ORIGINAL ARTICLE

BIBLIOMETRIC INDICATORS OF PERUVIAN SCIENTIFIC OUTPUT ON MEDICINAL PLANTS

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ABSTRACT

Objective: To describe the scientific output on medicinal plants published between 2000 and 2019 with at least one author with Peruvian affiliation. **Materials and methods:** A bibliometric study was carried out by conducting a systematic search in the Scopus database, from which original articles or short communications on medicinal plants that had at least one author with Peruvian institutional affiliation were selected. The characteristics of the publications, institutions, countries and authors who participated in this research are described. The ratio of international collaboration, the transience index, and the institutional and co-authorship collaboration networks were calculated. **Results:** A total of 200 original articles published in 83 journals were included. The quantity of articles showed an increasing, though irregular trend during the studied period. The most productive institution was the Universidad Nacional Mayor de San Marcos, and the journal in which most of the articles were published was the Journal of Ethnopharmacology. Authorship and institutional collaboration networks showed the influence of international collaboration in these publications (53.0%). **Conclusions:** Peruvian scientific output on medicinal plants shows an increasing trend, observed mainly in academic university settings. The articles are published on high-impact journals, due in part to the high level of international cooperation.

Keywords: Information Science; Plants, Medicinal; Bibliometrics; Knowledge Discovery; Publishing; International Cooperation; Complementary Therapies; Journal Article; Health Communication; Databases, Bibliographic (Source: MeSH NLM).

INTRODUCTION

Since recent times, humans have used medicinal plants as a for therapeutic purposes, and knowledge about their properties is passed on from generation to generation [1,2]. With industrialization, medicinal plants were used as an input to isolate compounds with biological activity to develop drugs and treat various diseases; these procedures were possible thanks to the application and generation of knowledge through the scientific method [3].

In recent years, the use of medicinal plants has increased worldwide, representing a market growth from 60 billion dollars in 2003 to nearly 80 billion dollars in 2012 [4,5]. Peru is a country with a great wealth and diversity of medicinal plants. Peruvian population is known to use at least 5,000 different species of plants in activities such as food, construction, crafts and ornaments, and for their therapeutic or toxic properties [6]. There is evidence that their use is widespread in the population, and even its consumption takes place well before going to the health services [7,8].

Pamo-Reyna found 45 investigations on medicinal plants' properties published in Peruvian medical journals in the period 2004-2008 [9]. However, the context for promoting scientific research in our country has changed dramatically. For example, from the legal point of view, principles and measures have been applied, such as the Law that promotes scientific research, technological development and technological innovation (Ley 30309), or the new University Law (Ley 30220). In this sense, there are local studies that have reported the positive impact on national scientific production in all fields of knowledge [10], but the situation

in specific areas, such as the use of medicinal plants, is still unknown.

Bibliometric studies help to determine the impact of scientific output in a given area of knowledge and, through the study of collaborative networks, visualize the dynamics of production, analyzing authors, institutions and contributing countries [11]. There are studies that describe the scientific output on medicinal plants in international contexts [12,13], or their use to treat diverse pathologies [14]; however, in Peru there are few precedents that describe the dynamics of research in this area. Therefore, the objective of the study is to describe the scientific output on medicinal plants with at least one author with Peruvian affiliation, published between 2000 and 2019 in journals indexed in Scopus.

MATERIALS AND METHODS

Study design

We conducted a bibliometric study using Scopus. This database was created in 2004 and contains the abstracts and citations of academic publications from peer-reviewed journals, which go through a rigorous selection process, which ensures the quality of the scientific information provided [15].

Population and sample

A systematic search for information was carried out on Scopus. This study included original articles or short communications (or similar denominations) on the properties of plant species recognized as "medicinal" in management documents of the Peruvian health systems; these publications had at least one author with a Peruvian institutional affiliation (regardless of the author's position), published between January 1, 2000 and December 31, 2019. For this purpose, the Floristic Catalogue of Peruvian Medicinal Plants, issued by the Instituto Nacional de Salud and the National Petition for Products, Resources and Related Therapeutic Inputs for Use in Complementary Medicine of the Social Health Insurance (EsSalud) were considered. These documents were useful to make a list of a list of Peruvian medicinal plants (Supplementary material 1), due to the inconveniences to find information on medicinal plants [16].

Finally, the search terms were chosen: *"plant extracts"* OR *"medicinal plants"* OR *"plants, medicinal"* OR *"phytotherapy"* OR *"medicinal herbs"* OR *"phytomedicine"* (Supplementary material 2).

Studies with designs that analyze the process of plant drug development with a traditional perspective [17] were included, either in the discovery phase (ethnobotanical, observational and phytochemical studies) or in the development phase (preclinical studies [*in vivo* and *in vitro*] and clinical trials).

KEY MESSAGES

Motivation for the study: There is little information about the current state of scientific output on medicinal plants produced by Peruvian authors and institutions.

Main findings: The Peruvian scientific output on medicinal plants has a growing trend; besides, international authors and institutions participated in more than half of the articles published, which shows a strong impact, reflected in the number of citations.

Implications: This analysis states the importance of scientific output on medicinal plants and helps to establish it as a research priority in order to obtain funding opportunities.

Studies in which synthetic substances based on components of plant species were used. Studies on physical properties or cultivation aspects, narrative reviews, systematic reviews, book chapters, clinical practice guidelines or case reports were excluded.

Study variables

The information collected from the selected articles was about the year of publication, language of publication (English, Spanish or Portuguese), areas of knowledge according to the Scopus classification (pharmacology, medicine, biochemistry/molecular biology, chemistry, immunology and microbiology, health professions, social sciences, etc.), Peruvian institutions that participated in the research (frequency, H index, average number of citations per document), as well as research designs (ethnobotanical, observational, phytochemical, preclinical and clinical studies). Articles were manually classified as per their design. Additionally, the characteristics of the most productive institutions (more than five published articles), the number of accumulated citations and the citations per publication were described.

Subsequently, we evaluated institutional collaboration networks and some associated bibliometric indicators: percentage of international collaboration, proportion of Peruvian authors in collaborative publications, frequent-collaboration countries, and association between the number of citations and the presence of international collaboration.

Likewise, the number of authors for each study was determined and the characteristics of the most productive authors (with more than ten publications), their filiations and H indexes were presented. As a bibliometric indicator, the tran-

sience index was calculated, defined as the proportion of authors who published only one article during the study period.

Finally, we identified the journals in which these studies were published, their country, H index, Scopus quartile, citations per document and percentage of international cooperation. This information was obtained from the Scimago Journal & Country Rank website (https://www.scimagojr.com/).

Database construction

The results of the systematic search went through a quality control process, where we verified that the records met the selection criteria, then saved the data in a Scopus list and exported it as .csv and .ris files.

We exported the .ris file to Mendeley Desktop version 1.19.4 ® (2008-2019 Mendeley Ltd.), where the authors' writing was standardized and possible duplications were checked. Then, we analyzed the resulting file and used the BibExcel ® program, version 2016-02-20, to create files with extension .net and .vec; which were used to make the collaboration networks graphics with the program Gephi 0.9.2. ® (Gephi contributors, 2008-2017).

Statistical analysis

The .xlsl file was imported into the STATA v.13.0 program (College Station, TX: StataCorp LP. 2013 ®), from which we obtained absolute frequencies, relative frequencies (percentages) and summary measurements (mean and standard deviation or median and interquartile range). We evaluated the association between the number of citations and the presence of international cooperation with the Mann-Whitney U test, and considered a value of $p < 0.05$ as statistically significant. The figures and tables were elaborated with the program Microsoft Excel ® 2019.

Ethical aspects

Scopus was accessed by using an institutional license (Consejo Nacional de Ciencia y Tecnología), but it was not necessary to access the full versions of the articles included in this analysis. The ethical considerations of the World Medical Association's health and biobanking databases were followed [18].

RESULTS

Production indicators

The search strategy retrieved 300 articles, of which 200 were included. Exclusions: the objective of 35 studies was other than evaluating the properties of medicinal plants; 31 arti-

cles evaluated the physicochemical and other properties related to the cultivation of the plants; 10 articles did not have Peruvian affiliation; 10 articles used synthetic derivatives. Additionally, 2 book chapters, 2 systematic reviews, 7 narrative reviews, 1 clinical practice guide and 2 case reports were found.

Regarding the areas of knowledge, most of the publications covered pharmacology and toxicology (27.0%), medicine (22.7%), biological sciences/agriculture (17.4%), and biochemistry (13.4%). Preclinical *in vivo* studies (in animals) represented 29.5% of the designs found, followed by preclinical *in vitro* studies (25.5%). Additionally, 48 studies (24.0%) had the objective of detecting phytochemical compounds and 15 publications (7.5%) were the product of transversal observational studies that evaluated the use of medicinal plants in different populations. Ethnobotanical studies was the main topic in 11 studies (5.5%) and only 1 study with a qualitative design was found. 14 clinical studies were conducted in humans, 9 were pre-post studies (4.5%) and 5 were randomized clinical trials (2.5%).

The articles included were published in 83 journals. A sixth-order polynomial trend was observed in publications between 2000 and 2019 (R2=0.706), with an average annual growth rate of 18.6%. This rate was negative in the years 2003, 2005, 2008, 2010, 2012, 2014, and 2018 (Figure 1). Most of the publications (73.5%) were in English, only 51 (25.5%) in Spanish, and 2 (0.1%) in Portuguese.

The most cited article was "Antimicrobial activity of selected Peruvian medicinal plants" by Rojas *et al.,* published in 2003 in the *Journal of Ethnopharmacology*, with 179 citations. This journal had the most articles published (15.5%), followed by the *Revista Peruana de Biología* (6.5%) and the *Revista Peruana de Medicina Experimental y Salud Pública* (6.0%) (Table 1).

Collaboration indicators

In this study, 237 institutions were found as affiliations of the retrieved articles, 79 of them were Peruvian (33.3%). The Universidad Nacional Mayor de San Marcos (UNMSM) was the institution with the highest production, with 54 articles, followed by the Universidad Peruana Cayetano Heredia (UPCH) with 52 articles and the Universidad Agraria La Molina (UNALM) with 17 articles; although these last two institutions had a higher average of citations per publication than the UNMSM (Table 2).

International cooperation was found in 53.0% of the articles, with 29 countries overall, including the United States
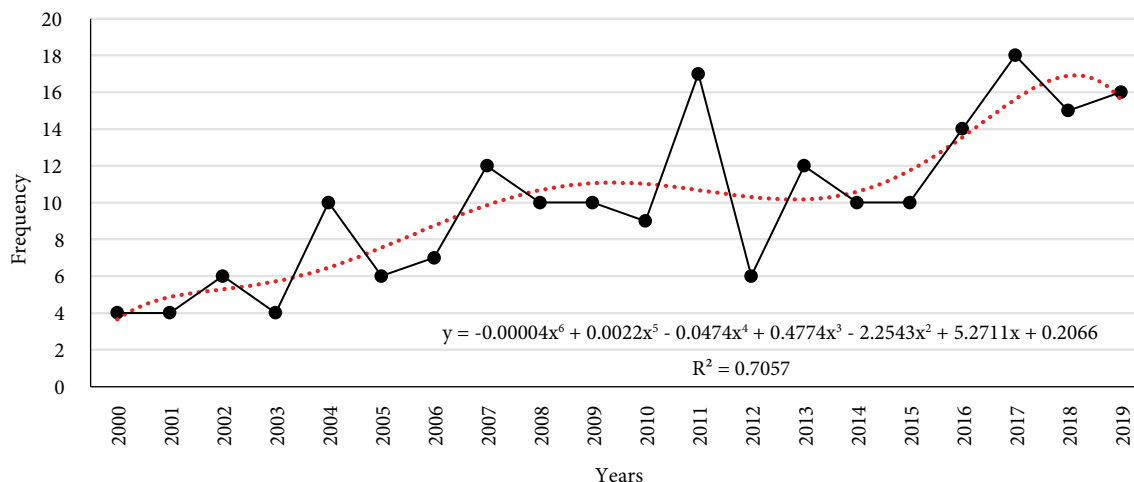
$$y = -0.00004x^6 + 0.0022x^5 - 0.0474x^4 + 0.4774x^3 - 2.2543x^2 + 5.2711x + 0.2066$$

$$R^2 = 0.7057$$

Figure 1. Publication trend of original / short original articles on medicinal plants by authors with at least one Peruvian affiliation (2000-2019).

(26 publications), France (19 publications) and Spain (15 publications). In the collaborative articles, the average percentage of Peruvian authors participation was 87.5% (7.1%-87.5%). In 28 (26.4%) collaborative articles the first author had Peruvian affiliation and in 19 (17.9%) he was a corresponding author. The articles that had international cooperation had a median of 17 (IQR: 33) citations, while those with only Peruvian authors were cited 5 (IQR: 15) times; the difference found was significant (p < 0.001).

We found 809 authors, of which only 8 had an output greater than or equal to 10 publications. Among the most productive authors, we found Gustavo Francisco Gonzáles with 24 pu-

blications (H index of 36), Manuel Gasco with 13 publications (H index of 21) and Rosario Rojas Durán with 13 publications (H index of 16). Four authors were affiliated with the UPCH, 2 had French affiliation and 2 were from the UNMSM (Table 3). Among the researchers, 632 were 1-article-authors, which provided a transience index of 78.0%.

Collaboration networks

When assessing the levels of inter-institutional collaboration, a collaborative network led by the UNMSM, the UPCH and supported by French institutions was found. Both Peruvian institutions also collaborate with other smaller networks led by the Universidad Nacional de la Amazonía Peruana

Table 1. The 10 journals that most frequently published articles on medicinal plants with at least one Peruvian affiliation (2000-2019).9)

Journal	Country	n	%	H Index	Quartile (2018)	Cites per document	International collaboration
Journal of Ethnopharmacology	Netherlands	31	15.5	170	Q1	3.5	28.5
Revista Peruana de Biología	Peru	13	6.5	18	Q3	0.3	21.9
Revista Peruana de Medicina Experimental y Salud Pública	Peru	12	6.0	16	Q3	0.6	14.6
Journal of Natural Products	USA	7	3.5	124	Q1	4.4	50.0
Food Chemistry	Netherlands	7	3.5	221	Q1	5.7	27.3
Boletín Latinoamericano y del Caribe de Plantas Medicinales y Aromáticas	Cuba	6	3.0	16	Q3	0.5	14.3
Andrología	United Kingdom	6	3.0	52	Q2	1.8	18.2
Revista de Gastroenterología del Perú	Peru	6	3.0	14	Q4	0.3	34.7
Planta Medica	Germany	4	2.0	103	Q1	2.6	31.8
Toxicology Mechanisms and Methods	United Kingdom	4	2.0	35	Q2	2.8	23.7

Source: Scimago SJR

Table 2. Characteristics of the Peruvian institutions with the highest scientific research output on medicinal plants (2009-2019).

Institution	Number of publications	Number of authors	Number of citations	Cites per publication
Universidad Nacional Mayor de San Marcos	54	94	737	13.6
Universidad Peruana Cayetano Heredia	52	80	1,701	32.7
Universidad Nacional Agraria La Molina	17	24	531	31.2
Universidad Nacional San Luis Gonzaga de Ica	12	5	110	9.2
Universidad Nacional de la Amazonía Peruana	12	15	198	16.2
Universidad Nacional de Trujillo	11	20	37	3.4
Pontificia Universidad Católica del Perú	10	10	378	37.8
Universidad Nacional Agraria de la Selva	6	3	234	39.0
Instituto de Investigaciones de la Amazonía Peruana	5	4	178	29.7
Universidad Nacional de Ingeniería	5	5	15	NA
Universidad Nacional de San Agustín de Arequipa	5	11	20	4.0
Universidad Peruana de Ciencias Aplicadas	5	9	39	7.8
Instituto Nacional de Medicina Tradicional	5	2	174	34.8

Source: Scopus

(UNAP), the Universidad Nacional San Luis Gonzaga and the Pontificia Universidad Católica del Perú (Figure 2).

When evaluating the collaboration networks among authors, we found a close collaboration among three networks led by Rosario Rojas Durán, Michel Sauvain and Gustavo Francisco Gonzáles; all researchers affiliated to UPCH. On the other hand, we found a network led by Oscar Herrera Calderon and Jorge Arroyo Acevedo, researchers affiliated to the UNMSM. Up to 10 isolated collaborative networks were found, with groups of researchers who have published at least three articles on the subject of study (Figure 3).

DISCUSSION

Scientific production in medicinal plants by authors with at least one Peruvian affiliation has shown a growing, though irregular, trend. This tendency is not different to the one found in other studies; for example, Wai Kan Yeung *et al.* carried out an analysis of the publications linked to ethnopharmacology indexed in World of Science from 1958 to 2018, in which they showed an increasing tendency of publications since 2006 [13]. However, the results are not similar to those obtained by studies from other countries such as Cuba, in which we observe a constant production since 2004 [19].

Institutions involved in the publication of these articles are usually academic, which shows the great importance of universities as knowledge generators in the use of medicinal plants. These data reinforce the findings made by Córdova Rengifo, who proposes a model about research interest on medicinal plants in universities, based on the observation of their use in the general population, with the motivation of validating the

Table 3. The 10 authors with the largest number of original articles on medicinal plants with at least one Peruvian affiliation.

| Autor	Articles	Filiation	Country	H Index
Gustavo Francisco González	23	Universidad Peruana Cayetano Heredia	Peru	36
Manuel Gasco	13	Universidad Peruana Cayetano Heredia	Peru	21
Rosario Rojas Durán	13	Universidad Peruana Cayetano Heredia	Peru	16
Genieve Bourdy	12	IRD Institut de Recherche pour le Developpement	France	12
Jorge Luis Arroyo-Acevedo	12	Universidad Nacional Mayor de San Marcos	Peru	6
Abraham Vaisberg	10	Universidad Peruana Cayetano Heredia	Peru	22
Michel Sauvain	10	IRD Institut de Recherche pour le Developpement	France	26
Oscar Herrera Calderón	10	Universidad Nacional Mayor de San Marcos / Universidad Nacional San Luis Gonzaga	Peru	7

Source: Scopus
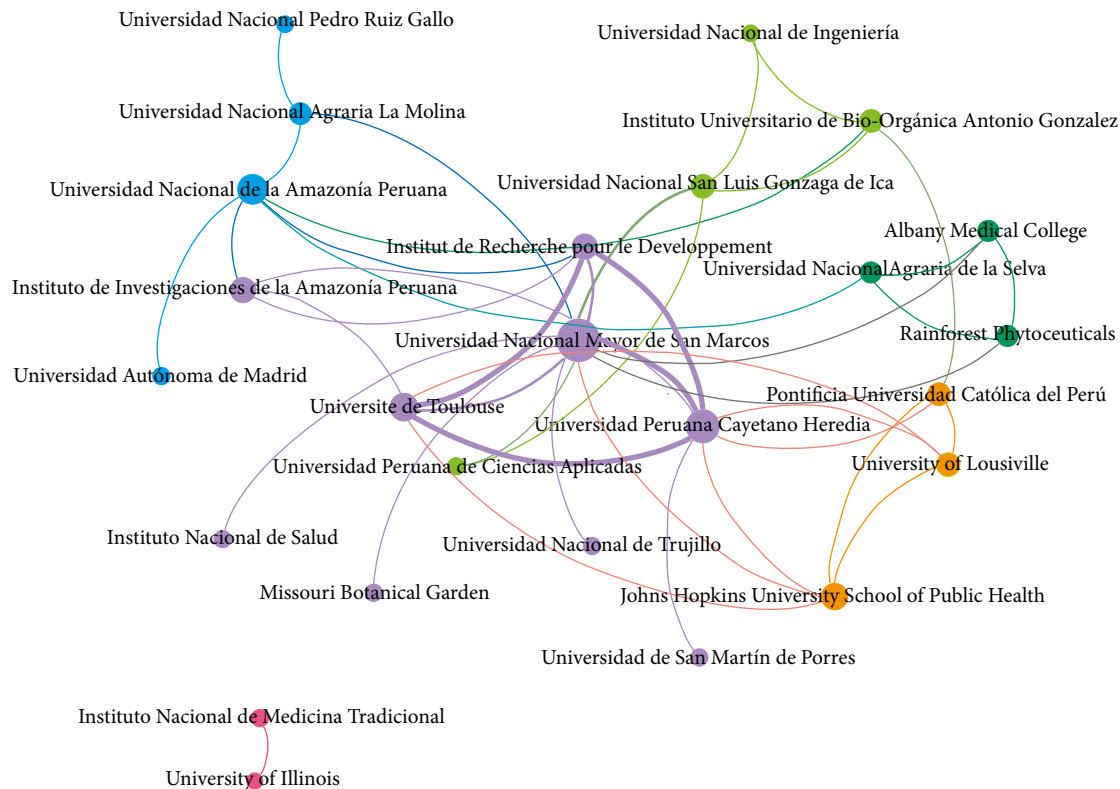
Figure 2. Inter-institutional collaborative networks in scientific publications on medicinal plants with at least one Peruvian affiliation (2000-2019). The size of the node is proportional to the publication frequency, and the thickness of the thread, to the intensity of the collaboration.

Source: Gephi ®

medicinal properties attributed to them from the scientific point of view [20]. Likewise, the consensus document of a group of experts on medicinal plants, promoted by the Pan American Health Organization, mentions that, although there is a wide variety of research lines in universities, the limitations in scientific research at this level are summarized as the lack of accredited laboratories to carry out specialized studies and the little innovation culture that does not encourage the generation of national patents [21].

These deficiencies may partially explain the high proportion of international collaboration found and the resulting inter-institutional collaborative networks, led by UNMSM, UPCH and UNAP, and supported by French and American institutions. In this regard, it should be remembered that the World Health Organization encourages the formation of research networks on medicinal plants [22], while the most developed traditional medical systems, such as traditional Chinese medicine or AYUSH (Ayurveda, Yoga, Unani, Siddha and Homeopathy) see international collaboration as an effective method for disseminating and using their natural resources in other populations [23].

Although it is observed that the greatest production of articles comes from Peruvian public universities, such as UNMSM

or UNALM, the highest number of citations per publication was found in the articles produced by UPCH (private university) researchers. Likewise, articles with international cooperation were more cited in comparison to those that only included Peruvian authors, this coincides with the high proportion of international cooperation found. These characteristics, associated to a transience index higher than 60%, show a field of knowledge in which scientific information is not yet totally consolidated [24]. Finally, the evident interpretation for researchers in these areas is that international cooperation will bring them publications of greater impact.

Additionally, it is highlighted that within the journals with the highest output of articles, there is a large proportion of publications that are in Scopus' first quartile (Q1). *The Journal of Ethnopharmacology* was found to be the most used diffusion media by the researchers of the area. This journal is one of the few specialized in the publication of interdisciplinary research on ethnopharmacology, ethnobotany and ethnochemistry with the objective of documenting and preserving this knowledge [25]. Subsequently, the journals preferred by researchers to publish their findings were *Revista Peruana de Biología* of the UNMSM and *Revista Peruana de Medicina Ex-*
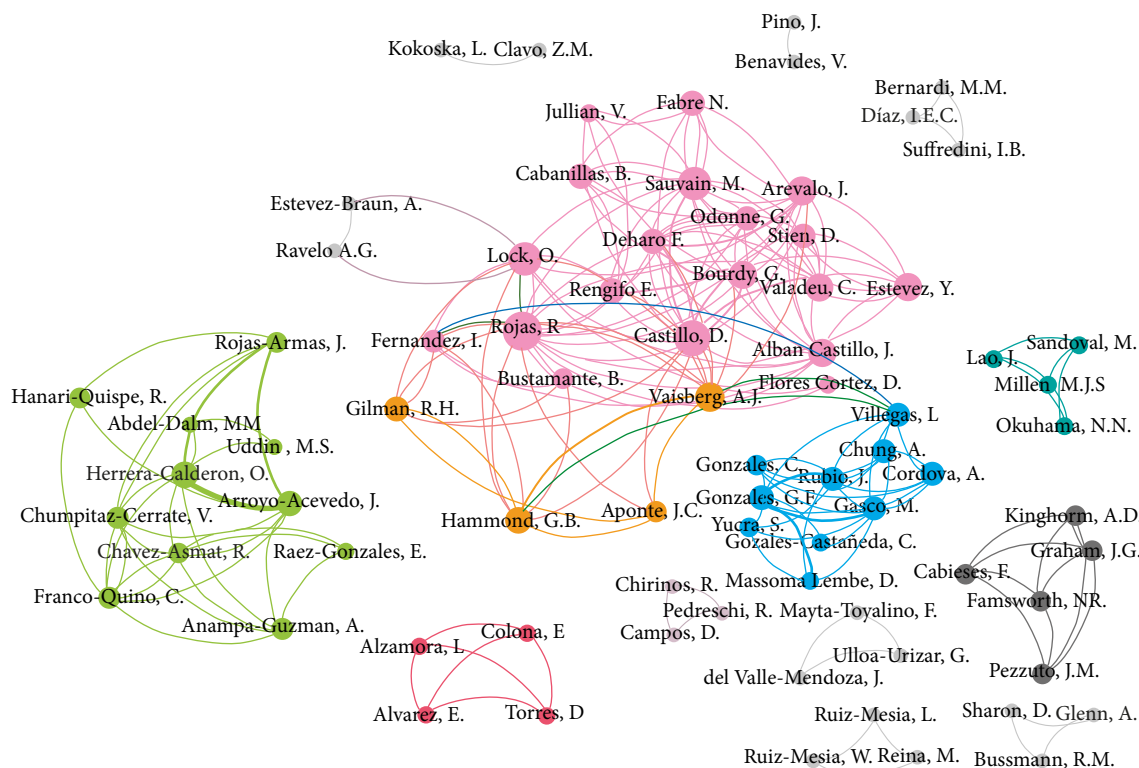
Figure 3. Authorship networks in scientific publications on medicinal plants with at least one Peruvian affiliation (2000-2019). The size of the node is proportional to the frequency of publications, and the thickness of the thread, to the intensity of the collaboration.

Source: Gephi ®

perimental y Salud Pública of the Instituto Nacional de Salud.

This situation reflects some of the usual circumstances in Latin American research groups, who seek to send their manuscripts not only to the best positioned journals, but also to those that offer open access options and no publication costs [26,27]. However, these difficulties do not diminish the quality of the studies produced by Latin American researchers and, in this case by Peruvian institutions, since many of them have been published in Q1 journals that offer accessible publication costs or are accessible thanks to international cooperation [28].

Among the most outstanding precedents, we found that Gonzáles Alonso *et al.* published a study that sought to determine the impact of scientific research on medicinal plants, published from 1947 to 2017, in Scopus [29]. However, in this study, a much more detailed search strategy was used and more accurate bibliometric indicators were obtained, which are more useful for decision making. Nonetheless, both studies coincide in the growing tendency of publications in recent years and the importance of international cooperation in the studies that finally get to be published in indexed magazines.

One of the biggest limitations of this study is that it only shows what has been published in a database relevant to the local sphere, but it does not cover the entire scientific output of Peru. For example, there are 12 health science journal titles indexed in SciELO Peru, and only 3 of them are included in this search because they are also indexed in Scopus. Likewise, the search for information does not include academic repositories, so the production of undergraduate and graduate theses is not being considered, which could have a significant impact on this area of knowledge, given that this study already evidences that universities are the most important centers for production of knowledge on Peruvian medicinal plants.

Other studies have highlighted that one of the most relevant difficulties for medicinal plants researchers is the dispersion of the necessary information to structure a coherent study in accordance with the current state of the art. However, Peru does not have a specialized repository to classify and preserve the scientific knowledge generated on medicinal plants, despite being a natural resource protected by the nation.

It is concluded that there is a growing trend in scientific research on medicinal plants with, at least, one author with Peruvian affiliation published between 2000 and 2019 in jour-

nals indexed in Scopus; this trend is mostly observed in university academic environments and the output is published in journals of diverse quartiles, including Q1, due, in part, to the high level of existing international cooperation.

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Supplementary material: Available in the electronic version of the *RPMESP*.

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