Review Article
Ethnotherapeutic Uses and Phytochemical Composition of Physalis peruviana L.: An Overview

Félicien Mushagalusa Kasali 1,2,3, Jonans Tusiimire 3, Justin Ntokamunda Kadima 4, Casim Umba Tolo 1, Anke Weisheit 1, and Amon Ganafa Agaba 5

1 Pharm-Bio Technology and Traditional Medicine Center (PHARMBIOTRAC), Mbarara University of Science and Technology, P.O. Box 1410, Mbarara, Uganda
2 Department of Pharmacy, Faculty of Pharmaceutical Sciences and Public Health, Official University of Bukavu, P.O. Box 570, Bukavu, Congo
3 Department of Pharmacy, Faculty of Medicine, Mbarara University of Science and Technology, P.O. Box 1410, Mbarara, Uganda
4 Department of Pharmacology, School of Medicine and Pharmacy, University of Rwanda, P.O. Box 117 Huye, Kigali, Rwanda
5 Department of Pharmacology and Therapeutics, Faculty of Medicine, Mbarara University of Science and Technology, P.O. Box 1410, Mbarara, Uganda

Correspondence should be addressed to Félicien Mushagalusa Kasali; felicienkasali@gmail.com

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1. Introduction

According to the World Health Organization (WHO), about 80% of the population in developing countries uses herbal medicine to meet their primary healthcare requirements [1]. Humans have used natural products since prehistoric times, which include animals, marine organisms, microorganisms, and plants, in medicines to prevent, diagnose, and treat diseases [2]. Plants still contribute primarily to health care, so many specific herbal extracts have been demonstrated to be productive for particular conditions [3]. More than 50,000 plants would possess therapeutic virtues globally. In Africa and Asia, it is estimated that more than 80 percent of the population uses traditional medicine for primary health care. This form of therapy remains prevalent in all world regions, and its use is rapidly spreading in developed countries [4].
**Physalis peruviana** (Solanaceae) is a native plant from the Andean region and a semipurplish herbaceous shrub or perennial, producing a group of branched stems native to the Andean region. *P. peruviana* is adapted to a wide range of altitudes, soils, and climatic conditions. It is also the most widely distributed species from the *Physalis*. *Physalis* genus contains several species with a long history of ethnomedical use to treat diverse diseases, especially asthma, cancer, dermatitis, hepatitis, bacterial infections, kidney and liver disorders, and malaria and has immunomodulatory antipyretic properties [5]. It contains different types of compounds, including physalins and alkaloids, flavonoids, carotenoids, vitamins, and polysaccharides [6, 7]. The health benefits of the plant are related to the content of phytochemicals.

This report summarizes ethnomedicinal use and phytoconstituents identified in *P. peruviana*. Previous reviews have focused on nutritional values, pharmacological evidence, and phytochemical profiling of isolated compounds from the plant [8].

This review aimed to highlight the ethnotherapeutic use and phytochemical status of identified compounds in *P. peruviana*.

### 2. Literature Review Method

Different search databases, including Google Scholar, PubMed/Medline, Science Direct, Scopus, the Wiley Online Library, Web of Science, and any other helpful search engines using *P. peruviana* as the primary keyword, were used. Full articles in English or French languages were retrieved without time limit restriction.

### 3. Results and Discussion

#### 3.1. Ethnopharmacological Data of *P. peruviana* L.

The following Table 1 presents the uses of *P. peruviana* in traditional medicines in different countries.

According to this table (Table 1), fourteen countries worldwide use *P. peruviana* in their traditional medicinal system to treat several diseases. India represented the most cited country with twelve references, followed by Uganda (10), Kenya (7), Cameroon, Democratic Republic of Congo, Nepal, South Africa, and Tanzania, each with three references. Colombia and Indonesia were cited only twice.

Referring to the number of diseases treated by country, India is the most representative country (20.27%), followed by Uganda (16.22%), the Democratic Republic of Congo (12.16%), Cameroon (6.76%), Colombia, Nepal, and South Africa (5.41%). It is known that the plant (mainly le fruit) is produced predominantly in Colombia and South Africa but exported in Netherlands, Germany, Belgium, and Canada [61]. However, its use in traditional medicine is widespread in other countries, including India and Uganda.

The plant is widely known in various local names and used in Ayurvedic medicine for many human and animal purposes. The fruit is available from January to April [62]. In Uganda, the plant grows naturally in abandoned bush falls, and it is helpful for income. It has been identified as a priority plant for commercialization (used popularly for its berries and associated derivative products such as juice, jam, and wine). It is also used as food and has medicinal applications [63].

Local names, parts used, traditional utilization, preparation, and administration modes were documented.

Figure 1 indicates that the leaves are the most used part (49.28%) followed by fruits (14.49%), whole plant (11.59%), roots (7.5%), stem (4.35%), aerial parts, and seeds (2.9%). However, bulbs, flowers, ripe fruits, and twigs were cited once (1.45%). In some cases, the used parts were not specified (1.45%). Leaves are the most used in the formulation of remedies, as indicated above. The frequent use of leaves is associated with ease of accessibility among the aboveground parts of plants in natural ecosystems [50].

Decoction has often been found as the effective formulation of herbal remedies as it is easy to prepare by mixing a drug with boiling water [64]. In this study (Figure 2), the decoction was used in almost 31.58% of all cases. However, other preparation modes have been found including juice (14.04%), maceration (8.77%), infusion (7.02%), extraction, and raw material (5.1%). In 19.30% of cases, the preparation mode was not reported.

*P. peruviana* is indicated to treat various diseases, mainly in humans. Rarely, it is used in the management of diseases in veterinary medicine. For example, in western Kenya, it is used for livestock tick prevention and control. The results in Figure 3 show that diseases and disorders of the gastrointestinal tract were the most treated by the plant (25.33%), followed by female genital tract and breast (13.33%), skin (9.33%), liver and biliary tract (8.01%), eye and ear (8.01%), immune system (5.33%), endocrine system (5.33%), respiratory system (2.67%), and metabolic disorders (2.67%). Diseases of bones, joints, skeletal muscle, and body fluid-related diseases and disorders represent 1.33%. Another category of diseases, including helminthiasis, inflammations, malaria, snake bite, fungal infections, bacterial infections, and smallpox, represents 17.33%. About 4000 species had ethnomedical data supporting the use of these plants to treat, and most of them were native to tropical countries due to the extraordinary biodiversity in these countries [65].

Mostly, oral route is the way of drug administration based on different formulations. Because of safety, good patient compliance, ease of ingestion, pain avoidance, and versatility to accommodate various types of drugs, the oral administration route is preferred over the different other administration routes of drug delivery [66]. Nevertheless, the route of the administration is not specified in a few cases (20.41%). Secondarily, bathe, tropical application, scratches, and steam inhalation are reported (Figure 4).

There are some specific indications in formulations or modes of drug administration. For example, in India, the plant is associated with *Impatiens royleri* and *Stephania hermandifolia* to treat jaundice. In the same way, in Uganda, the plant is combined with *Solanum esculentum* and *Solanum melongena* to manage skin problems in babies and
Table 1: Ethnomedicinal uses of *P. peruviana* L. in different countries.

| Countries                      | Vernacular names | Part(s) used | Traditional uses                                      | Formulation/method of administration | Voucher number | References |
|--------------------------------|------------------|--------------|-------------------------------------------------------|---------------------------------------|----------------|------------|
| Cameroon                       | —                | Twigs        | Cancer or disease relevance to cancer or cancer-like symptoms | —                                     | Yes            | [9]        |
|                                | Ajijieuh         | Leaf and stem | Bile, swelling of legs and ankles for pregnant women | Maceration/oral                       | Yes            | [10]       |
|                                | Ma pe pie        | Leaf and stem | Fungal infections                                     | Maceration/oral                       | Yes            | [11]       |
| Colombia                       | Uchuva           | Fruit        | Ear pain and diabetes                                 | —                                     | No             | [12]       |
|                                | Uchuva           | Fruit        | Conjunctivitis and prevention of cataract             | Juice/oral                            | No             | [13]       |
| Equator                        | Uvilla           | Flower       | Disinfectant and healing of wounds                    | Decoction/bathe                       | Yes            | [14]       |
| Democratic Republic of the Congo | Mbuma            | Leaf          | Malaria, intestinal worms, and splenomegaly           | Decoction and infusion/oral           | Yes            | [15]       |
|                                | Mbuma, Mbupurui, Umuhire | Aerial part   | Diabetes mellitus, colic in children, spleen, malaria, and inflammation |
|                                |                   |              |                                                       |                                       |                |            |
|                                |                   |              | Decoction/oral                                        | No                                    | [16]           |
|                                | Mpuhuhu          | Whole plant  | Helminthiasis                                         | Maceration/oral                       | Yes            | [17]       |
|                                | Donam as Fatki   | Leaf and root | Gastric                                               | Mastication/oral                      | No             | [18]       |
|                                | Kititutu         | Leaf         | Leucorrhrea and hydrocele                              | Decoction/oral                        | No             | [19]       |
|                                | Kopalphoota      | Whole plant  | Induction of labor and ease childbirth                 | Decoction/oral                        | No             | [20]       |
|                                | Phakphake        | Ripe fruit   | Jaundice                                              | Raw/oral                              | No             | [21]       |
|                                | Pottipalam       | Leaf and dried seed | Jaundice and glaucoma                            | Decoction and raw/oral               | No             | [22]       |
|                                | Rashbharhi       | Leaf         | Abdominal disorder during pregnancy                    | Juice/oral                            | No             | [23]       |
|                                | Tsibobopro       | Leaf and fruit | Diarrhea and dysentery                               | Decoction and raw/oral               | No             | [24]       |
|                                | Sodukku thakkali | Whole plant  | Skin diseases                                         | Extraction/-                         | No             | [25]       |
|                                | —                | Leave        | Jaundice                                              | Decoction/oral                        | No             | [26]       |
|                                | —                | Whole plant  | Gout                                                   | —                                     | No             | [27]       |
|                                | —                | Leaf         | Jaundice                                              | Paste/-                               | Yes            | [28]       |
| Indonesia                      | Depuk-depuk      | Fruit and whole plant | Smallpox                                             | Decoction/oral                        | No             | [29]       |
|                                | Pultak-pulta     | All parts of the plant | Stomach ache                                         | Decoction/oral                        | No             | [30]       |
| Java                           | Ciplukan         | Leaf and fruit | Diabetes mellitus                                     | —                                     | No             | [31]       |
| Kenya                          | Embunwe, emiilwa (wanga) | Stem, root, fruit, and leaf | Inflammation and abdominal ailments* | Raw and infusion/poultices and enema Decoction/steam inhalation | Yes            | [32]       |
|                                | Mayengo          | Leaf         | Malaria                                               | Decoction/steam inhalation            | Yes            | [33]       |
|                                | Münathi          | Leaf         | Postpartum pain                                       | Decoction/steam inhalation            | Yes            | [34]       |
|                                | Münathi          | Leaf         | Anthelmintic, postpartum pains, and typhoid           | —                                     | No             | [35]       |
|                                |                   | Seed, bulb, fruit, leaf, and root | Diarrhea                                             | —                                     | No             | [36]       |
|                                |                   | Leaf         | Diabetes, malaria, and pneumonia                      | Decoction/oral                        | No             | [37]       |
|                                |                   | Leaf         | Typhoid and pneumonia                                 | Decoction/oral                        | No             | [38]       |
|                                |                   | Root         | Jaundice                                              | Maceration/oral                       | No             | [39]       |
|                                |                   | Root         | Piles                                                  | —                                     | No             | [40]       |
|                                |                   | Leaf         | Sore throat and abdominal pain                         | Juice/oral                            | No             | [41]       |
honey in treating malaria. It is possible that combining several plants can produce a more pronounced pharmacological response than using a single plant due to the synergy of action between different constituents. According to Sofowora et al. [67], the combined effects were much more effective than individual ones. Rarely, duration of treatment and posology were mentioned. However, those two factors depended on the type of diseases treated and the parts used. For example, in Uganda, treating malaria needs seven days by taking two teaspoons three times a day of a decoction or half a glass thrice a day. In Tanzania, an application of leaf juice on the affected area twice a day was indicated to treat skin fungal infections or heating/topical application on to cuts and scratches in New Guinea for boils and ulcers. In Nepal, the treatment of jaundice in children could take from four to ten days.

Table 1: Continued.

| Countries       | Vernacular names | Part(s) used | Traditional uses | Formulation/method of administration | Voucher number | References |
|-----------------|------------------|--------------|------------------|---------------------------------------|----------------|------------|
| New Guinea      | Mondon           | Leaf         | Boils and ulcers | Heating/topical application on to cuts and scratches* | No             | [43]       |
| Rwanda          | Umuhuhu          | Leaf         | Facilitates the issuance of the placenta and abortifacient | —                      | No             | [44]       |
| South Africa    | Igquzu           | Leaf         | Diarrhea and associated ailments. | As food/oral              | No             | [45]       |
|                 | —                | Whole plant  | Diarrhea         | Decoction/oral                | Yes            | [46]       |
| Tanzania        | Kitutun kikubwa  | Leaf         | Malaria          | Maceration/oral                | Yes            | [48]       |
|                 | Msupu            | Leaf         | Skin fungal infections | Juice/topical application*    | Yes            | [49]       |
|                 | Ntuntunu         | Fruit        | Typhoid fever    | Juice/oral                    | Yes            | [50]       |
|                 | Entuutu          | Leaf and fruit | Snakebite        | Infusion/oral                 | No             | [51]       |
|                 | Entuutu          | Fresh leaf   | Skin problems in babies Wounds (fresh) | Decoction/bathe* | No             | [52]       |
|                 | —                | Leaf         | Induce of labor during childbirth | —                       | No             | [53]       |
|                 | Kitutu           | Leaf         | Vomiting         | Juice/oral                    | No             | [54]       |
|                 | Ntuntunu         | Leaf         | Malaria          | Decoction/oral*               | Yes            | [56]       |
|                 | Ntuntunu         | Leaf         | Infections (antibacterial) | Juice/oral                | No             | [57]       |
|                 | Ntuntunu enene   | Leaf         | Ear and eye infection | Chewing and swallowing/oral   | Yes            | [58]       |
|                 | —                | Whole plant  | HIV/AIDS         | —                            | Yes            | [59]       |
|                 | Ntuntunu enene   | Aerial part and leaf | Rash and ringworm | Juice/-                     | Yes            | [60]       |

Veterinary use (Ψ); specific characteristics (*); not specified (—).

Figure 1: Frequencies of parts used.
3.2. Phytoconstituents Identified in Different Parts of P. peruviana L. Table 2 summarizes the chemical compounds identified and characterized from other parts and extracts of P. peruviana. Therefore, various classes of phytoconstituents have been found, including terpenes (monoterpenes, sesquiterpenes, diterpenes, triterpenes, and carotenoids), phenolic compounds (phenolic acids, phenolic esters, phenolic aldehydes, chalcones, coumarins, cinnamic acid derivatives, flavonoids, and glucosides), alcohols, aldehydes, ketones, carboxylic acids, lactones, steroids and withanolides, alkaloids, sucrose esters, glucosides, siloxanes, vitamins, phytosterogens, phytol derivatives, enols, heterocycles, alkanes, alkenes, benzimidazoles, and diverse functional groups.

Different parts of P. peruviana contain terpenes, and polyphenols represent the main two classes of identified phytoconstituents. They represent 26.09% and 14.94%, respectively. In the terpenes category, carotenoids are the most representative (11.15%), followed by monoterpene (8.76%), sesquiterpene (5.57%), and diterpene (3.18%). A considerable amount of sesquiterpene (22.3%) and fatty acids (22.8%) has been found in P. angulata, a Physalis species close to P. peruviana, as volatile components of leaf essential oil [91]. However, phytol (17.88%) was the most diterpenes found in ethanolic extracts of leaves, roots, and fruits of P. minima, beyond other phytoconstituents, including fatty acids [92]. According to our results, phytol was identified right now, only in calyces and leaves of P. peruviana.

The presence of phytoene can justify the richness of the plant in carotenoids. Therefore, phytoene is an alkene hydrocarbon with 40 carbon atoms intermediate in the biosynthesis of carotenoids. The synthesis of phytoene is necessary for that of carotenoids in plants. The biosynthetic pathway from phytoene to violaxanthin is common to the genus Physalis [70]. Furthermore, carotenoid pigments from different species of the Physalis genus are primarily used in the food industry as food dyes for fats and oils. Their seeds can contain up to 30% fatty oil [93]. The presence of carotenoids in the Physalis genus has been confirmed by Ramadan [94]. All-trans-β-carotene, 9-cis-β-carotene, and all-trans-α-cryptoxanthin were the primary carotenoids found in the fruits.

Referring to phenolic compounds, flavonoids are the most phytoconstituents found (5.17%) in the plant than cinnamic acid derivatives (3.98%), monophenolic compounds (1.79%), phenolic acids (1.39%), coumarins (0.79%), phenolic esters (0.79%), chalcones (0.39%), phenolic aldehydes (0.39%), and stilbenes (0.19%). Similarly, phenolic, flavonoid, and phenolic acid contents were identified and quantified in different parts of five members of the Physalis genus including P. angulata, P. patula, P. subulata, P. solanacea, and P. hederifolia. However, quercetin, kaempferol, and phenolic acids were identified as the major phenolic phytoconstituents in those five plant species, in different
Table 2: Chemical compounds identified from different parts and extracts of *P. peruviana*.

| Organs     | Phytoconstituents                                      | Source                                | References |
|------------|--------------------------------------------------------|---------------------------------------|------------|
| Aerial     |                                                        |                                       |            |
| parts      | 3α-Tigloylnxytropane                                    | Ethanol                               | [69]       |
|            | 3β-Acetoxytropane                                       | Ethanol                               | [69]       |
|            | Antheraxanthin                                          | Hexane/acetone/ethanol                | [70]       |
|            | Cuscohygrine                                            | Ethanol                               | [69]       |
|            | Hygrine                                                | Ethanol                               | [69]       |
|            | Lutein                                                 | Hexane/acetone/ethanol                | [70]       |
|            | Neoxanthin                                             | Hexane/acetone/ethanol                | [70]       |
|            | N-Methylpyrrolidinylhygrine A                           | Ethanol                               | [69]       |
|            | N-Methylpyrrolidinylhygrine B                           | Ethanol                               | [69]       |
|            | Physoperuvine                                          | Ethanol                               | [69]       |
|            | Phytofluene                                            | Hexane/acetone/ethanol                | [70]       |
|            | Tropine                                                | Ethanol                               | [69]       |
|            | Violaxanthin                                           | Hexane/acetone/ethanol                | [70]       |
|            | Zeaxanthin                                             | Hexane/acetone/ethanol                | [70]       |
|            | γ-Carotene                                             | Hexane/acetone/ethanol                | [70]       |
|            | (S)-4-Iodo-1,2-epoxybutane                             | —                                     | [71]       |
|            | 1,1,1,5,7,7,7-Heptamethyl-3,3 bis(trimethylsiloxy) tetrasiloxane | —                                     | [71]       |
|            | 1,2,3-Tri(t-butyl) cyclopropenyl tribromide            | —                                     | [71]       |
|            | 1,2-Benzenedicarboxylic acid                           | —                                     | [71]       |
|            | 3,3-Dimethyl-hexane                                     | —                                     | [71]       |
|            | 3,3-Dimethyl-octane                                     | —                                     | [71]       |
|            | Diethyl ester                                           | —                                     | [71]       |
|            | Docosane                                               | —                                     | [71]       |
|            | Eicosamethyl cyclodecasiloxane                         | —                                     | [71]       |
|            | Eicosamethyl cyclodecasiloxane                         | —                                     | [71]       |
| Body       |                                                        |                                       |            |
|            | (all-E)-Lutein                                          | Hexane/acetone/ethanol                | [72]       |
|            | (all-E)-Lutein 3-O-myristate                           | Hexane/acetone/ethanol                | [72]       |
|            | (all-E)-Neoxanthin                                      | Hexane/acetone/ethanol                | [72]       |
|            | (all-E)-Neoxanthin palmitate                           | Hexane/acetone/ethanol                | [72]       |
|            | (all-E)-Taraxanthin                                     | Hexane/acetone/ethanol                | [72]       |
|            | (all-E)-Taraxanthin ester                              | Hexane/acetone/ethanol                | [72]       |
|            | (all-E)-Violaxanthin or (all-E)-neoxanthin ester       | Hexane/acetone/ethanol                | [72]       |
|            | (all-E)-α-Carotene                                      | Hexane/acetone/ethanol                | [72]       |
|            | (all-E)-α-Cryptoxanthin myristate                      | Hexane/acetone/ethanol                | [72]       |
|            | (E)-Vanillic acid                                      | Ethyl acetate                         | [73]       |
|            | (E)-α-Carotene                                         | Hexane/acetone/ethanol                | [72]       |
|            | (Z)-Lutein 1                                           | Hexane/acetone/ethanol                | [72]       |
|            | (Z)-Lutein 2                                           | Hexane/acetone/ethanol                | [72]       |
|            | (Z)-Lutein ester                                       | Hexane/acetone/ethanol                | [72]       |
|            | (Z)-Taraxanthin                                        | Hexane/acetone/ethanol                | [72]       |
|            | (Z)-Taraxanthin-α-linolenic acid                       | Hexane/acetone/ethanol                | [72]       |
|            | (Z)-β-Carotene                                         | Hexane/acetone/ethanol                | [72]       |
|            | α-Copaeneol                                            | Ethanol/ethyl acetate                 | [74]       |
|            | 13-Epimananol                                          | Ethanol/ethyl acetate                 | [74]       |
|            | 16-B1-PhytoP                                          | Ethanol/ethyl acetate                 | [74]       |
|            | 16α-Methylpregnenolone                                 | Ethanol/ethyl acetate                 | [74]       |
|            | 17,27-Dihydroxylated withanolide D isomer 1            | Ethanol/ethyl acetate                 | [74]       |
|            | 2,3-Dihydro-17,27-hydroxylated withanolide D derivative | Ethanol/ethyl acetate                 | [74]       |
|            | 2,3-Dihydro-27-hydroxylated withanolide D isomer 1     | Ethanol/ethyl acetate                 | [74]       |
|            | 2,3-Dihydro-27-hydroxylated withanolide D isomer 2     | Ethanol/ethyl acetate                 | [74]       |
|            | 2,3-Dihydro-27-hydroxy-4β- hydroxywithanolide E isomer | Ethanol/ethyl acetate                 | [74]       |
|            | 2,3-Dihydro-4β-hydroxywithanolide E                    | Ethanol/ethyl acetate                 | [74]       |
|            | 2,3-Dihydro-hydroxylated 4β-hydroxywithanolide E derivative | Ethanol/ethyl acetate                 | [74]       |
|            | 2′,4′-Dimethoxy-3-hydroxy-6-methylflavone              | Methanol                              | [75]       |
|            | 2′,5′-Dimethoxyflavone                                 | Methanol                              | [75]       |
|            | 27-Hydroxy-4β-hydroxywithanolide E isomer              | Ethanol/ethyl acetate                 | [74]       |
|            | 2-Hydroxy-2′,4′,6′-trimethoxychalcone                  | Methanol                              | [75]       |
|            | 3-(3,4-Dimethoxyphenyl)-6-methyl-4-phenylcoumarin      | Methanol                              | [75]       |
|            | 3-(3,4-Dimethoxyphenyl)-7- hydroxy-4-methylcoumarin    | Methanol                              | [75]       |
| Organs | Phytoconstituents | Source | References |
|--------|------------------|--------|------------|
|        | 3,2′,4′,5′-6-Pentamethoxyflavone | Methanol | [75] |
|        | 3,4,5-Methoxy cinnamic | Ethyl acetate | [73] |
|        | 3,5,3′,5′-Tetra-tert-butylphenol | Methanol | [75] |
|        | 3,6,2′,3′-Tetramethoxyflavone | Methanol | [75] |
|        | 3,6,3′,4′-Tetramethoxyflavone | Methanol | [75] |
|        | 3′-Benzyloxy-5,6,7,4′-tetramethoxyflavone | Methanol | [75] |
|        | 3-Hydroxy-7,8,2′-trimethoxyflavone | Methanol | [75] |
|        | 3-O-Caffeoylquinic acid | Methanol/water/formic acid | [76] |
|        | 3-O-Feruloylquinic acid | Methanol/water/formic acid | [76] |
|        | 3-O-p-Coumaroylquinic acid | Methanol/water/formic acid | [76] |
|        | 4,4-Dimethyl-5-α-cholestan-3-one | Ethyl acetate | [74] |
|        | 4-Aminobenzoic acid | Methanol | [75] |
|        | 4-Hydroxy chalcone | Methanol | [75] |
|        | 4-O-Feruloylquinic acid | Methanol/water/formic acid | [76] |
|        | 5-(7α-Isopropenyl-4,5-dimethyl-octahydroinden-4-yl)-3-methyl-pent-2-en-1-ol | Ethanol/ethyl acetate | [74] |
|        | 5,6-Epoxy-β-carotene | Hexane/acetone/ethanol | [72] |
|        | 5-O-Caffeoylquinic acid (chlorogenic acid) | Methanol/water/formic acid | [76] |
|        | 5-O-Feruloylquinic acid | Methanol/water/formic acid | [76] |
|        | 7-Hydroxycoumarin-3-carboxylic acid | Methanol | [75] |
|        | 76-Ergosterol | Ethanol/Ethyl acetate | [74] |
|        | 9-D_{14,-}-PhytoP | Methanol | [76] |
|        | 9-Epi-9-D_{14,-}-PhytoP | Methanol | [76] |
|        | 9-Epi-9-F_{14,-}-PhytoP | Methanol | [76] |
|        | 9-F_{14,-}-PhytoP | Methanol | [76] |
|        | 9-L_{1}-PhytoP | Methanol | [76] |
|        | Accetin | Ethyl acetate | [73] |
|        | Ambrial | Ethanol/ethyl acetate | [74] |
|        | Apg 6 arabinose 8 glucose | Ethyl acetate | [73] |
|        | Apg 6 glucose 8 rhamnose | Ethyl acetate | [73] |
|        | Apg 6 rhamnose 8 glucose | Ethyl acetate | [73] |
|        | Apig-7-O-neohesperidoside | Ethyl acetate | [73] |
|        | Apigenin | Ethyl acetate | [73] |
|        | Apigenin 7 glucose | Ethyl acetate | [73] |
|        | Benzonic acid | Methanol | [75] |
|        | Biotin | Ethanol/Ethyl acetate | [74] |
|        | Caffeic acid | Ethanol/Ethyl acetate | [74] |
|        | Caffeine | Ethyl acetate | [73] |
|        | Catechol | Ethyl acetate | [73] |
|        | Chlorogenic acid | Ethyl acetate | [73] |
|        | Chlorophyll a | Hexane/acetone/ethanol | [72] |
|        | Chlorophyll a derivative | Hexane/acetone/ethanol | [72] |
|        | Chlorophyll b | Hexane/acetone/ethanol | [72] |
|        | Chlorophyll b derivative 2 | Hexane/acetone/ethanol | [72] |
|        | Cinnamic acid | Ethyl acetate | [73] |
|        | Coniferol | Ethanol/ethyl acetate | [74] |
|        | Copalol isomer 1 | Ethanol/ethyl acetate | [74] |
|        | Copalol isomer 2 | Ethanol/ethyl acetate | [74] |
|        | Copalol isomer 3 | Ethanol/ethyl acetate | [74] |
|        | Coumarin | Ethyl acetate | [73] |
|        | Cryptomeridinol | Ethanol/ethyl acetate | [74] |
|        | Diepicedrene-1-oxide | Ethanol/ethyl acetate | [74] |
|        | Dihydro-4β-hydroxyxywithanolide E | Ethanol/ethyl acetate | [74] |
|        | Dihydromanoyloxide 7-carboxylic acid methyl ester | Ethanol/ethyl acetate | [74] |
|        | Di-O-isobutanoyl-O-(2-methylbutanoyl)-O-pentenoylsucrose | Ethanol/ethyl acetate | [74] |
|        | Di-O-isobutanoylsucrose | Ethanol/ethyl acetate | [74] |
| Organs                  | Phytoconstituents                              | Source                  | References |
|-------------------------|------------------------------------------------|-------------------------|------------|
| Di-O-isobutanoyl-O-nonanoylsucrose | Ethanol/ethyl acetate | [74]                   |
| Di-O-isobutanoyl-O-decanoylsucrose | Ethanol/ethyl acetate | [74]                   |
| Di-O-isobutanoyl-O-octanoylsucrose | Ethanol/ethyl acetate | [74]                   |
| Di-O-isobutanoyl-O-pentenoylsucrose | Ethanol/ethyl acetate | [74]                   |
| Ellagic acid            | Ethyl acetate                                 | [73]                   |
| Ent-16-B1-PhytoP        | Methanol                                      | [76]                   |
| Ent-9-L1-PhytoP         | Methanol                                      | [76]                   |
| Ent-16-epi-16-F1t-PhytoP | Methanol                                      | [76]                   |
| Ent-16-F1t-PhytoP       | Methanol                                      | [76]                   |
| Epicatechin             | Ethyl acetate                                 | [73]                   |
| Epimanoxy oxide         | Ethanol/ethyl acetate                         | [74]                   |
| Eudesmadienol           | Ethanol/ethyl acetate                         | [74]                   |
| Farnesol acetate        | Ethanol/ethyl acetate                         | [74]                   |
| Ferulic acid-hexoside   | Methanol                                      | [76]                   |
| Feruloyquinic acid      | Methanol                                      | [76]                   |
| Friedel-3-one           | Ethanol/ethyl acetate                         | [74]                   |
| Ferulic acid            | Ethanol/ethyl acetate                         | [74]                   |
| Gallic acid             | Ethanol/ethyl acetate                         | [74]                   |
| Gardenin                | Methanol                                      | [75]                   |
| Germacratrienol isomer 1| Ethanol/ethyl acetate                         | [74]                   |
| Germacratrienol isomer 2| Ethanol/ethyl acetate                         | [74]                   |
| Germacratrienol isomer 3| Ethanol/ethyl acetate                         | [74]                   |
| Hesperetin              | Ethyl acetate                                 | [73]                   |
| Hydroxylated 4β-hydroxywithanolide E derivative | Ethanol/ethyl acetate | [74]   |
| Isoaromadendrene epoxide | Ethanol/ethyl acetate | [74]      |
| Isoferulic acid         | Ethyl acetate                                 | [73]                   |
| Isorhamnetin            | Ethanol/ethyl acetate                         | [74]                   |
| Isovitexin              | Methanol                                      | [75]                   |
| Kaempferol              | Ethanol/ethyl acetate                         | [74]                   |
| Kaempferol-3-O-rhamnosyl(1→6)glucoside | Methanol/water/formic acid | [76]  |
| Kaempferol-3-O-rhamnosyl(1→6)glucoside- 7-O-glucoside | Methanol/water/formic acid | [76]   |
| Kaempferol-hexoside     | Ethanol/ethyl acetate                         | [74]                   |
| Kaempferol-rutinoside   | Ethanol/ethyl acetate                         | [74]                   |
| Kamp3[2-p-manyl]glucose | Ethyl acetate                                 | [73]                   |
| Kamp3-7 di-rhamnoside   | Ethyl acetate                                 | [73]                   |
| Khusiol                 | Ethyl acetate                                 | [74]                   |
| Limonene                | Ethyl acetate                                 | [73]                   |
| Luteo 6 glucose 8 arabinose | Ethyl acetate                           | [73]       |
| Luteo 7 glucose         | Ethyl acetate                                 | [73]                   |
| Maalialcohol            | Ethanol/ethyl acetate                         | [74]                   |
| Methyl-3,7-bis(acetloyloxy)cholestan-26-oate | Ethanol/ethyl acetate | [74]   |
| Methylprednisolone succinate | Methanol                                    | [75]       |
| Myricetin               | Ethyl acetate                                 | [73]                   |
| Naringin                | Ethyl acetate                                 | [73]                   |
| Naringin                | Ethyl acetate                                 | [73]                   |
| O-Butanoyl-di-O-isobutanoylsucrose | Ethanol/ethyl acetate | [74] |
| O-Decanoyl-O-isobutanoylsucrose | Ethanol/ethyl acetate | [74] |
| O-Isobutanoyl-O-(2-methylbutanoyl)-O-octanoylsucrose | Ethanol/ethyl acetate | [74] |
| O-Isobutanoyl-O-(2-methylbutanoyl)-O-pentenoylsucrose | Ethanol/ethyl acetate | [74] |
| O-Isobutanoyl-O-(2-methylbutanoyl)sucrose | Ethanol/ethyl acetate | [74] |
| O-Isobutanoyl-O-octenoylsucrose | Ethanol/ethyl acetate | [74] |
| O-Isobutanoylsucrose    | Ethanol/ethyl acetate                         | [74]                   |
| p-Coumaric acid         | Ethanol/ethyl acetate, ethyl acetate           | [73, 74]              |
| Pheophytinn a           | Ethyl acetate                                 | [73]                   |
| p-Hydroxy benzoic acid  | Ethyl acetate                                 | [73]                   |
| Phytoene                | Ethyl acetate                                 | [73]                   |
| Phytof 3(2-p-manyl)glucose | Ethanol/ethyl acetate                           | [74]       |
| Protocatechuic acid     | Ethanol/ethyl acetate, ethyl acetate           | [73, 74]              |
| Pyrogallol              | Ethyl acetate                                 | [73]                   |
| Organs          | Phytoconstituents                              | Source                                           | References |
|-----------------|-----------------------------------------------|--------------------------------------------------|------------|
| Fruits          | (-)-Caryophyllene oxide                       | —                                                | [77]       |
|                 | (5a)-Pregnan-3,20a-diol                        | Juice                                            | [78]       |
|                 | (9Z)-β-Carotene                                | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-Antheraxanthin myristate-palmitate     | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-Lutein                                 | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-Lutein 3'O-palmitate                  | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-Lutein 3'-O-myrystate                 | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-Lutein dimyristate                    | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-Lutein dipalmitate                   | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-Neoxanthin                            | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-Neoxanthin dimyristate                | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-Neoxanthin palmitate                  | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-Taraxanthin                           | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-Taraxanthin ester                     | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-Violaxanthin                           | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-Violaxanthin dimyristate              | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-Violaxanthin palmitate                | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-Violaxanthin myristate-palmitate      | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-Zeaxanthin dimyristate                | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-Zeaxanthin palmitate                  | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-Zeaxanthin myristate-palmitate        | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-Zeinoxanthin                          | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-α-Carotene                             | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-α-Cryptoxanthin                        | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-α-Cryptoxanthin myristate             | Hexane/acetone/ethanol                          | [72]       |
|                 | (all-E)-α-Cryptoxanthin palmitate             | Hexane/acetone/ethanol                          | [72]       |
| Organ | Phytoconstituents | Source | References |
|-------|------------------|--------|------------|
| Palmitate | Hexane/acetone/ethanol | [72] |
| (E)-2-Hexenol | — | [79] |
| (E)-Non-2-enal | Dichloromethane | [80] |
| (E)-α-Carotene | Hexane/acetone/ethanol | [72] |
| (E2, Z6)-Nona-2,6-dienal | Dichloromethane | [80] |
| (S)-4-Iodo-1,2-epoxybutane | — | [71] |
| (Z)-Lutein 1 | Hexane/acetone/ethanol | [72] |
| (Z)-Lutein ester | Hexane/acetone/ethanol | [72] |
| (Z)-Neoxanthin- or (Z)-violaxanthin ester | Hexane/acetone/ethanol | [72] |
| (Z)-Stigmasta-5,24(28)-dien-3β-ol | Dichloromethane | [80] |
| (Z)-Taraxanthin | Hexane/acetone/ethanol | [72] |
| (Z)-β-Carotene | Hexane/acetone/ethanol | [72] |
| (Z)-γ-Carotene | Hexane/acetone/ethanol | [72] |
| Δ5-Avenasterol | Crude oil | [81, 82] |
| Δ7-Avenasterol | Crude oil | [81, 82] |
| 1,1,5,7,7,7-Heptamethyl-3,3-bis(trimethylsiloxy) tetrasiloxane | — | [71] |
| 1,25-Dihydroxyvitamin D2 | Juice | [71] |
| 1,2-Benzenedicarboxylic acid | — | [71] |
| 1,8-Menthadien-4-ol | — | [77] |
| 1-Phenyl-1,2-propanediol | — | [79] |
| 2,3-Diethyl-5-methyl pyrazine | Hexane and ethanol | [83] |
| 2,3-Dimethyl-1-butanol | — | [77] |
| 2-Acetyl-1-pyrroline | Dichloromethane | [80] |
| 2-Butanone | — | [77] |
| 2-Heptanol | — | [79] |
| 2-Heptanone | — | [77] |
| 2-Methylbutanal | — | [77] |
| 2-Methylbutanol | — | [77] |
| 2-Methylbutanoic acid | — | [79] |
| 2-Methylbutyl acetate | — | [77] |
| 2-Methylpropanol | — | [79] |
| 2-Methylpropanoic acid | — | [79] |
| 2-Methylpropanal | Dichloromethane | [80] |
| 2-Methylpropenal | — | [77] |
| 2-Nonadecanol | — | [77] |
| 2-Norbornanone | — | [77] |
| 2-Pentanone | — | [77] |
| 2-Phenyl ethyl alcohol | Juice | [78] |
| 2-Phenylethylacetalddehyde | Dichloromethane | [80] |
| 2-Phenylethanol | Dichloromethane | [79, 80] |
| 2-Propanone | — | [77] |
| 2-Undecenal | Hexane and ethanol | [83] |
| 3,3-Dimethyl-hexane | — | [71] |
| 3,3-Dimethyl-octane | — | [71] |
| 3,4-Dimethylbenzoic acid | — | [71] |
| 3,5-Octadienone | Hexane and ethanol | [83] |
| 3,7-Dimethyl-1-octene | — | [77] |
| 3-Ethyl-4-heptanol | — | [77] |
| 3-Hydroxy-2-butanoic acid | — | [79] |
| 3-Methyl-1-hexanol | — | [77] |
| 3-Methyl-1-penten-3-ol | — | [84] |
| 3-Methyl-3-vinyl-1-cyclopentene | — | [84] |
| 3-Methyl butyl butanoate | — | [77] |
| 3-Octenol | — | [77] |
| 3-Octenoic acid | — | [77] |
| 3-Oxo-7,8-dihydro-α-ionol | Dichloromethane | [80] |
| 3-Phenyl propanol | — | [77] |
| 4-Hydroxy butyl acrylate | Hexane and ethanol | [83] |
| 4-Isopropyl-1-methyl-2-cyclohexen-1-ol | — | [77] |
| 4-Methyl-1-pentanol | — | [77] |
| 4-Nonanone | — | [77] |
| Organs                      | Phytoconstituents                        | Source                      | References |
|-----------------------------|------------------------------------------|-----------------------------|------------|
| 4-Octanol                   | —                                        | [77]                        |            |
| 4-Propyl guaiacol           | Hexane and ethanol                       | [83]                        |            |
| 4-Terpineol                 | —                                        | [77]                        |            |
| 4-Vinylguaiacol             | —                                        | [79]                        |            |
| 4-Vinylphenol               | —                                        | [79]                        |            |
| 4-Vinylsyringol             | —                                        | [79]                        |            |
| 4β-Hydroxywithanolide E     | Hexane and ethanol                       | [83]                        |            |
| 5,6-Epoxy-β-carotene        | —                                        | [72]                        |            |
| 5,8-Epoxy-α-carotene        | —                                        | [72]                        |            |
| 6-Methyl-2-heptanone        | —                                        | [77]                        |            |
| 6-Methyl-5-heptene-2-one    | —                                        | [84]                        |            |
| 6-Methyl-hept-5-en-2-ol     | —                                        | [77]                        |            |
| 9-(Z)-Octadecenoic acid     | Ethanol or water                         | [85]                        |            |
| Acetaldehyde                | Ethanol or water                         | [85]                        |            |
| Allyl caproate              | Ethanol or water                         | [85]                        |            |
| Apigenin                    | Ethanol or water                         | [85]                        |            |
| Apigenin 7 glucose          | Ethyl acetate                            | [73]                        |            |
| Benzaldehyde                | —                                        | [77, 84]                    |            |
| Benzoic acid                | Ethanol/ethyl acetate, ethanol, or water | [72, 85]                    |            |
| Benzyl acetate              | Hexane and ethanol                       | [83]                        |            |
| Benzyl alcohol              | Juice                                    | [78]                        |            |
| Betulin                     | —                                        | [77]                        |            |
| Butanal                     | —                                        | [77]                        |            |
| Butane-2,3-dione            | —                                        | [77]                        |            |
| Butanoic acid               | —                                        | [77, 79]                    |            |
| Butanol                     | —                                        | [77, 79]                    |            |
| Butanol-2-methyl            | Hexane and ethanol                       | [83]                        |            |
| Butyl 3-hydroxybutyrate     | Crude oil                                | [77, 84]                    |            |
| Butyl acetate               | —                                        | [77]                        |            |
| Butyl butanoate             | —                                        | [77]                        |            |
| Butyl decanoate             | —                                        | [77]                        |            |
| Butyl dodecanoate           | —                                        | [77]                        |            |
| Butyl octanoate             | —                                        | [77]                        |            |
| Butyl-3-hydroxybutanoate    | —                                        | [77, 79]                    |            |
| Caffeic acid                | Methanol, ethanol/ethyl acetate          | [78]                        |            |
| Caffeine                    | Ethanol or water                         | [85]                        |            |
| Campesterol                 | Dichloromethane                          | [86]                        |            |
| Camphene                    | —                                        | [77]                        |            |
| Capric acid, methyl ester   | —                                        | [84]                        |            |
| Carvacrol                   | —                                        | [77]                        |            |
| Caryophyllene oxide         | —                                        | [84]                        |            |
| Catechin                    | Ethanol and isopropanol                  | [87]                        |            |
| Catechol                    | Ethanol or water                         | [85]                        |            |
| Ceder-8-en-9-alpha-ol acetate| Hexane and ethanol                       | [83]                        |            |
| Cedrenol                    | Hexane and ethanol                       | [83]                        |            |
| Chlorophyll a               | Hexane/acetone/ethanol                   | [72]                        |            |
| Chlorophyll b               | Hexane/acetone/ethanol                   | [72]                        |            |
| Chlorophyll b derivative 1  | Hexane/acetone/ethanol                   | [72]                        |            |
| Chlorophyll b derivative 2  | Hexane/acetone/ethanol                   | [72]                        |            |
| Cinnamic acid               | -/ethanol or water                       | [72, 85]                    |            |
| cis-3-Hexenol               | —                                        | [77]                        |            |
| cis-Myrtanol                | —                                        | [77]                        |            |
| cis-Piperitone oxide        | —                                        | [77]                        |            |
| cis-p-Mentha-1(7),8-dien-2-ol| —                                        | [77]                        |            |
| cis-Verbena                 | —                                        | [77]                        |            |
| Citronellyl acetate         | Hexane and ethanol                       | [83]                        |            |
| Cyclooctatetraene           | —                                        | [77]                        |            |
| Cyclosativene               | Hexane and ethanol                       | [83]                        |            |
| Cymenene                    | —                                        | [77]                        |            |
| Organs | Phytoconstituents | Source | References |
|--------|-------------------|--------|------------|
|        | Decanal           | Juice, crude oil | [77, 79, 81, 82] |
|        | Decanoic acid     | Juice, crude oil | [77, 79, 81, 82] |
|        | Dehydroabobinene  | —      | [77]       |
|        | Diethyl ester     | —      | [71]       |
|        | Diethylene glycol | Methanol | [88]       |
|        | Dihomo-γ-linolenic acid | Crude oil | [81] |
|        | Dihydroactinidiolide | —     | [77] |
|        | Dihydrocarveol     | Hexane and ethanol | [83] |
|        | Dimethylene glycol | Methanol | [88] |
|        | Dihydroactinidiolide | —     | [77] |
|        | Docosane           | —      | [77]       |
|        | Docosenoic acid    | —      | [77]       |
|        | Dodecane           | —      | [77]       |
|        | Dodecanoic acid, methyl ester | — | [84] |
|        | Eicosamethylocyclocasiloxane | — | [71] |
|        | Docosane           | —      | [77]       |
|        | Docosenoic acid    | —      | [77]       |
|        | Ethanol            | —      | [77]       |
|        | Ethyl 2-methyl propanoate | Dichloromethane | [80] |
|        | Ethyl acetate      | —      | [77]       |
|        | Ethyl benzoate     | Juice  | [78]       |
|        | Ethyl butanoate    | Dichloromethane | [77, 80] |
|        | Ethyl caprate      | —      | [84]       |
|        | Ethyl caproate     | —      | [84]       |
|        | Ethyl decanoate    | —      | [77]       |
|        | Ethyl dodecanoate  | —      | [77, 84]   |
|        | Ethyl hexanoate    | —      | [77, 80]   |
|        | Ethyl hexanol      | —      | [77]       |
|        | Ethyl hydroxyethyl hexanoate | Dichloromethane, hexane, and ethanol | [77, 80, 83] |
|        | Ethyl octanoate    | —      | [77]       |
|        | Ethyl pentanoate   | —      | [77]       |
|        | Ethyl-2-butoanoate | —      | [77]       |
|        | Ethyl-3-hydroxybutanoate | — | [79] |
|        | Ethyl-3-hydroxyhexenoate | — | [79] |
|        | Ethyl-3-hydroxyoctanoate | — | [79] |
|        | Ethyl-5-hydroxyoctanoate | — | [79] |
|        | Eucalyptol         | Hexane and ethanol | [77, 83] |
|        | Farnesol           | —      | [77]       |
|        | Fenchol            | —      | [77]       |
|        | Ferulic acid       | Methanol, ethanol/ethyl acetate | [78, 88] |
|        | Furanol            | Dichloromethane | [80] |
|        | Gallic acid        | Ethanol and isopropanol, ethanol, or water | [85, 87] |
|        | Geranialdehyde     | —      | [77]       |
|        | Geraniol           | —      | [77]       |
|        | Geranoic acid      | —      | [79]       |
|        | Geranyl acetone    | —      | [77]       |
|        | Guaiacol           | —      | [79]       |
|        | Heptan-2-ol        | —      | [77]       |
|        | Heptanol           | —      | [77]       |
|        | Hexadecanolic acid | Crude oil, dichloromethane | [72, 76, 77] |
|        | Hexadecanoic acid ester | Hexane and ethanol | [83] |
|        | Hexanal            | Crude oil, dichloromethane | [77, 80, 84] |
|        | Hexanoic acid      | —      | [77, 79]   |
|        | Hexanol            | —      | [77, 79]   |
|        | Hexyl butanoate    | —      | [77]       |
| Organ                              | Phytoconstituents                  | Source                        | References |
|-----------------------------------|-----------------------------------|-------------------------------|------------|
| Homofuranol                       | —                                 | Hexane and ethanol            | [83]       |
| Hydrocinnamic alcohol             | —                                 | —                             | [77]       |
| Isoamyl octanoate                 | —                                 | —                             | [77]       |
| Isobutyl acetate                  | —                                 | —                             | [77]       |
| Isobutyl alcohol                  | —                                 | —                             | [77]       |
| Isobutyl butanoate                | —                                 | —                             | [77]       |
| Isobutyl decanoate                | —                                 | —                             | [77]       |
| Isobutyl dodecanoate              | —                                 | —                             | [77]       |
| Isobutyl octanoate                | —                                 | —                             | [77]       |
| Isoeugenol                        | Hexane and ethanol                | —                             | [83]       |
| Isophorone                        | —                                 | —                             | [77]       |
| Isopropenyl ethyl ketone          | —                                 | —                             | [77]       |
| Linalool                          | —                                 | —                             | [77, 84]   |
| Linoleic acid                     | Crude oil                         | —                             | [81, 82]   |
| Lutein ester                      | Juice                             | —                             | [72]       |
| Methional                         | Dichloromethane                   | —                             | [80]       |
| Methyl-11-cyclopentylundecanoate  | —                                 | —                             | [77]       |
| Methyl-2-methoxyoct-2-enolate     | —                                 | —                             | [84]       |
| Myrcenol                          | —                                 | —                             | [77]       |
| Naringenin                        | Ethanol or water                  | —                             | [85]       |
| Nervonic acid                     | Crude oil                         | —                             | [81, 82]   |
| Neryl acetate                     | Hexane and ethanol                | —                             | [83]       |
| Nonanal                            | —                                 | —                             | [77]       |
| Nonanoic acid                     | —                                 | —                             | [77]       |
| Nonanol                            | Hexane and ethanol                | —                             | [83]       |
| Nopol                              | —                                 | —                             | [77]       |
| O-Coumaric acid                   | Ethanol or water                  | —                             | [85]       |
| Oct-1-en-3-ol                     | Dichloromethane                   | —                             | [80]       |
| Octadecanoic acid                 | Crude oil                         | —                             | [81, 82]   |
| Octanal                           | —                                 | —                             | [77, 80]   |
| Octanoic acid                     | —                                 | —                             | [77, 79]   |
| Octanoic acid, 3-methylbutyl ester| —                                 | —                             | [84]       |
| Octanol                           | —                                 | —                             | [77]       |
| Oleic acid                        | Crude oil                         | —                             | [81, 82]   |
| Palmitoleic acid                  | Crude oil                         | —                             | [81, 82]   |
| p-Anisaldehyde                    | Hexane and ethanol                | —                             | [83]       |
| p-Cymen-8-ol                      | —                                 | —                             | [77]       |
| p-Cymene                          | —                                 | —                             | [77]       |
| Pentyl alcohol                    | —                                 | —                             | [84]       |
Table 2: Continued.

| Organs | Phytoconstituents                  | Source                      | References       |
|--------|-----------------------------------|-----------------------------|------------------|
| Phenethyl alcohol                      | —                             | [77]                      |
| Phenol                                    | —                             | [79]                      |
| Phenyl ethyl benzoate                    | Hexane and ethanol            | [83]                      |
| Phenylethyl acetate                     | —                             | [77]                      |
| Pheophytin b                            | Hexane/acetone/ethanol        | [72]                      |
| p-Hydroxy benzoic acid                  | Ethanol or water              | [85]                      |
| Phytoene                                | Hexane/acetone/ethanol        | [72]                      |
| Phytofluene                             | Hexane/acetone/ethanol        | [72]                      |
| p-Menth-4(8)-ene-1,2-diol               | —                             | [79]                      |
| Propyl decanoate                        | —                             | [77]                      |
| Propyl hexanoate                        | Hexane and ethanol            | [83]                      |
| Propyl octanoate                        | —                             | [77]                      |
| Quercetin 3,4',7-trimethyl ether        | Juice                        | [78]                      |
| Rosoxide                                | —                             | [77]                      |
| Salicylic acid                          | Ethanol or water              | [85]                      |
| sec-Butyl butyrate                      | —                             | [77]                      |
| Stigmasterol                            | Dichloromethane              | [86]                      |
| Syringic acid                           | Ethanol or water              | [85]                      |
| Terpinen-4-ol                           | —                             | [84]                      |
| Terpinolene                             | —                             | [84]                      |
| Tetradecanoic acid                      | Crude oil                    | [81, 82]                  |
| Tetracosanoic acid                      | Crude oil                    | [81, 82]                  |
| trans-3-Hexenol                         | —                             | [77]                      |
| trans-Citral                            | —                             | [77]                      |
| Trimethyl phenyl butenone               | Hexane and ethanol            | [83]                      |
| Vanillic acid                           | Ethanol/Ethyl acetate, ethanol, or water | [74, 85] |
| Vanillin                                | Ethanol/Ethyl acetate, ethanol, or water | [74, 85] |
| Verbenene                               | Hexane and ethanol            | [77, 83]                  |
| Verbenone                               | —                             | [77]                      |
| Vitamin B9 (folic acid)                 | Juice                        | [78]                      |
| Vitamin E                               | Crude oil, dichloromethane   | [81, 86]                  |
| Vitamin K₄                               | Crude oil                    | [81]                      |
| α-Cubebene                              | Juice                        | [78]                      |
| α-Linolenic acid                        | Crude oil                    | [81, 77]                  |
| α-Pinene                                | Hexane and ethanol            | [77, 83]                  |
| α-Terpinene                             | —                             | [77]                      |
| α-Terpineol                             | —                             | [77, 79, 84]              |
| α-Terpinolene                           | —                             | [77]                      |
| α-Tocopherol                            | Crude oil, ethanol/ethyl acetate | [74, 81, 82] |
Table 2: Continued.

| Organs            | Phytoconstituents                                      | Source | References |
|-------------------|-------------------------------------------------------|--------|------------|
| **Leaves**        | (S)-4-Iodo-1,2-epoxybutane                            | —      | [71]       |
|                   | 1,1,1,5,7,7,7-Heptamethyl-3,3                        | —      | [71]       |
|                   | 1,2-Benzenedicarboxylic acid                          | —      | [71]       |
|                   | 3,3-Dimethyl-hexane                                   | —      | [71]       |
|                   | 3,3-Dimethyl-octane                                   | —      | [71]       |
|                   | Campesterol                                           | Dichloromethane | [86]   |
|                   | Diethyl ester                                          | —      | [71]       |
|                   | Docosane                                               | —      | [77]       |
|                   | Eicosamethylcyclodecasiloxane                         | —      | [71]       |
|                   | Ethyl isoallocholate                                   | Dichloromethane | [86]   |
|                   | Hexadecanoic acid                                     | —      | [86]       |
|                   | Perulactone B                                         | —      | [90]       |
|                   | Physalin B                                            | —      | [90]       |
|                   | Physalin D                                            | —      | [90]       |
|                   | Physalin F                                            | —      | [90]       |
|                   | Phytol                                                 | Methanol, dichloromethane | [81, 86] |
|                   | Stigmasterol                                           | Dichloromethane | [86]   |
|                   | Vitamin E                                             | Dichloromethane | [86]   |
|                   | Withanolide E                                          | —      | [90]       |
|                   | Withanolide F                                          | —      | [90]       |
| **Peel**          | (all-E)-Antheraxanthin myristate-palmitate            | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-Lutein                                         | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-Lutein 3'-O-palmitate                         | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-Lutein 3-O-myristate                          | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-Lutein 3-O-palmitate-3'-O-myristate           | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-Lutein dimerystate                            | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-Lutein dipalmitate                            | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-Neoxanthin                                     | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-Neoxanthin dipalmitate                        | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-Neoxanthin myristate                          | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-Neoxanthin palmitate                          | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-Taraxanthin                                    | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-Violaxanthin                                   | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-Violaxanthin dimyristate                      | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-Violaxanthin dipalmitate                      | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-Violaxanthin myristate-palmitate              | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-Zeaxanthin dimerystate                        | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-Zeaxanthin dipalmitate                        | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-Zeaxanthin myristate-palmitate                | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-Zeaxanthin dimerystate                        | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-Zeaxanthin dipalmitate                        | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-α-Carotene                                     | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-α-Cryptoxanthin myristate                     | Hexane/acetone/ethanol | [72]   |
|                   | (all-E)-α-Cryptoxanthin palmitate                     | Hexane/acetone/ethanol | [72]   |
|                   | (E)-α-Carotene                                         | Hexane/acetone/ethanol | [72]   |
|                   | (Z)-Lutein 1                                           | Hexane/acetone/ethanol | [72]   |
|                   | (Z)-Lutein ester                                       | Hexane/acetone/ethanol | [72]   |
|                   | (Z)-Neoxanthin- or (Z)-violaxanthin ester             | Hexane/acetone/ethanol | [72]   |
|                   | (Z)-Taraxanthin                                        | Hexane/acetone/ethanol | [72]   |
|                   | (Z)-β-Carotene                                         | Hexane/acetone/ethanol | [72]   |
|                   | (Z)-γ-Carotene                                         | Hexane/acetone/ethanol | [72]   |
|                   | 5,6-Epoxy-β-carotene                                   | Hexane/acetone/ethanol | [72]   |
|                   | 5,8-Epoxy-α-carotene                                   | Hexane/acetone/ethanol | [72]   |
|                   | Lutein ester                                           | Hexane/acetone/ethanol | [72]   |
|                   | Phytoene                                               | Hexane/acetone/ethanol | [72]   |
|                   | Phytofluene                                            | Hexane/acetone/ethanol | [72]   |
| Organs                  | Phytoconstituents                                                                 | Source                        | References |
|-------------------------|------------------------------------------------------------------------------------|-------------------------------|------------|
| Pulp                    | (all-E)-Lutein                                                                     | Hexane/acetone/ethanol        | [72]       |
|                         | (all-E)-Lutein 3-O-myristate                                                      | Hexane/acetone/ethanol        | [72]       |
|                         | (all-E)-Lutein 3-O-palmitate-3′-O-myristate                                       | Hexane/acetone/ethanol        | [72]       |
|                         | (all-E)-Lutein dimyristate                                                       | Hexane/acetone/ethanol        | [72]       |
|                         | (all-E)-Neoaxanthin                                                               | Hexane/acetone/ethanol        | [72]       |
|                         | (all-E)-Neoaxanthin dipalmitate                                                  | Hexane/acetone/ethanol        | [72]       |
|                         | (all-E)-Neoaxanthin myristate                                                    | Hexane/acetone/ethanol        | [72]       |
|                         | (all-E)-Taraxanthin                                                               | Hexane/acetone/ethanol        | [72]       |
|                         | (all-E)-Taraxanthin ester                                                        | Hexane/acetone/ethanol        | [72]       |
|                         | (all-E)-Violaxanthin                                                              | Hexane/acetone/ethanol        | [72]       |
|                         | (all-E)-Violaxanthin dimyristate                                                  | Hexane/acetone/ethanol        | [72]       |
|                         | (all-E)-Violaxanthin dipalmitate                                                 | Hexane/acetone/ethanol        | [72]       |
|                         | (all-E)-Violaxanthin myristate-palmitate                                          | Hexane/acetone/ethanol        | [72]       |
|                         | (all-E)-α-Carotene                                                                | Hexane/acetone/ethanol        | [72]       |
|                         | (all-E)-α-Cryptoxanthin                                                           | Hexane/acetone/ethanol        | [72]       |
|                         | (all-E)-α-Cryptoxanthin myristate                                                | Hexane/acetone/ethanol        | [72]       |
|                         | (E)-α-Carotene                                                                    | Hexane/acetone/ethanol        | [72]       |
|                         | (Z)-Lutein 1                                                                      | Hexane/acetone/ethanol        | [72]       |
|                         | (Z)-Lutein ester                                                                 | Hexane/acetone/ethanol        | [72]       |
|                         | (Z)-β-Carotene                                                                    | Hexane/acetone/ethanol        | [72]       |
|                         | (Z)-γ-Carotene                                                                    | Hexane/acetone/ethanol        | [72]       |
|                         | Δ5-Avenasterol                                                                    | Crude oil                    | [81, 82]   |
|                         | Δ7-Avenasterol                                                                    | Crude oil                    | [81, 82]   |
| 5,6-Epoxy-β-carotene    |                                                                                   | Hexane/acetone/ethanol        | [72]       |
| 5,8-Epoxy-α-carotene    |                                                                                   | Hexane/acetone/ethanol        | [72]       |
| Campesterol             |                                                                                   | Crude oil                    | [81, 82]   |
| Decanoic acid           |                                                                                   | Crude oil                    | [81, 82]   |
| Eicosenoic acid         |                                                                                   | Crude oil                    | [81, 82]   |
| Eicosanoic acid         |                                                                                   | Crude oil                    | [81, 82]   |
| Eruvic acid             |                                                                                   | Crude oil                    | [81, 82]   |
| Ergosterol              |                                                                                   | Crude oil                    | [81, 82]   |
| Hexadecanoic acid       |                                                                                   | Crude oil                    | [81, 82]   |
| Homo-γ-linolenic acid   |                                                                                   | —                             | [82]       |
| Lanosterol              |                                                                                   | Crude oil                    | [81, 82]   |
| Linoleic acid           |                                                                                   | Crude oil                    | [81, 82]   |
| Lutein ester            |                                                                                   | Hexane/acetone/ethanol        | [72]       |
| Nervonic acid           |                                                                                   | Crude oil                    | [81, 82]   |
| Octadecanoic acid       |                                                                                   | Crude oil                    | [81, 82]   |
| Oleic acid              |                                                                                   | Crude oil                    | [81, 82]   |
| Palmitoleic acid        |                                                                                   | Crude oil                    | [81, 82]   |
| Phytoene                |                                                                                   | Crude oil                    | [81, 82]   |
| Phytofluene             |                                                                                   | Crude oil                    | [81, 82]   |
| Stigmasterol            |                                                                                   | Crude oil                    | [81, 82]   |
| Tetradecanoic acid      |                                                                                   | Crude oil                    | [81, 82]   |
| Tetracosanoic acid      |                                                                                   | Crude oil                    | [81, 82]   |
| α-Linolenic acid        |                                                                                   | Crude oil                    | [81, 82]   |
| α-Tocopherol            |                                                                                   | Crude oil                    | [81, 82]   |
| β-Carotene              |                                                                                   | Crude oil                    | [81, 82]   |
| β-Sitosterol            |                                                                                   | Crude oil                    | [81, 82]   |
| β-Tocopherol            |                                                                                   | Crude oil                    | [81, 82]   |
| γ-Linolenic acid        |                                                                                   | Crude oil                    | [81, 82]   |
| γ-Tocopherol            |                                                                                   | —                             | [82]       |
| δ-Tocopherol            |                                                                                   | Ethanol/ethyl acetate         | [78]       |
concentrations according to organs [95]. Overall, monophenolic and polyphenolic compounds are synthesized and then accumulated in all plant tissues, but their concentration can be varied from different parts. Among phenolic compounds, phenolic acids and flavonoids are the most studied, mainly pharmacological properties exploited for medical purposes [96]. Gupta et al. [97] noted the strong influence of phenolic compounds and the carotenoid content with bioactivity.

The plant also contains fatty acids, which are the most cited in the literature. For example, hexadecanoic acid (palmitic acid) was the most cited, five times (0.82%), followed by decanoic acid, linoleic acid, and octadecanoic acid, which were mentioned four times (0.66%). Hexadecanoic acid (palmitic acid) is the most common saturated fatty acid in plants, animals, and microorganisms, and linoleic acid is central in plant lipids. It is essential for humans (animals) because it is derived mainly from dietary plant oils [98].

Beyond the sucrose esters identified in plants (2.58%), others such as peruvioses A, B, C, D, and F had already been isolated before in the dichloromethane extract of the sticky exudate that covers the fruit [99, 100]. Nicandroes, other sucrose esters, have been isolated in the Physalis genus. Their presence is confirmed in different species including P. nicandroides var. attenuata, P. solanaceus, P. sordida, and P. viscosa [5].

Steroids and withanolides (a group of naturally occurring polyoxygenated steroidal lactones) were also identified in the plant and represented 6.97%. Physalins (steroidal constituents) are the most active representatives of secondary metabolites of the genus [101]. Most withanolide compounds are produced by Solanaceae plants, in particular 19 genera of Solanaceae, including Acnistus, Datura, Deprea, Dunalis, Discopodium, Exodeconus, Hyoscyamus, Iochroma, Jaborosa, Larnax, Lycium, Nicandra, Physalis, Salpichroa, Trechonaetes, Tubocapsicum, Vassobia, Withania, and Witheringia [102, 103]. Nowadays, several withanolides have been isolated and characterized from different parts of P. peruviana, including dihydrowithaferins, physachenolides, physacoztolides, perulactones, withaperuvins, alkekenginins, withaferins, hydroxy-withanolides, physagulins, withaperuvins, physalolactones, withalongolide, physapuruvins, withaphysanolides, viscosalactones, and phyperunolides [5, 8]. Almost 351 withanolides have been identified and isolated from the Physalis genus, mainly from P. peruviana and P. angulata [104].

| Organ       | Phytoconstituents                                                                 | Source | References |
|-------------|-----------------------------------------------------------------------------------|--------|------------|
| Roots       | Dimethyl-flubendazole                                                            |        | [71]       |
|             | Diethyl ester                                                                     |        | [71]       |
|             | Eicosamethylcyclohexasiloxane                                                     |        | [71]       |
|             | Hygrine                                                                           |        | [69]       |
|             | N-Methylpyrrolidinylhygrine A                                                     |        | [69]       |
|             | N-Methylpyrrolidinylhygrine B                                                     |        | [69]       |
|             | Physoperuvine                                                                     |        | [69]       |
|             | Tropine                                                                           |        | [69]       |
|             | Dimethyl-flubendazole                                                             |        | [71]       |

Steroids such as ergosterol, campesterol, stigmasterol, lanosterol, β-sitosterol, Δ5-avenasterol, and Δ7-avenasterol have been reported in P. peruviana pomace and fruit juice. A number of the vitamins have been identified primarily in pomace and fruits, including 1,25-dihydroxy vitamin D2 (derived from vitamin D), vitamin B9 (folic
acid), vitamin K, vitamin E (α,β,γ,δ-tocopherols), and biotin. A study on the phytochemical composition of goldenberry pomace confirmed the presence of these vitamins. In addition to vitamins A, D, and K, niacin, riboflavin, thiamin, pyridoxine, vitamin B12, choline chloride, and p-aminobenzoic acid have been identified and quantified [105, 106].

Among ten alkaloids identified in the plant, cuscohygrine was subsequently isolated from the roots [107], and physoperuvine has already been isolated from P. peruviana roots [108]. The other alkaloids have been explicitly isolated in the aerial and roots. They are the only parts of plants where alkaloids were identified.

4. Conclusion

P. peruviana plays a significant role in managing various pathologies of different organ systems, but its ethno-therapeutic use is strongly limited to a few countries. The plant is very rich in compounds, considering the number of identified compounds. Regarding phytochemical profiling, effort must be directed towards isolating and characterizing more compounds, particularly those that can present a significant therapeutic interest via extensive pharmacological investigations.

5. Disclosure

This study is part of the Ph.D. training of FMK. The funding agent had no role in the study design, data collection, data analysis, and writing of the present manuscript.

Data Availability

All relevant data are presented in the manuscript. However, any required further information can be provided by the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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