Advances in biology through agronomy, aquaculture, coastal and environmental sciences

Leandris Argentel Martínez
Ofelda Peñuelas Rubio
Editors

Pantanal Editora

2023

Leandris Argentel Martínez
Ofelda Peñuelas Rubio

Advances in biology through agronomy, aquaculture, coastal and environmental sciences

Pantanal Editora

2023

Editor Chefe: Prof. Dr. Alan Mario Zuffo
Editores Executivos: Prof. Dr. Jorge González Aguilera e Prof. Dr. Bruno Rodrigues de Oliveira

Diagramação: A editora. **Diagramação e Arte:** A editora. **Imagens de capa e contracapa:** Canva.com. **Revisão:** O(s) autor(es), organizador(es) e a editora.

Ficha Catalográfica

Catalogação na publicação
Elaborada por Bibliotecária Janaina Ramos – CRB-8/9166

A244

Advances in biology through agronomy, aquaculture, coastal and environmental sciences / Organizers Leandris Argentel Martínez, Ofelda Peñuelas Rubio. – Nova Xavantina-MT: Pantanal, 2023.
105p. ; il.

PDF book

ISBN 978-65-81460-82-2
DOI https://doi.org/10.46420/9786581460822

1. Agricultural sciences. I. Martínez, Leandris Argentel (Organizer). II. Rubio, Ofelda Peñuelas (Organizer). III. Title.

CDD 630

Índice para catálogo sistemático

I. Agricultural sciences

Pantanal Editora

Rua Abaete, 83, Sala B, Centro. CEP: 78690-000.
Nova Xavantina – Mato Grosso – Brasil.
Telefone (66) 99682-4165 (Whatsapp).
https://www.editorapantanal.com.br
contato@editorapantanal.com.br

Prologue

Advances in biology through agronomy, aquaculture, coastal and environmental sciences is an electronic book, edited by Pantanal Editora, based on the compilation of research papers where the authors of the different chapters have used highly current scientific methodologies and research equipment.

The biological sciences as the main object of research in agriculture, aquaculture, coastal and environmental sciences generate every day an understanding of knowledge that allows raising the scientific level of society as part of universal access to knowledge.

This book mainly addresses issues related to the use of plants extracts as sustainable alternatives for biocontrol of pests and bacterial diseases. It also brings together information on viruses and other diseases in aquatic organisms. In addition, studies of mangroves structure and their contribution to carbon sinks in experimental sites in northwestern Mexico are presented. Finally, an analysis on educational strategies for environmental education based on plant biology is carried out.

Editors appreciate the participation of the authors who have come from higher education institutions and research centers of great scientific prestige in Mexico. The majority of them are members of the National Research System of CONACyT, Mexico.

The authors

Summary

Chapter 2

Evaluation of the antioxidant and antimicrobial activity of hydroalcoholic extracts of *Larrea tridentata* leaves

Recibida em: 27/02/2023
Aprobado em: 02/03/2023
10.46420/9786581460822cap2

Francisco Cadena Cadena[1]
Joe Luís Arias Moscoso[1,*]
Alba Rocio Meza Ochoa[1]
Iveth Esmeralda Camacho Velazquez[1]
Jaime Edzael Mendivil Mendoza[1]
Reinaga Franco Felipe Jesus[1]
Dulce Alondra Cuevas Acuña[2]
Aaron Jonary Santiaguin Padilla[2]

ABSTRACT

Approximately 80% of the world's traditional medicines use plant species to meet primary health care needs. In recent years, it has been discovered that the essential oil compounds of *larrea tridentata* have beneficial activities: antioxidant, antitumor, neuroprotective, regenerative, antibacterial, antiviral, antifungal, anthelmintic, antiprotozoal and insecticidal activities. However, few investigations have evaluated the secondary metabolites of their ethanolic extracts. The objective of present study is evaluation of the antioxidant and antimicrobial activity of hydroalcoholic extracts of *larrea tridentata* leaves. The ethanolic extracts evaluated contained 25.08±2.47 mg of anthocyanins 100 g^{-1} of plant and 228.88±3.45 mg gae polyphenols 100 g^{-1} of plant. The antioxidant activity evaluated by dpph is 47.12±2.43%. The ethanolic extracts had a high efficiency in inhibiting the growth of *staphylococcus aureus, escherichia coli, salmonella* and *shigella,* with inhibition halos of 13.41±0.51 to 19.67±0.41 mm. The determination of the minimum inhibitory concentration (mic) was 0.5 µg ml^{-1} against *escherichia coli*, 7.74 µg ml^{-1} against *salmonella,* 9.14 µg ml^{-1} against *shigella* and 12.25 µg ml^{-1} against *staphylococcus aureus*. These results showed that the tested ethanolic extracts possess antibacterial activities against bacteria that cause foodborne illness.

Keywords: foodborne illness; inhibition halos; anthocyanins; polyphenols; gae polyphenols; minimum inhibitory concentration (mic).

[1] Tecnológico Nacional de México/Instituto Tecnológico del Valle del Yaqui. Bacum, Sonora, México.
[2] Departamento de Ciencias de la Salud, Universidad de Sonora, Campus Cajeme, C.P 85199, Cd. Obregón, Sonora, México
*Corresponding author: jarias.moscoso@itvy.edu.mx

INTRODUCTION

Human beings have used medicinal plants since ancient times to meet primary health care needs. In general, these plants are one of the main sources of phytochemicals (Martins et al., 2013). Approximately 80% of the world's traditional medicines are made up of bioactive compounds found in plants (Oliveira et al., 2005). Due to the biodiversity present on our planet, science has shown that many plants can be used in medicine (Corell-Doménech, 2019). *L. tridentata,* commonly known as gobernadora, is a plant that grows in the northern part of Mexico and the southwestern United States (Ross, 2005).

Mexico and especially the state of Sonora have great biodiversity, with more than 26,500 species of flowering plants, 1,600 ferns, 976 species of mosses and 1,700 species of lichens recorded. Several cultures have used diverse plant species, including *L. tridentatta*, for medicinal purposes (Andrango-Quisaguano, 2022). Today, scientific reports on these species are very limited, with less than 10% of the world's angiosperm species evaluated for their chemical composition and pharmacological properties, which motivates research on medicinal plants, as they possess valuable phytochemical and pharmacological information, becoming important in modern medicine. Other species can be a direct source of therapeutic agents as raw material for the manufacture of semisynthetic drugs. The chemical structure of their active principles can serve as a model for the development of synthetic drugs, and these principles can be used as taxonomic markers in the search for new drugs (Marcano; Hasegawa, 2018).

The increase in diseases caused by pathogenic microorganisms is a generalized concern and constitutes a risk factor for public health, which is why compounds from natural sources that inhibit bacterial growth are being sought (Corzo-Barragán, 2012). *L. tridentata* is an exceptional source of polyphenols, and its main exponent in this plant is nordihydroguaiaretic lignan (NDGA), which has been noted as being responsible for the biological activity of *L. tridentata* (Lambert et al., 2004; Martins et al., 2013).

However, the secondary metabolites found in *L. tridentata* leaves include lignans, flavonoids, saponins, triterpenes and triterpenoids, among others. Most of these compounds are studied for their antimicrobial, antiviral (Reyes-Melo et al., 2021), antifungal (Tequida-Meneses et al., 2002; Tucuch-Pérez et al., 2020) and antibacterial (Núñez-Mojica et al., 2021) properties. Nevertheless, only a few studies have reported the antibacterial and antioxidant activity of ethanolic extracts of *L. tridentata* leaves. These types of plants are an important source of antioxidants, which have an impact on food quality and consumer health.

MATERIALS AND METHODS

Experimental area

The equivalent of 2 kg of governor's weed was used. The grass was obtained in the proximity of Ciudad Obregón, Sonora. With coordinates 27°28'55.9 "N 110°00'02.0 "W. Once the plant was collected, it was transported to the Tecnológico Nacional de México campus Valle del Yaqui, located at Avenida

Tecnológico, Block 611, Bácum, Sonora, México. C.P. 85276, to the ultrasonic pulse laboratory and the aquaculture laboratory. These laboratories have the appropriate equipment for this research.

Extraction of phytochemicals from L. tridentata

For the extraction of phytochemicals, an ethanol-acetic acid-water solution was prepared in a 50:10:40 v/v ratio for both corns in a 1:30 w/v ratio, and the pH was adjusted to 1 by adding 2 molar acetic acid and placed in constant agitation for 15 days. Finally, the sample was centrifuged at 4000 g, and the supernatant was collected. The extract obtained was concentrated to dryness in a Rotavapor (DLAB model RE100-S) at 50 °C and stored in the dark at -20 °C until use. The total phenol content was expressed as mg 100 g^{-1} (Abdel-Aal; Hucl, 1999; Ju; Howard, 2003).

Determination of total phenols

Based on the determination of Singleton and Rossi (1965). For the reaction, 90 µL of a 50 mg mL^{-1} solution of extract (per genotype) was added, 1.91 mL of deionized water and 200 µL of Folin-Ciocalteu's reagent were mixed; after 2 minutes, 0.8 mL of 15.9% sodium carbonate was added and then incubated at a temperature of 50 °C for five minutes, and the absorbance was measured at 765 nm. The total phenol content was expressed as mg gallic acid equivalent (GAE). 100 g^{-1} dry extract (Pérez-Pérez et al., 2014; Singleton; Rossi, 1965).

Determination of total flavonoids

For this variable, 0.5 mg mL^{-1} of the extract in solution was mixed with 2 mL of distilled water and 150 µL of sodium nitrite, left to stand for five minutes by adding 150 µL of a 2.5% aluminum chloride solution, and then left to stand for six minutes by adding 1 mL of 0.5 N sodium hydroxide and 5 mL of distilled water, the absorbance was measured at 510 nm. To determine the flavonoid content, a calibration curve with quercetin was generated, and the total flavonoid content was expressed as mg of kersetin 100 g^{-1} of dry extract (Reyes et al., 2013; Zhishen et al., 1999).

Antioxidative capacity by DPPH

The capacity to scavenge the DPPH radical (2,2-Diphenyl-1-(2,4,6-trinitrophenyl)hydrazin-1-il) is based on the reduction of the absorbance at 517 nm by the action of antioxidants. The performance of this experiment consisted of mixing 3.9 mL of 100 µM DPPH radical dissolved in 80% methanol with 0.1 mL of the sample or standard and kept in the dark for 30 minutes. The reading was made at 517 nm after an incubation period of 30 minutes, and the results were expressed in % inhibition (Molyneux, 2004).

Antimicrobial activity by disk diffusion

The qualitative analysis of the antimicrobial activity was performed using the disk diffusion method, and the bacteria used were the following: *Staphylococcus aureus* (ATCC 8532), *Escherichia coli* (ATCC 12210), *Salmonella* (ATCC 8230) and *Shigella* (ATCC 4837). Bacteria were grown in 2% (w/v) trypticase soy broth (TSB). Purity control assays were used to verify the status of the bacteria. The strains were preserved in TSB broth with 20% sterile glycerol (v/v) at -20 °C (Ma et al., 2019).

The procedure was performed by impregnating sterile 6 mm diameter Whatman No. 1 filter paper discs with a concentration of 10 mg/disc of extract. Gentamicin was used as a positive control (30 μg/disc), and sterile distilled water was used as a negative control. The inhibition halo was measured after 24 hours of incubation at 37 °C. The criterion for interpretation was gentamicin (450 μg $disc^{-1}$) as a reference. Subsequently, inhibition halos were measured starting from the center of the discs to the end of the inhibition halo (Riverón-Rodríguez et al., 2012).

Statistical analysis

Biochemical analyses were performed in triplicate using Statgraphics Software (Version 18) to calculate the mean and standard deviation. The significant difference between two mean values was determined by analysis of variance (ANOVA) at the 95% confidence level ($p \leq 0.05$), and the significant difference between groups was determined by Tukey's comparison of means ($p<0.05$).

RESULTS AND DISCUSSION

Table 1 shows the concentrations of polyphenols extracted from *L. tridentata*, evidencing the presence of 228.88±3.45 mg of GAE 100 g^{-1} of plant. One possible justification for this high value is the environmental and surface conditions. This is because the environment directly affects a plant's ability to produce phytochemicals (Björkman et al., 2011). Studies on medicinal plants have found that factors such as water stress and temperature influence the phytochemical composition of medicinal plants (Shin et al., 2021). They also found that secondary metabolites play an important role in plant adaptation to the environment and plant recovery under stress conditions (Oh et al., 2009). Among the different types of stresses, water shortage, temperature and salt water are considered negative factors, as they lead to reduced yields of various crops. However, plants grown under dry conditions often produce higher concentrations of active ingredients that protect against free radicals and reactive oxygen species and help prevent photosynthetic damage (Albergaria et al., 2020; Oh et al., 2009).

The total amount of anthocyanins obtained from ethanol was higher than that reported for L. tridentatta elsewhere in Mexico (Saldívar-Lira, 2003). With respect to food technology and the use of medicinal herbs, it has been found that adding herbs to juice reduces the anthocyanin content due to the soaking effect of the extract on the phytochemicals in dried herbs (Teneva et al., 2022). Therefore, it is difficult to retain sufficient anthocyanins in the juice. However, although it is difficult to link the increase in anthocyanins with their stability, it is certain that plant extracts can protect juice components from decomposition during processing. However, the effectiveness of phenolic compounds in food preparations was not related to the polyphenol content or the resulting antioxidant properties but to their quality, suggesting that the phenolic composition is qualitative. was more important than the total polyphenol content of the extract (Klisurova et al., 2019).

Table 1. Anthocyanin composition, polyphenols and antioxidant activity of gobernadora.

	Anthocyanins mg 100 g^{-1} de plant	**Polyphenols mg of GAE 100 g^{-1} de plant**	**DPPH (% of inhibition)**
L. tridentatta	25.08±2.47	228.88±3.45	47.12±2.43

[1] Gallic Acid Equivalents (GAE); 2,2-diphenyl-1-picrylhydrazyl (DPPH)

The total amount of anthocyanins obtained from the extract was superior to that reported for L. tridentatta in other places of Mexico (Saldívar-Lira, 2003; Urias-Lugo et al., 2015). With respect to food technology and the use of medicinal herbs, it has been found that adding herbs to juice reduces the anthocyanin content due to the soaking effect of the extract on the phytochemicals in dried herbs (Teneva et al., 2022). Therefore, it is difficult to retain sufficient anthocyanins in the juice. Nevertheless, the effectiveness of phenolic compounds in food preparations was not related to the polyphenol content or the resulting antioxidant properties but to their quality, suggesting that the phenolic composition is qualitative. was more important than the total polyphenol content of the extract (Klisurova et al., 2019).

Antimicrobial activity

The bioassays were evaluated with strains of *Staphylococcus aureus* (ATCC 8532), *Escherichia coli* (ATCC 12210), *Salmonella* (ATCC 8230) and *Shigella* (ATCC 4837). The inhibition range shown is between 13.41 and 19.67 mm. This was compared to the gentamicin positive control, where an inhibitory halo of 16.01±1.17 to 22.47±0.41 mm was observed, and no inhibition was observed in the water negative control. However, it is important to note that the dose of gentamicin is 22.5 times the amount of plant extract used. A recent study demonstrated the in vitro growth inhibitory effect of 14 strains of *Xanthomonas axonopodis* using methanolic extracts of leaves and stems of *Bixa orellana, Gliricidia sepium, Ocimum basilicum* and *Petiveria alliacea*. The study concluded that these four plants have fungicidal effects and may be promising for controlling plant diseases (Nalimova et al., 2005). The inhibition halos reported were 17 to 21 mm in diameter for the four extracts used, very similar to the results obtained in this study (Table 2). Martinez-Valverde and Colmenares (1999) studied the effects of several extracts, including eucalyptus and *L. tridentata,* and found that the growth of pathogen colonies was inhibited by 90-100%. Similarly, results were obtained for 7 monocots, 46 dicots, 1 gymnosperm and 2 ferns. However, they reported that only nine showed in vitro growth inhibition of common pathogens. These inhibitory halos were similar to eucalyptus extract (12.4 mm) and palo santo extract (11.3 mm) (Martínez-Valverde et al., 2000; Stauffer et al., 2000).

Table 2. Inhibition of extracts against pathogens.

	Inhibition zone size (mm) Bacteria			
	Staphylococcus aureus	***Escherichia coli***	***Salmonella***	***Shigella***
L. tridentata extract	12.25[b]	0.5[c]	7.74[a]	9.14[a]
Gentamicin	21.35[a]	19.88[b]	14.21[c]	17.44[b]
Water	NA	NA	NA	NA

[1]NA, no activity; Values are expressed in μg mL^{-1}. Different letters in the columns indicate significant differences ($p \leq 0.05$)

The antimicrobial efficacy of *L. tridentata* extracts is shown in Table 3. The lowest concentration was observed for Escherichia coli at 0.5 mg mL^{-1}, which agrees with the sensitivity and inhibition rate reported in Table 2. The other bacteria were affected by the extract of *L. tridentata*. However, the highest minimum concentration was for Staphylococcus aureus (ATCC 8532). Previous studies found that the antibacterial activity of the plant was equal for gram-positive and gram-negative bacteria (Mendez et al., 2012). The range of action of antibacterial activity in crude methanol extracts ranges from 62.5 to 250 μg mL^{-1} (Snowden et al., 2014). However, other authors have found inhibition ranges from 0.35 to 15 μg mL^{-1} (Gerstel et al., 2018), similar to the concentrations reported in our study (0.5-12.5 g mL^{-1}). In addition, the evaluation of *L. tridentata* flower extracts against Staphylococcus aureus yielded an MIC of 60 μg mL^{-1} (Gerstel et al., 2018).

Although the concentrations between studies differ from one another, the antibacterial activity is still present. Different factors can influence the nature and quantity of the secondary metabolites extracted. among the most important of which are solvent, pH, temperature, extraction time and sample composition, which could explain the different concentrations determined among the different studies, including the present investigation (Dirar et al., 2019; Do et al., 2014). Among the wide variety of bacteria to which *L. tridentatta* has shown inhibitory activity are *Clavibacter michiganensis* subspecies *michiganensis* and *P. syringae* at a concentration of 6.25 mg mL^{-1}. However, the concentration reported for these species is higher than the range of action of the antibacterial activity. This difference may be related to the extraction solvent (Morales-Ubaldo et al., 2021). The low concentrations to inhibit bacteria may be associated with the polarity of the compounds extracted with different solvents; for example, compounds extracted with ethyl acetate can easily penetrate bacterial cell walls and, therefore, can disrupt the barrier function of the cell membrane or cause membrane fusion, a process that results in the leakage of intramembranous materials. This mechanism of action decreases the necessary concentration of the compound to inhibit a specific bacterium (Renzetti et al., 2020); therefore, compounds of medium and low polarity may have a higher activity against microorganisms (Gómez-Guiñán et al., 2003; Lobiuc et al., 2023; Martínez-Aguilar et al., 2012).

Table 3. Inhibitory minimum concentration.

	Concentration (µg mL^{-1})	Inhibition zone size (mm)			
		Staphylococcus aureus	***Escherichia coli***	***Salmonella***	***Shigella***
L. tridentata extract	20±0.45	13.41±0.51^{a}	17.33±1.54^{a}	14.67±0.90^{a}	19.67±0.41^{a}
Gentamicin	450 ±1.53	21.11±1.21^{b}	21.04±0.58^{b}	16.01±1.17^{a}	22.47±0.41^{b}
Water	0	0	0	0	0

[1]Different letters in the columns indicate significant differences ($p \leq 0.05$)

The use of natural extracts is a promising alternative in the control of bacterial infections (Esposito; Turku, 2023). There is considerable variation among the results in the study of secondary metabolites of *L. tridentata* because of the variety of phytochemicals contained in the plant (Qaderi et al., 2023; Reyes-Melo et al., 2021). Some secondary metabolites reported are terpenes, saponins, tannins, quercetin, kaempferol, ellagic acid, gallic acid, methyl gallate, resorcinol, cinnamic acid, catechins and lignans. However, these vary according to the environmental conditions of the area. In conclusion, phytochemicals exist in nature as nutraceuticals that are beneficial to human health, especially for their antioxidant and antimicrobial effects. The great variety of different compounds present in plants provide a rich source of potential pharmaceuticals to improve human health. Moreover, these compounds are very diverse in their mode of action, making them unlikely to cause bacterial resistance.

REFERENCES

Abdel-Aal, E. S., Hucl, P. (1999). A rapid method for quantifying total anthocyanins in blue aleurone and purple pericarp wheats. Cereal Chemistry, 76(3):350-354.

Albergaria, E. T. et al. (2020). The effect of water deficit stress on the composition of phenolic compounds in medicinal plants. South African Journal of Botany, 131:12-17.

Andrango-Quisaguano, N. P. (2022). Plantas medicinales en el tratamiento de enfermedades culturales según la cosmovisión de sanadores y pobladores.

Björkman, M. et al. (2011). Phytochemicals of Brassicaceae in plant protection and human health – Influences of climate, environment and agronomic practice. Phytochemistry, 72(7):538-556.

Corell-Doménech, M. (2019). Terapeutas alternativos en México y la estrategia de la OMS sobre medicina tradicional 2014-2023: comunicación, creencias y factores socio-económicos. Perspectivas de la comunicación, 12(1):59-77.

Corzo-Barragán, D. C. (2012.) Evaluación de la actividad antimicrobiana del extracto etanólico. Revista mexicana de ciencias farmacéuticas, 43(3):81-86.

Dirar, A. I. et al. (2019). Effects of extraction solvents on total phenolic and flavonoid contents and biological activities of extracts from Sudanese medicinal plants. South African Journal of Botany, 120:261-267.

Do, Q. D. et al. (2014). Effect of extraction solvent on total phenol content, total flavonoid content, and antioxidant activity of *Limnophila aromatica*. Journal of food and drug analysis, 22(3):296-302.

Esposito, M. M., Turku, S. (2023). The Use of Natural Methods to Control Foodborne Biofilms. Pathogens, 12(1):45.

Gerstel, J. et al. (2018). Identification of botanicals with potential therapeutic use against methicillin-resistant Staphylococcus aureus (MRSA) infections. Phytotherapy Research, 32(12):2577-2585.

Gómez-Guiñán, Y. et al. 2003. Obtención de extractos orgánicos con actividad antimicrobiana a partir de *Penicillium sp.* (Moniliales) aislado de la esponja *Ircinia felix* (Porifera: Demospongiae). Revista de biología tropical:141-147.

Ju, Z. Y., Howard, L. R. (2003). Effects of solvent and temperature on pressurized liquid extraction of anthocyanins and total phenolics from dried red grape skin. Journal of Agricultural and Food Chemistry, 51(18):5207-5213.

Klisurova, D. et al. (2019). Co-pigmentation of black chokeberry (Aronia melanocarpa) anthocyanins with phenolic co-pigments and herbal extracts. Food chemistry, 279:162-170.

Lambert, J. et al. (2004). Nordihydroguaiaretic acid: a review of its numerous and varied biological activities. Pharmaceutical biology, 42(2):149-158.

Lobiuc, A. et al. (2023). Future Antimicrobials: Natural and Functionalized Phenolics. Molecules, 28(3):1114.

Ma, Y. et al. (2019). Antimicrobial activity of anthocyanins and catechins against foodborne pathogens *Escherichia coli* and *Salmonella*. Food Control, ,106:106712.

Marcano, D., Hasegawa, M. (2018). Fitoquímica Orgánica. Caracas: Consejo de Desarrollo Científico y Humanístico, Universidad Central de Venezuela (CDCH-UCV).

Martínez-Aguilar, Y. et al. (2012). Metabolitos secundarios y actividad antibacteriana in vitro de extractos de hojas de *Anacardium occidentale* L.(marañón). Revista Cubana de Plantas Medicinales, 17(4):320-329.

Martínez-Valverde, I. et al. (2000). Significado nutricional de los compuestos fenólicos de la dieta. Archivos latinoamericanos de nutrición, 50(1):5-18.

Martins, S. et al. (2013). Antibacterial activity of crude methanolic extract and fractions obtained from Larrea tridentata leaves. Industrial Crops and Products, 41:306-311.

Mendez, M. et al. (2012). Antibacterial activity of plant extracts obtained with alternative organics solvents against food-borne pathogen bacteria. Industrial Crops and Products, 37(1):445-450.

Molyneux, P. (2004). The use of the stable free radical diphenylpicrylhydrazyl (DPPH) for estimating antioxidant activity. Songklanakarin J. sci. technol, 26(2):211-219.

Morales-Ubaldo, A.L. et al. (2021). Bactericidal activity of *Larrea tridentata* hydroalcoholic extract against phytopathogenic bacteria. Agronomy, 11(5):957.

Nalimova, M.S. et al. (2005). Efecto in vitro de extractos de plantas sobre especies bacterianas del gênero Xanthomonas. Fitosanidad, 9(3):49-51.

Núñez-Mojica, G. et al. (2021). New cyclolignans of *Larrea tridentata* and their antibacterial and cytotoxic activities. Phytochemistry Letters, 43:212-218.

Oh, M.-M. et al. (2009). Secondary metabolism and antioxidants are involved in environmental adaptation and stress tolerance in lettuce. Journal of plant physiology, 166(2):180-191.

Oliveira, M. et al. (2005). La investigación etnobotánica sobre plantas medicinales. Revista de Ciencia y Tecnología de América, 30(8):453-459.

Pérez-Pérez, E. et al. (2014). Determinación de fenoles y flavonoides totales en hojas de guayabo (*Psidium guajava* L.). Revista de la Facultad de Agronomía, 60-77.

Qaderi, M. M. et al. (2023). Environmental Factors Regulate Plant Secondary Metabolites. Plants, 12(3):447.

Renzetti, A. et al. (2020). Antibacterial green tea catechins from a molecular perspective: Mechanisms of action and structure–activity relationships. Food & function, 11(11):9370-9396.

Reyes, S. R. et al. (2013). Capacidad antioxidante in vitro de los flavonoides totales obtenidos de las hojas de *Sambucus peruviana* HBK (sauco) proveniente de la ciudad de Huamachuco. Pharmaciencia, 1(2):57-64.

Reyes-Melo, K. Y. et al. (2021). Larrea tridentata and its Biological Activities. Current Topics in Medicinal Chemistry, 21(26):2352-2364.

Riverón-Rodríguez, E. et al. (2012). Estación de trabajo para el estudio de la cinética de crecimiento de Escherichia coli mediante el método de turbidez. Revista CENIC. Ciencias Biológicas, 43(2):1-5.

Ross, I. A. (2005). Medicinal plants. In, Traditional and Modern Medicinal Uses. Springer.

Saldívar-Lira, R. H. (2003). Estado actual del conocimiento sobre las propiedades biocidas de la gobernadora [*Larrea tridentata* (DC) Coville]. Revista Mexicana de Fitopatología, 21(2):214-222.

Shin, Y. K. et al. (2021). Effect of drought stress on chlorophyll fluorescence parameters, phytochemical contents, and antioxidant activities in lettuce seedlings. Horticulturae, 7(8):238.

Singleton, V. L., Rossi, J. A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. American journal of Enology and Viticulture, 16(3):144-158.

Snowden, R. et al. (2014). A comparison of the anti-*Staphylococcus aureus* activity of extracts from commonly used medicinal plants. The Journal of Alternative and Complementary Medicine, 20(5):375-382.

Stauffer, A. et al. (2000). Selección de extractos vegetales con efecto fungicida y/o bactericida. Revista de Ciencia y Tecnología, 1(2):29-33.

Teneva, D. et al. (2022). Addition of medicinal plants increases antioxidant activity, color, and anthocyanin stability of black chokeberry (*Aronia melanocarpa*) functional beverages. Plants, 11(3):243.

Tequida-Meneses, M. et al. (2002). Efecto de extractos alcohólicos de plantas silvestres sobre la inhibición de crecimiento de *Aspergillus flavus*, *Aspergillus niger, Penicillium chrysogenum, Penicillium expansum*, *Fusarium moniliforme* y *Fusarium poae*. Revista iberoamericana de micología, 19(1):84-88.

Tucuch-Pérez, M. A. et al. (2020). Antifungal activity of phytochemical compounds of extracts from Mexican semi-desert plants against *Fusarium oxysporum* from tomato by microdilution in plate method. Nova scientia, 12(25).

Urias-Lugo, D. A. et al. (2015). Total phenolics, total anthocyanins and antioxidant capacity of native and elite blue maize hybrids (*Zea mays* L.). CyTA-Journal of Food, 13(3):336-339.

Zhishen, J. et al. (1999). The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. Food chemistry, 64(4):555-559.

Index

Editors

Dr. Leandris Argentel Martínez

Profesor e Investigador Titular "C" del Tecnológico Nacional de México, Campus Valle del Yaqui (ITVY). Miembro del Sistema Nacional de Investigadores, Nivel 1 **(SNI-1)**. Profesor Perfil Deseable (**PRODEP**) de la Secretaría de Educación Pública de México, **Líder del Cuerpo Académico ITVAYA-CA-3**. Líneas de investigación: Fisiología Vegetal, Bioquímica, Biología Celular y Molecular en plantas y microorganismos. Doctorado en Ciencias Biotecnológicas. Desarrollo de investigaciones sobre mecanismos fisiológicos, rutas anapleróticas y mecanismos moleculares activados por los organismos durante su adaptación a condiciones adversas como el cambio climático. Aplicación de técnicas experimentales univariadas y multivariadas para el monitoreo de germoplasmas a través de indicadores moleculares. Uso de marcadores moleculares de tolerancia de los organismos al estrés abiótico (salinidad, sequía y calor). Manejo de técnicas de isótopos estables para el seguimiento de reacciones bioquímicas en células y tejidos. Síntesis de metabolitos secundarios en plantas con fines farmacológicos. Entre sus principales proyectos, se encuentra vigente en 2022 "Aplicaciones del microbioma y el metaboloma de la *Parkinsonia aculeata* L. Sp. Pl. para la mitigación de estreses biótico y abiótico en el semidesierto y en especies de interés agrícola en México" correo electrónico para contacto: oleinismora@gmail.com.

Dra. Ofelda Peñuelas Rubio

Profesor e Investigador Titular "C" del Tecnológico Nacional de México, Campus Valle del Yaqui (ITVY). Miembro del Sistema Nacional de Investigadores, Nivel 1 **(SNI-1)**. Profesora con Perfil Deseable (**PRODEP**) de la Secretaría de Educación Pública de México, miembro del Cuerpo Académico ITVAYA-CA-3. México. Realizó dos estancias posdoctorales (Enero 2016-Diciembre 2017) dentro del programa de Estancias Nacionales de CONACYT en el Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional unidad Sinaloa del Instituto Politécnico Nacional en el área de Ecología Molecular de la Rizósfera. Es Doctora en Ciencias especialidad en Biotecnología. Su quehacer científico lo desarrolla en el área agrícola, principalmente en el manejo sustentable de los recursos implicados en los agroecosistemas y el aprovechamiento de la microbiota del suelo. Ha participado en colaboración con distintos grupos de investigación lo que le ha permitido participar en proyectos multidisciplinarios y en publicaciones científicas. Email para contacto: ofeperub@gmail.com.

9 786581 460822

Pantanal Editora
Rua Abaete, 83, Sala B, Centro. CEP: 78690-000
Nova Xavantina – Mato Grosso – Brasil
Telefone (66) 99682-4165 (Whatsapp)
https://www.editorapantanal.com.br
contato@editorapantanal.com.br