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Technology Watch Report for the transformation processes of the epidermis and almond of the indica mangifera – Mango

Luis Alberto Rojas Farfán[1], Luis Felipe Lozada Valencia[2]

luis.rojas@uniminuto.edu, Corporación Universitaria Minuto de Dios – UNIMINUTO (Colombia) [1]

llozadavale@uniminuto.edu.co, Corporación Universitaria Minuto de Dios – UNIMINUTO (Colombia)[2]

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Abstract

The article focuses on the situation of the agricultural sector in Colombia, with a specific focus on mango production and the challenges faced by farmers of the Agropecuaria y Ambiental Santa Rosa Association (ASAGRAT) in the municipality of Tocaima. The purpose of the research is to identify technological alternatives to address losses in agricultural production, particularly through the transformation of mango by-products, such as the skin and the kernel, to generate added value. To achieve this, the methodology of Technological Surveillance (TS) was employed, which involved defining objectives, identifying information sources, data searching, analysis, and validation. The article highlights global trends in research, dynamics of scientific publications related to the transformation of mango by-products, and the main research themes. Finally, the article provides an in-depth view of how research in this field can contribute as input for decision-making by farmers in reducing losses in agricultural production and utilizing mango by-products.

Keywords: Mango, Technological Surveillance, Byproduct, Mango almond, Mango Epidermis, Transformation

1. Introduction

The agricultural sector is one of the most important for the Colombian economy, given the fertility and properties of the soil, the various thermal floors and the variety of crops, which is why it has been considered a megadiverse country, with 111.5 million hectares (ha) of which 38.6% is dedicated to agricultural use. Among the different crops we can highlight mango, because according to the Ministry of Agriculture and Rural Development it is produced in 17 departments of Colombia; Cundinamarca, Tolima and Magdalena represent 68% of the total planted area, making them the main mango producing departments in the Colombian territory.(DNP, 2018)

Specifically in Cundinamarca, the fruit group is the second most representative in food production, reporting during 2020 a total of 261,154 tons compared to 260,300 tons in 2019, obtaining an increase of 854 tons or 0.33%; as far as mangoes are concerned, the department of Tolima is the largest producer with 93,650 hectares, however, in 2019 Cundinamarca ranked first in the national ranking in terms of planted area with 7,260 hectares. (Ministro de Agricultura y Desarrollo Rural, 2020)(SIOC, 2020)

In this same sense, it is worth noting that the advances in mango production have been strengthened in large part thanks to the organization of the mango chain that began its processes in 2010, thus supporting exports, mainly to countries such as Canada and France. Additionally, since November 2021, the United States authorized the import and marketing of Colombian mangoes, thereby expanding the demand of the international market. From the mango as an input to generate ideas and production strategies in terms of the transformation of the product, integrated into production chains, agro-industrial methods and techniques that can serve to increase its value in the national and international market, enhancing the development of regional and national economies. (MINAGRICULTURA, 2021)(Portafolio, 2021)

In the mango production process, some "losses" are identified, understanding this term as that decrease in the volume of food available for consumption generated in the phases of agricultural production, post-harvest and storage and industrial processing, and these are generally generated due to the inefficiency of the production chains. At a general level, losses in agricultural production correspond to 17.8% of world production and of these, 45% correspond to the production of fruits, roots and tubers. According to the Institute of Urban Studies – IEU of the National University of Colombia, in the country the percentage of losses is 40.5% in agricultural production, 20.6% in distribution, 19% in post-harvest and storage and 3.5% in industrial processing, and the regions with the most food losses are the central-eastern zone. made up of Cundinamarca, Norte de Santander and Boyacá, with an equivalent of 27.7% of the losses. (FAO, 2011)(FAO, 2014)(IEU, 2021)

To further understand the situation faced by farmers in terms of loss management, emphasis is placed on the mango taking a specific community, in this case the Municipality of Tocaima-Cundinamarca will be addressed, which is characterized by producing one of the best mangoes nationwide.

Tocaima, located two and a half hours from Bogotá and about forty minutes from Girardot, is known as the "Health City" for its sulfur and thermal springs. According to DANE (2018), it has an estimated population for 2021 of 17,271 people, 66% located in the urban area and the remaining 34% in the rural area. Its first economic activity is agriculture followed by tourism. As far as agricultural production is concerned, it is highlighted that 85% of permanent crops correspond to mangoes. (Tocaima Mayor's Office 2019). There is the Santa Rosa Agricultural and Environmental Association of the municipality of Tocaima -ASAGRAT, made up of 70 small producers from the villages of Santa Rosa, Soleto, Capotes and Verdal, who are mostly older adults; One of the main pillars of the association is the production and marketing of mangoes, thus guaranteeing their income, as well as the economic stability of the families that make them up. ASAGRAT only sells fresh mangoes to intermediaries who visit their farms during the harvest seasons, and when the product exceeds the harvest time, the quality is low, preventing its proper marketing in the market.

This mango is not widely marketed and is usually discarded or donated to inhabitants of the municipality, to this is added the waste of by-products derived from mangoes such as epidermis and almonds that generate an inappropriate impact, both for the economy of its members and that of other farmers and associations that are in the same situation. In this way, there is evidence of a disintegration of the value chain of mango production, lacking good marketing, diversity of products, integration of the youngest community into the production system, as well as an appropriate organizational system in the management of innovation and development of differential products.

2. Background of production systems

Initially, the concept of the production chain should be clarified as the spontaneous relationship between different actors involved in the economic relations and the provision of goods and services from primary production to the final consumer (RedEAmerica, 2016), another concept defines it as the set of economic agents that participate directly in production, then in the transformation and in the transfer to the market of realization. of the same agricultural product. The production chain understood as a production system comprises the relationship and synergy generated by the iteration between the different links or agents, which contribute significantly to production, storage, distribution and marketing until reaching the final consumer. (Bourgeois & Herrera, 1996)

The first writings that contribute to the identification and production of the mango are given in the West, thanks to the botanist Clusius in 1605, however, the scientific name is due to Bontius in 1685 who called it Mangifera Tree, years later Linnaeus called it Mangifera indica (Bajpai, Shukla, & Chaturvedi, 1985). Despite the commercial boom of mango in the sixteenth century, its largest plantings are from the twentieth century, in Darbhanga in Bihar with almost 100,000 trees grafted, thus expanding the quality, variety, characteristics of the product and new cultivation practices.

2.1. Theoretical framework and/or literature review

Since ancient times the mango has been listed as a religious symbol of India, as related by Hindu mythology in the Prajapati (lord of creatures), it is also mentioned that the Amradarika (Amra is the name given to the mango in the Sanskrit language, which means belonging to the people) was offered to Buddha as a place of rest, or in different legends extracted by Proponoe (Galán, 2009). In different parts of Africa, the mango tree is called the tree of words because in its shade the problems of the populations were discussed (Goguey, 1995). Other names awarded are: Mango, Mangot, Manga, Mangou (Infoagro, 2008)

The mango boasts a history that transcends six thousand years, dates back to the Indo-Burmanic region, has been cultivated for more than 4,000 years, in South and Southwest Asia, as mentioned with great frequency in the early Sanskrit literature of India (Bailey 1941, as cited in). Since the sixteenth century it has been gradually distributed throughout the world. It is recorded that its arrival in America is thanks to the Portuguese transporting it to Brazil in the eighteenth century, likewise the Spaniards favored its expansion due to their various voyages of colonization and/or commercialization, they transported in small trees such as on their journeys from the Philippines to Mexico, in the same way, it is mentioned that it was transported to Hawaii in 1809 and to California in 1880. Since then, the mango has been cultivated and naturalized so extensively that its distribution can be considered as pantropical. (GALAN, 2009) (Bernal, y otros, 2009)(Crane & Balerdi, 2019)(frutas-hortalizas, 2019)(Bernal, y otros, 2009)

2.2. Methodology

To develop the methodological process of Technology Watch (VT), the economic and technological intelligence report has been taken as a reference, which established the parameters to structure the VT reports in a simple way, see illustration 1-1:

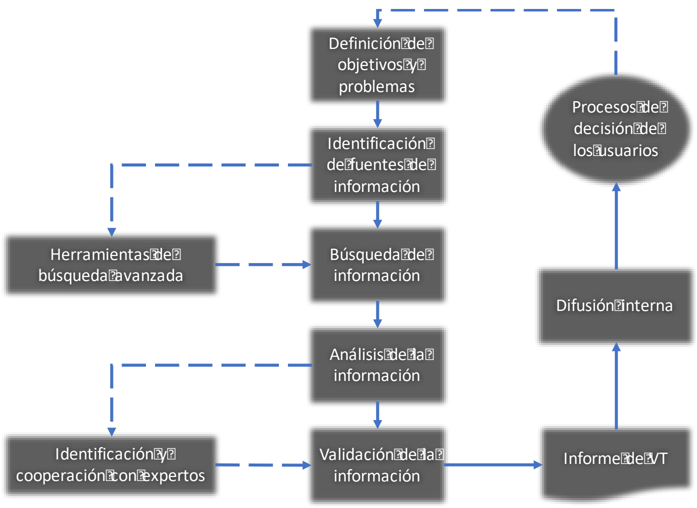

Figure 1-1. Methodological process of technological surveillance. In original language Spanish
Fountain: Fuente especificada no válida.

Step 1. Definition of objectives and problems: In this stage, the objectives were clearly defined and at the same time, the topic to be monitored and its scope were understood through the planning and definition of the main theme and the specific topics.

Step 2. Identification of sources of information: In this step, the criteria for the definition of the topic and subtopics to be addressed were selected, based on the specific interest. The topics to be monitored were prioritized and the descriptors and keywords of the topic and subtopics were defined, carrying out a preliminary review of the topic combining the theme with trends, these keywords were guided by secondary information and by documents focused on the topic addressed.

Step 3. Information search: Accessible sources of information were identified, preferably magazines, metasearch engines, specific web pages, etc. At first, an unstructured search was carried out on the web to refine the topic. Finally, scientific information was consulted and patent databases searched. After conducting the information searches, the information obtained was validated before processing it. For the validation, new queries, new sources of information, new search equations, new subtopics, new objectives, new priority topics, among others, were developed.

Step 4. Analysis of the information: Two types of analysis were limited: statistical analysis and in-depth analysis. The statistical analyses were presented for the institutions, countries, journals, and the most prominent researchers in the topics consulted. He also presented the number of scientific publications, patents, networks, research groups, companies, among others. Among the techniques with which in-depth analyses were carried out and generate intelligence and knowledge for decision-making were scientometrics and the cross-referencing of scientific information and patents.

Step 5. Validation of the information: The results were validated due to the specific rigor of the topic proposed for surveillance.

Step 6. Technology Watch Report: The main product obtained was technology watch, which is the knowledge to support and facilitate decision-making with less risk and anticipation of changes. The final report contains recommendations for action.

Within Table 1-1, the information from steps 1, 2 and 3 was condensed for the surveillance focus of the use of the epidermis and almond of the mangifera indica in value-added production processes through specialized equipment, which summarizes the keywords of the topics to be described and the search equation yielded by the Scopus database. likewise, this information was validated based on the search for secondary information, where both the focus and the search topics were established.

Table 1-1. Search log process transformation of almond and mango epidermis

Central Theme	**Agricultural Sciences**
Focus of surveillance	Use of the epidermis and almond of the indica mangifera
Keywords	Mangifera indica, mango, mangoes, transformation, processing, transforming, manufacturing, manufacture, dried, industry, drying, by-products, byproducts, dry, seed, "mango almond", epidermis, skin.
Search equation	
('TITLE-ABS-KEY ("mangifera indica") OR TITLE-ABS-KEY (mango) OR TITLE-ABS-KEY (mangoes) AND TITLE-ABS-KEY (transformation) OR TITLE-ABS-KEY (processing) OR TITLE-ABS-KEY (transforming) OR TITLE-ABS-KEY (manufacturing) OR TITLE-ABS-KEY (manufacture) OR TITLE-ABS-KEY (dried) OR TITLE-ABS-KEY (industry) OR TITLE-ABS-KEY (drying) OR TITLE-ABS-KEY (by-products) OR TITLE-ABS-KEY (byproducts) OR TITLE-ABS-KEY (dry) AND TITLE-ABS-KEY (seed) OR TITLE-ABS-KEY ("mango almond") OR TITLE-ABS-KEY (epidermis) OR TITLE-ABS-KEY (skin)) AND (EXCLUDE (SUBJAREA , "VETE") OR EXCLUDE (SUBJAREA , "SOCI") OR EXCLUDE (SUBJAREA , "COMP") OR EXCLUDE (SUBJAREA , "PHYS") OR EXCLUDE (SUBJAREA , "MATH") OR EXCLUDE (SUBJAREA , "MULT") OR EXCLUDE (SUBJAREA , "BUSI") OR EXCLUDE (SUBJAREA , "EART") OR EXCLUDE (SUBJAREA , "ECON") OR EXCLUDE (SUBJAREA , "ARTS") OR EXCLUDE (SUBJAREA , "DECI") OR EXCLUDE (SUBJAREA , "HEAL"))	
Results	372 documents (June 2022 cut-off)

Source: Authors.

1.1. Trending in publications

In the exploration of the publications framed in the search equation that allowed to evidence the trend of development of the subject in projects of science, technology and innovation activities ACTI and Innovation and R+D development worldwide, a total of 372 publications were found. The publications made in the period between 1999 and 2022 on the subject matter of this document are presented below, see illustration 1-2.

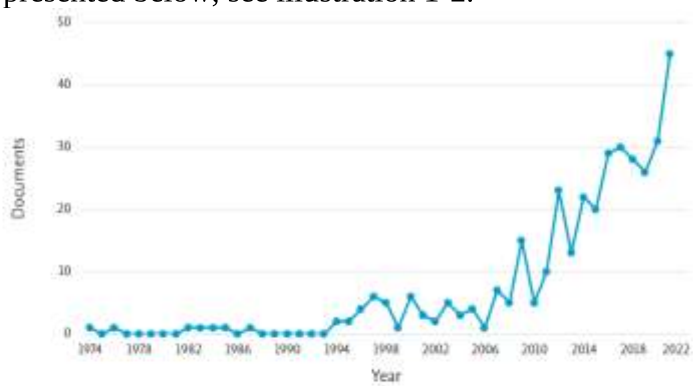

Figure 1-2. Dynamics of scientific publications in the process of transforming almond and mango epidermis. In original language Spanish
Source: Scopus

The ten main publications with the highest number of citations found in scopus (see table 1-2) stand out for their topics on Plants used in cosmetic products, Characterization and quantification of polyphenolic compounds in mango bark, grain, leaves and peel (Mangifera indica L.), Phytochemicals and antioxidant activity of different parts of bambangan (Mangifera pajang) and tarap (Artocarpus odoratissimus) (Aburjai & Natsheh, 2003)(Barreto, y otros, 2008)(Abu Bakar et al., 2009), Quantification of Bioactive Compounds in Pulps and By-Products of Tropical Fruits from Brazil (L. M. R. Da Silva et al., 2014), By-products of Mango (Mangifera indica L.) and its valuable components: a review (Jahurul et al., 2015), By-product of Egyptian mango 1. Compositional quality of mango seed grain (Abdalla et al., 2007), Screening of phenolic compounds in extracts of mango by-products (Mangifera indica L.) using HPLC-ESI-QTOF-MS and multivariate analysis for use as a food ingredient (Dorta et al., 2014), Antioxidant and tyrosinase inhibitory activity of mango seed grain by product (Maisuthisakul & Gordon, 2009), Effect of the grain Magnifera indica as a feed additive on immunity and resistance to Aeromonas hydrophila in fingerlings of Labeo rohita (Sahu et al., 2007) and Reuse of mango by-products: Study of the effect of extraction solvent and temperature on its antioxidant properties (Dorta, Lobo, & González, 2012).

Table 1-2. Ten most cited research on the processing of almonds and mango epidermis

No.	**Title in English**	**Authors**	**Magazine**	**Citation Quantity**	**Year of publication**
1	Plants Used in Cosmetics	Aburjai T., Natsheh F.M.,	Phytotherapy Research	328	2003
2	Characterization and quantitation of polyphenolic compounds in bark, kernel, leaves, and peel of mango (Mangifera indica L.)	Barreto J.C., Trevisan M.T.S., Hull W.E., Erben G., De Brito E.S., Pfundstein B., Würtele G., Spiegelhalder B., Owen R.W.,	Journal of Agricultural and Food Chemistry	312	2008
3	Phytochemicals and antioxidant activity of different parts of bambangan (Mangifera pajang) and tarap (Artocarpus odoratissimus)	Abu Bakar M.F., Mohamed M., Rahmat A., Fry J.,	Food Chemistry	306	2009
4	Quantification of bioactive compounds in pulps and by-products of tropical fruits from Brazil	Da Silva L.M.R., De Figueiredo E.A.T., Ricardo N.M.P.S., Vieira I.G.P., De Figueiredo R.W., Brazil I.M., Gomes C.L.,	Food Chemistry	265	2014
5	Mango (Mangifera indica L.) by-products and their valuable components: A review	Jahurul M.H.A., Zaidul I.S.M., Ghafoor K., Al-Juhaimi F.Y., Nyam K.-L., Norulaini N.A.N., Sahena F., Mohd Omar A.K.,	Food Chemistry	228	2015
6	Egyptian mango by-product 1. Compositional quality of mango seed kernel	Abdalla A.E.M., Darwish S.M., Ayad E.H.E., El-Hamahmy R.M.,	Food Chemistry	164	2007
7	Screening of phenolic compounds in by-product extracts from mangoes (Mangifera indica L.) by HPLC-ESI-QTOF-MS and multivariate analysis for use as a food ingredient	Dorta E., González M., Lobo M.G., Sánchez-Moreno C., de Ancos B.,	Food Research International	147	2014
8	Antioxidant and tyrosinase inhibitory activity of mango seed kernel by product	Maisuthisakul P., Gordon M.H.,	Food Chemistry	141	2009

No.	Title in English	Authors	Magazine	Citation Quantity	Year of publication
9	Effect of Magnifera indica kernel as a feed additive on immunity and resistance to Aeromonas hydrophila in Labeo rohita fingerlings	Sahu S., Das B.K., Pradhan J., Mohapatra B.C., Mishra B.K., Sarangi N.,	Fish and Shellfish Immunology	135	2007
10	Reutilization of mango byproducts: Study of the effect of extraction solvent and temperature on their antioxidant properties	Dorta E., Lobo M.G., Gonzalez M.,	Journal of Food Science	127	2012

Source: Scopus

1.2. Main researchers/ Experts.

Table 1-3 and illustration 1-3 include the researchers with the highest number of publications in the area. Among the authors, authors from China and the United States stand out.

Table 1-3. Ranking of authors with the most publications.

Author	Documents	Work center
Hofman, Peter J	9	Queensland Department of Agriculture and Fisheries, Maroochy Research Facility, Nambour, Australia
Joyce, Daryl C.	6	Queensland Department of Agriculture and Fisheries, Brisbane, Australia
Aguilar, Cristóbal N.	5	Universidad Autónoma de Coahuila, Coahuila, Mexico
Haque Akanda, Md Jahurul	5	University Malaysia Sabah, Kota Kinabalu, Malaysia
Lobarbio, Camila Flor Y.	5	University of San Carlos, Cebu, Philippines
Segura Carretero, A.	5	University of Granada, Granada, Spain
Serna-Cock, Liliana	5	Universidad Nacional de Colombia - Palmira Campus, Palmira, Colombia
Taboada, Evelyn B.	5	University of San Carlos, Cebu, Philippines
Torres-León, Cristian	5	Universidad Autónoma de Coahuila, Coahuila, Mexico
Amin, Muhammad Faisal	4	Shaheed Benazir Bhutto University, Nawabshah, Pakistan

Source: Scopus.

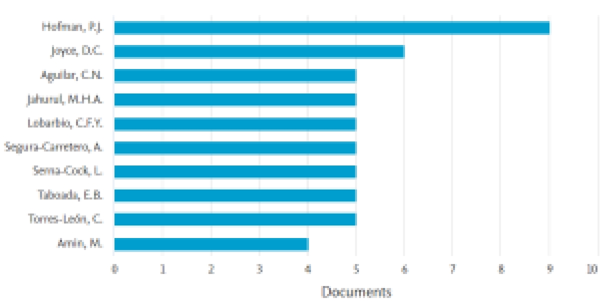

Figure 1-3. Authors with the most publications on the process of transforming almonds and mango epidermis . In original language Spanish
Source: Scopus

1.3. Main research topics on the topics of almond transformation process and mango epidermis.

Once the advanced information search process was carried out within the scopus database, the analysis of the data collected in the Vos viewer software was carried out, where it evidences systematic, organized and interconnected information in the key terms used for research articles or indexed documents. Therefore, it is important to mention that the topics with the greatest coincidence are plant extracts, antioxidants, plant seeds, unclassified drugs, control studies, medicinal plants, bioactive components, mango by-products, food industry, nutritional value, which are evidenced in the density map (see illustration 1-4).

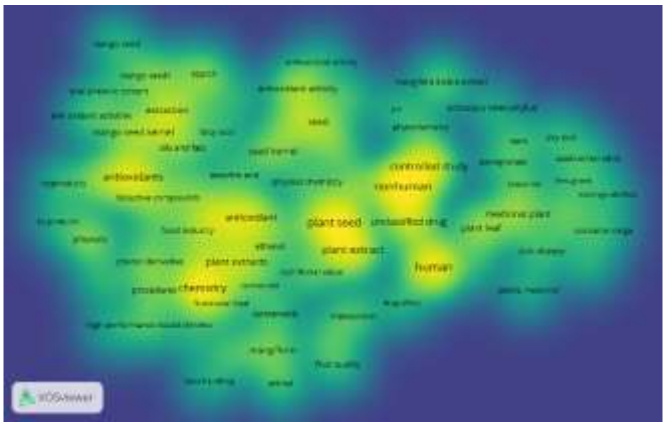

Figure 1-4. Density analysis of the most important topics in the area of almond and mango epidermis processing
Source: Vosviewer with scopus data

The Vos viewer software allows the analysis of the clusters of topics established within the analyzed documents, which is why 4 main focuses are evidenced within the process of transformation of almond and mango epidermis in this technological surveillance (see illustration 1-5). The first focus shows a trend towards research on bioactive compounds, antioxidants, extraction focused on mango by-products (green color), the red focus evidences research in industrial processes, food industry, value and nutritional function of mango, the blue focus evidences the cluster of control studies for the extraction processes of unclassified drugs for human and non-human consumption (animals) and the cluster Amarillo shows the work being done in the area of microbial activities derived from mango by-products such as the seed and epidermis.

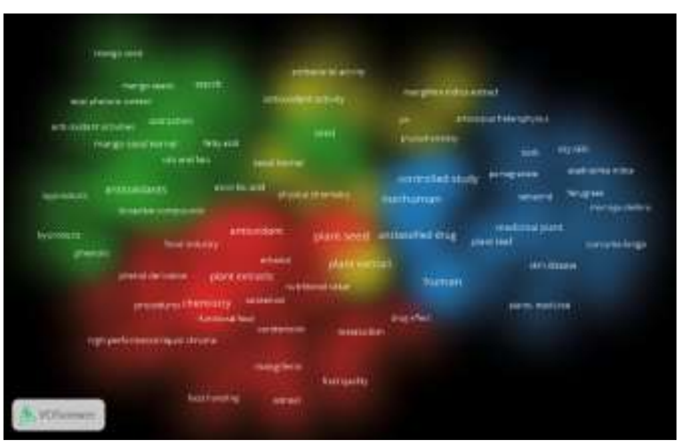

Figure 1-5. Analysis of clusters of the most important topics in the area of almond and mango epidermis processing

Source: Vosviewer with scopus data

Among the research found in the area of almond and mango epidermis processing (see Figure 1-6), the topics that have had the greatest strength are those related to bioactive compounds, antioxidants, extraction focused on mango by-products, industrial processes, food industry, value and nutritional function of mango, control studies for the extraction processes of drugs not classified for human and non-human consumption (animals) and microbial activities derived from mango by-products such as the seed and epidermis, topics that have been developed by the best universities and institutes in the world. Below is a description of some related articles:

From the point of view of the bioactive compounds in mangoes, the authors (A. C. da Silva & Jorge, 2017) determined in their study of tropical fruits from Brazil, that products derived from cashew, papaya, mango, passion fruit (passionflowers) and Suriname cherry showed high levels ($P < 0.05$) of anthocyanins obtained in their pulps, which provide potential applications for nutraceutical supplements, dietary additives and/or pharmaceutical products. Likewise, in the literature review on the bioactive compounds of mango and its different by-products carried out by the authors (Jahurul et al., 2015), highlight that the peel and seed contain high levels of bioactive compounds that have health benefits (i.e., phenolic compounds, carotenoids, vitamin C, and dietary fiber). Mango seed fat has attracted considerable interest from scientists due to its unique physicochemical characteristics, which are similar to those of commercial cocoa butter. The use of mango by-products, such as peels and seeds, has become an important aspect in waste management to contribute to more sustainable production in the food and pharmaceutical industry (Muchiri et al., 2012).
From the identification of antioxidant compounds in mango skin and seed, the authors (Dorta, Lobo, & González, 2012; Dorta, Lobo, & González, 2012; Maisuthisakul & Gordon, 2009; Stangeland et al., 2009) They have carried out studies where they show the efficiency in the extraction and use of antioxidants in the development of the cosmetics, nutraceuticals, pharmaceuticals and animal feed industry.

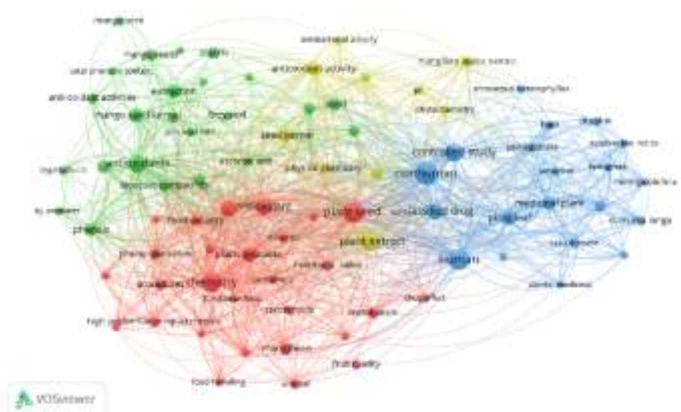

Figure 1-6. Nodal analysis of the interconnection of the most important topics in the area of almond and mango epidermis transformation **Source:** Vosviewer with scopus data

According to the clusters established during this study, the theme of plant and fruit extracts is evidenced (see illustration 1-7), which establishes a direct relationship with the other clusters of process development in the use of mango by-products, for this reason it has been determined that the most relevant research on the extraction of mango by-products has to do with what was developed by the authors (Babbar et al., 2015) who show that during the processing of mango (Mangifera indica

Linn.), by-products are generated in the form of peel and seed, the latter being a significant component, representing about 17-22% of the fruit. The fatty acid profile of the oil extracted from the mango seed is characterized by a balanced composition of saturated and unsaturated fatty acids, with a high content of stearic acid. In addition (Kittiphoom, 2012), has found that mango seed is rich in essential amino acids, especially leucine, valine, and lysine. These findings support its potential as a source of functional food ingredients and bioactive compounds in the food, pharmaceutical and cosmetic industries. It has also been observed that the mango stone resulting from the decortication of the seed can be used as an adsorbent in various applications. However, more research is required to fully explore the potential of these natural resources.

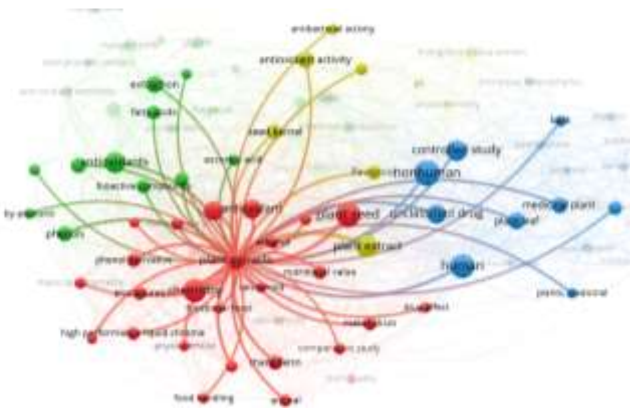

Figure 1-7. Nodal analysis of interconnection between the cluster of plant extracts with antioxidants (emphasis on mango skin and seed)
Source: Vosviewer with scopus data

On the other hand, the composite cluster of industrial chemical processes for mango and the development of antioxidants through phytochemistry studies (see illustrations 1-8), have shown that phenolic compounds are one of the most important biologically active components in M. indica extracts. To extract bioactive molecules, such as phenolic acids, terpenoids, carotenoids and fatty acids, ultrasound-assisted extraction techniques, microwaves and supercritical fluids have been employed. These phytochemicals exhibit antioxidant, antimicrobial, anti-inflammatory, and anticancer activity (Quintana et al., 2021). The structure and bioactivity vary depending on the source (bark, leaves, seeds, flowers or peel) and the extraction method used. In particular, mango seed has proven to be a potentially valuable source of bioactive compounds. Binary mixtures of ethanol and water have been used as efficient solvents for the recovery of phenolic compounds from mango seeds. These ethanolic extracts have shown significant contents of phenolic compounds and antioxidant activities. In addition (Lim et al., 2019) has identified compounds such as gallic acid, caffeic acid, rutin, and penta-O-gallol-β-d-glucose in mango seeds. These findings suggest that mango seed could be harnessed as a valuable source of bioactive compounds with potential therapeutic applications and in functional foods.

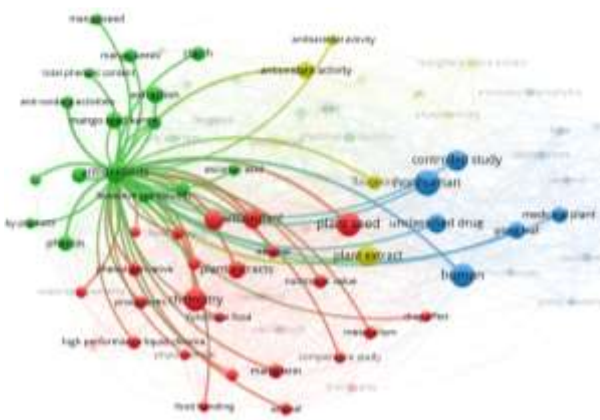

Figure 1-8. Nodal analysis of the interconnection between antioxidant compounds and industrial chemical processes of the mango (skin and seed)
Source: Vosviewer with scopus data

Similarly, for the cluster of industrial processes for the mango seed core (see Figure 1-9), there is evidence of research related to the use of alternative technologies, as well as the authors (Bucklin et al., 2013) where in their book chapter called "Design of grain storage systems" they show that agricultural grains, including cereal grains such as wheat, corn and rice, and oilseeds such as soybeans and canola, must be stored, transported and transported using methods that preserve their quality such as seeds, food or raw materials. Grain quality is maintained by drying the grain to moisture contents suitable for long-term storage on the farm or in commercial facilities. Grain storage facilities must be designed to withstand loads imposed by grain along with other environmental loads. Methods for calculating loads on storage structures and the applicable design codes are described. Grain handling and transport methods and modeling techniques for modeling loads and flow behavior are explained (Holmes et al., 1985; Lai & Aldis, 1978).

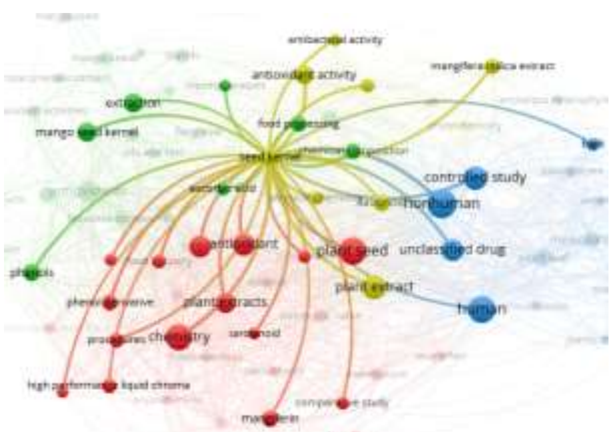

Figure 1-9. Nodal analysis of interconnection between industrial processes of the mango seed core
Source: Vosviewer with scopus data

For the last cluster, which is made up of processes related to drying equipment (see Figure 1-10), research has been found on the design of drying equipment, energy efficiency for drying, development of new technologies for drying cereals, and drying parameters in cereals. The authors were found (Bennett et al., 2007) with his research on drying corn kernels using combustion systems and cogeneration of corn stover, (Atungulu & Sadaka, 2018) with the post-harvest technology for rice drying, (W. Li et al., 2018) with the experiment on the performance of the corn drying system with the combination of heat pipes and heat pump equipment for multi-stage series and (Y. Li et al., 2016) with multiscale and multilayer structural heat and mass transfer modeling and experiment on drying rice in containers.

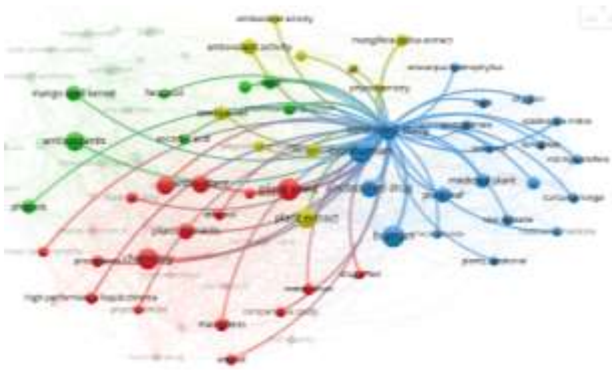

Figure 1-10. Nodal analysis of interconnection between control studies for human and animal consumption of the transformation of mango skin and seeds
Source: Vosviewer with scopus data

For the last cluster, which is made up of the processes related to post-harvest and agricultural processes (see Figure 1-11), research has been found on energy efficiency, types of energy to be used for drying cereals, of which the research carried out by the authors stands out (Raghavan & Sosle, 2014) through the book chapter he mentions how grain has been an important agricultural commodity and a primary source of food for centuries. The current distribution of the world's population has placed strong demands on grain handling technology. Regardless of whether it is international trade or demands within a country, grain needs low moisture levels for safe storage. Drying has always been the most common method of grain preservation. In the days of pre-mechanization of agriculture, enough grain was usually stored by hanging corn ears in barns and attics to meet the needs of a community. As the mechanization of agriculture spread to meet the needs of a population that was growing and urbanizing rapidly, methods for drying large quantities of grain were needed. Grain now travels thousands of miles, either on large grain transport ships or different types of wheeled carriers, and it must arrive at its destination in a high-quality condition. Proper drying of these huge quantities of grain is a prerequisite for storage and final delivery (Huang et al., 2013).

1.4. Main countries where research is carried out on cereal drying process issues

Among the countries with the most publications, based on the search equation carried out and the review of topics addressed in the cereal drying process, the United States stands out with 32 documents, of which the studies carried out on "Design of grain storage systems" by the authors stand out (Bucklin et al., 2013), "Applications of the discrete element method in the modeling of grain postharvest operations" (Boac et al., 2014), China with 23 written documents related to aspects such as "Study on cracking of raw rice during intermittent drying" (Y. B. Li et al., 1998), "Discrete particle simulation of drying food grains in a fluidized bed" (Azmir et al., 2018), Brazil with outstanding studies in "Life Cycle Greenhouse Gas Emissions from Rice Production Systems in Brazil: A Comparison Between Minimum Tillage and Organic Agriculture" by the authors (Nunes et al., 2016), "PAHs in maize kernels subjected to firewood drying" by the authors (de Lima et al., 2017) and Canada with 10 investigations on "Evaluation of fan control strategies for natural air-drying of wheat in the container in Western Canada" by the authors (Singh et al., 2014) and the study of (Epstein et al., 2020) which describes the evaluation of the performance of a non-equilibrium model for the drying of grains at low temperature and simulation of the seasonal operation of the dryer. Finally, Australia, India and Germany with 4 investigations in the field of cereal drying (see illustration 3-11). It should be noted that academic production has a greater impact when the documents produced have a greater number of citations within the databases, which is why in the value/impact index the main country with the best quality research is the United States, with a ratio of 64.3 citations per written document. followed by Canada with a ratio of 54.3.

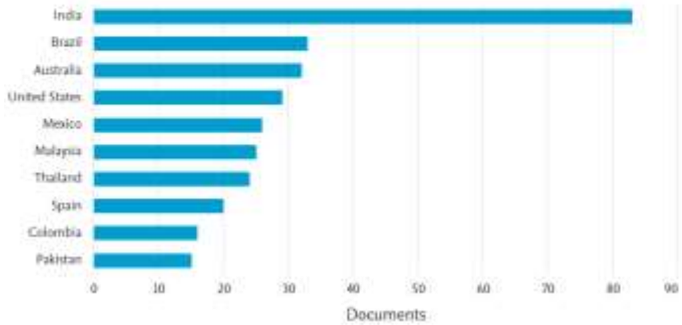

Figure 1-12. Countries with the highest publications in the area of cereal drying process. In original language Spanish
Source: Scopus

2.3. Analysis of results

Bioactive compounds and antioxidants:

The bioactive compounds present in different parts of the mango, such as the peel, the seed, and the pulp, have aroused great interest due to their antioxidant properties and health benefits. These compounds include anthocyanins, phenolic compounds, carotenoids, vitamin C, and dietary fiber.

Anthocyanins are natural pigments responsible for the red, purple, and blue colors in some fruits and vegetables. In mango, various anthocyanins have been identified with antioxidant properties and potential health benefits, such as protection against cardiovascular disease and cancer.

The phenolic compounds present in mango, such as hydroxycinnamic acids and flavonoids, have also shown antioxidant properties. These compounds can help neutralize free radicals and protect the body against oxidative stress, which is associated with various chronic diseases.

Carotenoids, such as beta-carotene and lutein, are pigments responsible for the yellow and orange color in mango. These compounds have antioxidant properties and have been shown to play an important role in eye health and reducing the risk of certain types of cancer.

In addition, mango is a good source of vitamin C, which acts as an antioxidant and helps strengthen the immune system. The dietary fiber present in mango can also have beneficial health effects, such as improving digestion and regulating blood sugar levels.

Extraction of by-products from mango:

Mango by-products, such as peel and seed, have sparked interest in using them to reduce waste and promote more sustainable production in the food and pharmaceutical industry.

The extraction of bioactive compounds from the peel and seed of the mango has been carried out using different techniques, such as ultrasound-assisted extraction, microwave and supercritical fluids. These techniques allow you to efficiently obtain the desired compounds with antioxidant properties and other health benefits.

Oil extracted from mango seed has proven to be a potentially valuable source of bioactive compounds. This oil has been observed to have a balanced fatty acid profile, similar to commercial cocoa butter. This has sparked interest in its use as an alternative in the food and cosmetics industry.

In addition, the stone resulting from the decortication of mango seed has been the subject of research to explore its applications as an adsorbent in various industries. Studies have shown its ability to adsorb pollutants and heavy metals, which could have applications in wastewater treatment and soil decontamination.

Industrial processes and applications:

Industrial processes related to mango have focused on the extraction of bioactive compounds and the production of antioxidants for application in various fields.

The extraction of bioactive compounds from mango has involved different methods, such as maceration, solvent extraction, and membrane technology. These methods make it possible to obtain extracts rich in bioactive compounds with antioxidant, antimicrobial, anti-inflammatory and anticancer properties.

These bioactive compounds from mango have found applications in the food, pharmaceutical, cosmetic and animal feed industries. In the food industry, they have been used as natural additives and in the development of functional foods. In the pharmaceutical industry, its medicinal properties and potential in drug development have been explored. In the cosmetic industry, they have been used in the formulation of skin and hair care products. In addition, in the animal feed industry, its effects on animal health and performance have been studied.

Control studies and microbial activity:

Control studies have been carried out to ensure the quality and safety of the processes for extracting bioactive compounds from mangoes, both for use in human consumption and in animal products.

The microbial activity derived from mango by-products, such as the seed and epidermis, has also been investigated. The antimicrobial effects of these byproducts have been evaluated in both in vitro and in vivo studies. It has been observed that certain compounds present in mangoes can inhibit the growth of pathogenic bacteria and fungi, which could have implications for food preservation and the development of antimicrobial products.

Poultry Feed Development:

Creating chicken or poultry feed by-products from mango waste is a practice that has gained interest in the poultry industry due to its potential to reduce feed waste and provide an additional source of nutrients for livestock. This strategy takes advantage of mango by-products, such as the peel and pulp unfit for human consumption, and transforms them into valuable ingredients in animal feed.

Mango is a tropical fruit rich in nutrients, such as carbohydrates, dietary fiber, vitamins, and minerals. However, during the production and processing of mangoes, large amounts of waste are generated that, if not used properly, could represent an environmental problem. Creating poultry feed by-products from this waste offers a sustainable solution by turning it into a valuable resource.

To obtain chicken feed by-products from mango waste, different processes can be followed. One of these is the drying and grinding of the discarded peel and pulp, resulting in the obtaining of a mango powder or flour. This meal can be used as an ingredient in the formulation of poultry feed, providing additional nutrients, such as fiber, vitamins, and minerals.

Another approach is the fermentation of mango waste to produce food by-products. Through fermentation, the sugars present in the pulp and peel are converted into more digestible and bioactive compounds, which improves their nutritional value. These fermented by-products can be used in animal feed, either as part of the daily ration or as a supplement.

In addition to providing additional nutrients, poultry feed by-products derived from mango may also have benefits for poultry health and performance. Some studies have shown that the inclusion of these by-products in the diet of birds can have positive effects on gut health, nutrient digestibility, and immune response.

Importantly, the creation of poultry feed by-products from mango waste must be carried out following the regulations and standards established for animal feed. Quality and food safety analyses should be carried out to ensure that these by-products meet the required standards and do not pose a risk to the health of birds or to the end consumers of poultry products.

In conclusion, creating chicken or poultry feed by-products from mango waste is a practice that takes advantage of available resources and reduces food waste. These by-products offer an additional source of nutrients for birds, improving their diet and potentially benefiting their health and performance. However, it is essential to follow up on animal feed regulations and standards to ensure the quality and safety of the poultry products obtained.

Conclusions

The agricultural sector in Colombia, especially in the department of Cundinamarca, plays a significant role in the national economy. The diversity of crops, soil fertility and different thermal floors contribute to making the country a megadiverse region in agricultural terms. Mango is one of the outstanding crops in the country, with Cundinamarca, Tolima and Magdalena as the main producing departments.

The strengthening of the mango production chain has boosted its growth and exports, mainly to countries such as Canada, France and, more recently, the United States. These advances in marketing and the expansion of international demand have boosted the development of regional and national economies, generating opportunities for the improvement of agro-industrial techniques and integration into production chains.

Despite advances in mango production, significant losses are identified along the value chain, from agricultural production to industrial processing. In Colombia, losses in agricultural production represent 40.5%, highlighting the regions of Cundinamarca, Norte de Santander and Boyacá as the most affected. These losses pose a challenge for farmers, who face difficulties in efficiently managing produce, distribution and storage.

Mango is a widely grown and consumed fruit globally due to its pleasant taste and nutritional properties. This tropical fruit is an excellent source of bioactive compounds, such as polyphenols, carotenoids, vitamin C, and dietary fiber, which contribute to its nutritional value and potential benefits for human health. The polyphenols present in mango, such as mangiferins and catechins, have been associated with antioxidant and anti-inflammatory properties. In addition, the carotenoids present in mango, such as beta-carotene and lutein, are precursors to vitamin A and have been shown to have beneficial effects on eye health. The dietary fiber present in mango also plays an important role in digestive health and can help regulate blood glucose and cholesterol levels.

The mango production chain involves a series of stages, from primary production in the crops to the marketing of the final product. During this process, it is essential to ensure good agricultural practices to guarantee the quality and food safety of mangoes. This includes the proper use of fertilizers and pesticides, pest and disease control, the choice of resistant varieties adapted to local conditions, and the implementation of efficient irrigation techniques. In addition, it is important to carry out proper harvesting and handling of the mango to avoid physical and microbiological damage. The quality of the mango is also influenced by the storage and transport conditions, where adequate temperatures must be maintained and exposure to factors that can accelerate its ripening or deterioration must be avoided.

Scientific research has revealed mango's potential as a source of bioactive compounds with antioxidant, anti-inflammatory, antimicrobial, and anticancer properties. These compounds can be used in the formulation of nutraceutical and pharmaceutical products, as well as in the cosmetics industry. Studies have shown that the polyphenols present in mango can help prevent oxidative stress and reduce inflammation in the body, which has been linked to the prevention of chronic diseases such as cardiovascular disease, diabetes, and certain types of cancer. In addition, mango extracts have shown antimicrobial activity against different types of bacteria and fungi, suggesting their potential use in the food industry as natural preservatives. In the cosmetic field, the compounds present in mango can contribute to the protection of the skin against damage caused by free radicals and ultraviolet radiation, as well as to the improvement of the appearance and health of the skin.

The use of mango by-products, such as the peel and seed, has aroused increasing interest due to their content of bioactive compounds. Efficient extraction techniques, such as ultrasound-assisted extraction and supercritical fluid extraction, have been developed to obtain and recover these compounds with high nutritional and functional value. The peel of the mango contains compounds such as mangiferins and catechins, which have been shown to have antioxidant and anti-inflammatory properties. The mango seed, on the other hand, is rich in phenolic compounds and flavonoids, which have been found to have antidiabetic, lipid-lowering and anticancer properties. These advanced extraction techniques allow for high-quality, high-purity extracts, which can be used in the formulation of dietary supplements, functional foods, or pharmaceuticals.

The valorisation of mango by-products not only makes it possible to make the most of resources and reduce waste, but also has a positive impact on the environmental and economic sustainability of the industry. The reuse of these by-products in the manufacture of food, feed, pharmaceuticals and cosmetics promotes a circular economy and contributes to the reduction of waste. By transforming mango by-products into value-added products, a more complete value chain is created and negative impacts on the environment are reduced. In addition, the valorization of mango by-products can generate new business and employment opportunities, boosting economic development in the producing regions.

Advances in processing and preservation technology have improved the quality and shelf life of mangoes and their derivatives. Methods such as minimal processing, dehydration, and active and modified packaging technology have made it possible to expand the reach of mango products in the market, both in fresh and processed form. Minimal processing, which involves cleaning, cutting and packing the mango under hygienic conditions, allows us to offer a ready-to-eat fruit that retains its quality and freshness for longer. Dehydration, on the other hand, makes it possible to obtain mango products such as chips, pieces or powder, which have a longer shelf life and can be used in the production of food and beverages. In addition, active and modified packaging technology helps extend the shelf life of fresh mango by controlling ripening and reducing oxidation and microbial growth.

Research and development in the field of mango continues to generate new knowledge about its chemical composition, functional properties and industrial applications. These advances offer opportunities for the creation of new products and the strengthening of the competitiveness of the mango industry at a global level. Collaboration between researchers, growers and companies in the sector is essential to further explore the potential of mango, develop new varieties, improve production and processing techniques, and expand the spectrum of applications. In addition, it is important to encourage knowledge transfer and training in the sector, as well as to establish regulations and quality standards that promote excellence and trust in mango products

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