Journal of
Plant Development Sciences
Meerut, India

REVIEW ARTICLE

PHYSALIS MINIMA L.– A COMPREHENSIVE REVIEW ON MORPHO-ANATOMICAL, PHYTOCHEMICAL AND THERAPEUTIC PROPERTIES

Bapi Ghosh*

Department of Botany, ABN Seal College, Cooch Behar 736101, West Bengal, India
Email: bpghosh88@gmail.com

Received-01.06.2025, Revised-16.06.2025, Accepted-29.06.2025

Abstract: *Physalis minima* Linn is an important medicinal plant widely used in traditional medicine in India. Various parts of the plant are employed in the treatment of several conditions such as inflammation, fever, hypertension, cancer, spleen disorders, and diabetes. Characterization of the plant across multiple aspects has been determined to enable accurate identification. Key phytochemicals such as flavonoids, phenols, steroids, and tannins have been extracted from different plant parts using various extraction methods and these compounds possess anti-inflammatory, anti-cancer, antimicrobial, and antioxidant properties. Physalin and withanolides, two potent steroidal compounds that exhibit anti-inflammatory activates through mechnanisms such as inhibition of NO production, NF-κB pathway, COX-2 expression, STAT3, upregulation of HO-1 expression, blocking MAPK signalling pathway and secretion of IL-6, IL-1β, and TNF-α. These compounds also exhibit anti-cancerous activity through caspase-3, P53 and c-Myc apoptotic pathways and PI3K/AKT and RAS/MAPK signalling pathways.

Keywords: Anti-inflammatory, Anti-cancer, Antioxidant, Antimicrobial, *Physalis minima*, Phytochemicals

INTRODUCTION

Plants are a promising source of natural products that are extensively utilized in both traditional and modern medical systems. In recent years, due to the increasing demand, natural products are constantly being explored for the development of novel drugs (Singh *et al*., 2012). Since ancient times, they have been widely used in traditional medicine for the treatment of various diseases. Moreover, the pharmaceutical industry has shown growing interest in plant-derived bioactive compounds, using traditional medicinal knowledge for modern drug development. Various bioactive compounds, particularly secondary metabolites, have been isolated from the plants (Singh *et al*., 2012, Gad *et al*., 2013). Therefore, an in-depth understanding of these plants areessential for exploring the diverse array of herbal products and their potential pharmacological actions in healthcare.

Physalis minima Linn, commonly known as Rashbary, is an annual herb belonging to Solanaceae family that has long been recognized for its medicinal significance in traditional Indian healthcare systems (Patel *et al*., 2011). This plant is found in India, China, Baluchistan, Afghanistan, Singapore, Tropical Africa, Malaysia and Australia (Joseph and Ravi 2022). Traditionally, the plant is used for the treatment of inflammation, diuretic, purgative, fever, high blood pressure, cancer, spleen disorder, diabetes, snake bite and malaria (Lem *et al*., 2022). Several phytochemical compounds have been identified in all parts of the plant--roots, leaves, fruits, and seeds--contributing to its wide range of medicinal applications. This review provides a comprehensive overview of *P. minima*, covering its botanical characteristics, ethnomedicinal uses, phytochemical compounds, and therapeutic potential. The information compiled herein aims to enhance current understanding of *P. minima* as a promising medicinal agent and to support its potential role in future drug development.

*Corresponding Author

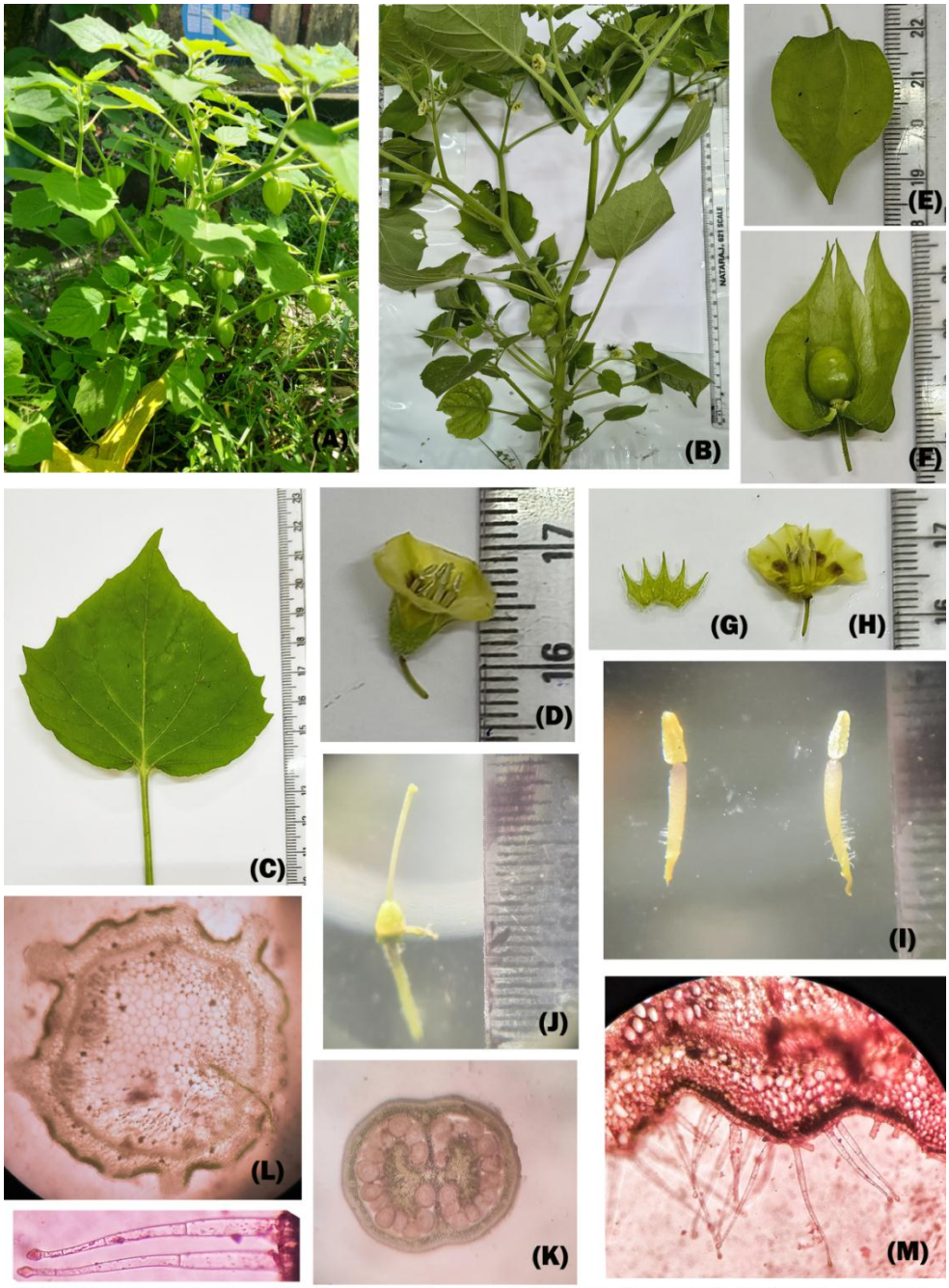

Figure: ***Physalis Minima L. (A-B) A floweing twigs; (C) Leaf; (D) Single Flower; (E) Fruit; (F) Split open Fruit; (G) Calyx; (H) plit open Fruit; (I) Stamen; (J) Carpel; (K) T.S. of Ovary; (L) T.S. of Stem; (M) T.S. of Leaf; (N) Hair***

Systematic Position:

Kingdom	Plantae
Division	Tracheophyta
Class	Magnoliopsida
Order	Solanales
Family	Solanaceae
Genus	*Physalis*
Species	*P. minima*

Taxonomical description:

The plant is annual, herb, pubescent with long many-celled hairs, 15- 45 cm tall; Stems are erect, solid with narrow cavity, branched, with angular-ribbed above. Leaves are simple, alternate, ovate or ovate-lanceolate, 2-3 × 1-1.5 cm, pubescent along veins, with hairs, base cuneate, tip acuminate, repand-dentate margin petiolate, stipulate; Inflorescences are solitary cymose & axillary; Flowers are actinomorphic, complete, bisexual, bracteates, pentamerous, hypogynous, cream in colour; Sepals - 5, gamosepalous, campanulate, 2.5-3 mm long, valvate, sepaloid, persistent, pubescent; lobes dentate, densely ciliate; Corolla yellow, shortly tubular, ca. 5mm., pubescent, Petals – 5, gamopetalous, valvate; stamens – 5, epipetalous, anther light yellow, 1-1.5 mm long, filament ca. 2 mm long, dithecous, basifixed, dehiscence by apical pores; Carpel – 2, syncarpous, bilocular, many ovules

in each locule; style filiform; stigma capitates; superior ovary; Fruits are berry, fleshy, orange, ca. 6 mm in diameter, pendulous, globose, enclosed by calyx; Pubescent, densely ciliated lobes,; Seeds are numerous, brown, compressed and endospermic sub-reniform, ca. 2 mm long, minutely reticulate-undulate (Flora of China 1994, San 2021).

Anatomical Studies:

Anatomical studies revealed that the epidermal cells on both of the lamina are parenchymatous and thin walled. The stomata are anisocytic type, oval in outline, and more frequent on the lower surfaces. Thick and wavy cuticular layers are located on both surfaces. In transverse section (T.S.) of the leaf, the mesophyll layer consists of a single layer of palisade cells and 2–3-layers of spongy mesophyll cells. Calcium oxalate crystals are abundant in mesophyll cells of the leaf. The midrib is semicircular in outline. The cortex is composed of both collenchymatous cells and parenchymatous cells. Vascular bundles are collateral type in lamina, midrib and petiole and crescent-shaped in midrib and petiole. Unicellular hairs are present on the epidermal layer of the midrib and petiole. The T. S. of stem is more or less circular or irregularly quadrangular in outline with four prominent ridges. Unicellular hairs are also present on the stem surface. The parenchymatous pith consists of 9-12 layers, irregularly rounded to polygonal. In mature stems, the pith cells are disorganized and broken leaving a hollow pith cavity at the center. The vascular bundles form a circular ring and are of the collateral type. Anatomically, roots are circular in outline and consist of compactly arranged and rectangular epiblema cells. The vascular bundles in the root are pentarch in arrangement (San 2021).

Cytological analysis:

Cytological studies indicates that *P. minima* is a tetraploid species with a chromosome number 2n=4x=48 (Bhaduri 1951). PMC squash preparations reveal the gametic chromosome number of n=12 with a normal configuration 12 II at Metaphase-I and diakinesis. Various meiotic anomalies have also been reported in these studies, including chromosome clumping, univalent and multivalent formations, chromosomal laggards, simple chromosomal bridges, tripolarity, multipolarity, and unequal separation of chromosomes in the observed PMCs (Choudhary, 2021).

Palynological studies:

Ashfaq *et al*. (2020) reported that pollen grains are monad, subspheroidal, tricorporate, circular in polar view and elliptical in equatorial view. The exine is microechinate and scabrate, the surface of the colpus is psilate and sparsely scabrate and the tip of the colpus is obtuse. The pollen grain is medium-sized.

Phytochemical constituents:

Phytochemical analysis of the whole plant of *Physalis minima* L. revealed the presence of wide range of bioactive compounds such as Alkaloids, flavonoids, cardiac glycosides, phenols, saponins, steroids, tannins and terpenoids. Among these, two classes of steroidal compounds- physalins and withanolides have been extensively studied due to their diverse pharmacological properties, such as antioxidant, anti-inflammatory and anti-cancer activities. Physalins are highly oxidized ergosteroid compound, whereas withanolides constitute a group of lactone-based natural products primarily composed of phenylpropanoids and steroidal backbones (Liang *et al*., 2024). A list of identified physalin and withanolides are presented in Table 1.

Table 1: Physalin and withanolides present in *P. minima*

	Extraction method	Chemical formula	References
Physalins	25-hydroxyphysalin D	$C_{28}H_{32}O_{11}$	Wu *et al*. (2018)
	Physalin D	$C_{28}H_{32}O_{11}$	Wu *et al*. (2022)
	Withaphysalin P	$C_{28}H_{34}O_7$	
	14, 18-di-O-acetylwithaphysalin C	$C_{32}H_{40}O_9$	(Zhou *et al*. 2015)
	Withaphysalin Q	$C_{30}H_{42}O_7$	
	Withaphysalin T	$C_{28}H_{34}O_8$	
	Withaphysalin U	$C_{28}H_{36}O_6$	
	Physaminin P	$C_{28}H_{31}O_{12}S$	
	Physaminin Q	$C_{29}H_{37}O_{13}$	
	Physaminin R	$C_{27}H_{32}O_{11}$	Wu *et al*. (2025)
	Physaminin P	$C_{35}H_{41}O_{16}$	
Withanolides	Physaliolide A	$C_{30}H_{42}O_9$	
	Physaliolide B	$C_{30}H_{42}O_9$	
	Physaliolide C	$C_{30}H_{42}O_{10}$	Wu *et al*. (2018)
	Physaliolide D	$C_{28}H_{40}O_8$	
	Physaliolide E	$C_{30}H_{42}O_8$	
	Physaliolide G	$C_{30}H_{40}O_{10}$	
	Physaliolide H	$C_{30}H_{42}O_{10}$	
	Physaliolide I	$C_{29}H_{40}O_8$	Wu *et al*. (2020)
	Physaliolide J	$C_{28}H_{38}O_8$	

	Physaliolide K	$C_{28}H_{36}O_7$	
	Physminin A	$C_{28}H_{34}NaO_5$	
	Physminin B	$C_{28}H_{36}NaO_5$	
	Physminin C	$C_{29}H_{40}NaO_6$	
	Physminin D	$C_{29}H_{38}$ Na O_6	
	Physminin E	$C_{28}H_{38}NaO_8$	Liu *et al*. (2022)
	Physminin F	$C_{28}H_{36}NaO_6$	
	PhysminiG	$C_{29}H_{38}NaO_6$	
	PhysminiH	$C_{29}H_{38}NaO_7$	
	Withaminima A	$C_{27}H_{35}O_5$	
	Withaminima B	$C_{28}H_{34}ClO_8$	
	Withaminima C	$C_{28}H_{32}ClO_9$	Wei *et al*. (2019)
	Withaminima D	$C_{28}H_{34}ClO_6$	
	Withaminima E-F	$C_{28}H_{34}ClO_7$	
	Physaminilide H	$C_{30}H_{38}O_7$	
	Physaminilide I	$C_{30}H_{42}O_9$	
	Physaminilide J	$C_{28}H_{40}O_8$	Zhang *et al*. (2020)
	Physaminilide K	$C_{30}H_{40}O_{10}$	
	3-Methoxy-2,3-dihydrophysagulide P	$C_{31}H_{44}O_{10}$	
	3-Methoxy-2,3-dihydrophysagulide J		
	Phyminimolide I-III	$C_{31}H_{45}O_{10}$	
	Phyminimolide IV		
	Phyminimolide V	$C_{29}H_{40}O_7$	
	Phyminimolide VI	$C_{29}H_{39}O_7Cl$	Su *et al*. (2025)
	Phyminimolide VII-XI	-	
		$C_{28}H_{34}O_5$	
		-	

Therapeutic Uses:

Anti-inflammatory activity:

The ethanolic extract of the whole plant of *P. minima* L. exhibit anti-inflammatory activity by inhibiting NO production of LPS -stimulated mouse macrophage RAW 264.7 cells and it has been suggested that withanolides containing 5β,6β-epoxy groups display enhanced anti-inflammatory properties (Wu *et al*., 2018 & Wu *et al*., 2020).

Six compounds of Withaminis (namely Withaminis A-F) have been identified from the aerial parts of *P. minima* L. Among them, compounds 1-4 show significant anti-inflammatory effects by inhibiting NO production in LPS activated RAW 264.7 macrophages with IC^{50} values ranging from 3.91–18.46 μmol·L^{-1} (Wei *et al*., 2019).

Hu *et al*. (2022) isolated 24 withaphysalins from the whole plants of *P. minima* among which compounds 2, 5, 6, 9, 10, 11, and 20 exhibits potent anti-inflammatory activity with IC_{50} values 3.01–13.39 μM. They also revealed that compounds 2 and 10 exhibited better anti-inflammatory effects by inhibiting the NF-κB pathway, resulting in decreased expression of COX-2 and secretion of IL-6, IL-1β, and TNF-α in LPS-stimulated THP1-doublet cells.

Withaphysalin A and 2, 3-dihydro-withaphysalin C are the two major withanolide-type compounds isolated from *P. minima* exhibited anti-inflammatory effect by significantly inhibiting NO production, prostaglandin E_2 and several pro-inflammatory cytokines (IL-1β, IL-6 and TNF-α in LPS-activated RAW264.7 macrophages. It is also suggested that this reduction in inflammation is due to downregulating of STAT3, nuclear translocation of NF-*κ*B p65, upregulated HO-1 expression and blocking MAPK signalling pathway by WA (Li *et al*., 2017).

Liu *et al*. (2022) conducted a phytochemical evaluation of methanol extract of the aerial parts of *P. minima* and reported ten withanolides compounds. Among them, compounds 1 and 3–5 exhibited anti-inflammatory effect by downregulating iNOS and COX-2 protein levels.

Su *et al*. (2025) isolated 19 withanolides from whole plant of *P. minima*. Among these, compounds 4, 6, 13 and 15 exhibits strong anti-inflammatory effect (IC_{50} values = 1.16 to 11.74 μM) by inhibiting NF-κB inhibitors which significantly downregulating NF-κB- dependent reporter gene transcription. Additionally compound 4 and 13 inhibited IL-6 pathways. The presence of the α, β-unsaturated ketone moiety in ring A and the trans-configuration of rings A and B were identified as key structural features contributing to their anti-inflammatory efficacy.

Antimicrobial activity:

Patel *et al*. (2011) reported that the chloroform and methanolic leaf extracts of *P. minima* shows antimicrobial activity against all the studied bacterial strains and the minimum inhibitory concentration is 100 μg for both extracts.

The antimicrobial activity of *P. minima* extract was performed against seven bacterial strains and the methanolic extract showed the highest antimicrobial

efficacy, particularly against *M. smegmatis*, *E. coli* and *P. aeruginosa*. These extracts were also effective against *C. violaceum*, *M. smegmatis*, and *P. aeruginosa*, all of which are resistant to standard antibiotics ampicillin (Rohilla *et al*., 2024).

Shill *et al* (2021) suggested that petroleum ether extract and ethanolic root extract of *P. minima* exhibited in vitro antibacterial activity against both *S. aureus* and *E. coli* bacteria but three times less than standard ciprofloxacin.

Pradeepkumar *et al*. (2022) performed antimicrobial activity of ethanolic fruit extract of *Physalis minima* against *Streptococci acidominimus* and *Pseudomonas aeuriginosa* by the cup diffusion method and showed good inhibition against the studied bacteria.

Yazhiniprabha *et al*. (2022) synthesized zinc oxide nanoparticles from the of *Physalis minima* fruit extract and this Pm-ZnO NPs shows strong antibacterial activity against Gram-positive (*E. faecalis*) and Gram-negative (*P. aeruginosa*) bacteria.

Antioxidant Activity:

Singh and Prakash (2014) reported that the methanolic leaf extract reduced the stable DPPH radical to yellow DPPH-H upto 78.29% at concentration 800 µg/mL while stem showed 76.02% of inhibition. This result clearly indicates that methanolic extract of *P. minima* leaves exhibit higher antioxidant activity compared to other extracts such as stem and leaves. So, it was effective in scavenging free radical and had the potential to be a powerful antioxidant.

Ethanolic extract of *P. minima* leaves shows dose-dependent antioxidant activity, attributing this effect to the presence of phytochemicals, particularly flavonoids. (Karpagasundari and Kulothungan 2014).

The in vitro anti-oxidant activity is performed in the methanolic extract of leaves from *P. minima* by DPPH radical scavenging assay and found that chloroform fraction of methanolic extract exhibited better anti-oxidant activity with IC_{50} = 38.6 µg/mL in comparison to standard ascorbic acid with IC_{50} = 42.6 µg/mL (Velemurugan *et al*., 2024).

Prabhu *et al*., (2021) evaluated anti-oxidant activity of methanolic leaf extract from *P. minima* using ABTS assay, DPPH radical scavenging assay and hydroxyl radical scavenging assay and dose-dependent increase in scavenging activity is found in all three assays. IC_{50} values of this extract is 78.6 in DPPH, 46.2 in ABTS, 76.7 in Hydroxyl.

Anti-cancer Activity:

Among the ten withanolides isolated from P. minima, withaphysalin C exhibits potent cytotoxicity against both human cancer HCT-116 and NCI-H460 cell lines. It is further suggested that 2,3-unsaturated ketone moiety in ring A and the 5b,6b-epoxy group in ring B are essential for this cytotoxicity effects (Chen *et al*., 2011).

Physalin F, also isolated from *P. minima* demonstrated significant dose-dependent cytotoxic effects against T-47D human breast cancer cells, with a low EC_{50} value (3.60 µg/ml) mediated through caspase-3 and c-Myc apoptotic pathways (Ooi *et al*. 2013). Additionally, it also reported that physalin F inhibits NSCLC cell growth by modulating PI3K/AKT and RAS/MAPK signalling pathways (Li *et al*., 2025).

Wu *et al* (2018) investigated anticancer effects of withanolides isolated from *P. minima* and reported moderate cytotoxic activities against lung adenocarcinoma cells, hepatic carcinoma cells and breast cancer cell lines with IC50 values in the range of 40.01–82.17µM.

Zang *et al*. (2020) isolated 25 withanolides compounds from *Physalis minima* and analysed their cytotoxic activities against A375 human melanoma cells. Several compounds possessed significant cytotoxicity with IC_{50} values in the range of 1.3–7.5 µM. The study further revealed that the 5β,6β-epoxy or 5,6-double bond moieties are essential for its cytotoxicity and the 2,3-double bond in ring A enhances this effect.

Le Canh *et al*. (2021) investigated the cytotoxic potential of six withanolides isolated from *P. minima* against HepG2, SK-LU-1, and MCF7 cancer cell lines. These compounds exhibited potent cytotoxicity, with IC_{50} values ranging from 0.051 ± 0.004 to 0.86 ± 0.09 µg/mL.

Leishmanicidal activity:

Choudhary *et al*. (2005) isolated six physalin compound from the whole plant of *P. minim*a, which exhibited significant in vitro leishmanicidal activities (0.92 ± 19.4 µg/ml) against promastigotes of *Leishmania major*.

Anti- Alzheimer activity:

Joseph and Ravi (2022) suggested that the ethanolic extract of *P. minim*a L. fruit exhibits a protective effect against D- galactose-induced Alzheimer's disease by inhibiting acetylcholinesterase activity. Additionally, the extract enhanced cognitive performance, similar to donepezil, as measured by spontaneous alternation behavior in the Y-maze test.

CONCLUSION

Botanical, anatomical, cytological and palynological characteristics of *P. minima* have provided valuable insights for the proper documentation and indexing of its germplasm, which is crucial for its accurate identification and the further exploration of its bioactive potential. The entire plant contains a variety of bioactive compounds, including flavonoids, cardiac glycosides, phenols, steroids, and tannins. Among these, two steroidal compounds-physalin and withanolides have been extensively studied for their anti-inflammatory, antitumor and antioxidant activities.

REFERENCES

Ashfaq, S., Ahmad, M., Zafar, M., Sultana, S., Bahadur, S., Ahmed, S.N., Gul, S. and Nazish, M. (2020) Pollen morphology of family solanaceae and its taxonomic significance. *An. Acad. Bras. Cienc.*, **92**(3): e20181221.

Google Scholar

Bhaduri, P.N. (1951). Interrelationship ofnon-tuberiferous species of *Solanum* with some consideration on the origin of Brinjal. *Ind. J. Genetics and Pl. Breed*., **11:**75–82.

Google Scholar

Chen, L.X., He H. and Qiu F. (2011). Natural withanolides: An overview. *Nat. Prod. Rep.*,**28**(4): 705–740.

Google Scholar

Choudhary, M.I., Yousaf, S., Ahmed, S. and Yasmeen, K. (2005). Antileishmanial physalins from *Physalis minima*. *Chem. Biodivers.*,**2** (2005): 1164–1173.

Google Scholar

Choudhary, R.K. (2021). The cyto-morphological studies in *Physalis minima* Linn.*Bull. Pure appl. sci. Sec. B-Bot.*,**40B** (1): 13–18.

Google Scholar

Flora of China Editorial Committee (1994). Flora of China (Verbenaceae through Solanaceae). In C. Y. Wu, P. H. Raven& D. Y. Hong (eds.) Fl. China. Science Press & Missouri Botanical Garden Press, Beijing & St. Louis. pp. 17: 1–378.

Google Scholar

Gad, H.A., El-Ahmady, S.H., Abou-Shoer, M.I. and Al-Azizi, M.M. (2013) Application of chemometrics in authentication of herbal medicines: a review. *Phytochem. Anal.*, **24**(1):1–24. doi: 10.1002/pca.2378.

Google Scholar

Hu, B., Li, H., Tang, C., Ke, C.Q., Geng, M., Yao, S., Xie, Z. and Ye, Y. (2022) Withaphysalins from medicinal and edible *Physalis minima* and their anti-inflammatory activities. *J. Agric. Food Chem.*,**70**: 5595–5609.

Google Scholar

Joseph, L. and Ravi, C. (2022). *Physalis minima* L. Fruit- A Promising Approach to Alzheimer's Disease. *Pharmacol. Res. Mod. Chinese Med.*,**2:** 100038.

Google Scholar

Karpagasundari, C. and Kulothungan, S. (2014). Free radical scavenging activity of *Physalisminima* Linn. leaf extract (PMLE). *J.M.P.S.***2**(4): 59–64.

Google Scholar

Le Canh, V.C., Le Ba, V., Thi Hai Yen, P., Le Thi, L., Thi Thuy Hoai, P., Huu Dat, T.T., Thao, D.T., Bach, L.G., Kim, Y.H. and Tuan Anh, H.L. (2021). Identification of potential cytotoxic inhibitors from *Physalis minima*. *Nat. Prod. Res.*,**35**(12):2082-2085. doi: 10.1080/14786419.2019.

Google Scholar

Lem, F.F., Yong, Y.S., Goh, S., Chin, S.N. and Chee, F.T. (2022). Withanolides, the hidden gem in *Physalis minima*: A mini review on their anti-inflammatory, anti-neuroinflammatory and anti-cancer effects. *Food Chem.*,**377**: 132002, DOI: 10.1016/j.foodchem.2021.132002.

Google Scholar

Li, J.M., Yang, K.T. and Wu C.P. (2025). Physalin F inhibits cell viability and induces apoptosis in non-small cell lung cancer cells. *Anticancer Res.*,**45**(7):3031–3044. doi: 10.21873/anticanres.17668.

Google Scholar

Li, R.J., Gao, C.Y., Guo, C., Zhou, M.M., Luo, J. and Kong, L.Y. (2017). The anti-inflammatory activities of two major withanolides from *Physalis minima* via acting on NF-κB, STAT3, and HO-1 in LPS-stimulated RAW264.7 cells. *Inflammation*, **40**(2): 401–413.

Google Scholar

Liang, Y., Liang, L., Shi, R., Luo, R., Yue, Y., Jiamin, Yu., Wang, X., Lin, J., Zhou, T., Yang, M., Zhong, L., Wang, Yi. and Shu, Z. (2024). Genus *Physalis* L.: a review of resources and cultivation, chemical composition, pharmacological effects and applications. *J. Ethnopharmacol.*,**324**:117736.

Google Scholar

Liu, W., Zhang, H., Wan, H., Hou, J., Lee, D., Xu, J. and Guo, Y. (2022). Anti-inflammatory withanolides from the aerial parts of *Physalis minima*. *Phytochem.*,**202**: 113301.

Google Scholar

Ooi, K.L., Tengku Muhammad, T.S. and Sulaiman, S.F. (2013). Physalin F from *Physalis minima* L. triggers apoptosis-based cytotoxic mechanism in T-47D cells through the activation caspase-3- and c-myc-dependent pathways. *J. Ethnopharmacol.*, **150**: 382–388.

Google Scholar

Patel, T., Shah, K., Jiwan, K. and Shrivastava, N. (2011). Study on the Antibacterial Potential of *Physalis minima* Linn. *Indian J. Pharm. Sci.*, **73**(1):111–115. doi: 10.4103/0250-474X.89770.

Google Scholar

Prabhu, V., Arunkumar, K., Monika, B., Latha, V. and Sibi, G. (2021). Bioactive phytochemical compounds of *Physalis minima* L. and its anticholinesterase and antioxidant activities. *Asian J. Chem.*,**33**(4): 741–746.

Google Scholar

Pradeepkumar, S., Muthukrishnan, S., Eswaran, A., Kumar, N., Ganesan, T., and Jayaprakash, R. (2022). Screening of genetic variants, phytochemical analysis, characterization and antimicrobial activity of *Physalis minima* fruits extract. *Rasayan J. Chem.*, **15**: 1517–1524.

Google Scholar

Rohilla P., Chhikara A. and Dahiya P. (2024). Assessing Antimicrobial Potential of *Physalis*

minima L. Aerial Vegetative Parts. Annals of Agri-Bio Research, **29** (1): 36-44.

Google Scholar

San, M.M. (2021). Morphological and Histological Characters of *Physalis minima* L. *J. Myanmar Acad. Arts Sci.*,**XIX** (4): 79–81.

Google Scholar

Shil, D., Sarma, T., Roy, S.D., Chakraborty, J.,Das, S.R.C., Das, T. and Rohman, T.A. (2021). Exploring quality control standards and potential antibacterial property of different extracts of the root of *Physalis minima* L.*Int. J. Res. Pharm. Sci.*,**12**(4): 2350-2360.

Google Scholar

Singh, R.J., Lebeda, A. and Tucker, O. (2012). Chapter 2. Medicinal plants—nature's pharmacy. In: Singh RJ, editor. Genetic resources, chromosome engineering, and crop improvement. Medicinal plants. Boca Raton: CRC Press: pp. 13–51.

Google Scholar

Singh, S. and Prakash, P. (2014). Evaluation of Antioxidant Activity of *Physalis Minima*. *Chem. Sci. Trans.*,**3**(3): 1179–1185.

Google Scholar

Su, G., Chai, L., Chen, Y., Xia, H., Li, Y., Zhang, Z., Liu, G., Wang, S., Yang, C., Jin, J.,Wu, L. and Li, Y. (2025). Anti-inflammatory withanolides from *Physalis minima* and their therapeutic potential against ulcerative colitis in mice. *Phytochem.*,**235:** 114451.

Google Scholar

Velemurugan, S., Sethuraman, S.P. and Kamaraj, R. (2024). In-vitro Antioxidant and Cytotoxic Effects of *Physalis minima* Linn. in HeLa Cell Lines Against Cervical Cancer. *Curr. Trends Biotechnol. Pharm.,* **18**(1): 1581–1585.

Google Scholar

Wei, S.S., Gao, C.Y., Li, R.J., Kong, L.Y. and Luo, J. (2019). Withaminimas A-F, six withanolides with potential anti-inflammatory activity from *Physalis minima*. *Chin. J. Nat. Med.*,**17** (6): 469–474.

Google Scholar

Wu, J., Li, X., Zhao, J., Wang, R., Xia, Z., Li, X., Liu, Y., Xu, Q., Khan, I.A. and Yang, S. (2018) Anti-inflammatory and cytotoxic withanolides from *Physalis minima*. *Phytochem.,* **155**: 164–170.

Google Scholar

Wu, J., Zhang, T., Yu, M., Jia, H., Zhang, H., Xu, Q., Gu, Y. and Zou, Z. (2020). Anti-inflammatory withanolides from *Physalis minima*. *ACS Omega*,**5**: 12148–12153.

Google Scholar

Wu, J.P., Li, L.Y., Li, J.R., Yu, M., Zhao, J., Xu, Q.M., Gu, Y.C., Zhang, T. and Zou, Z.M. (2022). Silencing tautomerization to isolate unstable physalins from *Physalis minima*. *J. Nat. Prod.*,**34**: 15–21.

Google Scholar

Wu, J., Li, Z.,Zhao, J., Zhang, T., Jun Zhang, J., Lv, Q., Li, J., Wang, G., Han, J. and Zou, Z. (2025). Atypical sulfur-containing physalin from *Physalis minima* and protective effect against ischemia-reperfusion injury. *Phytochem.,* **235**: 114478.

Google Scholar

Yazhiniprabha, M., Banu, S., Ishwarya, R., Vinotha, V., Govindarajan, M., Wadaan, M.A., Mahboob, S., Nicoletti, M. and Vaseeharan, B. (2022). Biomimetically synthesized *Physalis minima* fruit extract-based zinc oxide nanoparticles as eco-friendly biomaterials for biological applications. *J. Drug Delivery Sci. Technol.*,**73**: 103475.

Google Scholar

Zhang, M., Zhang, B.Y., Guang, C.X., Jiang, B.K., He, X.Y., Cao, S.J., Ding, L.P., Kang, N., Chen, L.X. and QiuF. (2020). New withanolides from *Physalis minima* and their cytotoxicity against A375 human melanoma cells. *RSC Adv.*,**10** (2020): 22819–22827.

Google Scholar

Zhou, Y.M., Shi, X.M., Ma, L. and Zhang, S.F. (2015). Isolation and identification of withaphysalins from *Physalis minima*. *J. China Pharm. Univ.*,**46** (1): 62–65.

Google Scholar