



Scientia Agropecuaria

Web page: <http://revistas.unitru.edu.pe/index.php/scientiaagrop>

Facultad de Ciencias
Agropecuarias

Universidad Nacional de
Trujillo



REVIEW

Peruvian native chili peppers (*Capsicum* spp.): A comprehensive review of their diversity, phytochemical richness, industrial potential, and future perspectives

Roífer Pérez-Vásquez^{1,2} ; José Luis Pasquel-Reátegui^{*} ; Eliana Marcela Vélez-Erazo^{1*}

¹ Grupo de Investigación en Ingeniería y Tecnología Agroindustrial, Facultad de Ingeniería Agroindustrial, Universidad Nacional de San Martín (UNSM), Tarapoto, SM, Perú.

² Department of Food Engineering and Technology, School of Food Engineering, University of Campinas, Monteiro Lobato Street, 80, 13083-862, Campinas, SP, Brazil.

* Corresponding author: evelezer@unsm.edu.pe (E. M. Vélez-Erazo); jlpasquel@unsm.edu.pe (J. L. Pasquel-Reátegui).

Received: 3 March 2026. Accepted: 28 September 2026. Published: 10 October 2026.

Abstract

Peru is one of the countries with the greatest diversity of native chili peppers, which make a significant contribution to the highly valued gastronomy of this nation. However, the use of these chili peppers remains localized, resulting in a limited number of studies focused on these species, which restricts their industrial utilization and increases the risk of extinction. For this reason, this review addresses topics ranging from their geographical distribution and genetic resources (encompassing national collections such as INIA with 712 accessions within a global germplasm context including the WVC with 8,264 accessions) to their industrial applications, including morphological characteristics, sensory profiles, and chemical composition. It was observed that native Peruvian chili peppers have the potential to be used in the development of pharmaceutical, cosmetic, and food products, due to their content of compounds with biological activity such as capsaicinoids, carotenoids, phenolic compounds, vitamins, and minerals; they also present a wide range of pungency levels according to the Scoville scale. Finally, a bibliometric analysis was conducted using Bibliometrix and VOSviewer, where it was found that despite an increase in publications in recent years, native Peruvian chili peppers are still poorly represented in international scientific databases. Overall, this work addresses important information for the sustainable valorization and conservation of Peruvian *Capsicum* genetic resources, as it highlights its potential as a source of bioactive compounds to be used in different fields of industry.

Keywords: *Capsicum*; Bioactive compounds; Volatile profile; Geographical distribution; Industrial applications; VOSviewer; Bibliometrix.

DOI: <https://doi.org/10.17268/sci.agropecu.2026.058>

Cite this article:

Pérez-Vásquez, R., Pasquel-Reátegui, J. L., & Vélez-Erazo, E. M. (2026). Peruvian native chili peppers (*Capsicum* spp.): A comprehensive review of their diversity, phytochemical richness, industrial potential, and future perspectives. *Scientia Agropecuaria*, 17(3), 867-890.

1. Introduction

Given the growing interest in discovering the chemical and functional properties of bioactive compounds derived from plant matrices and the benefits of healthy foods (Baenas et al., 2019), the study of the *Capsicum* genus becomes particularly relevant, as it is also one of the most important crops worldwide (Ortiz et al., 2010). These species are valued for their exceptional sensory characteristics and health benefits (Morales-Soriano et al., 2019), being a rich source of various phytonutrients that can provide protection against cardiovascular diseases, cancer, anemia, and diabetes (Bosland & Votava, 2012). Frequent

consumption of chili peppers has positive health effects due to a wide variety of bioactive compounds such as capsaicinoids, phenols, carotenoids, vitamins (de Sá Mendes & Branco de Andrade Gonçalves, 2020), while their by-products (peels, seeds, and stems) represent potential alternatives to synthetic additives for industrial applications (Rodríguez et al., 2026; Sandoval-Castro et al., 2017; Viacava et al., 2013).

In Peru, chili peppers exhibit a wide range of colors, flavors, sizes, and levels of pungency, and are mainly cultivated by smallholder farmers (Sudré et al., 2010), and they play an important role at the gastronomic level and in cultural traditions (Jäger et

al., 2013b; SENASA, 2024). National production exceeds 200,000 tons, and the most commercially relevant varieties include *Escabeche* (*C. baccatum*), *Limo*, *Panca* (*C. chinense*), and *Rocoto* (*C. pubescens*) (Jäger et al., 2013b; MIDAGRI, 2020).

Although the National Germplasm Bank of Peru, under the Instituto Nacional de Innovación Agraria (INIA) preserves over 700 accessions, native species remain underutilized, and farmers often shift toward more commercially viable crops, posing a risk of genetic erosion and extinction (Morales-Soriano et al., 2019; Van Zonneveld et al., 2015). Despite collaborative conservation efforts, comprehensive studies on their physicochemical, nutritional, and sensory attributes remain scarce (Aliaga Camarena et al., 2021; Espichán et al., 2022; Morales-Soriano et al., 2018).

Bibliometric analysis provides quantitative assessments of scientific output, mapping research networks, publication trends, and gaps in high-impact literature to guide funding and future research agenda (Akmal et al., 2020; de Freitas Marinho et al., 2023). To date, no review integrating the available literature on Peruvian native *Capsicum* species with a bibliometric analysis of this research field has been identified.

In this context, the main objective of this study was to synthesize and organize existing information on Peruvian native chili peppers. Specifically, this review aimed (a) to examine the chemical composition and key attributes of these native species (geographical distribution and genetic resources, morphology, sensory profile, chemical composition), and analyze their current and potential industrial applications, and (b) conduct a bibliometric analysis to evaluate scientific production, identify collaboration patterns among authors, and determine the main research trends in this field. This work provides a basis for future studies and, in turn, contributes to the valorization and conservation of native Peruvian chili pepper species.

2. Methodology

2.1 Study design

This study was divided into two parts that complement each other. The first consists of a literature review, where topics related to geographical distribution, genetic resources, morphological characteristics, phytochemical composition, and industrial applications are covered. To carry it out, scientific articles, theses, books, and technical reports were included, because an important part of the research on this topic is found in local databases. The second part consists of a bibliometric analysis, based on scientific articles found in Scopus and Web of Science, that is, an analysis based on information available in international databases.

2.2 Literature review

The search was conducted through Google Scholar on September 11, 2026, using the following equation: ("Ajíes nativos peruanos" OR "Native Peruvian chili peppers" OR "Capsicum Peruano" OR "Peruvian Capsicum") AND ("distribución geográfica" OR "geographical distribution" OR "recursos genéticos" OR "genetic resources" OR "características morfológicas" OR "morphological characteristics" OR "composición química" OR "chemical composition" OR "aplicaciones industriales" OR "industrial applications"). Searches were performed in Spanish and English to cover literature available in international databases, local journals, university repositories, books, theses, and institutional sources. Publications released between 2009 and 2026 were considered. The initial search identified 208 records; then, after applying the inclusion and exclusion criteria (Table 1), 127 publications were selected for the literature review. Additionally, relevant information was obtained from official sources of the Peruvian government. The methodological workflow followed for the literature review is presented in Figure 1a.

Table 1
Eligibility criteria applied to the literature review and bibliometric analysis

Criterion	Literature review	Bibliometric analysis
Information source	Google Scholar and complementary institutional sources	Scopus and Web of Science
Period	2009 - 2026	2009 - 2026
Scope	Peruvian native <i>Capsicum</i> ; additional <i>Capsicum</i> studies when relevant to their potential applications	Research directly addressing Peruvian native <i>Capsicum</i> or <i>Capsicum</i> germplasm from Peru
Eligible documents	Articles, books, chapters, theses, technical/institutional documents	Indexed scientific publications with adequate bibliographic metadata
Main exclusions	Duplicates, irrelevant/inaccessible records, and publications outside the review scope	Duplicates, review articles, book chapters, conference proceedings, theses, and studies not directly related to Peruvian native <i>Capsicum</i>

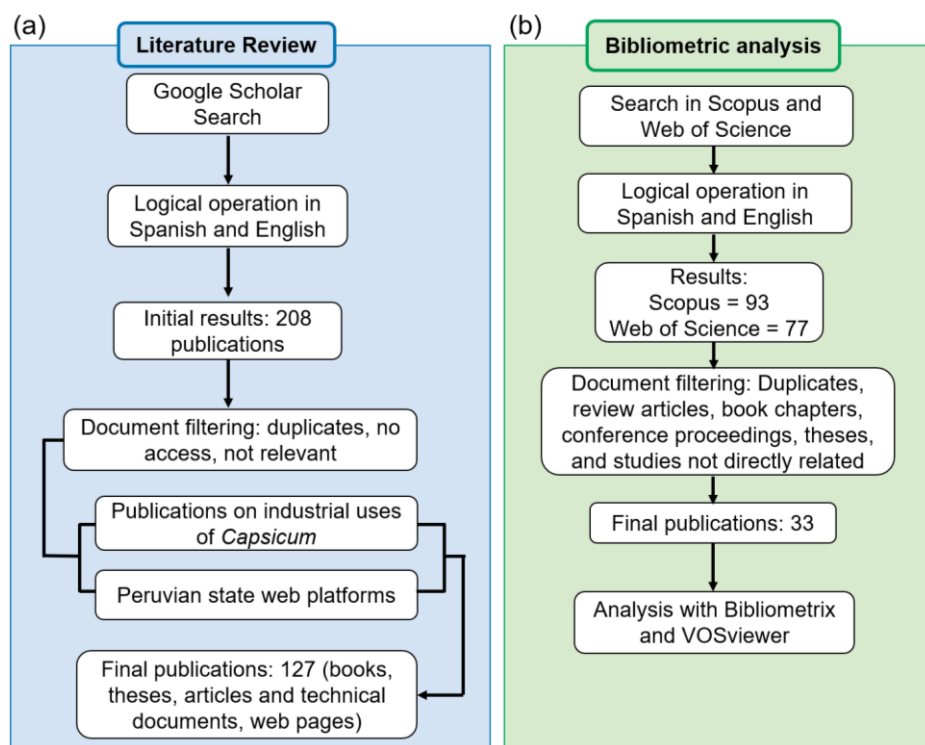


Figure 1. Methodological workflow for (a) the literature review and (b) the bibliometric analysis.

2.3 Bibliometric analysis

A bibliometric analysis was conducted using publications indexed in Scopus and Web of Science. The databases were searched on September 11, 2026, using the following Boolean search strategy: "Peruvian chili pepper*" OR "Peruvian chilli pepper*" OR "Peruvian Capsicum" OR "native Peruvian chili*" OR "native Peruvian Capsicum" OR "ají nativo*" OR "ajíes nativos" OR "ají peruano*" OR "ajíes peruanos" OR "Peruvian pepper*" OR Charapita OR "ají charapita" OR "ají amarillo" OR "ají panca" OR "ají limo" OR "ají mochoero" OR "ají escabeche" OR rocoto. The search was restricted to publications published between 2009 and 2026. The retrieved records were subsequently screened according to the predefined inclusion and exclusion criteria (Table 1). A total of 33 publications were retained for the bibliometric analysis. The methodological workflow followed for the literature review is presented in Figure 1b.

2.4 Data processing and analysis

Data from the literature review were organized and processed in Microsoft Excel 2019, which was also used to generate descriptive figures. For the comparative visualization of biochemical attributes across *Capsicum* accessions, reported values were standardized using a row-wise robust Z-score

transformation (based on row medians and median absolute deviations), allowing comparison across different measurement units and reported central tendency metrics. The resulting data were visualized using Python version 3.10 with the Seaborn and Matplotlib libraries.

For the bibliometric analysis, records retrieved from Scopus and Web of Science were processed using the bibliometrix package in R within RStudio version 2026.09.0-174. Author names and keywords were standardized to minimize duplication caused by differences in spelling, abbreviations, and singular/plural forms. Bibliometric networks were constructed and visualized using VOSviewer version 1.6.21. Co-authorship analysis was used to examine collaboration patterns, while keyword co-occurrence analysis was performed to identify the main thematic relationships. A minimum occurrence threshold of two was applied to keywords.

3. Geographical distribution and genetic resources

A total of 38 species has been identified within the *Capsicum* genus, of which only five have been domesticated by humans (Table 2): *C. annum*, *C. baccatum*, *C. chinense*, *C. frutescens*, and *C. pubescens* (Bosland & Votava, 2012; Espichán et al., 2022; Patel et al., 2016b).

Peru is one of the countries with the greatest diversity of cultivated chili peppers in the world and one of the few where varieties of domesticated species are both cultivated and consumed as part of the local diet (Meckelmann et al., 2013; Porta et al., 2024). At least 19 varieties of native chili peppers belonging to the five mentioned species are cultivated throughout the Peruvian territory (Table 3), with most production systems characterized by small-scale farming (Jäger et al., 2013b; Porta et al., 2024). *C. baccatum* is the most relevant species in the industrial context, with the *ají amarillo* being the most prominent commercial variety, known as *mirasol* when dried (Sociedad Peruana de Gastronomía et al., 2009; Ugás, 2012).

Chili peppers are used fresh or processed in various industrial and gastronomic forms, taking into account their unique characteristics of flavor, aroma, color, and other attributes (Jäger et al., 2013a). Although common names are widely

accepted in local markets, they are often used to refer to more than one type of fruit, even within the same region (Ugás, 2012). However, relying solely on traits such as shape or color does not ensure accurate botanical identification. When studying species of the *Capsicum* genus, it is important to include ethnobotanical aspects, particularly when they reflect cultural self-expressions (Baba et al., 2016). Palombo & Carrizo García (2022) investigated the genomic-level genetic diversity and structure of rocoto pepper (*Capsicum pubescens*) across several American countries using RAD-seq sequencing, of which 10 accessions were from Peru.

INIA maintains 413 accessions of native chili peppers and 299 accessions of *rocotos* in its germplasm collections (Espichán et al., 2022; Libreros et al., 2013). The germplasm bank in Peru comprises 712 accessions collected from various regions of the country (Table 4; Figure 2).

Table 2
Genetic resources of *Capsicum* species (domesticated, wild, and unclassified) according to the World Vegetable Center (WVC, Tainan, Taiwan) and the U.S. Department of Agriculture (USDA, Washington, DC)

Category	Taxon	Number of accessions	
		WVC	USDA
Domesticated	<i>C. annuum</i> L.	5489	3417
	<i>C. baccatum</i> L.	388	383
	<i>C. chinense</i> Jacq.	505	483
	<i>C. frutescens</i> L.	741	280
	<i>C. pubescens</i> Ruiz & Pay.	30	78
	Sub total	7153	4641
Wild	<i>C. chacoense</i> Hunz.	25	20
	<i>C. praetermissum</i> Heiser & P. G. Sm.	9	3
	Miscellaneous	10	12
	Sub total	44	35
Unclassified		1067	277
Total		8264	4953

Adapted from *Capsicum – An Abbreviated Compendium*, by Jarret et al. (2019). Journal of the American Society for Horticultural Science.

Table 3
Most common Peruvian *Capsicum* species and varieties, and their main producing regions in Peru

Species	Common name	Producing regions
<i>Capsicum annuum</i>	Cerezo	Lambayeque and northern Peru
<i>Capsicum baccatum</i> var. <i>pendulum</i>	- Escabeche (Amarillo, verde, criollo, or mirasol when dried) - Pacae - Cacho de cabra or de venado - Ayuchllo	Peruvian coast from southern Tacna to Lambayeque; valleys of Chancay-Hualal, Supe, and Barranca; some areas of the Amazon regions.
<i>Capsicum chinense</i>	- Panca (especial, colorado, or rosado) - Limo (paringo, miscucho, banana) - Mochero - Ají dulce	Peruvian coast, coastal Lambayeque in the north, La Libertad, Amazon region, Lima, Ancash, and Ica
<i>Capsicum frutescens</i>	- Ají charapita - Pipi de mono (montana)	Coastal and Amazon regions
<i>Capsicum pubescens</i>	- Rocoto (locoto), wild and highland types	Highlands (from Tacna to Piura) and Amazon regions (from Cajamarca to Puno)

Adapted from Market Opportunities Guide for Native Chili Peppers of Peru. Compilation of market studies conducted within the framework of the project "Rescue and Promotion of Native Chili Peppers in Their Center of Origin" for Peru (p. 15), by Jäger et al., (2013a), Bioversity International.

Table 4
Taxonomic identification of Capsicum collections from INIA

Taxon	Accessions in the INIA-Peru collection
Domesticated species	
<i>C. annuum</i> L.	46
<i>C. chinense</i> Jacq.	213
<i>C. frutescens</i> L.	48
<i>C. baccatum</i> L.	70
<i>C. pubescens</i> Ruiz & Pav.	301
Wild species	-
<i>C. baccatum</i> var. <i>baccatum</i>	-
<i>C. caballeroi</i> Nee	-
<i>C. cardenasii</i> Heiser & P. G. Sm.	-
<i>C. eximium</i> Hunz.	-
Unidentified accessions	34
Total	712

Adapted from Screening Genetic Resources of Capsicum Peppers in Their Primary Center of Diversity in Bolivia and Peru (p. 10), by Van Zonneveld et al. (2015).

Yseki et al. (2024) through an archaeobotanical study, evidenced the presence and use of four chili pepper species in Vichama (*C. baccatum*, *C. chinense*, *C. frutescens*, and *C. pubescens*),

highlighting the use of these fruits not only as food, but also in ceremonial activities. Furthermore, it places the use of peppers in the period between 1800 and 1500 BCE, indicating the presence of these species in ancient Peru.

4. Morphological characteristics

Understanding commercially valuable traits, such as fruit and seed morphometrics, is key to promoting the production and commercialization of agricultural crops and provides a basis for future breeding and conservation programs (López Medina et al., 2020).

To study agro-morphological characteristics, descriptors established by the International Plant Genetic Resources Institute are used for both plant and fruit traits. These include criteria such as stem shape, plant height, branching density, leaf color and shape, and flower characteristics. For example, fruit shape may be elongated, nearly round, triangular, bell-shaped, blocky, or other forms (Quispe et al., 2019).

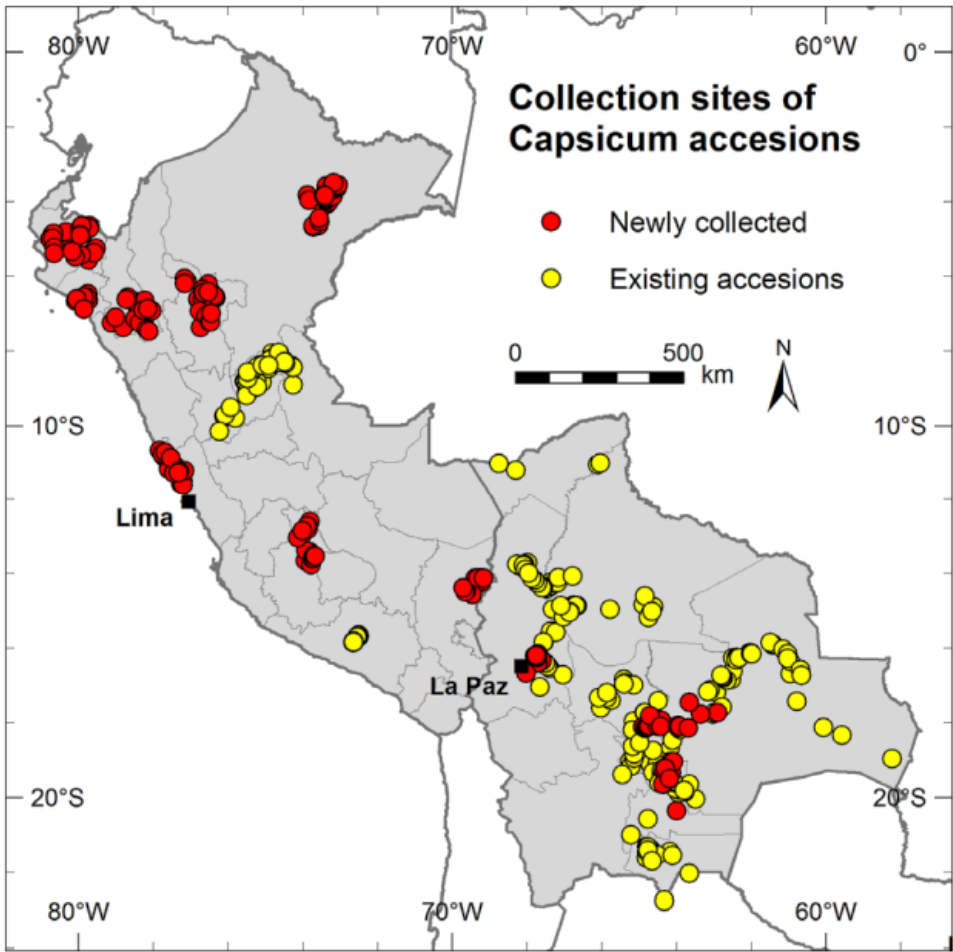


Figure 2. Collection sites of Capsicum accessions in Peru and Bolivia. Adapted from Screening Genetic Resources of Capsicum Peppers in Their Primary Center of Diversity in Bolivia and Peru (p. 10), by Van Zonneveld et al. (Van Zonneveld et al., 2015).

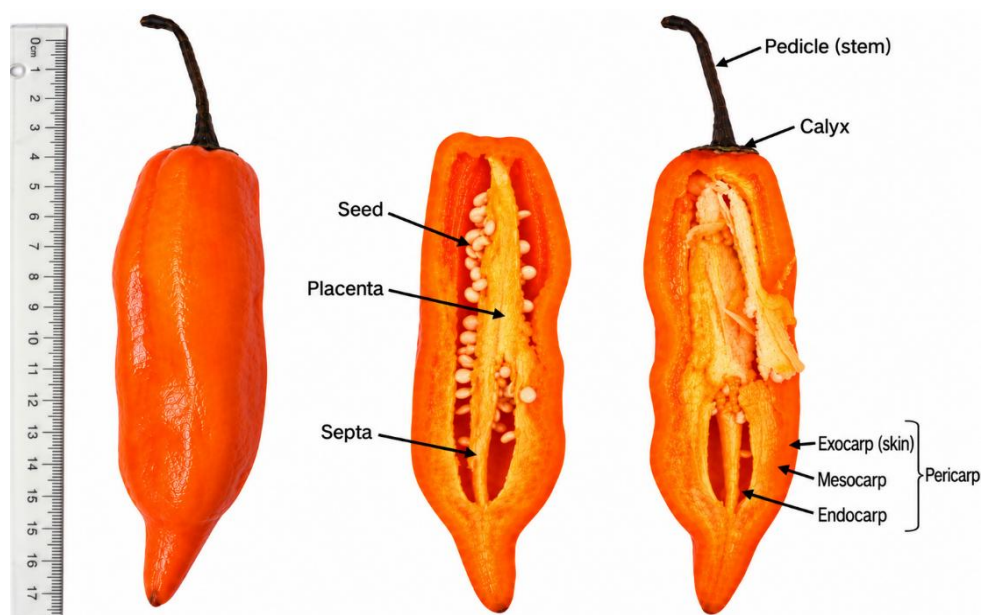


Figure 3. Cross-sectional view of a chili pepper fruit (Ají amarillo - *Capsicum baccatum*).

Morphological differences can occur even among fruits of the same species, possibly due to the effects of genetic variation, which in turn may be influenced by their geographic origin (Araújo et al., 2018; González-López et al., 2021). Studies such as that by Albrecht et al. (2012) demonstrated a correlation between genetic variability and geographic distribution among *C. baccatum* accessions (Peruvian hot pepper). The authors also proposed that Peruvian and Ecuadorian accessions of this pepper species probably originated from wild types in Bolivia. Iglesias Cruz (2020) also reported variability in the fruits of “charapita” pepper (*Capsicum frutescens* L.) marketed in the Peruvian Amazon, particularly in terms of shape, color, weight, length, diameter, and seed number and weight. The main factors associated with this variability were genetic diversity, environmental influences, and agricultural practices. Ortega Morales et al. (2025) observed that larger fruit size does not necessarily correspond to a thicker pericarp.

Despite differences in size, color, and shape, *Capsicum* fruits share a very similar basic anatomy (Figure 3) (Bosland & Votava, 2012; Meckelmann et al., 2013; Sociedad Peruana de Gastronomía et al., 2009).

Table 5 presents the morphological characteristics of fruits at physiological maturity for some of the most common native Peruvian *Capsicum* species, based on the results of studies conducted by Rojas et al. (2016), which consider their shape, color, diameter, length, and weight.

Table 5

Agro-morphological characteristics of 50 native Peruvian chili peppers

Characteristic	Detected range
Length	6.4 – 122.2 mm
Diameter	5.1 – 64.4 mm
Weight	0.2 – 90.2 g
Plant height	27.4 – 197.6 cm
Number of fruits per plant	13 – 1128
Total fruit weight per plant	0.1 – 4.4 kg
Yield	0.6 – 44.2 t/ha

Adapted from *Ajies nativos peruanos - caracterización agro-morfológica, químico-nutricional y sensorial* (p. 20), by Rojas et al. (2016).

It has been demonstrated that there is no correlation between morphological indicators and the results of molecular analyses; in other words, morphological characteristics alone do not allow for the grouping of accessions according to their origin. This suggests the use of both methods to achieve a comprehensive and detailed characterization of germplasm data, thereby enabling a better understanding and differentiation among accessions (Baba et al., 2016).

5. Sensory Profile

Considering the growing demand for Peruvian chili peppers at the national and international levels, the study of the sensory profiles of these species would contribute greatly both to producers, chefs, and possible genetic improvement programs. It has been demonstrated that sensory attributes are not determined by the species or by physical characteristics (Patel et al., 2016a).

Some of the most representative examples are the Amazonian chili pepper known as “Charapita” (*Capsicum frutescens* L.), characterized by its flavor, aroma, pungency, and vitamin C content (Iglesias Cruz, 2020). Another example is the “ají mochoero” (*C. chinense* Jacq.), recognized as part of Peru’s gastronomic heritage due to its pleasant pungency and its use as a condiment in internationally renowned dishes, such as ceviche (López Medina et al., 2020).

The radar chart (Figure 4) compares the sensory profiles of some of the most common Peruvian chili peppers (*ají amarillo*, *ají panca*, *ají limo*, *ají charapita*, and red *rocoto*) and shows that each chili pepper exhibits a unique sensory profile, highlighting the remarkable diversity of these native species. The data were obtained from the study conducted by Patel et al. (2016a), in which panelists identified four flavor attributes (acidic, peppery, sweet, and tomato-like) and six aroma attributes (apple, citrus, fruity, herbal, oregano, and passion fruit). Each sensory attribute was referenced as follows: Citrus: mandarin, orange, lime; Fruity: pear, banana, papaya, apricot, pineapple, mango; Herbal: chamomile, mint, lemongrass, parsley; Acidic: green pepper, watermelon, green and red apple; Sweet: *ají amarillo* and bell pepper.

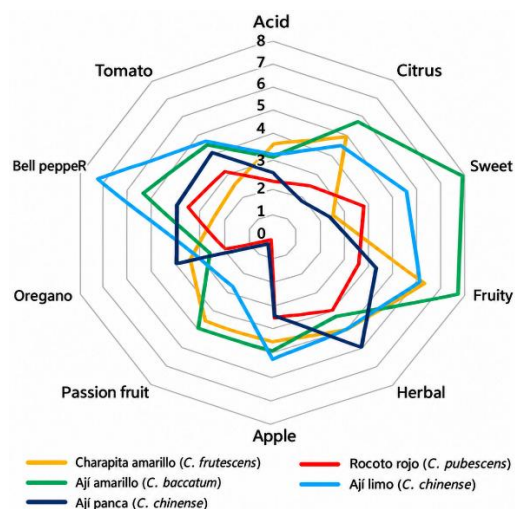


Figure 4. Sensory profile of the most common native Peruvian chili peppers.

6. Chemical composition

The phytochemical content of chili peppers is influenced by various factors, including genotype, ripeness, environmental conditions, agricultural practices, and postharvest treatments (Hernández-Pérez et al., 2020). It has been suggested that larger fruits contain lower amounts of chemical metabolites (González-López et al., 2021).

Comparisons between the findings of different studies are complex and unreliable, as even minor methodological variations can significantly impact the results (Dawidowicz & Olszowy, 2011; Meckelmann et al., 2015b).

Industrial interest in chili peppers stems from their diverse range of bioactive compounds, which confer numerous functional and technological properties (de Sá Mendes, Favre, et al., 2019; de Sá Mendes, Santos, et al., 2019). The chemical composition and diversity of these compounds vary depending on the species, cultivation type, and extraction methods used (Gurnani et al., 2016). Figure 5 shows the standardized concentration levels (Z-score) and ranges of key biochemical attributes across accessions of the five domesticated *Capsicum* species. Due to the significant influence of multiple factors, it is challenging to compare results across studies, even for the same *Capsicum* species (Valková et al., 2021).

Overall, the heatmap in Figure 5 shows that *C. frutescens* accessions stand out for exhibiting higher capsaicinoids and antioxidant capacity values than the remaining species, whereas *C. annuum* accessions display the highest values for tocopherols and extractable color (ASTA).

The color of chili pepper fruits is determined by chlorophyll (green), anthocyanins (violet/purple), and mainly by their carotenoid content and profile, such as α - and β -carotene, zeaxanthin, lutein, and β -cryptoxanthin, which produce yellow to orange hues (Aza-González et al., 2011; Hernández-Pérez et al., 2020; Rodríguez-Burruezo, González-Mas et al., 2010), as well as capsanthin and capsorubin, which define the characteristic red color of some chili fruits (Kumar et al., 2011).

Van Zonneveld et al. (2015) selected 23 accessions of native Peruvian chili peppers based on their biochemical and agro-morphological properties and classified them into six groups using cluster analysis:

1. Very pungent small peppers with high antioxidant capacity and elevated polyphenol levels (*C. chinense*–*C. frutescens*).
2. Pungent peppers (*C. baccatum*–*C. chinense*).
3. Moderately pungent peppers with high tocopherol content, elevated fat levels, and high extractable color values (ASTA) (*C. annuum*).
4. Mild peppers with large and heavy fruits (*C. baccatum*–*C. chinense*).
5. Mild peppers with high concentrations of flavonoids and quercetin (*C. baccatum*–*C. chinense*).
6. Sweet peppers (*C. chinense*).

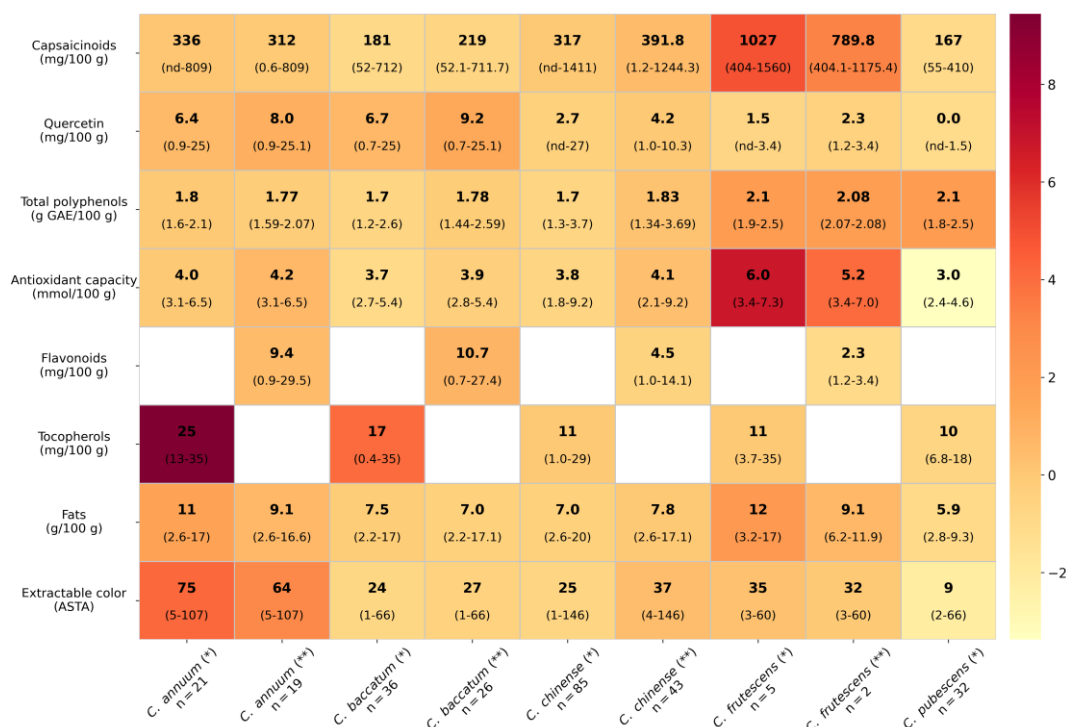


Figure 5. Heatmap comparison of key biochemical traits in native Peruvian chili pepper species. Numerical values inside each cell display the original central values (in bold) along with their respective concentration ranges (minimum–maximum). Asterisks indicate data reporting metrics: * reported as medians by Meckelmann et al. (2015a); ** reported as mean values by Van Zonneveld et al. (2015). GAE: gallic acid equivalent; antioxidant capacity: Trolox equivalent – ABTS assay; n: number of accessions studied; nd: not detectable; blank cells: data not reported.

In another study conducted by Morales-Soriano et al. (2019), who performed cluster analysis on twenty local varieties, the authors concluded that there is no relationship between botanical classification and the studied pepper attributes (Bostwick index, syneresis percentage, dry matter, insoluble, soluble, and total dietary fiber, alcohol-insoluble residue, galacturonic acid content, L*, a*, b* color parameters, total and individual carotenoid content, Scoville units, and volatile compounds).

Recent studies highlight the bioactive compound content in accessions of native Peruvian chili peppers. Salas-Zeta et al. (2026) reported average values of 1382 mg GAE/100 g DW (dry weight), 19.62 mg β -carotene eq/100 g DW, and antioxidant activity values of 113.3, 16.82, and 54.93 μ mol TE/g DW measured by ABTS, DPPH, and FRAP assays, respectively, across 78 accessions of *Capsicum pubescens* from the National Rocoto Germplasm Collection (INIA, Peru). Pérez-Vásquez et al. (2026) performed ultrasound-assisted extraction on three varieties of Charapita chili pepper (*Capsicum frutescens*), discovering that the red variety stood out for its high yield (up to 32.24%) and total carotenoid content (up to 874.21 μ g β -carotene/g dm). In contrast, the yellow variety obtained the highest TPC values (up to 5.63 ± 0.16) and antioxidant capacity (up to 55.47 and 7.00 μ mol

TE/g dm according to ABTS and DPPH assays, respectively).

6.1 Total polyphenols

Phenolic compounds contribute to the color, aroma, and flavor of chili fruits, in addition to providing health-promoting properties (Baenas et al., 2019). For example, they are known to have free-radical scavenging activity in biological systems (Bogusz et al., 2018).

Phenols reach their maximum concentration in immature fruits and subsequently decrease as they ripen, whereas carotenoid and capsaicinoid concentrations are inversely proportional in unripe fruits (Tundis et al., 2013). Peruvian *C. chinense* accessions reported polyphenol values ranging from 967.38 to 2258.97 mg/100 g DW (Ortega Morales et al., 2025).

6.2 Flavonoids

These compounds, which are also present in chili peppers, have antioxidant, anti-inflammatory, and anticancer effects (Baenas et al., 2019). In a study conducted by Meckelmann et al. (2013), high quercetin levels were found in 141 out of 147 accessions studied, with this flavonoid being the dominant compound and reaching concentrations of up to 26.6 mg/100 g.

It has been demonstrated that plants under stress conditions, such as the presence of pathogens, nutrient deficiency, or UV radiation, enhance the production of flavonoids. These stressors, together with other environmental factors, influence the biosynthesis of these compounds (Butcher et al., 2012; Meckelmann et al., 2015b).

6.3 Tocopherols

Tocopherols are congeners of vitamin E, which comprises eight lipid-soluble compounds (α -, β -, γ - and δ -tocopherol and α -, β -, γ -, and δ -tocotrienol) (Greibenstein & Frank, 2012). Meckelmann et al. (2015), reported that α -tocopherol had the highest concentration in most of the accessions studied, followed by γ -tocopherol. In contrast, β -tocopherol was present at low levels in a small number of accessions. α -tocopherol is located mainly in the pericarp, while γ -tocopherol predominates in the seeds; therefore, the proportion of these parts in the fruit affects the results (Bosland & Votava, 2012).

6.4 Carotenoids

Carotenoid content is influenced by environmental variations at the cultivation site, agricultural practices, genetic factors, season, ripeness stage, and storage conditions (Morales-Soriano et al., 2019). Species of the *Capsicum* genus are important sources of carotenoids, and their wide color diversity results from each variety's specific carotenoid profile (Carvalho et al., 2015). Carotenoids have biological importance due to their anti-inflammatory, antioxidant, and photoprotective properties, and are used in pharmaceutical, nutraceutical, and cosmetic products (Hernández-Pérez et al., 2020; Villa-Rivera & Ochoa-Alejo, 2020).

Among the native Peruvian chili peppers studied by Morales-Soriano et al. (2019), total carotenoid content ranged from 330 to 28,418 μg β -carotene equivalent/100 g fresh weight, with the highest value corresponding to *C. chinense* (ají panca). Red and orange samples showed a wide diversity of carotenoids, whereas yellow fruits contained lower levels. In the study by Ortega Morales et al. (2025), Peruvian *C. chinense* accessions ranged from 32.05 to 89.97 mg/100 g DW. These results are consistent with previous studies by Rodríguez-Burruezo, González-Mas, et al. (2010) and Pugliese et al. (2013).

Molnár et al. (2018) examined spice paprika powders from different countries, including samples from Peru, which exhibited the highest carotenoid content ($3810 \pm 1206 \mu\text{g/g}$) and the highest ASTA color value (140 ± 35.4). However, contaminants such as aflatoxins ($12.16 \pm 1.93 \mu\text{g/kg}$) and cadmium

($254.9 \pm 1.8 \mu\text{g/kg}$) were also detected. These results show that despite the high nutritional quality of Peruvian paprika, good storage and processing practices are required to reduce contamination.

The color of the fruit epicarp is influenced by the type and concentration of carotenoids. Orange fruits are associated with high β -carotene content, while red fruits are rich in capsanthin, each combined with other carotenoids; in contrast, yellow fruits exhibit low levels of these compounds (Morales-Soriano et al., 2019).

6.5 Capsaicinoids

The pungency of chili peppers is attributed to a group of compounds called capsaicinoids, which are exclusive to the genus *Capsicum*. These compounds are produced in the fruit placenta and possess medicinal and antimicrobial properties (Jarret et al., 2019; Marini et al., 2015; Reyes-Escogido et al., 2011).

Although the capsaicinoid profile depends on the accession, variety, and environmental conditions (Gurung et al., 2011; Meckelmann et al., 2015b), in general, carotenoid and capsaicinoid contents increase as the fruit ripens (Menichini et al., 2009); however, under water stress conditions, capsaicinoid levels decrease due to the co-localization with peroxidase enzymes capable of degrading capsaicin and dihydrocapsaicin (Ruiz-Lau et al., 2011; Zamudio-Moreno et al., 2014).

Meckelmann et al. (2013) studied 147 accessions of native Peruvian chili peppers and found that the predominant capsaicinoids were capsaicin and dihydrocapsaicin. However, these have not always been shown to be the main capsaicinoids, as some accessions have also been reported to have dihydrocapsaicin isomers and homodihydrocapsaicin as the predominant compounds.

Scoville Heat Units (SHU) are commonly used to represent the pungency or heat level of chili peppers (Meckelmann et al., 2015a). The SHU value of pure capsaicin ranges from 15 to 16 million (Günel et al., 2021). Figures 6 and 7 show some Peruvian chili peppers and their pungency levels expressed in SHU. For the data from the accessions studied by Meckelmann et al. (2013), the SHU values were calculated using Equation 1, as described by González-Zamora et al. (2013).

$$\text{Total SHU} = [C(\text{ppm}) + \text{DHC}(\text{ppm})] \times 16.1 + [n - \text{DHC}(\text{ppm}) \times 9.3] \quad (1)$$

Where C, DHC y n-DHC represent the concentrations (in ppm) of capsaicin, dihydrocapsaicin, and nordihydrocapsaicin, respectively, while 16.1 and 9.3 are the heat coefficients for each compound.

Central markers represent the midpoint of reported values, while error bars indicate the concentration range (minimum and maximum) compiled from data published by Meckelmann et al. (2013), Morales-Soriano et al. (2018) and Villar (2019). Single markers without error bars denote accessions with a single reported value.

Based on the Scoville Heat Unit (SHU) scale, there are five pungency levels: non-pungent (0 – 700 SHU), slightly pungent (700 – 3,000 SHU), moderately pungent (3,000 – 25,000 SHU), highly pungent (25,000 – 70,000 SHU), and extremely pungent (>80,000 SHU) (Hernández-Pérez et al., 2020). Ortega Morales et al. (2025) studied seven underutilized *Capsicum* accessions, four of which were from Peru (C34, C37, C39, and SP4) belonging to *C. chinense*. Among the Peruvian genotypes evaluated, C37 achieved the highest pungency value (148,518.3 SHU), whereas C39 exhibited the lowest (14,346.38 SHU). The great variability in terms of pungency makes them attractive for application in different formulations according to their properties. In Figure 7, it can be observed that the varieties belonging to *C. chinense* and *C. frutescens* present the highest levels of pungency, which is in line with other investigations (Menichini et al., 2009; Sarpras et al., 2016). However, Salas-Zeta et al. (2026) reported a maximum value of 83,961 SHU in their study on 78 accessions of *Capsicum pubescens*. All

of this is evidence of the enormous diversity and variation in the phytochemical content of the Peruvian *Capsicum* germplasm.

6.6 Volatile compounds

Ecological and geographical factors directly influence the volatile compounds responsible for the aroma of species of the genus *Capsicum*. Likewise, new aroma combinations may appear due to geographical expansion (Joshi et al., 2022).

Rodríguez-Burruezo, Kollmannsberger, et al. (2010) studied 16 accessions of *C. annum*, *C. chinense*, and *C. frutescens* cultivated in a greenhouse in Spain. More than 300 volatile compounds responsible for the aroma of the fruits were detected by headspace solid-phase microextraction (HS-SPME), where esters and terpenoids were the most abundant groups.

Morales-Soriano et al. (2018) studied 20 accessions of native Peruvian chili peppers, where more than 100 volatile compounds were identified, among which terpenes, nitrogen-containing compounds, esters, phenolic derivatives, norcarotenoids, alcohols, lipoxygenase cleavage products, ketones, and hydrocarbons were found, among which the saturated ester 4-methylpentyl 3-methylbutanoate was the most abundant. Molnár et al. (2018) analyzed powdered paprika from several countries and found that only the Peruvian samples had a compound called geranylacetone.

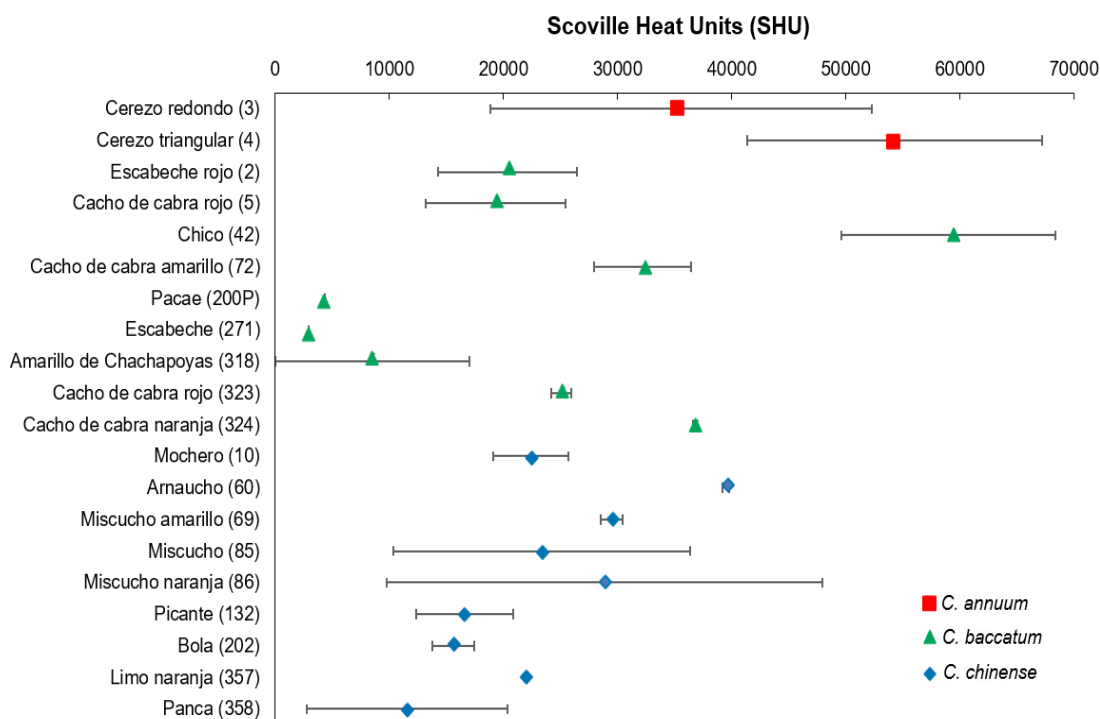


Figure 6. Pungency levels (SHU) of native Peruvian *Capsicum* accessions.

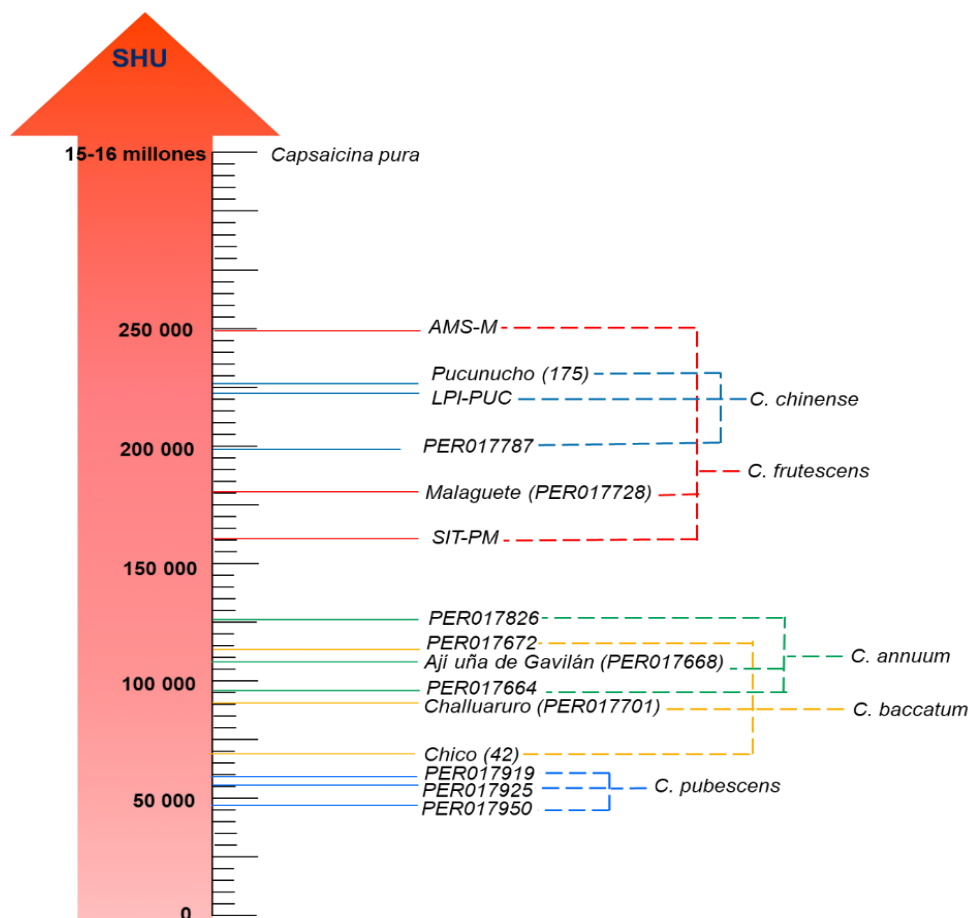


Figure 7. Scoville Heat Scale (SHU) of some native Peruvian chili peppers. Scale based on data reported by Meckelmann et al. (2013), selecting the top three accessions with the highest pungency levels for each *Capsicum* species evaluated.

In another study, Patel et al. (2016b) analyzed a total of 50 native Peruvian chili peppers and found 127 volatile compounds, where terpenes and esters were the most abundant, followed by hydrocarbons, ketones, and aldehydes. When fresh and dried samples of *ají panca* and *ají amarillo* were compared, a decrease in hydrocarbons and esters was observed, but an increase in terpenes, ketones, and aldehydes. The 50 samples were classified into seven groups: A (high content of hydrocarbons, low in ketones and aldehydes), B (high content of hydrocarbons, ketones, and aldehydes), C (low content of hydrocarbons, high in ketones and aldehydes), D (high content of terpenes), E (low content of terpenes), F (average of all groups), and G (high content of esters). Ortega Morales et al. (2025) found more than 400 volatile compounds, with the *C. chinense* species presenting the highest levels of esters and terpenoids, responsible for fruity aromatic notes.

The aromatic characteristics of each species are due to the predominance of certain compounds. It has been found that in *C. chinense*, norcarotenoids, esters, and ectocarpene predominate. In *C. pubescens*, green, spicy, herbaceous, and cucumber-like aromas are associated with aldehydes, while vegetable-type odors are due to compounds containing nitrogen and sulfur. In *C. baccatum*, the presence of certain terpenes and a low concentration of pyrazines and aldehydes result in a lower intensity of the vegetable aroma (Bogusz et al., 2015; Kollmannsberger et al., 2011).

6.7 Insoluble Dietary Fiber (IDF)

Native Peruvian chili peppers have been reported to have high levels of dietary fiber (IDF), which are of great importance in terms of their technological and nutritional properties. However, it should be noted that IDF concentration depends on both genetic factors and the degree of fruit maturity (Morales-Soriano et al., 2019).

7. Industrial Applications

The *Capsicum* genus is among the crops that have been domesticated and used since ancient times. The main bioactive substances in *Capsicum* fruits include carotenoids, phenols, capsaicinoids, and capsinoids (Duranova et al., 2022). Despite this wide range of phytochemicals with notable antioxidant properties, their beneficial effects depend on their bioavailability (Hervert-Hernández et al., 2010).

Some of their applications include use as a natural food colorant, in pharmaceutical products, and as a spicy extract in personal defense items, repellents, and insecticides (Estrada et al., 2024). In the case of Peruvian chili peppers, mirasol (*Capsicum baccatum* var. *pendulum*), also known as dried yellow chili pepper, is a source of natural colorants used in the production of paints and cosmetics. Ají panca (*Capsicum chinense* Jacq.), on the other hand, is not only a popular culinary condiment but has also found applications in the cosmetic and pharmaceutical industries (Guevara Pérez et al., 2021). These native species exemplify how local germplasm can move beyond traditional markets into high-value industrial applications.

Although native Peruvian chili peppers have been little studied and their industrial use remains limited, applications developed with *Capsicum* species from other regions can serve as a reference to promote research and industrialization of local varieties. Below are several applications, not only of the chili fruits but also of parts considered as by-products or waste.

7.1 Food Applications

In the Lima market, chili peppers are mainly consumed fresh, but sauces, pastes, and powder forms are also available (Jäger et al., 2013a). Given this diversity and industrial potential, more research on Peruvian chili peppers is needed; for example, in sauce production, understanding the structuring potential is essential (Morales-Soriano et al., 2019). Another important observation is that phenolic

compounds and antioxidant capacity tend to be higher in cooked samples, as the thermal breakdown of cell walls facilitates the release of these compounds (Juániz et al., 2016a; Juániz et al., 2016b). Red chili pepper powder (*Capsicum annuum*), known as paprika, is highly valued for its color and pungency, due to the presence of carotenoids and capsaicinoids, respectively. Studies have indicated that these compounds are highly correlated and tend to decrease following thermal treatments and during storage, suggesting the need for process optimization to preserve the quality of this ingredient (Ferrando et al., 2024; Giuffrida et al., 2014).

Specifically, in the case of *Capsicum pubescens* (rocoto), its popularity in gastronomy and growing interest in exports are associated with its characteristic aroma, fleshy pericarp, and possibly its pungency. However, it exhibits low levels of bioactive compounds compared with other species of the genus *Capsicum* (Meckelmann et al., 2015a). On the other hand, a combination of fruity and sweet aromas paired with moderate to low pungency levels has been observed in *C. chinense* accessions, making them potentially suitable for the formulation of food products with a rich sensory profile and a moderate heat levels (Ortega Morales et al., 2025). Table 6 shows some of the uses in the food field that species of the genus *Capsicum* have.

7.2 Pharmacological and cosmetic applications

The antioxidant effect of chili peppers results from the synergy of their compounds rather than any single one (Carvalho et al., 2015; Gurnani et al., 2016), including flavonoids, phenolic acids, capsaicinoids, and vitamins C and E, among others (Meckelmann et al., 2013). Chili peppers are a significant source of vitamin C (ascorbic acid) and contain high concentrations of phenolic compounds-particularly quercetin, which can protect against chronic diseases (Meckelmann et al., 2015a).

Table 6

Applications of products derived from *Capsicum* in the food industry

Compound/product	Food application	Outcome	Reference
Ají amarillo sauce (<i>Capsicum baccatum</i>)	Canned beef tripe (<i>Bos taurus</i>)	Improvement of sensory and nutritional quality	(Ligarda Samanez et al., 2023)
Capsaicin and tocopherol	Pepper oil	Prevention of thermal oxidation during frying	(Yang et al., 2010)
Peppers	Lamb nuggets	Improvement of functional and sensory quality	(Mendiratta et al., 2013)
Antioxidants (Carotenoids)	Durum wheat bread with ají amarillo flour	High antioxidant content and low glycemic index	(Danza et al., 2014)
Microencapsulation (spray drying) and phenolic profiling	Pepper flour (<i>Capsicum pubescens</i>)	Production of powders with potential use as functional ingredients	(de Sá Mendes et al., 2020)
Functional foods	Fruit and vegetable residue flours with added <i>Capsicum baccatum</i> powder	Ingredients for coating or seasoning.	(de Sá Mendes, Favre, et al., 2019)

Another important group is carotenoids, which, as noted earlier, directly influence color diversity but also help reduce the risk of chronic diseases and cancer. Carotenoids such as β -carotene, capsanthin, lutein, and zeaxanthin not only have high antioxidant activity (Morales-Soriano et al., 2019). Studies have shown that, for example, capsanthin (the primary carotenoid in red pepper, *Capsicum annuum* L.) improves lipid metabolism (Kim et al., 2017), while lutein and zeaxanthin protect against ocular diseases (Bernstein et al., 2016; Nwachukwu et al., 2016).

Diets rich in β -carotene and α -carotene reduce the risk of type 2 diabetes in generally healthy individuals (Sluijs et al., 2015). The importance of α - and β -carotene, as well as β -cryptoxanthin, lies in their provitamin A activity (Carvalho et al., 2015; Topuz et al., 2011). Several chili genotypes can provide between 50% and over 100% of the recommended daily intake of vitamin C (Wahyuni, Ballester, Sudarmonowati, et al., 2013). Another compound present in chili peppers is vitamin E, which offers protection against cardiovascular diseases, diabetes, anemia, and certain types of cancer (de Sá Mendes & Branco de Andrade Gonçalves, 2020). Capsaicinoids, responsible for pungency, have been associated with cancer prevention, beneficial effects on cardiovascular and gastrointestinal systems, weight reduction, and analgesic activity (Arora et al., 2011; Reyes-Escogido et al., 2011). Capsaicin has garnered pharmaceutical interest due to its effects in treating neurological and cardiac conditions, lowering blood pressure and cholesterol levels, and alleviating pain. Evidence also suggests that capsaicin acts as a gastroprotective agent against stomach lining damage caused by ethanol and indomethacin (Baenas et al., 2019; Fattori et al., 2016). Although capsaicinoids possess antioxidant, anticancer, anti-inflammatory, and thermogenic properties (Giuffrida et al., 2013; Lu et al., 2017), excessive consumption of capsaicin can be toxic; therefore, spicy chili peppers should be consumed in moderation (Fernández-Bedmar & Alonso-Moraga, 2016). Next, Table 7 presents some examples of applications in the pharmaceutical industry that may also extend to cosmetic use.

From a cosmetic perspective, some interesting findings have been reported. Certain flavonoids have been shown to absorb UVB radiation (between 280 – 315 nm), acting as natural sunscreens that protect photosynthetic cells (Ghasemnezhad et al., 2011); this property suggests that these compounds could be incorporated into cosmetic formulations to protect the skin from the

harmful effects of sunlight. On the other hand, pepper oleoresin can dissolve in fats, oils, and lipids, unlike essential oils, which do not possess this property (Baenas et al., 2019).

7.3 Other potential applications

Finally, the use of chili peppers also extends to the agricultural field, material protection, and even the textile industry. For example, Ksibi et al. (2015) used phenolic-rich extracts obtained from red pepper by-products (*Capsicum annuum* L.) to apply them to wool fabric and evaluated their antimicrobial activity against *Pseudomonas aeruginosa* and *Staphylococcus aureus*. Oguzie et al. (2013) used phytochemicals present in *Capsicum frutescens* (alkaloids, tannins, and saponins) to investigate their anticorrosive effect on low-carbon steel and their antimicrobial efficacy against sulfate-reducing bacteria associated with corrosion.

7.4 Barriers and opportunities for the industrialization of Peruvian chili peppers

Despite the great diversity of native Peruvian chili pepper species, their use at the industrial level is still under development and presents several challenges. After having analyzed the information presented and taken as a reference the applications presented in Tables 6 and 7, we can notice interesting industrialization opportunities, but at the same time, the obstacles to industrial scaling are evident.

Native *Capsicum* species, such as chili pepper accessions like *C. baccatum* (ají amarillo/mirasol) and *C. chinense* (ají panca), are rich in total carotenoids, and therefore, have the potential to be sources of natural pigments, which could be used both at the food and cosmetic levels. *C. chinense* accessions such as ají limo and mochoero, characterized by a controlled level of pungency and profiles of fruity volatile compounds, have potential to produce sauces, oleoresins, and different microencapsulated products that preserve these characteristics.

Some of the barriers to industrial scaling could be the lack of standardized cultivation practices and a certified seed system, which are problems that trigger variability in the quality of batches, mainly variability in phytochemical content. Also, certain more artisanal practices, such as open-air drying and traditional grinding, could be causing thermal degradation of the analytes. It is precisely in this context that the study and optimization of processes that allow the extraction of these compounds of interest for their proper use are fundamental.

Table 7

Reported biological activities, potential pharmaceutical and cosmetic applications of Capsicum-derived materials

Effect	Source or Compounds	Main Findings	Reference
Antioxidant activity	Eight pepper genotypes (<i>Capsicum</i> sp., <i>Capsicum annuum</i> L., <i>C. chinense</i> Jacq. and <i>C. baccatum</i> L. var. <i>umbilicatum</i>)	Total phenols, anthocyanins, carotenoids, vitamin C	(Carvalho et al., 2015)
Hypoglycemic activity	Extracts from <i>Capsicum annuum</i> cultivars	Green fruits showed better inhibition of α -amylase and α -glucosidase enzymes.	(Tundis et al., 2013)
Analgesic	Capsaicin	Use of nanocolloidal carriers to reduce skin irritation	(Raza et al., 2014)
Antibacterial	Extracts of <i>Capsicum annuum</i> var. <i>annuum</i>	Capsianosides inhibited <i>L. monocytogenes</i>	(Bacon et al., 2017)
Anticancer	<i>C. annuum</i> varieties	Polyphenol mixture (quercetin)	(Jeong et al., 2011)
Anticancer	Purified L-asparaginase from <i>Capsicum annuum</i> L.	Inhibition of oral, cervical, and lung cancer cell growth	(Shanmugaprakash et al., 2015)
Anticancer	Nanoemulsomes loaded with capsaicin	Reduction of oxidative stress in the liver	(Giri et al., 2017)
Anticancer	<i>Capsicum annuum</i> L. seed extract	Antiproliferative activity against human tumor cells (liver, breast, stomach, and colon)	(Jeon et al., 2012)
Anticancer	Capsaicin	Reduction of colony formation and radiosensitization of prostate cancer cells	(Venier et al., 2015)
Antidiabetic and antioxidant	Hot pepper varieties	Phytochemicals from <i>Capsicum</i> oleoresin showed antidiabetic and antioxidant properties.	(Sricharoen et al., 2017)
Antifungal	Peptides isolated from <i>Capsicum baccatum</i> seeds	Active against yeasts: <i>Saccharomyces cerevisiae</i> , <i>Candida albicans</i> , <i>C. tropicalis</i> and <i>Kluyveromyces marxianus</i>	(Vieira-Bard et al., 2014)
Antihyperglycemic and antihypertensive	Extracts from Peruvian and Mexican peppers	Potential control of type 2 diabetes and hypertension	(Ranilla et al., 2010)
Anti-inflammatory	Aqueous extract of bell pepper leaves (<i>Capsicum annuum</i> L. var. <i>grossum</i>)	Inhibition of cytokine production, cell proliferation without cytotoxicity, and suppression of inflammatory protein expression	(Hazekawa et al., 2017)
Anti-inflammatory	Extracts of <i>C. baccatum</i>	Inhibition of neutrophil migration, edema, nitric oxide production, TNF- α , and reduction of myeloperoxidase levels	(Allemand et al., 2016)
Anti-inflammatory	Carotenoids from <i>Capsicum annuum</i> L.	Reduction of adjuvant-induced inflammation in rats	(Boiko et al., 2017)
Anti-inflammatory and antioxidant	Extract from red pepper stems (<i>Capsicum annuum</i> L.)	Significant inhibitory effect on nitric oxide (NO) production in LPS-stimulated RAW 264.7 macrophage cells.	(Chen & Kang, 2013)
Antimicrobial	Crude extracts from red chili seeds (<i>Capsicum frutescens</i> L.)	Active against <i>Pseudomonas aeruginosa</i> , <i>Klebsiella pneumoniae</i> , <i>Staphylococcus aureus</i> and <i>Candida albicans</i>	(Gurmani et al., 2016)
Antimicrobial	Isolated extracts from <i>Capsicum frutescens</i> (Pimenta Malagueta)	The flavonoid chrysoeriol was the most active compound against the tested microorganisms	(Nascimento et al., 2014)
Antimicrobial	Aqueous residual extract from <i>C. baccatum</i> seeds	Active against <i>S. epidermidis</i> and <i>P. aeruginosa</i>	(Von Borowski et al., 2019)
Antimicrobial and anticancer	Pepper (<i>Capsicum annuum</i> L.)	Kaempferol, quercetin, and caffeic acids were most effective against Gram-positive and Gram-negative bacteria; extract showed inhibition of leukemia cancer cells	(Mokhtar et al., 2015)
Cardioprotective	Capsaicin and dihydrocapsaicin	Anti-inflammatory effects on the endothelium, increased nitric oxide, and reduced monocyte adhesion to endothelial surface.	(Thongin et al., 2022)
Cardioprotective	<i>Capsicum</i> spp. extract and capsaicin	Induced endothelial nitric oxide release and protection against cell apoptosis	(Chularojmontri et al., 2010)
Glucoregulatory	Capsaicin	Improved glucose regulation in obese diabetic mice	(Song et al., 2017)
Lipolytic	Capsaicin and capsinoids	Activation of brown adipose tissue (increased energy expenditure and fat reduction) in humans.	(Saito & Yoneshiro, 2013)
Lipolytic	Red pepper (<i>Capsicum annuum</i> L.)	The main carotenoid (capsanthin) improves lipid metabolism and reduces the negative effects of obesity	(Kim et al., 2017)
Lipolytic	Phenolic and other protective compounds such as capsaicinoids and chlorophylls from fresh and processed jalapeño and serrano peppers	Protection against lipid oxidation in foods and human LDL cholesterol	(Alvarez-Parrilla et al., 2012)
Weight, BMI, and appetite reduction	Capsaicinoids	A daily 200 mg dose of Capsifen (4 mg capsaicinoids/day) for 28 days significantly reduced anthropometric parameters	(Ashil et al., 2021)
Effective treatment for overactive bladder	Capsaicin	Oral supplement based on <i>Cucurbita maxima</i> and <i>Capsicum annuum</i>	(Fabozzi et al., 2020)

8. Research trends and future opportunities

The use of chili peppers should not be limited to the sauces and pickles market; there is a strong need for research on the phytochemicals present in these plant structures, with potential for developing new products for medical, cosmetic, and other applications. It is also important to study the by-products derived from chili processing (stems, peel, seeds, and pulp), as they could be valuable sources of bioactive compounds (Rodríguez et al., 2026; Sandoval-Castro et al., 2017; Viacava et al., 2013).

In this context, a current research trend could be the evaluation of the biological activity of chili extracts for future applications. Valková et al. (2021) investigated the antioxidant and antimicrobial properties of ethanolic extracts from five chili species: Aji Amarillo (*C. baccatum* L.), Fidalgo Roxa (*C. chinense*), Cherry Chocolate (*C. annuum*), Rocoto Orange (*C. pubescens*), and Peruvian Purple (*C. frutescens*). They concluded that the Aji Amarillo extract was the most effective against the microorganisms studied and exhibited the highest antioxidant capacity. *Capsicum* derivatives, such as purified extracts, oleoresins, and others, should continue to be investigated for potential use as industry ingredients due to their beneficial health properties, including antioxidant, anti-inflammatory, and antimicrobial activities (Baenas et al., 2019).

Peruvian chili accessions generating the most interest are those with low to medium pungency and high levels of beneficial biochemical compounds (antioxidant capacity, flavonoids, quercetin, and tocopherols) (Van Zonneveld et al., 2015). A limitation in the pharmacological use of capsaicin is the irritation or burning sensation it causes as a side effect. Studies aimed at overcoming this limitation focus on using analogs (which have a similar effect without pungency), or nanocolloidal carriers to prevent adverse effects (Raza et al., 2014).

Many species of the genus *Capsicum* exhibit similar morphological characteristics, which makes it difficult to differentiate among species. To address this issue, molecular tools such as amplified fragment length polymorphism (AFLP), cytogenetic techniques, and, more recently, metabolomics approaches have been employed (Espichán et al., 2022; Wahyuni, Ballester, Tikunov, et al., 2013). Microscopic analysis is also employed to identify and classify species, as well as to observe changes at different maturation stages (Hernández-Pérez et al., 2020). Consequently, genomic studies of Peruvian chili species have gained significance, particularly for those with high diversity. For

example, the genome of the Arnaucho chili (*Capsicum chinense* Jacq.), a traditional vegetable used in Peru for its gastronomic properties, has been studied (Arbizu et al., 2022; Estrada et al., 2024).

Another area that has been gaining importance is the study of pests and diseases. Toledo et al. (2024) studied a disease that causes wilting in escabeche chili pepper crops (*Capsicum baccatum* var. *pendulum*), caused by *Phytophthora capsici* L. They found that temperature and irrigation were factors that influenced the spread of the disease, and that this could be reduced through proper water management. Alma Solis & Vergara Cobian (2023) reported that moths of the genus *Lineodes* feed on the leaves of chili pepper (*C. baccatum*) and sweet pepper (*C. annuum*). These two examples show a wide range of possibilities for future research projects involving the genetic improvement of chili peppers, the study of biological control agents, and the application of models that allow the occurrence of diseases to be anticipated.

In recent years, it has been observed that the focus on the study of Peruvian native chili peppers has shifted from qualitative morphological evaluations toward quantitative phenotypic and phytochemical analyses using high-precision tools, and optimization of extraction processes. Salas-Zeta et al. (2026) evaluated 28 variables in 78 accessions of rocoto (*Capsicum pubescens*) from the Peruvian Andes; applying multivariate analysis, they found that agronomic yield characteristics showed weak correlations with phytochemical traits. The authors indicated that this would allow plant breeding studies, where accessions with high yield can be selected without affecting the nutraceutical quality. Another point that has gained relevance is the optimization of extraction processes using green technologies. Pérez-Vásquez et al. (2026) studied the ultrasound-assisted extraction of bioactive compounds present in three varieties of charapita chili pepper (*Capsicum frutescens*); through kinetic modeling and response surface methodology, they demonstrated that short extraction times (60-180 seconds) maximize phytochemical yield without degrading its components.

9 Bibliometric analysis

9.1 Scientific production by year and country

Figure 8a shows the scientific production indexed in Web of Science and Scopus on Peruvian native chili peppers. The number of articles published remained low and fluctuated between 2009 and 2017 (0 to 3 articles/year). From 2020 onward, a

sustained growth phase began, reaching its highest peak in 2025, with 6 articles. This reflects a growing interest in recent years not only in the study of native chili pepper varieties, but also in publishing these findings in indexed journals to maximize their reach.

According to the authors’ affiliations, 71% of the authors appearing in the publications have links to institutions in Peru (Figure 8b); however, this figure also reveals important collaboration networks with institutions in other countries. It was also found that, according to the institutional affiliation of the authors, the National Institute of Agrarian Innovation (INIA) and the National Agrarian University La Molina are the public institutions that stand out in the production of scientific knowledge on Peruvian native chili peppers.

9.2 Thematic map

Words such as “Capsicum frutescens”, “Capsicum baccatum”, “Peru”, “capsaicin”, “chili pepper”, “mass spectrometry”, “multivariate analysis”, and “Capsicum spp.” were located in the Motor Themes quadrant, that is, they are themes with a high level of development and, at the same time, of great importance (Figure 9). With this, we could indicate that the main research drivers in this field are focused on the study of specific varieties and their components, through techniques such as spectroscopy and multivariate analysis methods. On the other

hand, words such as “pungency”, “esters”, and “gas chromatography” also show good development, but with slightly lower relevance.

In the Basic Terms quadrant, words such as “pepper”, “fruit”, and “plant extract” are observed. Terms with high centrality but low density are located here, that is, they are concepts that serve as a basis for studies, but by themselves lack specialization. Finally, topics such as “carotenoids”, “bioactive compounds”, “phenolic compounds”, “biotechnology”, “somatic embryos”, “vitamin C”, and “accessions” were in the Emerging or Declining Themes quadrant; here, words that are receiving less attention, or that are new research trends, are located. In the context of Peruvian native chili peppers, these could be the trending topics, that is, research is focusing on biotechnological applications, *in vitro* cultures (somatic embryogenesis), and the characterization of matrices (carotenoids and polyphenols).

9.3 Keyword co-occurrence

Figure 10a displays, using colored circles, the most frequent keywords and their relationships. A larger circle indicates that the word has been used more frequently in the articles. The keywords that stood out the most are “Capsicum,” “chili pepper”, “pepper”, “fruit”, and “Capsicum frutescens”, suggesting that the study of these species is the core of this field.

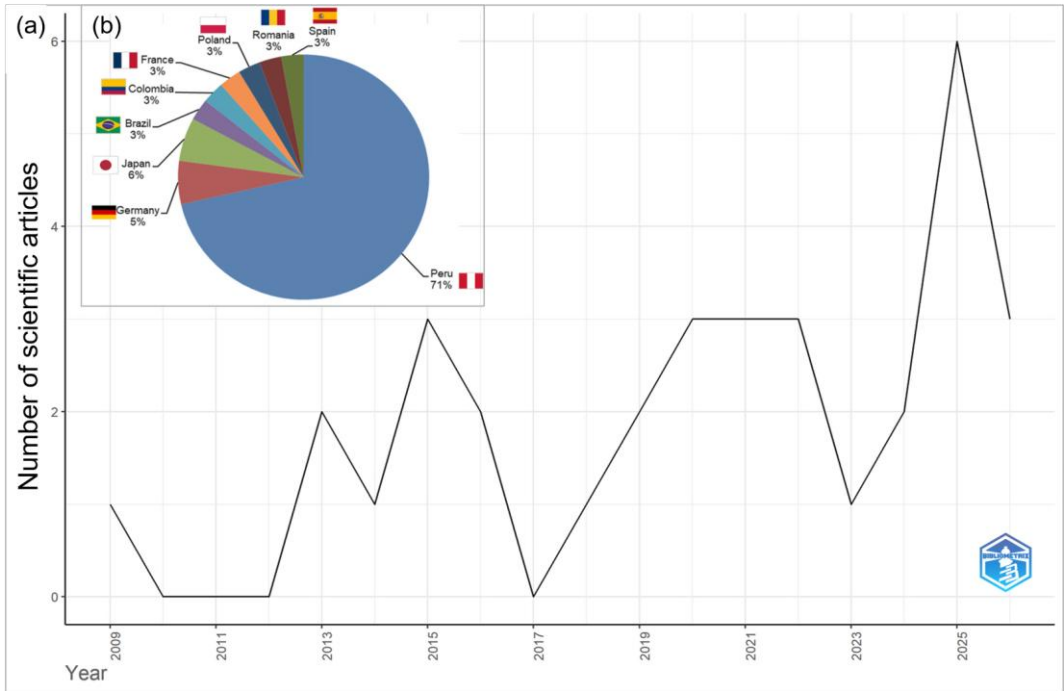


Figure 8. (a) Annual scientific production on Peruvian native *Capsicum* (2009 - 2026). (b) Geographic distribution of publications by authors’ country of affiliation.

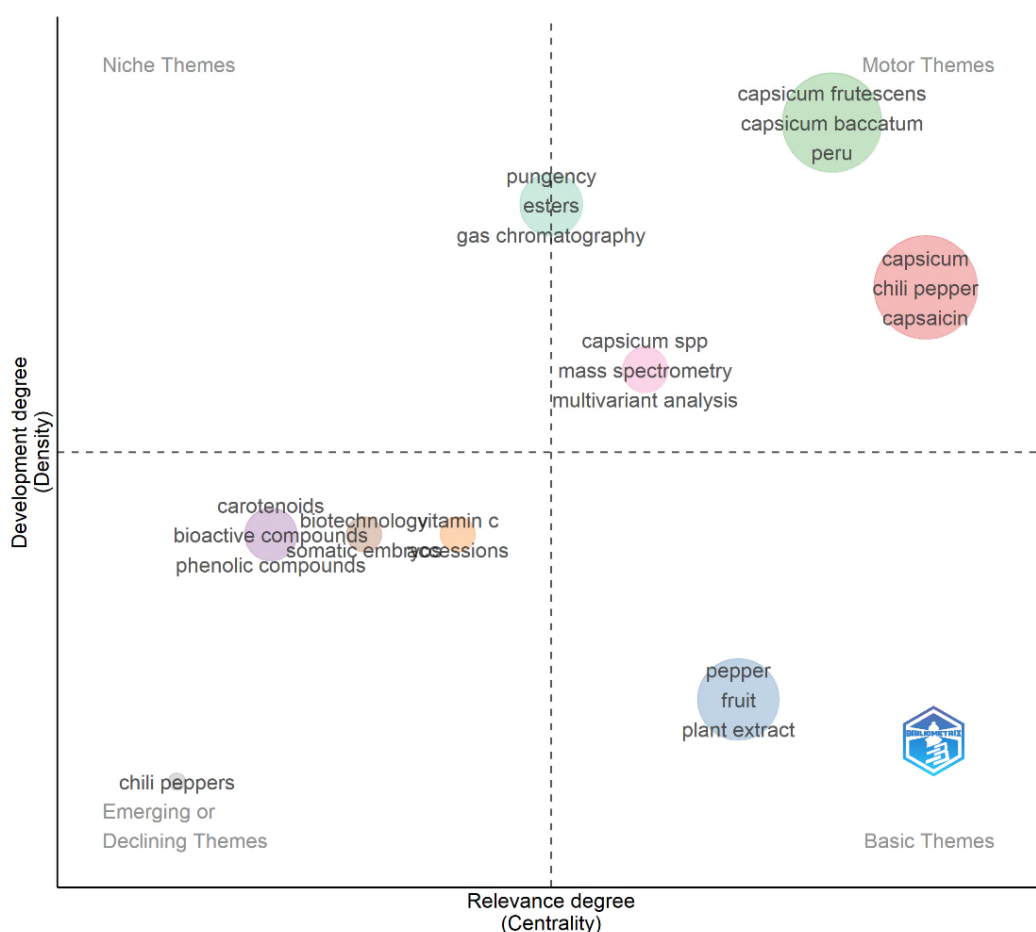


Figure 9. Thematic map of research on Peruvian native *Capsicum*.

When analyzing each cluster, we found interesting data. The red cluster could represent the interest in studying the species, varieties, and fruits of Peruvian native chili peppers. The blue cluster, where words such as “capsaicinoids”, “carotenoids”, “phenolic compounds”, “extraction” and “bioactive compounds” stand out, is associated with the interest in terms of chemical composition and compounds with functional characteristics. The green cluster where the terms “gas chromatography”, “mass spectrometry”, and “multivariate analysis” appear, reflects the techniques used for phytochemical characterization. In the yellow cluster, words related to genetic diversity, variability among accessions and the conservation of these genetic resources can be seen. And the purple cluster represents studies conducted specifically on *rocoto* with a biotechnological approach.

Figure 10b shows the evolution of the keywords used in studies on Peruvian native chili peppers between 2009 and 2026. In the first period, which covers from 2009 to 2015, words related to more exploratory studies appear, based on the

taxonomic and botanical profile, and also on the analysis of certain characteristics such as color and genetic variability. In the second period (2016 - 2020), topics related to chemical and analytical characterization already appear, which is why we can observe words such as “gas chromatography-mass spectrometry”, “volatile organic compounds”, and “esters”. And finally, in the third period (2021 - 2026), terms more related to biotechnology, antioxidant capacity, and the valorization of bioactive compounds are shown. This evolution of keywords over time shows a progressive change in the study of Peruvian native chili peppers, from a focus on identification and basic characterization, to studies more focused on the characterization of more specific bioactive compounds and the interest in exploring their industrial potential.

9.4 Co-authorship network analysis

Figure 11 shows the co-authorship network of researchers who conducted studies related to Peruvian native chili peppers. The size of the circles is proportional to the productivity of each author,

the lines represent collaborations between authors, and the colors indicate groups of authors who tend to collaborate with each other. The authors with the highest number of publications were Meckelmann, S. W.; Petz, M.; Peña, K.; Ríos, L. and Van Zonneveld, M. However, several groups that do not show connections can be observed, that is, there is a lack of collaboration between the different groups.

When analyzing the authors over time (Figure 11b), the emergence of new researchers can be observed, whose studies focused precisely on the trending topics. This trend could be of great importance for increasing studies on Peruvian native chili peppers, since in this way the study of a greater number of native species and different regions of Peru is ensured. However, it also highlights the need to promote collaborations between the different research groups.

9.5 Bibliometric gap and research opportunities

Considering that the bibliometric analysis was based on 33 studies found in indexed databases (Scopus and Web of Science), we could say that

Peruvian native chili peppers are still relatively underrepresented in the scientific literature, within the indexed literature retrieved under the defined search strategy, despite the great diversity of these genetic resources. A large part of these studies has focused on the characterization of species, genetic diversity, phytochemical composition, and bioactive compounds. This still leaves a wide knowledge gap where future research projects could be focused, such as the study of functional properties, industrial-level applications, and the sustainable valorization of these native chili pepper species.

On the other hand, the few connections in the co-authorship network reflect the need to promote interdisciplinary collaboration among the different groups. In this sense, strengthening collaboration networks, together with the publication of studies in international scientific databases, could notably increase the visibility of Peruvian native chili peppers, which in turn could result in the attraction of new collaboration opportunities and access to new funding sources.

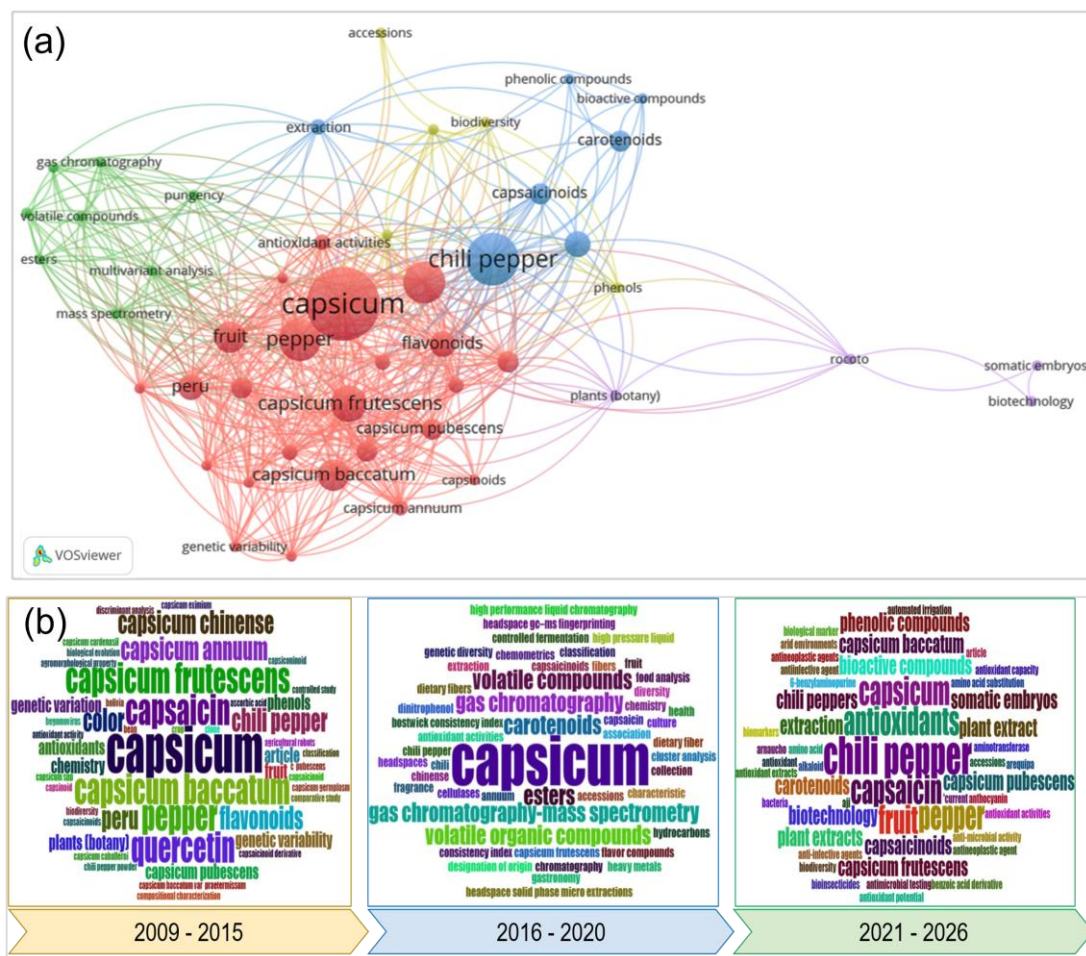


Figure 10. (a) Keyword co-occurrence network; (b) Evolution of research themes.

Author Contributions

Pérez-Vásquez R.: Conceptualization, methodology, visualization, Writing – original draft, investigation. **Pasquel-Reátegui J. L.**: Conceptualization, investigation, Methodology, Resources, Project administration, Supervision, Writing – review & editing. **Vélez-Erazo E. M.**: Conceptualization, investigation, Methodology, Resources, Project administration, Supervision, Writing – review & editing.

ORCID

R. Pérez-Vásquez  <https://orcid.org/0000-0001-6160-480X>

J. L. Pasquel-Reátegui  <https://orcid.org/0000-0001-6467-394X>

E. M. Vélez-Erazo  <https://orcid.org/0000-0002-8632-5329>

Referencias bibliográficas

- Akmal, M., Hasnain, N., Rehan, A., Iqbal, U., Hashmi, S., Fatima, K., Farooq, M. Z., Khosa, F., Siddiqi, J., & Khan, M. K. (2020). Glioblastoma multiforme: A bibliometric analysis. *World Neurosurgery*, 136, 270–282. <https://doi.org/10.1016/j.wneu.2020.01.027>
- Albrecht, E., Zhang, D., Mays, A. D., Saftner, R. A., & Stommel, J. R. (2012). Genetic diversity in *Capsicum baccatum* is significantly influenced by its ecogeographical distribution. *BMC Genetics*, 13(1), 1–15. <https://doi.org/10.1186/1471-2156-13-68>
- Aliaga Camarena, J. C., Jamanca Gonzales, N. C., & Vega Portalatino, E. J. (2021). Análisis proximal físicoquímico y metabólico de frutos del ecotipo *Capsicum chinense* JACQ. "Aji supano" para fines industriales. *REBIOL*, 40(2), 256–264. <https://doi.org/10.17268/rebiol.2020.40.02.12>
- Allemand, A., Leonardi, B. F., Zimmer, A. R., Moreno, S., Romão, P. R. T., & Gosmann, G. (2016). Red pepper (*Capsicum baccatum*) extracts present anti-inflammatory effects in vivo and inhibit the production of TNF- α and NO in vitro. *Journal of Medicinal Food*, 19(8), 759–767. <https://doi.org/10.1089/JMF.2015.0101>
- Alma Solis, M., & Vergara Cobian, C. E. (2023). Lineodes guenée (Crambidae: Spilomelinae) of Peru: New reports of larval feeding on solanaceae and new species. *Proceedings of the Entomological Society of Washington*, 124(4), 845–859. <https://doi.org/10.4289/0013-8797.124.4.845>
- Alvarez-Parrilla, E., De La Rosa, L. A., Amarowicz, R., & Shahidi, F. (2012). Protective effect of fresh and processed Jalapeño and Serrano peppers against food lipid and human LDL cholesterol oxidation. *Food Chemistry*, 133(3), 827–834. <https://doi.org/10.1016/j.foodchem.2012.01.100>
- Araújo, C. M. M., Silva Filho, D. F., Ticona-Benavente, C. A., & Batista, M. R. A. (2018). Morphoagronomic characteristics display high genetic diversity in Murupi chili pepper landraces. *Horticultura Brasileira*, 36(1), 83–87. <https://doi.org/10.1590/S0102-053620180114>
- Arbizu, C. I., Saldaña, C. L., Ferro-Mauricio, R. D., Chávez-Galarza, J. C., Herrera, J., et al. (2022). Characterization of the complete chloroplast genome of a Peruvian landrace of *Capsicum chinense* Jacq. (Solanaceae), arnaucho chili pepper. *Mitochondrial DNA Part B*, 7(1), 156–158. <https://doi.org/10.1080/23802359.2021.2014366>
- Arora, R., Gill, N. S., Chauhan, G., & Rana, A. C. (2011). An overview about versatile molecule capsaicin. *International Journal of Pharmaceutical Sciences and Drug Research*, 3(4), 280–286.
- Ashil, J., Febi, J., Jestin, V. T., Syam, D. S., Balu, M., Ratheesh, M., & Krishnakumar, I. M. (2021). Influence of a novel food-grade formulation of red chili extract (*Capsicum annum*) on overweight subjects: Randomized, double-blinded, placebo-controlled study. *Journal of Dietary Supplements*, 18(4), 387–405. <https://doi.org/10.1080/19390211.2020.1780363>
- Aza-González, C., Núñez-Palenius, H. G., & Ochoa-Alejo, N. (2011). Molecular biology of capsaicinoid biosynthesis in chili pepper (*Capsicum* spp.). *Plant Cell Reports*, 30(5), 695–706. <https://doi.org/10.1007/s00299-010-0968-8>
- Baba, V. Y., Rocha, K. R., Gomes, G. P., de Fátima Ruas, C., Ruas, P. M., Rodrigues, R., & Gonçalves, L. S. A. (2016). Genetic diversity of *Capsicum chinense* accessions based on fruit morphological characterization and AFLP markers. *Genetic Resources and Crop Evolution*, 63(8), 1371–1381. <https://doi.org/10.1007/s10722-015-0325-4>
- Bacon, K., Boyer, R., Denbow, C., O'Keefe, S., Neilson, A., & Williams, R. (2017). Antibacterial activity of jalapeño pepper (*Capsicum annum* var. *annuum*) extract fractions against select foodborne pathogens. *Food Science & Nutrition*, 5(3), 730–738. <https://doi.org/10.1002/FSN3.453>
- Baenas, N., Belović, M., Ilic, N., Moreno, D. A., & García-Viguera, C. (2019). Industrial use of pepper (*Capsicum annum* L.) derived products: Technological benefits and biological advantages. *Food Chemistry*, 274, 872–885. <https://doi.org/10.1016/j.foodchem.2018.09.047>
- Bernstein, P. S., Li, B., Vachali, P. P., Gorusupudi, A., Shyam, R., Henriksen, B. S., & Nolan, J. M. (2016). Lutein, zeaxanthin, and meso-zeaxanthin: The basic and clinical science underlying carotenoid-based nutritional interventions against ocular disease. *Progress in Retinal and Eye Research*, 50, 34–66. <https://doi.org/10.1016/j.preteyeres.2015.10.003>
- Bogusz, S., Libardi, S. H., Dias, F. F. G., Coutinho, J. P., Bochi, V. C., Rodrigues, D., Melo, A. M. T., & Godoy, H. T. (2018). Brazilian *Capsicum* peppers: capsaicinoid content and antioxidant activity. *Journal of the Science of Food and Agriculture*, 98(1), 217–224. <https://doi.org/10.1002/JSSFA.8459>
- Bogusz, S., Março, P. H., Valderrama, P., Damasceno, F. C., Aranda, M. S., et al. (2015). Analysis of volatile compounds in *Capsicum* spp. by headspace solid-phase microextraction and GC $\times$ GC-TOFMS. *Analytical Methods*, 7(2), 521–529. <https://doi.org/10.1039/C4AY01455C>
- Boiko, Y. A., Kravchenko, I. A., Shandra, A. A., & Boiko, I. A. (2017). Extraction, identification and anti-inflammatory activity of carotenoids out of *Capsicum Anuum* L. *Journal of Hermed Pharmacology Journal Homepage: J Hermed Pharmacol*, 6(1), 10–15.
- Bosland, P. W., & Votava, E. J. (2012). *Peppers: Vegetable and Spice Capsicums* (2nd ed.). <https://doi.org/10.1080/01140671.2012.745161>
- Butcher, J. D., Crosby, K. M., Yoo, K. S., Patil, B. S., Ibrahim, A. M. H., Leskovar, D. I., & Jifon, J. L. (2012). Environmental and genotypic variation of capsaicinoid and flavonoid concentrations in habanero (*Capsicum chinense*) peppers. *HortScience*, 47(5), 574–579. <https://doi.org/10.21273/HORTSCI.47.5.574>
- Carvalho, A. V., de Andrade Mattietto, R., de Oliveira Rios, A., de Almeida Maciel, R., Moresco, K. S., & de Souza Oliveira, T. C. (2015). Bioactive compounds and antioxidant activity of pepper (*Capsicum* sp.) genotypes. *Journal of Food Science and Technology*, 52(11), 7457–7464. <https://doi.org/10.1007/s13197-015-1833-0>
- Chen, L., & Kang, Y. H. (2013). Anti-inflammatory and antioxidant activities of red pepper (*Capsicum annum* L.) stalk extracts: Comparison of pericarp and placenta extracts. *Journal of Functional Foods*, 5(4), 1724–1731. <https://doi.org/10.1016/j.jff.2013.07.018>
- Chularojmontri, L., Suwatronnakorn, M., & Wattanapitayakul, S. K. (2010). Influence of capsicum extract and capsaicin on endothelial health. *Journal of the Medical Association of Thailand*, 93(2), 92–101.
- Danza, A., Mastromatteo, M., Cozzolino, F., Lecce, L., Lampignano, V., Laverse, J., & Del Nobile, M. A. (2014). Processing and characterization of durum wheat bread enriched with antioxidant from yellow pepper flour. *LWT - Food Science and Technology*, 59(1), 479–485. <https://doi.org/10.1016/j.lwt.2014.06.001>
- Dawidowicz, A. L., & Olszowy, M. (2011). Antioxidant properties of BHT estimated by ABTS assay in systems differing in pH or metal ion or water concentration. *European Food Research and*

- Technology*, 232(5), 837–842. <https://doi.org/10.1007/s00217-011-1451-7>
- de Freitas Marinho, L., Sganzerla, W. G., Ferreira, V. C., Jimenez Moreno, J. A., Rostagno, M. A., & Forster-Carneiro, T. (2023). Advances in green extraction methods, biological properties, and applications of betanin and vitexin: An updated review and bibliometric analysis. *Biocatalysis and Agricultural Biotechnology*, 51, 102744. <https://doi.org/10.1016/j.BCAB.2023.102744>
- de Sá Mendes, N., & Branco de Andrade Gonçalves, É. C. (2020). The role of bioactive components found in peppers. *Trends in Food Science & Technology*, 99, 229–243. <https://doi.org/10.1016/j.TIFS.2020.02.032>
- de Sá Mendes, N., Coimbra, P. P. S., Santos, M. C. B., Cameron, L. C., Ferreira, M. S. L., Buera, M. del P., & Gonçalves, É. C. B. A. (2020). *Capsicum pubescens* as a functional ingredient: Microencapsulation and phenolic profiling by UPLC-MSE. *Food Research International*, 135. <https://doi.org/10.1016/j.foodres.2020.109292>
- de Sá Mendes, N., Favre, L. C., Rolandelli, G., Ferreira, C. dos S., Gonçalves, É. C. B. de A., & Buera, M. del P. (2019). Flour from “fruits and vegetables” waste with addition of a South-American pepper (*Capsicum baccatum*) proposed as food ingredient. *International Journal of Food Science & Technology*, 55(3), 1230–1237. <https://doi.org/10.1111/IJFS.14358>
- de Sá Mendes, N., Santos, M. C. P., Santos, M. C. B., Cameron, L. C., Ferreira, M. S. L., & Gonçalves, É. C. B. A. (2019). Characterization of pepper (*Capsicum baccatum*) - A potential functional ingredient. *LWT*, 112, 108209. <https://doi.org/10.1016/j.LWT.2019.05.107>
- Duranova, H., Valkova, V., & Gabriny, L. (2022). Chili peppers (*Capsicum* spp.): the spice not only for cuisine purposes: an update on current knowledge. *Phytochemistry Reviews*, 20(21), 21(4), 1379–1413. <https://doi.org/10.1007/S11011-021-09789-7>
- Espichán, F., Rojas, R., Quispe, F., Cabanac, G., & Marti, G. (2022). Metabolomic characterization of 5 native Peruvian chili peppers (*Capsicum* spp.) as a tool for species discrimination. *Food Chemistry*, 386. <https://doi.org/10.1016/j.foodchem.2022.132704>
- Estrada, R., Tantalean, J. F. C., Saldaña, C. L., Romero, Y., Vilcar, E., & Arbizu, C. I. (2024). Draft genome and SSR data mining of a Peruvian landrace of *Capsicum chinense*, the arnaucho chili pepper. *Genetic Resources and Crop Evolution*, 1–9. <https://doi.org/10.1007/s10722-024-01941-4>
- Fabozzi, A., Della Corte, L., Formisano, C., Giampaolino, P., Nappi, C., & Bifulco, G. (2020). Effects of an oral supplement based on cucurbita maxima and *Capsicum annum* on symptoms of overactive bladder in female population: an observational study. *Advances in Integrative Medicine*, 7(3), 158–162. <https://doi.org/10.1016/j.AIMED.2020.05.003>
- Fattori, V., Hohmann, M. S. N., Rossaneis, A. C., Pinho-Ribeiro, F. A., & Verri, W. A. (2016). Capsaicin: Current understanding of its mechanisms and therapy of pain and other pre-clinical and clinical uses. *Molecules*, 21(7), 844. <https://doi.org/10.3390/MOLECULES21070844>
- Fernández-Bedmar, Z., & Alonso-Moraga, A. (2016). In vivo and in vitro evaluation for nutraceutical purposes of capsaicin, capsanthin, lutein and four pepper varieties. *Food and Chemical Toxicology*, 98, 89–99. <https://doi.org/10.1016/j.FCT.2016.10.011>
- Ferrando, B. O., Baenas, N., & Periago, M. J. (2024). Changes in carotenoids and quality parameters of sweet Paprika (*Capsicum annum*) after an accelerated heat treatment. *Antioxidants*, 13(12), 1492. <https://doi.org/10.3390/antiox13121492>
- Ghasemnezhad, M., Sherafati, M., & Payvast, G. A. (2011). Variation in phenolic compounds, ascorbic acid and antioxidant activity of five coloured bell pepper (*Capsicum annum*) fruits at two different harvest times. *Journal of Functional Foods*, 3(1), 44–49. <https://doi.org/10.1016/j.JFF.2011.02.002>
- Giri, T. K., Pramanik, K., Barman, T. K., & Maity, S. (2017). Nano-encapsulation of dietary phytoconstituent capsaicin on emulsome: Evaluation of anticancer activity through the measurement of liver oxidative stress in rats. *Anti-Cancer Agents in Medicinal Chemistry*, 17(12), 1669–1678. <https://doi.org/10.2174/1871520617666170419121322>
- Giuffrida, D., Dugo, P., Torre, G., Bignardi, C., Cavazza, A., Corradini, C., & Dugo, G. (2013). Characterization of 12 *Capsicum* varieties by evaluation of their carotenoid profile and pungency determination. *Food Chemistry*, 140(4), 794–802. <https://doi.org/10.1016/J.FOODCHEM.2012.09.060>
- Giuffrida, D., Dugo, P., Torre, G., Bignardi, C., Cavazza, A., Corradini, C., & Dugo, G. (2014). Evaluation of carotenoid and capsaicinoid contents in powder of red chili peppers during one year of storage. *Food Research International*, 65(PB), 163–170. <https://doi.org/10.1016/J.FOODRES.2014.06.019>
- González-López, J., Rodríguez-Moar, S., & Silvar, C. (2021). Correlation analysis of high-throughput fruit phenomics and biochemical profiles in native peppers (*Capsicum* spp.) from the primary center of diversification. *Agronomy*, 11(2). <https://doi.org/10.3390/agronomy11020262>
- González-Zamora, A., Sierra-Campos, E., Luna-Ortega, J. G., Pérez-Morales, R., Ortiz, J. C. R., & García-Hernández, J. L. (2013). Characterization of different *Capsicum* varieties by evaluation of their capsaicinoids content by high performance liquid chromatography, determination of pungency and effect of high temperature. *Molecules*, 18(11), 13471–13486. <https://doi.org/10.3390/MOLECULES18113471>
- Grebenstein, N., & Frank, J. (2012). Rapid baseline-separation of all eight tocopherols and tocotrienols by reversed-phase liquid-chromatography with a solid-core pentafluorophenyl column and their sensitive quantification in plasma and liver. *Journal of Chromatography A*, 1243, 39–46. <https://doi.org/10.1016/J.CHROMA.2012.04.042>
- Guevara Pérez, A., Villanueva-Quejia, E., Nolasco Cama, D., Llontop, G., & Cancino Chávez, K. (2021). Effects of applying saturated steam as an Organic Sterilization System (OSS) in mirasol chili pepper (*Capsicum baccatum* var. *pendulum*) and panca chili pepper (*Capsicum chinense* Jacq.). *Enfoque UTE*, 12(3), 1–10. <https://doi.org/10.29019/enfoqueute.675>
- Günel, Z., Varhan, E., Koç, M., Topuz, A., & Sahin-Nadeem, H. (2021). Production of pungency-suppressed capsaicin microcapsules by spray chilling. *Food Bioscience*, 40, 100918. <https://doi.org/10.1016/J.FBIO.2021.100918>
- Gurnani, N., Gupta, M., Mehta, D., & Mehta, B. K. (2016). Chemical composition, total phenolic and flavonoid contents, and in vitro antimicrobial and antioxidant activities of crude extracts from red chilli seeds (*Capsicum frutescens* L.). *Journal of Taibah University for Science*, 10(4), 462–470. <https://doi.org/10.1016/J.JTUSCI.2015.06.011>
- Gurung, T., Techawongstien, S., Suriharn, B., & Techawongstien, S. (2011). Impact of environments on the accumulation of capsaicinoids in *Capsicum* spp. *HortScience*, 46(12), 1576–1581. <https://doi.org/10.21273/HORTSCI.46.12.1576>
- Hazekawa, M., Hideshima, Y., Ono, K., Nishinakagawa, T., Kawakubo-Yasukochi, T., Takatani-Nakase, T., & Nakashima, M. (2017). Anti-inflammatory effects of water extract from bell pepper (*Capsicum annum* L. var. *grossum*) leaves in vitro. *Experimental and Therapeutic Medicine*, 14(5), 4349–4355. <https://doi.org/10.3892/ETM.2017.5106>
- Hernández-Pérez, T., Gómez-García, M. del R., Valverde, M. E., & Paredes-López, O. (2020). *Capsicum annum* (hot pepper): An ancient Latin-American crop with outstanding bioactive compounds and nutraceutical potential. A review. *Comprehensive Reviews in Food Science and Food Safety*, 19(6), 2972–2993. <https://doi.org/10.1111/1541-4337.12634>
- Hervet-Hernández, D., Sáyago-Ayerdi, S. G., & Goñi, I. (2010). Bioactive compounds of four hot pepper varieties (*Capsicum annum* L.), antioxidant capacity, and intestinal bioaccessibility.

- Journal of Agricultural and Food Chemistry*, 58(6), 3399–3406. <https://doi.org/10.1021/JF904220W>
- Iglesias Cruz, A. C. (2020). Vista de variabilidad del fruto en el ecotipo ají "charapita" (*Capsicum frutescens* L.) de la Amazonía peruana. *Ciencia Amazónica*, 8(2), 167–184. <https://doi.org/10.22386/ca.v8i2.295>
- Jäger, M., Jiménez, A., & Amaya, K. (2013a). *Guía de oportunidades de mercado para los ajíes nativos de Perú. Compilación de los estudios de mercado realizados dentro del marco del proyecto "Rescate y Promoción de Ajíes Nativos en su Centro de Origen" para Perú* (Bioversity International, Ed.).
- Jäger, M., Jiménez, A., & Amaya, K. (2013b). *Las cadenas de valor de los ajíes nativos de Perú. Compilación de los estudios realizados dentro del marco del proyecto "Rescate y Promoción de Ajíes Nativos en su Centro de Origen" para Perú*.
- Jarret, R. L., Barboza, G. E., da Costa Batista, F. R., Berke, T., Chou, Y.-Y., et al. (2019). *Capsicum*—An Abbreviated Compendium. *Journal of the American Society for Horticultural Science*, 144(1), 3–22. <https://doi.org/10.21273/JASHS04446-18>
- Jeon, G., Choi, Y., Lee, S. M., Kim, Y., Oh, M., Jeong, H. S., & Lee, J. (2012). Antioxidant and antiproliferative properties of hot pepper (*Capsicum annuum* L.) seeds. *Journal of Food Biochemistry*, 36(5), 595–603. <https://doi.org/10.1111/J.1745-4514.2011.00571.X>
- Jeong, W. Y., Jin, J. S., Cho, Y. A., Lee, J. H., Park, S., et al. (2011). Determination of polyphenols in three *Capsicum annuum* L. (bell pepper) varieties using high-performance liquid chromatography-tandem mass spectrometry: Their contribution to overall antioxidant and anticancer activity. *Journal of Separation Science*, 34(21), 2967–2974. <https://doi.org/10.1002/JSSC.201100524>
- Joshi, D. D., Somkuwar, B. G., Kharkwal, H., & Chander, S. (2022). Aroma based varieties of *Capsicum chinense* Jacq., geographical distribution and scope for expansion of the species. *Journal of Applied Research on Medicinal and Aromatic Plants*, 29, 100379. <https://doi.org/10.1016/j.jarmap.2022.100379>
- Juániz, I., Ludwig, I. A., Bresciani, L., Dall'Asta, M., Mena, P., Del Rio, D., Cid, C., & de Peña, M. P. (2016a). Catabolism of raw and cooked green pepper (*Capsicum annuum*) (poly)phenolic compounds after simulated gastrointestinal digestion and faecal fermentation. *Journal of Functional Foods*, 27, 201–213. <https://doi.org/10.1016/J.JFF.2016.09.006>
- Juániz, I., Ludwig, I. A., Huarte, E., Pereira-Caro, G., Moreno-Rojas, J. M., Cid, C., & De Peña, M. P. (2016b). Influence of heat treatment on antioxidant capacity and (poly)phenolic compounds of selected vegetables. *Food Chemistry*, 197, 466–473. <https://doi.org/10.1016/J.FOODCHEM.2015.10.139>
- Kim, J. S., Ha, T. Y., Kim, S., Lee, S. J., & Ahn, J. (2017). Red paprika (*Capsicum annuum* L.) and its main carotenoid capsanthin ameliorate impaired lipid metabolism in the liver and adipose tissue of high-fat diet-induced obese mice. *Journal of Functional Foods*, 31, 131–140. <https://doi.org/10.1016/J.JFF.2017.01.044>
- Kollmannsberger, H., Rodríguez-Burruezo, A., Nitz, S., & Nuez, F. (2011). Volatile and capsaicinoid composition of ají (*Capsicum baccatum*) and rocoto (*Capsicum pubescens*), two Andean species of chile peppers. *Journal of the Science of Food and Agriculture*, 91(9), 1598–1611. <https://doi.org/10.1002/JSFA.4354>
- Ksibi, I. El, Slama, R. Ben, Faidi, K., Ticha, M. Ben, & M'henni, M. F. (2015). Mixture approach for optimizing the recovery of colored phenolics from red pepper (*Capsicum annuum* L.) by-products as potential source of natural dye and assessment of its antimicrobial activity. *Industrial Crops and Products*, 70, 34–40. <https://doi.org/10.1016/J.INDCROP.2015.03.017>
- Kumar, R., Dwivedi, N., Singh, R. K., Kumar, S., Rai, V. P., & Singh, M. (2011). A review on molecular characterization of pepper for capsaicin and oleoresin. *International Journal of Plant Breeding and Genetics*, 5(2), 99–110. <https://doi.org/10.3923/IJPBG.2011.99.110>
- Libreros, D., Van Zonneveld, M. J., Petz, M., Meckelmann, S. W., Ríos, L., Peña, K., Amaya, K., & Ramírez, M. (2013). Catálogo de ajíes (*Capsicum* spp.) peruanos promisorios conservados en el banco de semillas del INIA - Perú. In *Instituto Nacional de Innovación Agraria. Bioersity International*. <https://repositorio.inia.gob.pe/handle/20.500.12955/88>
- Ligarda Samanez, C. A., Choque-Quipe, D., Allende Allende, L. F., Ramos Pacheco, B. S., & Peralta-Guevara, D. E. (2023). Calidad sensorial y proximal en conservas de mondongo de res (*Bos taurus*) en salsa de ají amarillo (*Capsicum baccatum*). *Ciencia y Tecnología Agropecuaria*, 24(1), 2741. https://doi.org/10.21930/rcta.vol24_num1_art2741
- López Medina, E., López Zavaleta, A., Gil Rivero, A. E., Mostacero León, J., De la Cruz Castillo, A. J., & Villena Zapata, L. (2020). Morfometría de frutos y semillas del "ají mochero" *Capsicum chinense* Jacq. *Ciencia y Tecnología Agropecuaria*, 21(3), 1–11. https://doi.org/10.21930/rcta.vol21_num3_art1598
- Lu, M., Ho, C. T., & Huang, Q. (2017). Extraction, bioavailability, and bioefficacy of capsaicinoids. *Journal of Food and Drug Analysis*, 25(1), 27–36. <https://doi.org/10.1016/J.JFDA.2016.10.023>
- Marini, E., Magi, G., Mingoia, M., Pugnaroni, A., & Facinelli, B. (2015). Antimicrobial and anti-virulence activity of capsaicin against erythromycin-resistant, cell-invasive group A streptococci. *Frontiers in Microbiology*, 6. <https://doi.org/10.3389/FMICB.2015.01281>
- Meckelmann, S. W., Jansen, C., Riegel, D. W., van Zonneveld, M., Ríos, L., Peña, K., Mueller-Seitz, E., & Petz, M. (2015a). Phytochemicals in native Peruvian *Capsicum pubescens* (Rocoto). *European Food Research and Technology*, 241(6), 817–825. <https://doi.org/10.1007/s00217-015-2506-y>
- Meckelmann, S. W., Riegel, D. W., van Zonneveld, M., Ríos, L., Peña, K., Mueller-Seitz, E., & Petz, M. (2015b). Capsaicinoids, flavonoids, tocopherols, antioxidant capacity and color attributes in 23 native Peruvian chili peppers (*Capsicum* spp.) grown in three different locations. *European Food Research and Technology*, 240(2), 273–283. <https://doi.org/10.1007/s00217-014-2325-6>
- Meckelmann, S. W., Riegel, D. W., Van Zonneveld, M. J., Ríos, L., Peña, K., Ugas, R., Quinonez, L., Mueller-Seitz, E., & Petz, M. (2013). Compositional characterization of native Peruvian chili peppers (*Capsicum* spp.). *Journal of Agricultural and Food Chemistry*, 61(10), 2530–2537. <https://doi.org/10.1021/jf304986q>
- Mendiratta, S. K., Shinde, A. T., & Mane, B. G. (2013). Effect of added vegetable (Carrot, Radish and *Capsicum*) as functional ingredients in mutton nuggets. *Journal of Meat Science and Technology*, 1(2), 71–76.
- Menichini, F., Tundis, R., Bonesi, M., Loizzo, M. R., Conforti, F., et al. (2009). The influence of fruit ripening on the phytochemical content and biological activity of *Capsicum chinense* Jacq. cv Habanero. *Food Chemistry*, 114(2), 553–560. <https://doi.org/10.1016/J.FOODCHEM.2008.09.086>
- MIDAGRI. (2020, September 3). *Más de 200 mil toneladas de ajíes se producen a nivel nacional*. Ministerio de Desarrollo Agrario y Riego, Gobierno Del Perú. <https://www.gob.pe/institucion/midagri/noticias/297684-mas-de-200-mil-toneladas-de-ajies-se-producen-a-nivel-nacional>
- Mokhtar, M., Soukup, J., Donato, P., Cacciola, F., Dugo, P., Riaz, A., Jandera, P., & Mondello, L. (2015). Determination of the polyphenolic content of a *Capsicum annuum* L. extract by liquid chromatography coupled to photodiode array and mass spectrometry detection and evaluation of its biological activity. *Journal of Separation Science*, 38(2), 171–178. <https://doi.org/10.1002/JSSC.201400993>
- Molnár, H., Kónya, É., Zalán, Z., Bata-Vidács, I., Tömösközi-Farkas, R., Székács, A., & Adányi, N. (2018). Chemical characteristics of spice paprika of different origins. *Food Control*, 83, 54–60. <https://doi.org/10.1016/j.foodcont.2017.04.028>
- Morales-Soriano, E., Kebede, B., Ugás, R., Grauwet, T., Van Loey, A., & Hendrickx, M. (2018). Flavor characterization of native Peruvian chili peppers through integrated aroma fingerprinting and pungency profiling. *Food Research International*, 109, 250–259. <https://doi.org/10.1016/j.foodres.2018.04.030>

- Morales-Soriano, E., Panozzo, A., Ugás, R., Grauwet, T., Van Loey, A., & Hendrickx, M. (2019). Carotenoid profile and basic structural indicators of native Peruvian chili peppers. *European Food Research and Technology*, 245(3), 717–732. <https://doi.org/10.1007/s00217-018-3193-2>
- Nascimento, P. L. A., Nascimento, T. C. E. S., Ramos, N. S. M., Silva, G. R., Gomes, J. E. G., et al. (2014). Quantification, antioxidant and antimicrobial activity of phenolics isolated from different extracts of *Capsicum frutescens* (pimenta malagueta). *Molecules*, 19(4), 5434–5447. <https://doi.org/10.3390/MOLECULES19045434>
- Nwachukwu, I. D., Udenigwe, C. C., & Aluko, R. E. (2016). Lutein and zeaxanthin: Production technology, bioavailability, mechanisms of action, visual function, and health claim status. *Trends in Food Science & Technology*, 49, 74–84. <https://doi.org/10.1016/j.TIFS.2015.12.005>
- Oguzie, E. E., Oguzie, K. L., Akalezi, C. O., Udeze, I. O., Ogbulie, J. N., & Njoku, V. O. (2013). Natural products for materials protection: Corrosion and microbial growth inhibition using *Capsicum frutescens* biomass extracts. *ACS Sustainable Chemistry and Engineering*, 1(2), 214–225. <https://doi.org/10.1021/sc300145k>
- Ortega Morales, C. F., Irie, K., & Kawase, M. (2025). A comparative analysis of fruit quality and flavor in *Capsicum chinense* and *Capsicum annuum* from Myanmar, Peru, and Japan. *International Journal of Plant Biology*, 16(3), 90. <https://doi.org/10.3390/ijpb16030090>
- Ortiz, R., Delgado de la Flor, F., Alvarado, G., & Crossa, J. (2010). Classifying vegetable genetic resources—A case study with domesticated *Capsicum* spp. *Scientia Horticulturae*, 126(2), 186–191. <https://doi.org/10.1016/j.SCIENTA.2010.07.007>
- Palombo, N. E., & Carrizo García, C. (2022). Geographical patterns of genetic variation in Locoto Chile (*Capsicum pubescens*) in the Americas Inferred by Genome-Wide Data Analysis. *Plants*, 11(21), 2911. <https://doi.org/10.3390/plants11212911>
- Patel, K., Calderon, R., Asencios, E., Vilchez, D., Marcelo, M., & Rojas, R. (2016a). Agro-morphological characteristics and sensory evaluation of native Peruvian chili peppers. *Journal of Agricultural Science and Technology B*, 6(3), 180–187. <https://doi.org/10.17265/2161-6264/2016.03.005>
- Patel, K., Ruiz, C., Calderon, R., Marcelo, M., & Rojas, R. (2016b). Characterisation of volatile profiles in 50 native Peruvian chili pepper using solid phase microextraction–gas chromatography mass spectrometry (SPME–GCMS). *Food Research International*, 89, 471–475. <https://doi.org/10.1016/j.foodres.2016.08.023>
- Pérez-Vásquez, R., Pasquel-Reátegui, J. L., & Vélez-Erazo, E. M. (2026). Recovery of bioactive compounds from three varieties of Charapita chili pepper (*Capsicum frutescens*) by ultrasound-assisted extraction. *Journal of Food Measurement and Characterization*, 20(4), 4675–4689. <https://doi.org/10.1007/S11694-025-03953-9>
- Porta, B., Ríos, M., Cañedo, V., & Aréstegui, K. (2024). Diversidad de uchu (*Capsicum* spp.) en Warmiragra, sierra central de Perú: criterios de selección, manejo tradicional y uso cultural. In Editorial de la Universidad Veracruzana (Ed.), *Chiles, ajíes y pimentas: Capsicum en el Caribe, Centro y Sudamérica* (pp. 333–359).
- Pugliese, A., Loizzo, M. R., Tundis, R., O'Callaghan, Y., Galvin, K., Menichini, F., & O'Brien, N. (2013). The effect of domestic processing on the content and bioaccessibility of carotenoids from chili peppers (*Capsicum* species). *Food Chemistry*, 141(3), 2606–2613. <https://doi.org/10.1016/J.FOODCHEM.2013.05.046>
- Quispe, F., Marcelo, M., Chanamé, J., Bederski, S., & Snachez, L. (2019). *Caracterización agro - morfológica y químico - nutricional de cinco ajíes promisorios del INIA - PERÚ* (F. Quispe Jacobo, Ed.; 1st ed.).
- Ranilla, L. G., Kwon, Y. I., Apostolidis, E., & Shetty, K. (2010). Phenolic compounds, antioxidant activity and in vitro inhibitory potential against key enzymes relevant for hyperglycemia and hypertension of commonly used medicinal plants, herbs and spices in Latin America. *Bioresource Technology*, 101(12), 4676–4689. <https://doi.org/10.1016/J.BIORTECH.2010.01.093>
- Raza, K., Shareef, M. A., Singal, P., Sharma, G., Negi, P., & Kataré, O. P. (2014). Lipid-based capsaicin-loaded nano-colloidal biocompatible topical carriers with enhanced analgesic potential and decreased dermal irritation. *Journal of Liposome Research*, 24(4), 290–296. <https://doi.org/10.3109/08982104.2014.911314>
- Reyes-Escogido, M. D. L., Gonzalez-Mondragon, E. G., & Vazquez-Tzompantzi, E. (2011). Chemical and pharmacological aspects of capsaicin. *Molecules*, 16(2), 1253–1270. <https://doi.org/10.3390/MOLECULES16021253>
- Rodríguez, G., Cervi, A., Citti, F., Aguirre, E., Estivi, L., de Fatima Arevalo-Oliva, M., et al. (2026). Characterization of cold-pressed oils extracted from seeds of different *Capsicum* species. *Food Production, Processing and Nutrition*, 8(1), 64–. <https://doi.org/10.1186/S43014-026-00423-7>
- Rodríguez-Burruezo, A., González-Mas, M. del C., & Nuez, F. (2010). Carotenoid composition and vitamin A value in ají (*Capsicum baccatum* L.) and rocoto (*C. pubescens* R. & P.), 2 pepper species from the andean region. *Journal of Food Science*, 75(8), S446–S453. <https://doi.org/10.1111/J.1750-3841.2010.01795.X>
- Rodríguez-Burruezo, A., Kollmannsberger, H., González-Mas, M. C., Nitz, S., & Fernando, N. (2010). HS-SPME comparative analysis of genotypic diversity in the volatile fraction and aroma-contributing compounds of *Capsicum* fruits from the *annuum*–*chinense*–*frutescens* complex. *Journal of Agricultural and Food Chemistry*, 58(7), 4388–4400. <https://doi.org/10.1021/JF903931T>
- Rojas, R., Patel, K., Ruiz, C., Calderón, R., Asencios, E., Quispe, F., & Marcelo, M. (2016). *Ajíes nativos peruanos - caracterización agro-morfológica, químico-nutricional y sensorial* (R. Rojas, Ed.; 1st ed.). Universidad Peruana Cayetano Heredia.
- Ruiz-Lau, N., Medina-Lara, F., Minero-García, Y., Zamudio-Moreno, E., Guzmán-Antonio, A., Echevarría-Machado, I., & Martínez-Estévez, M. (2011). Water deficit affects the accumulation of capsaicinoids in fruits of *Capsicum chinense* Jacq. *HortScience*, 46(3), 487–492. <https://doi.org/10.21273/HORTSCI.46.3.487>
- Saito, M., & Yoneshiro, T. (2013). Capsinoids and related food ingredients activating brown fat thermogenesis and reducing body fat in humans. *Current Opinion in Lipidology*, 24(1), 71–77. <https://doi.org/10.1097/MOL.0B013E32835A4F40>
- Salas-Zeta, E. L., Bernal-Canales, K. L., Delgado-Lazo, A., Pacheco-Lizárraga, G., Hermoza-Gutiérrez, M., et al. (2026). Comprehensive Morpho-Functional Profiling of Peruvian Andean *Capsicum pubescens* Germplasm Reveals Promising Accessions with High Agronomic and Nutraceutical Value. *Plants*, 15(2), 288. <https://doi.org/10.3390/plants15020288>
- Sandoval-Castro, C. J., Valdez-Morales, M., Oomah, B. D., Gutiérrez-Dorado, R., Medina-Godoy, S., & Espinosa-Alonso, L. G. (2017). Bioactive compounds and antioxidant activity in scalded Jalapeño pepper industrial byproduct (*Capsicum annuum*). *Journal of Food Science and Technology*, 54(7), 1999–2010. <https://doi.org/10.1007/S13197-017-2636-2>
- Sarpras, M., Gaur, R., Sharma, V., Chhakekar, S. S., Das, J., et al. (2016). Comparative analysis of fruit metabolites and pungency candidate genes expression between bhut jolokia and other *Capsicum* species. *PLOS ONE*, 11(12), e0167791. <https://doi.org/10.1371/JOURNAL.PONE.0167791>
- SENASA. (2024). *Exportación de ajíes peruanos superó las 27 mil toneladas certificadas este año*. Servicio Nacional de Sanidad Agraria Del Perú - Plataforma Del Estado Peruano.
- Shanmugaprakash, M., Jayashree, C., Vinothkumar, V., Senthilkumar, S. N. S., Siddiqui, S., Rawat, V., & Arshad, M. (2015). Biochemical characterization and antitumor activity of three phase partitioned L-asparaginase from *Capsicum annuum* L. *Separation and Purification Technology*, 142, 258–267. <https://doi.org/10.1016/J.SEPUR.2014.12.036>
- Sluijs, I., Cadier, E., Beulens, J. W. J., van der A, D. L., Spijkerman, A. M. W., & van der Schouw, Y. T. (2015). Dietary intake of

- carotenoids and risk of type 2 diabetes. *Nutrition, Metabolism and Cardiovascular Diseases*, 25(4), 376–381. <https://doi.org/10.1016/j.numecd.2014.12.008>
- Sociedad Peruana de Gastronomía, Programa de Hortalizas de la Universidad Nacional Agraria La Molina, Instituto de Innovación Agraria, & Instituto de Investigaciones en Hotelería y Turismo de la Universidad San Martín de Porres. (2009). *Ajías Peruanas sazón para el mundo* (Sociedad Peruana de Gastronomía, Ed.; 1st ed.). El Comercio S.A.
- Song, J. X., Ren, H., Gao, Y. F., Lee, C. Y., Li, S. F., Zhang, F., Li, L., & Chen, H. (2017). Dietary capsaicin improves glucose homeostasis and alters the gut microbiota in obese diabetic ob/ob mice. *Frontiers in Physiology*, 8, 602. <https://doi.org/10.3389/fphys.2017.00602>
- Sricharoen, P., Lamaiphan, N., Patthawaro, P., Limchoowong, N., Techawongstien, S., & Chanthai, S. (2017). Phytochemicals in *Capsicum* oleoresin from different varieties of hot chilli peppers with their antidiabetic and antioxidant activities due to some phenolic compounds. *Ultrasonics Sonochemistry*, 38, 629–639. <https://doi.org/10.1016/j.ultrasonch.2016.08.018>
- Sudré, C. P., Gonçalves, L. S. A., Rodrigues, R., Do Amaral, A. T., Riva-Souza, E. M., & Bento, C. D. S. (2010). Genetic variability in domesticated *Capsicum* spp as assessed by morphological and agronomic data in mixed statistical analysis. *Genetics and Molecular Research: GMR*, 9(1), 283–294. <https://doi.org/10.4238/VOL9-1GMR698>
- Thongin, S., Den-udom, T., Uppakara, K., Sriwantana, T., Sibmooh, N., Laolob, T., Boonthip, C., Wichai, U., Muta, K., & Ketsawatsomkron, P. (2022). Beneficial effects of capsaicin and dihydrocapsaicin on endothelial inflammation, nitric oxide production and antioxidant activity. *Biomedicine & Pharmacotherapy*, 154, 113521. <https://doi.org/10.1016/j.biopha.2022.113521>
- Toledo, A., Aragón, L., & Casas, A. (2024). Space-time analysis, severity of the wilt disease in escabeche pepper (*Capsicum baccatum* var. Pendulum) and identification of the causal agent (*Phytophthora capsici* L.) under subtropical climate conditions in Peru. *Scientia Agropecuaria*, 15(4), 557–567. <https://doi.org/10.17268/sci.agropecu.2024.041>
- Topuz, A., Dincer, C., Özdemir, K. S., Feng, H., & Kushad, M. (2011). Influence of different drying methods on carotenoids and capsaicinoids of paprika (Cv., Jalapeno). *Food Chemistry*, 129(3), 860–865. <https://doi.org/10.1016/j.foodchem.2011.05.035>
- Tundis, R., Menichini, F., Bonesi, M., Conforti, F., Statti, G., Menichini, F., & Loizzo, M. R. (2013). Antioxidant and hypoglycaemic activities and their relationship to phytochemicals in *Capsicum annum* cultivars during fruit development. *LWT - Food Science and Technology*, 53(1), 370–377. <https://doi.org/10.1016/j.lwt.2013.02.013>
- Ugás, R. (2012). Clasificación de los ajíes del Perú. In R. Ugás & V. Mendoza (Eds.), *El punto de ají* (1st ed., pp. 8–17). Programa de Hortalizas, UNALM y Programa de cooperación universitaria UNALM - VLIR.
- Valková, V., Ďuranová, H., Ivanišová, E., Galovičová, L., Godočiková, L., Borotová, P., et al. (2021). Antioxidant and antimicrobial activities of fruit extracts from different fresh chili peppers. *Acta Scientiarum Polonorum, Technologia Alimentaria*, 20(4), 465–472. <https://doi.org/10.17306/j.afs.0977>
- Van Zonneveld, M., Ramirez, M., Williams, D. E., Petz, M., Meckelmann, S., et al. (2015). Screening genetic resources of *Capsicum* peppers in their primary center of diversity in Bolivia and Peru. *PLOS ONE*, 10(9). <https://doi.org/10.1371/JOURNAL.PONE.0134663>
- Venier, N. A., Colquhoun, A. J., Sasaki, H., Kiss, A., Sugar, L., Adomat, H., Fleshner, N. E., Klotz, L. H., & Venkateswaran, V. (2015). Capsaicin: A novel radio-sensitizing agent for prostate cancer. *The Prostate*, 75(2), 113–125. <https://doi.org/10.1002/PROS.22896>
- Viacava, G. E., Ansorena, M. R., Roura, S. I., González-Aguilar, G. A., & Ayala-Zavala, J. F. (2013). Fruit processing byproducts as a source of natural antifungal compounds. *Antifungal Metabolites from Plants*, 447–461. https://doi.org/10.1007/978-3-642-38076-1_16
- Vieira-Bard, G. C., Nascimento, V. V., Oliveira, A. E. A., Rodrigues, R., Da Cunha, M., et al. (2014). Vicilin-like peptides from *Capsicum baccatum* L. seeds are α -amylase inhibitors and exhibit antifungal activity against important yeasts in medical mycology. *Peptide Science*, 102(4), 335–343. <https://doi.org/10.1002/BIP.22504>
- Villar, J. E. (2019). *Capsaicinoides, compuestos fenólicos, actividad antioxidante in vitro y color de 100 accesiones de Capsicum spp.* [Tesis de maestría]. Universidad Nacional Agraria La Molina.
- Villa-Rivera, M. G., & Ochoa-Alejo, N. (2020). Chili pepper carotenoids: Nutraceutical properties and mechanisms of action. *Molecules*, 25(23), 5573. <https://doi.org/10.3390/molecules25235573>
- Von Borowski, R. G., Zimmer, K. R., Leonardi, B. F., Trentin, D. S., Silva, R. C., et al. (2019). Red pepper *Capsicum baccatum*: source of antiadhesive and antibiofilm compounds against nosocomial bacteria. *Industrial Crops and Products*, 127, 148–157. <https://doi.org/10.1016/j.indcrop.2018.10.011>
- Wahyuni, Y., Ballester, A. R., Sudarmonowati, E., Bino, R. J., & Bovy, A. G. (2013). Secondary metabolites of *Capsicum* species and their importance in the human diet. *Journal of Natural Products*, 76(4), 783–793. <https://doi.org/10.1021/np300898z>
- Wahyuni, Y., Ballester, A. R., Tikunov, Y., de Vos, R. C. H., Pelgrom, K. T. B., et al. (2013). Metabolomics and molecular marker analysis to explore pepper (*Capsicum* sp.) biodiversity. *Metabolomics*, 9(1), 130–144. <https://doi.org/10.1007/s11306-012-0432-6>
- Yang, C. Y., Mandal, P. K., Han, K. H., Fukushima, M., Choi, K., Kim, C. J., & Lee, C. H. (2010). Capsaicin and tocopherol in red pepper seed oil enhances the thermal oxidative stability during frying. *Journal of Food Science and Technology*, 47(2), 162–165. <https://doi.org/10.1007/s13197-010-0032-2>
- Yseki, M., Crispin, A., Abad, T., Prado, A., Novoa, P., & Shady, R. (2024). The first comprehensive macroremains analysis of edible plants from Vichama, Peru (1800–1500 bce). *Vegetation History and Archaeobotany*, 34(1), 91–100. <https://doi.org/10.1007/s00334-024-01004-9>
- Zamudio-Moreno, E., Echevarria-Machado, I., Medina-Lara, M. de F., Calva-Calva, G., Miranda-Ham, M. de L., & Martínez-Estevéz, M. (2014). Role of peroxidases in capsaicinoids degradation in habanero pepper (*Capsicum chinense* Jacq.) plants grown under water deficit conditions. *Australian Journal of Crop Science*, 8(3), 448–454.