WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
SJIF Impact Factor 8.453
Volume 14, Issue 2, 212-229. Review Article ISSN 2277–7105

OVERVIEW ON: ISOLATION, ANALYSIS PROCESS, AND PHARMACOLOGICAL ACTIVITY OF GALLIC ACID

Priya Gandhi*

Parul Institute of Pharmacy & Research, Post Limda, Waghodia, Gujarat, India.

Article Received on
21 November 2024,

Revised on 11 Dec. 2024,
Published on 15 Jan. 2025

DOI: 10.20959/wjpr20252-35206

***Corresponding Author**
Priya Gandhi
Parul Institute of Pharmacy & Research, Post Limda, Waghodia, Gujarat, India.

ABSTRACT

Gallic acid (3, 4, 5-trihydroxybenzoic acid) is a phenolic acid compound. Nearly every component of the plant, including the bark, wood, leaf, fruit, root, and seed contains a significant amount of Gallic acid and its derivatives. Isolation of Gallic Acid from fresh or dried plant material by using different techniques like Soxhlet method, reflux, Column Chromatography, Matrix solid phase extraction, maceration, and Sonication etc. Based on in vitro studies Gallic acid has pharmacological activities, including as an antioxidant, anti-inflammatory, antineoplastic, gastrointestinal, neuropsychological, metabolic disease, and cardiovascular disorders. This article provides details on the isolation process, analysis, and pharmacological effect of Gallic acid. Gallic acid identification can be done using Thin Layer Chromatography (TLC), High-Performance Liquid Chromatography (HPLC), and High Performance Thin Layer Chromatography (HPTLC).

KEYWORDS: Gallic Acid, sources, isolation methods, physico-Chemical Properties, therapeutic effects, HPLC, HPTLC.

INTRODUCTION

Gallic acid, also known as 3, 4, and 5-trihydroxybenzoic acid, is one of the most prevalent phenolic acids in the plant kingdom and may be extracted from a variety of plants. Gallic acid was initially detected using thin-layer chromatography (TLC). In several investigations, its diverse pharmacological properties have been further discussed. The Soxhlet method, reflux, column chromatography, matrix solid-phase extraction, maceration, and sonication are additional methods for identifying or isolating Gallic acid. Thin-layer chromatography

(TLC), high-performance liquid chromatography (HPTLC), mass spectrometry, and high-performance liquid chromatography (HPLC) are also used for analysis.

From the background presented, this article was intended to provide a collection of information about a more efficient way to isolate, analyse, and determine the compound Gallic Acid's pharmacological activity.

Source of gallic acid

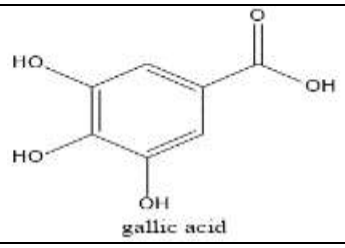
Many plants naturally contain gallic acid like *Phyllanthus Emblica, Embelica officinalis, Terminalia Chebula, Boswellia dalzielii, Pueraria lobata (Wild.) Ohw, Guazuma ulmifolia Lam., Sambucus nigra L., Sorocea guilleminina Gaudich., Abutilon pannosum, Phyllanthus amarus Schum. & Thonn., Camellia japonica L., Myrciaria dubia (Kunth) Mc Vaugh, Mentha spicata L., Bougainvillea Comm., Schisandra chinensis (Turcz.) Baill, Cucumis sativus L., Momordica charantia L, Tinospora cordifolia, Mangifera indica L., Rubus idaeus L., Vitis vinifera L.,* Etc.[1]

Table 1: Various sources of gallic acid.

Sr. No.	Plants	Family	Parts	Reference
1	*Pueraria lobata* (Wild.) Ohwi	Leguminosae	Roots	[1]
2	*Guazuma ulmifolia* Lam.	Malvaceae	Fruit	[2]
3	*Sambucus nigra* L.	Adoxaceae	Fruit	[3]
4	*Syzygium malaccense* (L.) Merr. & L.M. Perry	Myrtaceae	Fruit peels	[4]
5	*Sorocea guilleminina* Gaudich.	Moraceae	Leaves	[5]
6	*Abutilon pannosum* (G.Forst.) Schltdl.	Malvaceae	Stem Bark	[6]
7	*Barringtonia racemosa* (L.) Spreng	Lecythidaceae	Leaves	[7]
8	*Momordica charantia* L.	Cucurbitaceae	Leaves	[8]
9	*Fraxinus angustifolia* Vahl	Oleaceae	Bark	[9]
10	*Camellia japonica* L.	Theaceae	Seeds	[10]
11	*Myrciaria dubia* (Kunth) Mc Vaugh	Myrtaceae	Fruits	[11]
12	*Antidesma bunius* Spreng.	Phyllanthaceae	Fruits	[12]
13	*Mentha spicata* L.	Lamiaceae	Aerial parts	[13]
14	*Bougainvillea* Comm. ex Juss.	Nyctaginaceae	Flowers	[14]
15	*Schisandra chinensis* (Turcz.) Baill.	Schisandraceae	Fruits	[15]
16	*Caraipa densifolia* Mart.	Clusiacaeae	Leaves	[16]
17	*Citrullus colocynthis* (L.) Schrad.	Cucurbitaceae	Fruits	[17]

Physicochemical properties of gallic acid[18,19,20]

Table 2: Physicochemical Properties of Gallic Acid.

Molecular Formula	$C_7H_6O_5$
Chemical Name	3,4,5 trihydroxybenzoic acid
Appearance	White, Yellowish-white or pale fawn-colored crystals
Chemical Nature	Phenolic acids
Structure	 gallic acid
Storage Condition	At 15˚C to 25˚C
Melting Point	260˚C
Boiling point	501.1 ± 50.0˚C
Molecular weight	170.12 g/mol
Solubility	Alcohol, ether, glycerol, and acetone soluble It's hardly soluble in benzene, Chloroform, petroleum ether.
Density	1.694 g/cm^3
Log P	0.70

Isolation of gallic acid

The isolation technique can be used to synthesize Gallic acid compounds. A technique, also known as a standard separation process, is used to continuously separate fresh or dried plant material using solvents of increasing polarity. Methanol, diethyl ether, ethanol, and water are frequently employed as solvents for this. This is due to how easily these chemicals dissolve in these substances. Recent investigations have employed a variety of solvents, including methanol, water, and others (Ethanol, Ethyl acetate, Acetone and Diethyl ether).

A detailed description of the multistep method for extraction and purification of Gallic acid has recently been presented from several plant *Phyllanthus Emblica*, *Embelica officinalis* (Amalaki) & *Terminalia Chebula* (Haritaki) etc.

Table 3: Isolation methods of Gallic Acid.

Sr. No.	Isolation method	Solvent	Reference
1.	Maceration process Methanol was used to crush 100g of dry acorn and extract it using a cold maceration method. By using a rotating evaporator at 45 °C and lowered pressure, the final volume was concentrated to dryness.	Methanol	[21 & 30]
2.	Sonication A 100 ml volumetric flask should contain 0.250 g of the	Water	[22 & 29]

	sample raw material that has been finely powdered. This quantity should be dissolved in 50 ml of hot water, sonicated for 10 minutes, allowed to cool, and then the remaining 100 ml of water should be added. Filter via 0.45 micron thick membrane filter paper (PES filter papers only).		
3.	Column chromatography 50% methanol in water was used to extract 1000g of the powdered plant material, which was then filtered. A rotatory evaporator was used to extract the methanol under vacuum, and diethyl ether was used to further fractionate the aqueous part.	Methanol & diethyl ether	[23]
4.	Matrix solid phase extraction technique The sample was mixed with the same amount (0.5 g) of silica that had been octadecylsilyl-derivatized (C_{18}). The mixture was then moved to a column and packaged. Moreover, the column was eluted with 100% methanol. The fraction was collected and dried after the operation was repeated three times. 1 g correctly weighed piece of each dry extract was separately dissolved in methanol. The concentration from each sample was separately reconstituted in 50 ml of precisely measured methanol using volumetric flasks.	Methanol	[24]
5.	Soxhlet extraction Fresh fruits from *Embelica officinalis* were crushed, shade-dried, and then extracted with 70% alcohol in a Soxhlet extractor. The extracts were concentrated using vacuum evaporators.	Ethanol	[25]
6.	Reflux Separate extracts of various drug samples weighing accurately 0.5g each were made using 4625 ml of methanol over reflux for 30 minutes at a time in a water bath. The combined extracts from each sample were concentrated, transferred, and individually diluted with methanol to fill 25-ml volumetric flasks.	Methanol	[26]

Pharmacological activity of gallic acid

Many positive therapeutic properties of gallic acid have been demonstrated. It's antifungal, antibacterial, antiviral, allergic, anti-inflammatory, antimutagenic, antiulcer, anticholesterol, antiobesity, and immunomodulatory properties have all been demonstrated. It also has the potential to be neuroprotective, cardioprotective, hepatoprotective, and nephroprotective.

Table 4: Pharmacological Activity of Gallic Acid.

Pharmacological Activity	Effects	Reference
Anti-Fungal	With *Candida albicans* being the most susceptible fungus (MIC = 12.5 g/mL), in vitro tests indicated that Gallic Acid had broad spectrum antifungal action, whereas experiments	[35]

	on mice infected with the *Candida albicans* infection model showed that Gallic acid significantly reduced the death rate.	
Bovine respiratory disease (BRD) (Anti-Bacterial)	It has been demonstrated that the minimum inhibitory concentrations for gallic acid against Mannheimia haemolytica and Pasteurella multocisssda are 250 g/mL and 500 g/mL, respectively.	[36]
Anti-Viral	Gallic acid reduced HRV- 2 and -3 replications in human epitheloid carcinoma cervix (Hela) cells with antiviral activity more than 55% without cytotoxicity at a dose of 100 mug/ml.	[37]
Anti-Oxidant	By altering the equilibrium between antioxidants and pro-oxidants, Gallic acid has the potential to be both cytotoxic and antitumor. Superoxide dismutase (SOD), catalase (CAT), glutathione reductase (GR), and glutathione peroxidase (GPx) activity is increased while lipid peroxidation and ROS production are decreased. the substance may in certain situations be able to prevent the ROS-induced carcinogenesis. Gallic acid can also cause apoptosis, autophagy, and cell cycle arrest by activating the caspase pathway and generating ROS. Additionally, it can prevent invasion and metastasis by reducing the production and activity of matrix metalloproteinase.	[38 to 42]
Anti-Cancer	In in vivo cancer models, Gallic acid and its derivatives, such as isobutyl gallate-3, 5-dimethyl ether and methyl gallate-3, 5-dimethyl ether, can shrink tumours and improve survival rates. Gallic acid regulates the cell cycle-related proteins cyclin A, cyclin D1, and cyclin E and delays cell division by activating the p27KIP enzyme and reducing CDK activity. Gallic acid, which inhibits the proliferation of hepatic cells, reduced the size of the tumour and the serum levels of tumour marker enzymes in the case of hepatocellular carcinoma, including aspartate transaminase (AST), alanine transaminase (ALT), lactate dehydrogenase (LDH), alkaline phosphatase (ALP), and gamma-glutamyl transferase (GGT).	[43 to 45]
Gastrointestinal diseases		
Anti-Ulcer	Gallic acid protects the mucosal layer of the digestive tract against ulcers by lowering acid output, encouraging the generation of endogenous antioxidants and protective agents, and lowering oxidative stress and lipid peroxidation.	[46 to 48]
Inflammatory bowel Diseases (IBD)	Various intracellular inflammatory mechanisms that cause ulcerative colitis are blocked by Gallic acid. The substance reduces the expression of nuclear transcription factors that are associated with inflammation, including nuclear factor (NF)-B and signal transducer and activator of transcription 3 (STAT3). Additionally, it inhibits the production and infiltration of neutrophils and $CD68^{+}$ macrophages into the colon as well as the activity of pro-inflammatory cytokines and inflammatory proteins as TNF-, interferon-, interleukin (IL)-	[49 & 50]

	1, IL-6, IL-17, IL-21, IL-23, cyclooxygenase (COX)-2, and I-NOS.	
Cardiovascular diseases		
Myocardial ischemia	Gallic acid pre-treatment greatly reduces the detrimental oxidative effects of myocardial infarction when viewed in the context of its antioxidant potency by increasing the activity of antioxidant enzymes like SOD, CAT, GST, and GPx and/or by raising the level of non-enzymatic antioxidant agents like GSH, vitamin C, and vitamin E. Because all of these processes can stop the negative effects of free radicals on the integrity and functionality of myocyte membranes, the concentration of blood cardiac biomarkers such as cardiac troponin T (cTnT) and creatine kinase-MB (CK-MB) decreases after myocardial infarction.	[51 & 52]
Metabolic diseases		
Obesity, diabetes mellitus, and hyper-lipidemia	By encouraging the expression of peroxisome proliferator-activated receptor (PPAR), a nuclear transcription factor that promotes adipocyte differentiation and insulin sensitivity, Gallic acid reduces the size of adipocytes, prevents diet-induced hyper-glycemia and hypertriglyceridemia, and protects pancreatic beta-cells. By stimulating the phosphatidylinositol 3-kinase (PI3K)/p-Akt signalling cascade and the translocation of insulin-stimulated glucose transporters, Gallic acid also promotes cellular glucose uptake.	[53 to 57]
Neuro-protective	Gallic acid reduces the A-induced toxicity in cultured rat cortical neurons by limiting Ca^{2+} release from the endoplasmic reticulum into the cytoplasm, or Ca^{2+} influx, which in turn lessens ROS generation and cell death. The substance reverses the cerebellar oxidative stress and cognitive impairment brought on by streptozotocin (STZ) in rats by scavenging free radical molecules like ROS, lowering lipid peroxidation, and encouraging the activity of endogenous antioxidant agents such as SOD, CAT, and GPx. Moreover, gallic acid may be used to undo the amnesia that scopolamine induction in mice causes. This is most likely achieved by reducing acetylcholinesterase (AChE) enzyme activity in the brain and regulating oxidative stress.	[58]

Analytical methods

Thin-layer chromatography (TLC), high-performance liquid chromatography (HPLC), and high-performance thin-layer chromatography (HPTLC) may all be used to identify Gallic acid.

Table 5: Analytical methods of Gallic Acid.

Sr. No.	Title	Description	Ref. No.
1	Gallic acid	**Method:-** HPLC **Mobile phase:** Water: acetonitrile: acetic acid (88:10:2)%v/v/v **Stationary phase:** C_{18} column (250 mm × 4.6 mm, 5 µm) Visualization under UV at 280 nm. **Retention time:** 3.23min	[60]
2	Gallic acid in Polyherbal Tablet Formulation	**Method:-** RP - HPLC **Mobile phase:** Water : Acetonitrile (80 :20)%v/v **Stationary phase:** C_{18} column (250 mm × 4.6 mm, 5 µm) Visualization under UV at 272 nm. **Retention time:** 3.6 min	[61]
3	Gallic Acid in Ayurvedic Polyherbal Formulation Triphala churna	**For HPTLC,** **Solvent system:** Toluene: Ethyl acetate: Formic acid: Methanol (3: 3: 0.8: 0.2)%v/v **Stationary phase:** silica gel $^{60}F_{254}$ plates Visualization under UV at 254 nm and 366 nm. **R_f value:** 0.56 **For HPLC,** **Retention Time:** 5.829min **Flow rate:** 1.50 ml/min **Stationary phase:** C_{18} column (250 mm × 4.6 mm, 5 µm) **Solvent system:** Toluene: Ethyl acetate: Formic acid: Methanol (3: 3: 0.8: 0.2)%v/v	[62]
4	Gallic acid and Ascorbic acid herbal medicine: Triphala Churna	**Method:-** HPTLC **Mobile phase:** Ethyl acetate: toluene: acetone (4.5:4:1)%v/v/v **Stationary phase:** silica gel $^{60}F_{254}$ plates Visualization under UV at 254 nm. **R_f value:** 0.53	[63]
5	Gallic Acid in *Benincasa hispida*	**Method:-** HPLC **Mobile phase:** 0.01 M potassium dihydrogen phosphate-acetonitrile (85:15) %v/v. **Stationary phase:** C_{18} column (250 mm × 4.6 mm, 5 µm) Visualization under UV at 280 nm. **Retention time:** 1.98 min	[64]
6	Gallic acid and Embelin	**Method:-** HPTLC	[65]

	Manibhadra Yoga: A Polyherbal *Ayurvedic* Formulation	**Mobile Phase:-** toluene: ethyl acetate: methanol: formic acid (5: 4: 0.5: 0.5)% v/v **Stationary phase:** silica gel $^{60}F_{254}$ plates Visualization under UV at 254 nm. **R_f value:** 0.3	
7	Scopoletin and Gallic acid in the methanolic fraction of *Jatropha glandulifera*	**Method:-** HPTLC **Mobile Phase:-** toluene: ethyl acetate: glacial acetic acid (7.5:2.5:0.1)% v/v **Stationary phase:** silica gel $^{60}F_{254}$ plates Visualization under UV at 254 nm. **R_f value:** 0.4	[66]
8	Ellagic acid and Gallic acid in Triphala Churanam Formulation	**Method:-** HPTLC **Mobile Phase:-** toluene: ethyl acetate: formic acid: Methanol (3:3:0.8:0.2)%v/v **Stationary phase:** silica gel $^{60}F_{254}$ plates Visualization under UV at 280 nm. **R_f value:** 0.56	[67]
9	Gallic acid in Methanol extract of *Quercus griffithii Acorn*	**Method:-** HPTLC **Mobile phase:-** Toluene: ethyl acetate: formic acid (6:6:1)%v/v **Stationary phase:** silica gel $^{60}F_{254}$ plates Visualization under UV at 297 nm. **R_f value:** 0.41	[68]
10	Gallicin, Gallic Acid, Lupeol and b-Sitosterol from *Bergia suffruticosa, a Hitherto* Unexplored Plant	**Method:-** TLC **Mobile phase:-** Toluene: ethyl acetate: Methanol: formic acid (6:3:1:0.5)%v/v **Stationary phase:** silica gel $^{60}F_{254}$ plates Visualization under UV at 254 nm & 366nm. **R_f value:** 0.40	[69]
11	Ascorbic acid and Gallic acid from freeze dry pomegranate juice and herbal formulation	**Method:-** HPTLC **Mobile phase:-** ethyl acetate: acetone: water: formic acid (10:6:2:2)% v/v/v/v **Stationary phase:** silica gel $^{60}F_{254}$ plates Visualization under UV at 254 nm. **R_f value:** 0.54	[70]

12	curcumin and gallic acid in polyherbal formulation	**Method:-** HPTLC **Mobile phase:-** chloroform:ethyl acetate:formic acid (7.5 mL + 6mL + 0.5 mL) **Stationary phase:** silica gel $^{60}F_{254}$ plates Visualization under UV at 254 nm. **R_f value:** 0.24	[71]
13	Gallic acid and Ellagic acid in herbal raw materials	**Method:-** HPTLC **Mobile phase:-** Toluene: ethyl acetate: formic acid: methanol (3:3:0.8:0.2)% v/v **Stationary phase:** silica gel $^{60}F_{254}$ plates Visualization under UV at 280 nm. **R_f value:** 0.57	[72]
14	Gallic acid in selected plant extracts	**Method:-** HPLC **Mobile phase:** water: acetonitrile: acetic acid (88:10:2) %v/v/v. **Stationary phase:** C_{18} column (250 mm × 4.6 mm, 5 µm) Visualization under UV at 280 nm. **Retention time:** 3.23 min	[73]
15	Gallic Acid in Herbal Formulation: *Triphala churna*	**Method:-** HPTLC **Mobile Phase:-** Ethyl acetate – Methanol – Formic acid (8 : 2 : 1)% v/v/v **Stationary phase:** silica gel $^{60}F_{254}$ plates Visualization under UV at 280 nm. **R_f value:** Methanolic Gallic Acid: 0.77 Gallic Acid: 0.78	[74]
16	Gallic Acid in Ayurvedic Herbs and Formulations	**Method:-** TLC **Mobile phase:-** chloroform : ethyl formate :formic acid (5:4:1)%v/v **Stationary phase:** silica gel $^{60}F_{254}$ plates Visualization under UV at 593 nm. **R_f value:** 0.40	[75]
17	Gallic acid in *Schinopsis brasiliensis*	**Method:-** HPLC **Mobile phase:** Water acidified with phosphoric acid (0.1%) and acetonitrile (4:6) %v/v **Stationary phase:** C_{18} column (250 mm × 4.6 mm, 5 µm) Visualization under UV at 271 nm. **Retention time:** 8.497 min	[76]

18	Lupeol, gallic acid and β-sitosterol	**Method:-** HPLC **Mobile phase:** Components A:- Acetic Acid in HPLC Grade water Component B:- Acetonitrile: Acetic Acid (80:20) %v/v **Stationary phase:** C_{18} column (250 mm × 4.6 mm, 5 µm) Visualization under UV at 254 nm. **Flow rate:** 1ml/min **Retention time:** 4.527 min	[77]

CONCLUSION

The sources, isolation procedure, analysis, and pharmacological impact of gallic acid are all covered in length in this article.

There are various concentrations of Gallic acid and its derivatives in the bark, wood, leaves, fruits, roots, and seeds of a plant. The maceration and sonication processes used to extract Gallic acid from various plants. Thin layer chromatography, High performance thin layer chromatography & High performance liquid chromatography can be used to identify Gallic acid whereas TLC & HPTLC system of Toluene: Ethyl acetate: Methanol: Formic acid (5:4:0.5:0.5 %v/v/v/v) mobile phase, UV detention at 254 nm, silica gel $^{60}F_{254}$ plates Stationary phase has the fastest analytical time among other HPTLC system and HPLC system of Water : Acetonitrile (80 :20%v/v) mobile phase, UV detection at 272nm, C_{18} (250 mm × 4.6 mm, 5 µm) column, Flow rate 1.50 ml/min has the fastest analytical time among other HPLC system.

Gallic acid has pharmacological activities, including as an antioxidant, anti-inflammatory, antineoplastic, gastrointestinal, neuropsychological, metabolic disease, and cardiovascular disorders.

REFERANCES

1. L. Wei, P. Zhu, X. Chen, Y. Wang, Y. Xu, An ultra-high performance liquid chromatography with tandem mass spectrometry method for simultaneous determination of thirteen components extracted from Radix puerariae in rat plasma and tissues: application to pharmacokinetic and tissue distribution study, J. Sep. Sci, 2020; 43(2): 418–437.

2. G.A. Pereira, H.S. Arruda, D.R. de Morais, N.M. Peixoto Araujo, G.M. Pastore, Mutamba (Guazuma ulmifolia Lam.) fruit as a novel source of dietary fibre and phenolic compounds, Food Chem, 2020; 310: 125857.
3. R. Domínguez, L. Zhang, G. Rocchetti, L. Lucini, M. Pateiro, P.E.S. Munekata, J.M. Lorenzo, Elderberry (Sambucus nigra L.) as potential source of antioxidants. Characterization, optimization of extraction parameters and bioactive properties, Food Chem, 2020; 330: 127266.
4. M.M. Vuolo, ˆA.G. Batista, A.C.T. Biasoto, L.C. Correa, M.R.M. Júnior, R.H. Liu, Red-jambo peel extract shows antiproliferative activity against HepG2 human hepatoma cells, Food Res, Int, 2019; 124: 93–100.
5. F.F. Figueiredo, V. Cechinel Filho, A.S. Damazo, K. Arunachalam, E.M. Colodel, M. Ribeiro, C.L. Venturini, D.M. Oliveira, M.T.M. Machado, E. Pavan, R.L. Paes, A. Tenfen, P.O.A. Almeida, D.A. Siebert, L. Vitali, A. Macho, D.T.O. Martins,Sorocea guilleminiana Gaudich.: wound healing activity, action mechanisms, and chemical characterization of the leaf infusion, J. Ethnopharmacol, 2020; 248: 112307.
6. I. Khalil, M. Ghani, M.R. Khan, F. Akbar, Evaluation of biological activities and in vivo amelioration of CCl induced toxicity in lung and kidney with Abutilon pannosum (G. Forst.) Schltdl. In rat, J. Ethnopharmacol, 2020; 249: 112395.
7. K.W. Kong, S. Mat-Junit, A. Ismail, N. Aminudin, A. Abdul-Aziz, Polyphenols in Barringtonia racemosa and their protection against oxidation of LDL, serum and haemoglobin, Food Chem, 2014; 146: 85–93.
8. J.A. Saliu, S.I. Oyeleye, T.A. Olasehinde, G. Oboh, Modulatory effects of stonebreaker (Phyllanthus amarus) and bitter gourd (Momordica charantia) on enzymes linked with cardiac function in heart tissue of doxorubicin-stressed rats, Drug Chem, Toxicol, 2019; 1–9.
9. A. Attanzio, A. D'Anneo, F. Pappalardo, F.P. Bonina, M.A. Livrea, M. Allegra, L. Tesoriere, Fraxinus angustifolia, Phenolic composition of hydrophilic extract of manna from sicilian vahl and its reducing, antioxidant and anti-inflammatory activity in vitro, Antioxidants Basel (Basel), 2019; 8(10): 494.
10. C. Saenjum, T. Pattananandecha, K. Nakagawa, Camellia japonica, Detection of antioxidant phytochemicals isolated from seeds using HPLC and EPR imaging, Antioxidants Basel (Basel), 2020; 9(6): 493.
11. M. Fidelis, S.M. de Oliveira, J. Sousa Santos, G. Bragueto Escher, R. Silva Rocha, A. Gomes Cruz, M. Araújo Vieira do Carmo, L. Azevedo, T. Kaneshima, W.Y. Oh, F.

Shahidi, D. Granato, From byproduct to a functional ingredient: camu-camu (Myrciaria dubia) seed extract as an antioxidant agent in a yogurt model, J. Dairy Sci, 2020; 103(2): 1131–1140.

12. O. Krongyut, K. Sutthanut, Phenolic profile, antioxidant activity, and anti-obesogenic bioactivity of mao luang fruits (Antidesma bunius L.), Molecules, 2019; 24(22): 4109.
13. A.B. Saad, I. Rjeibi, N. Brahmi, E. Elaloui, N. Zouari, Nicotine-induced oxidative stress, testis injury, AChE inhibition and brain damage alleviated by Mentha spicata, Inflammopharmacology, 2019; 28(4): 939–948.
14. H. Saleem, T.T. Htar, R. Naidu, S. Anwar, G. Zengin, M. Locatelli, N. Ahemad, HPLC-PDA polyphenolic quantification, UHPLC-MS secondary metabolite composition, and in vitro enzyme inhibition potential of Bougainvillea glabra, Plants Basel (Basel), 2020; 9(3): 388.
15. A. Szopa, M. Klimek-Szczykutowicz, A. Kokotkiewicz, M. Dziurka, M. Luczkiewicz, H. Ekiert, Phenolic acid and flavonoid production in agar, agitated and bioreactor-grown microshoot cultures of Schisandra chinensis cv. Sadova No.1-a valuable medicinal plant, J. Biotechnol, 2019; 305: 61–70.
16. C.V. da Silveira, M.T. Trevisan, J.B. Rios, G. Erben, R. Haubner, B. Pfundstein, R. W. Owen, Secondary plant substances in various extracts of the leaves, fruits, stem and bark of Caraipa densifolia Mart, Food Chem. Toxicol, 2010; 48(6): 1597–1606.
17. T.A. Ibrahim, H.M. El-Hefnawy, A.A. El-Hela, Antioxidant potential and phenolic acid content of certain cucurbitaceous plants cultivated in Egypt, Nat. Prod. Res, 2010; 24(16): 1537–1545.
18. Quality Standards of Indian Medicinal Plants, 1: 205.
19. http://www.chemspider.com/Chemical-Structure.361.html.
20. https://pubchem.ncbi.nlm.nih.gov/compound/Gallic-acid.
21. Jinrong Bai, Yunsen Zhang, Ce Tang, Ya Hou, Xiaopeng Ai, Xiaorui Chen, Yi Zhang, Xiaobo Wang, Xianli Meng, Gallic acid: Pharmacological activities and molecular mechanisms involved in inflammation-related diseases, ELSEVIER Biomedicine & Pharmacotherapy, 2020; 133: 16.
22. Maria Daglia, Arianna Di Lorenzo, Seyed F Nabavi, Zeliha S Talas, Seyed M Nabavi, Polyphenols: well beyond the antioxidant capacity: gallic acid and related compounds as neuroprotective agents: you are what you eat!, National library of medicine, 2014; 15(4): 362-72.

23. Phiwayinkosi V Dludla, Bongani B Nkambule, Babalwa Jack, Zibusiso Mkandla, Tinashe Mutize, Sonia Silvestri, Patrick Orlando, Luca Tiano, Johan Louw, Sithandiwe E Mazibuko-Mbeje, Inflammation and Oxidative Stress in an Obese State and the Protective Effects of Gallic Acid, National library of medicine, 2018; 21, 11(1): 23.
24. Jambey Tsering, Baikuntha J. Gogoi, Vijay Veer, Pallabi Kalita and Hui Tag, HPTLC determination of Gallic acid in Methanol extract of Quercus griffithii Acorn, International Journal of PharmTech Research, 2014; 6, 4: 1341-1347.
25. Ajay Kumar Meena, Ch. V. Narasimhaji, D. Velvizhi, Arjun Singh, P. Rekha, Vijay Kumar, R. Ilavarasan, Narayanam Srikanth, K. S. Dhiman, Determination of Gallic Acid in Ayurvedic Polyherbal Formulation Triphala churna and its ingredients by HPLC and HPTLC, research journal of pharmacy and technology, *2018; 11(8).*
26. Sheetal Anandjiwala, Honnegowda Srinivasa, Mandapati Rajani, Isolation and TLC Densitometric Quantification of Gallicin, Gallic Acid, Lupeol and b-Sitosterol from Bergia suffruticosa, a Hitherto Unexplored Plant, Chromatographia, 2007; 9, 10: 26. September.
27. Prawez Alam, Y.T. Kamal, Saleh Ibrahim Alqasoumi, Ahmed Ibrahim Foudah, Mohammed Hamed Alqarni, Hasan Soliman Yusufoglu, HPTLC method for simultaneous determination of ascorbic acid and gallic acid biomarker from freeze dry pomegranate juice and herbal formulation, Saudi Pharmaceutical Journal, 2019; 16.
28. S. D. Sonawane, S. A. Nirmal, A. N. Patil & S. R. Pattan, DEVELOPMENT AND VALIDATION OF HPTLC METHOD TO DETECT CURCUMIN AND GALLIC ACID IN POLYHERBAL FORMULATION, Journal of Liquid Chromatography & Related Technologies, 2015; 26.
29. Milind Bagul, H. Srinivasa, Harish Padh, M. Rajani, A rapid densitometric method for simultaneous quantification of gallic acid and ellagic acid in herbal raw materials using HPTLC, Journal of separate science, 2005; 15, 28: 581–584.
30. Amirah, D.M. Reddy Prasad and Maksudur R. Khan, Comparison of extraction techniques on exctraction of gallic acid from stem bark of jatropha curcas, Journal of applied science, 2012; 12(11).
31. *Magdalena Karamae, Agnieszka Kosiñska, Ronald B. Pegg,* CONTENT OF GALLIC ACID IN SELECTED PLANT EXTRACTS**,** POLISH JOURNAL OF FOOD AND NUTRITION SCIENCES, 2006; 15, 56: 1, 55–58.

32. Kamal Kardani, Nilesh Gurav**,** Bhavna Solanki, Prateek Patel, Bhavna Patel, RP-HPLC Method Development and Validation of Gallic acid in Polyherbal Tablet Formulation, Journal of Applied Pharmaceutical Science, 2013; 3(05): 037-042.
33. Patil V. P., Kurhade S. D., Devdhe S.J., Kale S. H., Wakte P. S Determination of Gallic Acid by HPTLC as Quality Control Parameter in Herbal Formulation: Triphala churna, International Journal of Chemical and Analytical Science, 2012; 3(9): 1546-1549.
34. Zhentian Lei, Judith Jervis, and Richard F. Helm, Use of Methanolysis for the Determination of Total Ellagic and Gallic Acid Contents of Wood and Food Products, *J. Agric. Food Chem*, 2001; 49: 3.
35. Li, Z. J., Liu, M., Dawuti, G., Dou, Q., Ma, Y., Liu, H. G., & Aibai, S., Antifungal Activity of Gallic Acid in Vitro and In Vivo. *Phytotherapy Research*, 2017; *31*(7): 1039–1045.
36. Rajamanickam, K., Yang, J., & Sakharkar, M. K. Gallic acid potentiates the antimicrobial activity of tulathromycin against two key bovine respiratory disease (BRD) causing-pathogens. *Frontiers in Pharmacology*, 2019; *9*: 1–9.
37. Choi H. J., Song J. H., Bhatt L. R., Baek S.H., Anti-human rhinovirus activity of gallic acid possessing antioxidant capacity. Phytother Res, 2010; 24(9): 1292-6.
38. Giftson J, Jayanthi S, Nalini N. Chemopreventive efficacy of gallic acid, an antioxidant and anticarcinogenic polyphenol, against 1, 2-dimethyl hydrazine induced rat colon carcinogenesis. Invest New Drugs, 2010; 28: 251–259.
39. Subramanian V, Venkatesan B, Tumala A, Vellaichamy E. Topical application of gallic acid suppresses the 7, 12-DMBA/croton oil induced two-step skin carcinogenesis by modulating anti-oxidants and MMP-2/MMP-9 in Swiss albino mice. Food Chem Toxicol, 2014; 66: 44–55.
40. Balch C, Gershenwald J, Soong S, Thompson J, Atkins M, Byrd D, et al. Final version of 2009 AJCC melanoma staging and classification. J Clin Oncol, 2009; 27: 6199–6206.
41. Liao C, Lai K, Huang A, Yang J, Lin J, Wu S, et al. Gallic acid inhibits migration and invasion in human osteosarcoma U-2 OS cells through suppressing the matrix metalloproteinase-2/-9, protein kinase B (PKB) and PKC signaling pathways. Food Chem Toxicol, 2012; 50: 1734–1740.
42. Nemec M, Kim H, Marciante A, Barnes R, Talcott S, Mertens-Talcott S. Pyrogallol, an absorbable microbial gallotannins-metabolite and mango polyphenols (Mangifera Indica L) suppress breast cancer ductal carcinoma in situ proliferation in vitro. Food Funct, 2016; 7: 3825–3833.

43. Da Silva S, Chaar J, Yano T. Chemotherapeutic potential of two gallic acid derivative compounds from leaves of Casearia sylvestris Sw (Flacourtiaceae) Eur J Pharmacol, 2009; 608: 76–83.
44. Huang P, Hseu Y, Lee M, Kumar K, Wu C, Hsu L, et al. In vitro and in vivo activity of gallic acid and Toona sinensis leaf extracts against HL-60 human premyelocytic leukemia. Food Chem Toxicol, 2012; 50: 3489–3497.
45. Jagan S, Ramakrishnan G, Anandakumar P, Kamaraj S, Devaki T. Antiproliferative potential of gallic acid against diethylnitrosamine-induced rat hepatocellular carcinoma. Mol Cell Biochem, 2008; 319: 51–59.
46. Mard S, Mojadami S, Farbood Y, Gharib Naseri M. The anti-inflammatory and anti-apoptotic effects of gallic acid against mucosal inflammation- and erosions-induced by gastric ischemia-reperfusion in rats. Vet Res Forum, 2015; 6: 305–311.
47. Pal C, Bindu S, Dey S, Alam A, Goyal M, Iqbal MS, et al. Gallic acid prevents nonsteroidal anti-inflammatory drug-induced gastropathy in rat by blocking oxidative stress and apoptosis. Free Radicals Biol Med, 2010; 49: 258–267.
48. Chatterjee A, Chatterjee S, Biswas A, Bhattacharya S, Chattopadhyay S, Bandyopadhyay SK. Gallic acid enriched fraction of Phyllanthus emblica potentiates indomethacin-induced gastric ulcer healing via e-NOS-dependent pathway. Evid Based Complement Alternat Med, 2012; 2012: 487380.
49. Pandurangan A, Mohebali N, Norhaizan M, Looi C. Gallic acid attenuates dextran sulfate sodium-induced experimental colitis in BALB/c mice. Drug Des Devel Ther, 2015b; 9: 3923–3934.
50. Pandurangan A, Mohebali N, Mohd Esa N, Looi C, Ismail S, Saadatdoust Z. Gallic acid suppresses inflammation in dextran sodium sulphate-induced colitis in mice: possible mechanisms Int. Immunopharmacol, 2015a; 28: 1034–1043.
51. Kasper D, Hauser S, Jameson J, Fauci A, Longo D, Loscalzo J. Harrison's Principles of Internal Medicine. Mc Graw Hill, 2015; 19.
52. Priscilla D, Prince P. Cardioprotective effect of gallic acid on cardiac troponin-T, cardiac marker enzymes, lipid peroxidation products and antioxidants in experimentally induced myocardial infarction in wistar rats. Chem Biol Interact, 2009; 179: 118–124.
53. Gandhi G, Jothi G, Antony PJ, Balakrishna K, Paulraj M, Ignacimuthu S, et al. Gallic acid attenuates high-fat diet fed-streptozotocin-induced insulin resistance via partial agonism of PPARgamma in experimental type 2 diabetic rats and enhances glucose

uptake through translocation and activation of GLUT4 in PI3K/p-Akt signaling pathway. Eur J Pharmacol, 2014; 745: 201–216.

54. Kade I, Ogunbolude Y, Kamdem J, Rocha J. Influence of gallic acid on oxidative stress-linked streptozotocin-induced pancreatic dysfunction in diabetic rats. J Basic Clin Physiol Pharmacol, 2014; 25: 35–45.
55. Bak E, Kim J, Jang S, Woo G, Yoon H, Yoo Y, et al. Gallic acid improves glucose tolerance and triglyceride concentration in diet-induced obesity mice. Scand J Clin Lab Invest, 2013; 73: 607–614.
56. Hsu C, Yen G. Effect of Gallic acid on high fat diet-induced dyslipidaemia, hepatosteatosis and oxidative stress in rats. Br J Nutr, 2007; 98: 727–735.
57. Huang D, Chang W, Wu J, Shih R, Shen S. Gallic acid ameliorates hyperglycemia and improves hepatic carbohydrate metabolism in rats fed a high-fructose diet. Nutr. Res, 2016; 36: 150–160.
58. Nagpal K, Singh S, Mishra D. Nanoparticle mediated brain targeted delivery of Gallic acid: in vivo behavioural and biochemical studies for protection against scopolamine-induced amnesia. Drug Deliver, 2013; 20: 112–119.
59. Kahkeshani, N., Farzaei, F., Fotouhi, M., Alavi, S. S., Bahramsoltani, R., Naseri, R., Momtaz, S., Abbasabadi, Z., Rahimi, R., Farzaei, M. H., & Bishayee, A.; Pharmacological effects of gallic acid in health and disease: A mechanistic review; Iranian Journal of Basic Medical Sciences, 2019; 22(3): 225–237.
60. Magdalena Karamaæ, Agnieszka Kosiñska, Ronald B. Pegg, content of gallic acid in selected plant extracts, polish journal of food and nutrition sciences, 2006; 15, 56: 1, 55–58.
61. Kamal Kardani, Nilesh Gurav, Bhavna Solanki, Prateek Patel, Bhavna Patel, RP-HPLC Method Development and Validation of Gallic acid in Polyherbal Tablet Formulation, Journal of Applied Pharmaceutical Science, 2013; 3(05): 037-04.
62. Ajay Kumar Meena, Ch. V. Narasimha Ji, D. Velvizhi, Arjun Singh, P. Rekha, Vijay Kumar, R. Ilavarasan, Narayanam Srikanth, K. S. Dhiman, Determination of Gallic Acid in Ayurvedic Polyherbal Formulation Triphala churna and its ingredients by HPLC and HPTLC, Research J. Pharm. and Tech, 2018; 11(8): 3243-3249.
63. M. S. Kondawar, K. G. Kamble, D. S. Mali, Quantitative estimation of Gallic acid and Ascorbic acid in a marketed herbal medicine: Triphala Churna by High Performance Thin Layer Chromatography, International Journal of Pharmtech Research, 2011; 3: 1593-1599.

64. Z. FATARIAH, T.Y. TG. ZULKHAIRUAZHA & W.I. WAN ROSLI, Quantitative HPLC Analysis of Gallic Acid in Benincasa hispida Prepared with Different Extraction Techniques, Sains Malaysiana, 2014; 43(8): 1181–1187.
65. Gulzar alam and Arun K. Mishra; Simultaneous Estimation of Gallic acid and Embelin by Validated HPTLC Method in Three Marketed Formulations and In-house Formulated *Manibhadra Yoga*: A Polyherbal *Ayurvedic* Formulation; oriental journal of chemistry**;** Januray, 2020; 04, 36(1): 120-126.
66. Jyotsana Dwivedi, Abhishek Gupta, Sarvesh Paliwal, A. K. S. Rawat; Validated simultaneous HPTLC analysis of scopoletin and gallic acid in the methanolic fraction of *Jatropha glandulifera;* Journal of Planar Chromatography, 2020; 20: 457- 462.
67. N.S.Jeganathan, K. Kannan; HPTLC method for estimation of Ellagic acid and Gallic acid in Triphala Churanam Formulation; Research Journal of Phytochemistry, 2008; 2(1): 1-9.
68. Jambey Tsering, Baikuntha J. Gogoi, Vijay Veer, Pallabi Kalita and Hui Tag; HPTLC determination of Gallic acid in Methanol extract of Quercus griffithii Acorn; International Journal of PharmTech Research; Aug-Sept, 2014; 6, 4: 1341-1347.
69. Sheetal Anandjiwala, Honnegowda Srinivasa, Mandapati Rajani; Isolation and TLC Densitometric Quantification of Gallicin, Gallic Acid, Lupeol and b-Sitosterol from Bergia suffruticosa, a Hitherto Unexplored Plant; Chromatographia, 2007; 26: 725–734.
70. Prawez Alam, Y.T. Kamal, Saleh Ibrahim Alqasoumi, Ahmed Ibrahim Foudah, Mohammed Hamed Alqarni, Hasan Soliman Yusufoglu; HPTLC method for simultaneous determination of ascorbic acid and gallic acid biomarker from freeze dry pomegranate juice and herbal formulation; Saudi Pharmaceutical Journal, 2019; 27: 975–980.
71. S. D. Sonawane, S. A. Nirmal, A. N. Patil, and S. R. Pattan; development and validation of hptlc method to detect curcumin and gallic acid in polyherbal formulation; Journal of Liquid Chromatography & Related Technologies, 2011; 34: 2664–2673.
72. Milind Bagul, H. Srinivasa, Harish Padh, M. Rajani; A rapid densitometric method for simultaneous quantification of gallic acid and ellagic acid in herbal raw materials using HPTLC; Journal of separation science February, 2005; 15: 581–584.
73. Magdalena karamac, agnieszka kosiñska, ronald b. Pegg; content of gallic acid in selected plant extracts; polish journal of food and nutrition sciences, 2006; 15, 56: 55–58.
74. Patil V. P., Kurhade S. D., Devdhe S.J., Kale S. H., Wakte P. S.; Determination of Gallic Acid by HPTLC as Quality Control Parameter in Herbal Formulation: *Triphala churna;*

international Journal of Chemical and Analytical Science, 2012; 3(9): 1546-1549.

75. V.U. Borde, P.P. Pangrikar, S.U. Tekale; Gallic Acid in Ayurvedic Herbs and Formulations; Recent Research in Science and Technology, 2011; 3(7): 51-54.
76. Felipe H.A. Fernandes, Rayanne S. de A. Batista, Francinalva D. de Medeirosa, Fábio S. Santos, Ana C.D. Medeiros; Development of a rapid and simple HPLC-UV method for determination of gallic acid in Schinopsis brasiliensis; Brazilian journal of pharmacy, 2015; 11: 208-211.
77. Shashi Chauhan, Aditi Sharma, Navneet Kumar Upadhyay, Gajender Singh, Uma Ranjan Lal and Rohit Goyal, In-vitro osteoblast proliferation and in-vivo anti-osteoporotic activity of Bombax ceiba with quantification of Lupeol, gallic acid and β-sitosterol by HPTLC and HPLC, Chauhan et al. BMC Complementary and Alternative Medicine, 2018; 07: 233.