez-Uribe, J.A. | 11 | 295 | 26.82 | 82 |
| 12 | Vernon-Carter, E.J. | 11 | 132 | 12.00 | 41 |
| 13 | Escalante-Aburto, A. | 10 | 137 | 13.70 | 170 |
| 14 | Gutiérrez-Cortez, E. | 10 | 193 | 19.30 | 68 |
| 15 | Martínez-Bustos, F. | 10 | 83 | 8.30 | 55 |
| 16 | Rodríguez-García, M.E. | 10 | 260 | 26.00 | 68 |
| 17 | Milán-Carrillo, J. | 9 | 245 | 27.22 | 116 |
| 18 | Morales-Sánchez, E. | 9 | 117 | 13.00 | 25 |
| 19 | Reyes-Moreno, C. | 9 | 246 | 27.33 | 119 |
| 20 | Arámbula-Villa, G. | 8 | 81 | 10.13 | 11 |
| 21 | Gutiérrez-Dorado, R. | 8 | 59 | 7.38 | 52 |
| 22 | Palacios-Rojas, N. | 8 | 92 | 11.50 | 30 |
| 23 | Pérez-Carrillo, E. | 8 | 45 | 5.63 | 37 |

**Table 4.** Top documents that have been cited at least 40 times.

|  |  |  |  |
| --- | --- | --- | --- |
| **#** | **Documents** | **Citations** | **Links** |
| 1 | Nuss & Tanumihardjo, 2010 | 338 | 1 |
| 2 | Flores-Morales *et al.*, 2012 | 248 | 0 |
| 3 | Neme & Mohammed, 2017 | 170 | 0 |
| 4 | Gwirtz & Nieves Garcia-Casal, 2014 | 143 | 1 |
| 5 | Mora-Rochin *et al.*, 2010 | 143 | 2 |
| 6 | Grenier *et al.*, 2012 | 87 | 1 |
| 7 | Wang *et al.*, 2015 | 77 | 1 |
| 8 | Suri & Tanumihardjo, 2016 | 71 | 4 |
| 9 | Lopez-Martinez *et al.*, 2011 | 67 | 1 |
| 10 | Rodriguez-Miranda *et al.*, 2011 | 66 | 0 |
| 11 | Torres *et al.*, 2015 | 52 | 0 |
| 12 | Santiago-Ramos, de Dios Figueroa-Cardenas, *et al.*, 2018 | 44 | 1 |
| 13 | Grenier *et al.*, 2014 | 43 | 0 |
| 14 | Cornejo-Villegas *et al.*, 2010 | 43 | 0 |
| 15 | Chávez-Santoscoy *et al.*, 2016 | 42 | 1 |
| 16 | Palacios-Fonseca *et al.*, 2013 | 41 | 0 |
| 17 | Gutierrez-Cortez *et al.*, 2010 | 41 | 1 |

### **Table 5.** Top journal sources with more than five documents on corn nixtamalization

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **#** | **Source** | **Documents** | **Citations** | **Average citations per document** | **Impact factor (2021)** | **Total link strength** |
| 1 | Journal of Cereal Science | 26 | 482 | 18.54 | 4.075 | 87 |
| 2 | Cereal Chemistry | 17 | 123 | 7.24 | 2.534 | 35 |
| 3 | CyTA - Journal of Food | 16 | 207 | 12.94 | 2.478 | 27 |
| 4 | Food Chemistry | 13 | 203 | 15.62 | 9.231 | 34 |
| 5 | LWT - Food Science and Technology | 12 | 253 | 21.08 | 6.056 | 22 |
| 6 | Plant Foods for Human Nutrition | 12 | 227 | 18.92 | 4.124 | 36 |
| 7 | Revista Mexicana de Ingeniera Quimica | 10 | 107 | 10.70 | 2.093 | 8 |
| 8 | Revista Fitotecnia Mexicana | 9 | 67 | 7.44 | 0.418 | 4 |
| 9 | International Journal of Gastronomy and Food Science | 8 | 21 | 2.63 | 3.350 | 17 |
| 10 | Journal of Food Science | 8 | 105 | 13.13 | 3.693 | 19 |
| 11 | Journal of Food Engineering | 7 | 207 | 29.57 | 6.203 | 33 |
| 12 | Journal of Food Processing and Preservation | 7 | 27 | 3.86 | 2.609 | 16 |
| 13 | Journal of Food Process Engineering | 6 | 82 | 13.67 | 2.889 | 22 |
| 14 | Journal of Food Science and Technology | 6 | 56 | 9.33 | 3.117 | 10 |
| 15 | AIP Conference Proceedings | 5 | 3 | 0.60 | 0.400 | 0 |
| 16 | Food Control | 5 | 211 | 42.20 | 6.652 | 2 |
| 17 | IOP Conference Series: Materials Science and Engineering | 5 | 1 | 0.20 | 0.480 | 0 |
| 18 | Journal of Archaeological Science | 5 | 61 | 12.20 | 3.508 | 2 |
| 19 | Starch/Staerke | 5 | 19 | 3.80 | 2.688 | 6 |