Chapter 27

Functional food and nutra-pharmaceutical potential of goldenberry

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27.1 Introduction

Goldenberry (*Physalis peruviana* L.), originally indigenous to the warm continent of South America, is now widely distributed globally, reaching places like Africa, Asia, the Pacific, and Europe. It grows in diverse agroclimatic and agroecological conditions (Kasali et al., 2021). In temperate regions, *P. peruviana* showcases an annual growth habit. In contrast, in tropical areas, it showcases a perennial growth pattern characterized by a sympodial inclination and transforms into a herbaceous or semiwoody shrub that is extensively branched, achieving heights of 1.0−2.0 m (Morton, 1987). *P. peruviana* is regarded as a well-known and extensively cultivated species of the *Physalis* genus. Plants from this genus have been historically recognized for their folk medicinal potential and employed for remedial purposes to treat a wide range of disorders, especially infectious diseases, asthma, dermatitis, cancer, hepatitis, and malaria, and possess immunomodulatory and antipyretic effects (Kasali et al., 2022; Kasali et al., 2021).

Being a nutritious and delectable fruit, *P. peruviana* is valued as a beneficial medicinal plant and ornamental crop (Morton, 1987). *P. peruviana* contains a broad range of phytoconstituents/bioactives, including flavonoids/polyphenols, physalins, alkaloids, vitamins, carotenoids, and polysaccharides (Kasali et al., 2021). In addition, it is packed with an abundance of essential minerals, vitamins, high-value phytochemicals, and antioxidants (Chang et al., 2019; Kupska et al., 2016).

The goldenberry, known by various names across different countries, has gained popularity recently due to its numerous health benefits and unique taste. This fruit belongs to the nightshade family, commonly known as *cape gooseberry* and Peruvian groundcherry. However, it is called by several local names in different regions of the world (Lim, 2013). For example, in the Indo-Pak subcontinent, it is known as Macao, Makowi, and Rasbhari, while in Africa, it is renowned as cape gooseberry, goldenberry, pompelmoes, apelliefie, jamu, and peruvian cherry. In Asia, it goes by various names like Deng Long Cao, Suan Jiang, and Chinese lantern. In South America, it is commonly referred to as Cereza Del Peru, aguaymanto, uchuva, Uvilla, and capulí, and in Europe, it is known as Capische Stachelberre, Essbare Judaskirsche, Judenkirsche, Capulé, Fisalis, and Vescicaria (Duarte & Paull, 2015; Lim, 2013; Morton, 1987).

The fruit of this important berry is consumed all over the population and across the regions. A broad spectrum of medicinal and pharmaceutical benefits are associated with consuming goldenberry (Puente et al., 2011; Ramadan, 2011; Rodrigues et al., 2009; Yıldız et al., 2015). Due to the rare combination of natural antioxidants, antimicrobial, antidiabetic, anticancer, and antihypertensive agents, the fruit is regarded as a food with medicinal value and has excellent domestication potential (Tenorio, 2017). This chapter is an effort to present an overview of the distribution, nutritional, phytochemicals, and biological attributes of *P. peruviana* with the primary purpose of exploring the nutra-pharmaceutical potential of this valuable species.

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27.2 Origin/distribution

The *Physalis* (goldenberry), a native of Chile and Peru, has a rich and long history of cultivation that dates back to 4000 years ago. As a staple food in South American cuisine, the fruit has an impressive profile in the culinary world. While commonly known as the "cape gooseberry," the goldenberry is unrelated to actual gooseberries. Its cultivation in England dates back to the late 18th century, later reaching South Africa at the start of the 19th century.

It has been distributed and spread to other countries like India and Australia. Besides, *P. peruviana* has been cultivated in Hawaii, Jamaica, and Israel since the 19th century (Morton, 1987; Parker, 2022). Furthermore, the commercial cultivation of the fruit was started in Colombia (Muniz et al., 2014), spreading over 800−1000 ha. So now, countries such as Australia, New Zealand, Colombia, Zimbabwe, Kenya, Ecuador, and India are the main areas where *Physalis* is commercially cultivated. Additionally, the cultivation of *P. peruviana* has been extended to several other countries, including Latin America, the United States, South Africa, Japan, China, Japan, the Philippines, Malaysia, England, and Indonesia (Hassanien, 2011; Medina, 1991; Muniz et al., 2014; Yamika et al., 2019). So now, this fruit has captured the global market and is valued across the continents based on its unique nutritional benefits and functional food attributes (Yu et al., 2019).

The cultivation pattern and other agronomic aspects of goldenberries have been extensively studied (Paksi et al., 2007; Rockenbach et al., 2008; Seebens et al., 2017; Stoian et al., 2008). Due to favorable agroclimatic conditions, selected parts of India and Pakistan have become major hubs for its cultivation and the demand for its edible fruit is ever-growing. *P. peruvina* is one of three species found in Pakistan, mainly in the northern regions (Ahmad et al., 1999; Stewart et al., 1972).

Its recognition could be credited to its distinctive taste profile, blending sweet and tangy flavors, rendering it a sought-after complement to various culinary preparations (Paksi et al., 2007; Rockenbach et al., 2008; Seebens et al., 2017; Stoian et al., 2008). Furthermore, goldenberry is well known and famous for its rich profile of bioactives and high vitamin C levels, which help prevent various illnesses. In addition to its culinary uses, goldenberry is also used by the local communities as folk medicine to manage/treat multiple health disorders, including inflammation, fever, and respiratory problems (Etzbach et al., 2018).

27.3 Extraction of phytoconstituents from *Physalis peruviana*

Different parts (aerial part, body, calyces, peel, leaves, fruits, pulp, roots, and seeds) of *P. peruviana* contain a variety of bioactive phytoconstituents that can be extracted/obtained through different extraction methods. The main solvents for phytoconstituents extraction from aerial (Yu et al., 2019), calyces, pulp, and peel parts were hexane/acetone/ethanol. In another report, the common extraction solvent for the calyces (Etzbach et al., 2018) of this plant was examined to be hexane/acetone/ethanol (Kubwabo et al., 1993; Yu et al., 2019). Aerial part−based phytoconstituents including (3α-tigloylnxytropane, 3β-acetoxytropane, hygrine, *N*-methyl pyrrolidinyl hygrine, A, B, physoperuvine, and tropine) have been extracted using ethanol (Kubwabo et al., 1993). Ethanol/ethyl acetate is another extraction solvent for various phytoconstituents of calyces (Ballesteros-Vivas et al., 2019). The main components in extracts of calyces include methylprednisolone succinate, Isovitexin, Gardenin, Feruloylquinic acid, Ferulic acid-hexoside, and various flavonoid derivatives such as 3,5,3′,5′-tetra-tert-butyldiphenoquinone, 3-hydroxy-7,8,2′-trimethoxyflavone, 3,6,2′,3′-tetramethoxyflavone, 3,6,3′,4′-tetramethoxyflavone, 3′-benzyloxy-5,6,7,4′-tetramethoxyflavone, 7-hydroxycoumarin-3-carboxylic acid, and biotin (Wahdan et al., 2019). While using ethyl acetate, five and six carbon sugars were extracted from calyces (Abou Baker & Rady, 2020). Similarly, another group of researchers used dichloromethane to extract eicosamethyl cyclodecasiloxane, hexadecanoic acid, linoleic acid, and campesterol from the leaf (Peter et al., 2020). Hexane/acetone/ethanol (Etzbach et al., 2018) leaves extract contained (all-*E*)-zeaxanthin dipalmitate, (all-*E*)-zeaxanthin myristate-palmitate, and a few other phytoconstituents. A tri-solvent mixture combination (hexane/acetone/ethanol extraction) was used for the extraction of bioactives from Goldenberry pulp extracts (Etzbach et al., 2018; Ramadan & Moersel, 2007; Ramadan & Mörsel, 2003). Only δ-tocopherol was extracted by ethanol/ethyl acetate mixture from pulp (Al-Olayan et al., 2014). Ethanol and methanol are reported to be the most common solvents for the preparation of root and seed extracts (Darwish & Shaker, 2021; Kubwabo et al., 1993).

27.4 Nutritional and food/commercial aspects

The goldenberry is a multifaceted crop acknowledged for its high functionality as a food resource for the fragrance and cosmetic industries. As a result, it has become a fruit crop of significant economic value globally. It has been widely cultivated, processed, packed, and sold in markets (Novoa et al., 2006). Colombia and South Africa are the leading producers and exporters of goldenberries. The presence of a long list of bioactives/functional compounds (carotenoids, phytosterols, vitamins, polyphenols, antioxidants, polysaccharides) along with essential minerals and vitamins in goldenberry make this fruit a promising and impressive candidate for functional food applications. These compounds collectively give the fruit medicinal properties, making it a highly demanding commodity in the global market (Puente et al., 2011; Ramadan, 2011; Rodrigues et al., 2009; Yıldız et al., 2015).

Among these essential nutrients, vitamin C and β-carotene are found in abundance, along with appreciable levels of phenolic compounds, including phenolic acids (chlorogenic, ferulic, gallic, caffeic, and *p*-coumaric acids), and polyphenols/flavonoids (myricetin, catechin, quercetin, kaempferol, epicatechin). The antioxidant activity of cape gooseberry is also noteworthy. As depicted in Table 27.1, the amount of vitamin C in the goldenberry varied from 18 to 929 mg/100 g based on the selection of analytical methods, cultivars/varieties, and ecotypes (Tenorio, 2017). In comparison with other commonly available sources of vitamin C, goldenberry has emerged as an excellent source of this essential nutrient, with levels comparable to that of orange (Gomez & Lajolo, 2008; Hiwilepo-van Hal et al., 2012; Sogi et al., 2012).

Goldenberry's total phenolic contents (TPC) may vary from 2.5 to 934.9 galic acid equivalent mg/100 g (FW). The factors contributing to the variation in the reported contents are multifaceted, encompassing the type of extraction technique and solvent, the extraction conditions, the duration of the reaction, the standards employed as well as the type of cultivar/ecotype and the postharvest stage conditions. These variables are the primary driving forces/factors behind the observed differences in the reported TPC contents (Tenorio, 2017).

Goldenberry fruit is rich in phenolic acids and flavonoids, making it an excellent addition to one's diet for optimal health and well-being. For example, phenolic acids (ferulic, *p*-coumaric, chlorogenic, caffeic, and gallic acid) and flavonoids, including quercetin (0.1−10.9 mg/kg), rutin (1.7−6.7 mg/kg), myricetin (1.1−1.3 mg/kg), epicatechin (0.2−0.6 mg/kg), and catechin (3.8−6.7 mg/kg) have been identified and quantified in goldenberry fruit (Mier, 2012; Muñoz et al., 2021; Namiesnik et al., 2014; Rockenbach et al., 2008). The predominant carotenoid is β-carotene giving the fruit a yellow-orange hue. Its values are between 0.2 and 1074.7 (mg/100 g) of fresh weight. Such variation requires standardization in quantifying β-carotene content for optimal cultivation and harvesting practices to ensure consistent and reliable yields (Fischer et al., 1999).

The oils extracted from the berry plant contained varying amounts of tocopherols. Specifically, whole berry and seed oils had higher concentrations of β-and γ-tocopherols, while pulp part and skin oil had more significant amounts of δ- and α-tocopherols. The pulp oil was found to contain 28.3 (g/kg) of α-tocopherol, while 15.2 (g/kg) of β-tocopherol, 45.5 (g/kg) of γ-tocopherol, and 1.50 (g/kg) of δ-tocopherol, resulting in a total tocopherols content of 90.5 g/kg. These findings suggest using this oil as a high-value oil, thus highlighting its functional food importance. Especially the seed oil from this fruit can serve as an excellent source of dietary antioxidants and essential fatty acids such as polyunsaturated fatty acids (Ramadan & Moersel, 2007).

Goldenberries are highly nutritious functional products due to their excellent fiber, phenolic contents, and low-caloric value (Ozturk et al., 2017). The fruits are most valuable for human health due to the blend of essential nutrients and functional compounds/bioactives. Notably, *P. peruviana* fruit is a vital source of vitamins A, B, and C, carotene, phosphorous, and iron. Appreciable amounts of vitamins (B3 and B6) in the pulp part of cape gooseberry/goldenberry have been documented with a range of 26.6 and 24.8 mg/100 g DW (dry weight), correspondingly (Vega-Gálvez et al., 2016). Different parts have different levels of nutrients and bioactive compounds (Table 27.1). The protein contents of goldenberry fresh fruit may vary from 1.5 to 2.54 g/100 g. At the same time, waste powder and pomace contain much higher protein content (Table 27.1). Fresh fruit is also a rich source of minerals as well. Iron values in goldenberry fruit are approximately 1.47 mg/100 g, 5−15 times higher than strawberries, apples, oranges, and beans (Nawirska-Olszańska et al., 2017; Rodrigues et al., 2009).

Regarding food uses, these berries can be consumed fresh, dehydrated, or processed and used in various dishes, pastries, and confectionery items. Their sweet and sour flavor makes them popular as food ingredients in cakes, candies, jams, sauces, and salads. They can also be incorporated in jellies, yogurts, ice creams, dressings, fillings, and glazes for meat and seafood. Jellies obtained from Peruvian species are more suitable for processing and sensory acceptance, likely based on their high levels of pectin with gelling properties. In the current era of designer foods, Goldenberries have been developed into novel antidiabetic functional/designer foods with reduced sugar levels (Curi et al., 2017; Valdenegro et al., 2013).

Along with these uses, goldenberry waste is a valuable underutilized biomass that can be valorized for energy production as it generates electricity through microbial fuel cell technology (Segundo et al., 2022). When applied externally to the eye, the fruit (*P. peruviana*) juice also has traditional uses for treating pterygium. In addition, fruit juice contains different active agents of pharmacological importance with antiinflammatory and cytostatic activity (Pardo et al., 2008).

TABLE 27.1 Nutritional composition of goldenberry.

	Nutritional value	Fresh fruits (Ahmad et al., 1999; Fischer et al., 2014; Petkova et al., 2021; Tenorio, 2017)	Goldenberry waste powder (Petkova et al., 2021)	Pulp/100 g	Goldenberry pomace (seeds and skins) (Ramadan & Moersel, 2007)
1.	Energy value	49–76.8 kcal/100 g		73 kcal/100 g	
2.	Lipids/fats	0.5–1.01 g/100 g	13.7 g/100 g	0.2 g /100 g	
3.	Protein	1.5–2.54 g/100 g	15.89 g/100 g	0.3 g/100 gm	17.8 g/100 g
4.	Carbohydrates	10.23–17.3 g/100 g	61 g/100 g	19.6 g/100 g	24.5 g/100 g
5.	Reducing sugars	2.90 g/100 g			
6.	Pectin	1.16–1.85 g/100 g			
7.	Fiber	0.4–4.29 g/100 g	16.74 g/100 g	4.9 g/100 g	28.7 g/100 g
8.	Natural pigments (chlorophylls)	3.62 μg/g			
9.	Carotenoids	22.36 μg/g			
10.	Potassium	292.65–4876 g/kg	560 mg/100 g	320–4955 mg/100 g	
11.	Magnesium	91.42–455 mg/kg		33.65 mg/kg	
12.	Iron	1.24–20.91 mg/kg		1.2–16.44 mg	
13.	Sodium	48.09 mg/kg	170 mg/100 g	1–36.93 mg/100 g	
14.	Zinc	0.4–34.60 mg/kg		4.11 mg/kg	
15.	Phosphorus	37.9 mg/100 g	130 mg/100 g	55 mg/g	
16.	Calcium	10.55 mg/100 g		8–9.97 mg/100 g	
17.	Total phenolic contents	2.5–934.9 mg/100 g FW			
18.	Total flavonoid contents	0.8–9.48 mg QE/100 g			
19.	β-Carotene	236 mg/100 g FW		11.460 mg/g	
20.	Thiamine			0.10 mg/g	
21.	Riboflavin			0.03 mg/g	
22.	Niacin			1.70 mg/g	
23.	Vitamin C	18–929 mg/100 g FW		43 mg/g	

27.5 Phytochemistry, biological and nutra-pharmaceutical prospects of goldenberry

P. peruviana is extensively used in folk/traditional medicines in various countries and civilizations to treat particularly gastrointestinal tract disorders. The plant is an impressive source of various classes of phytochemicals, with over 500 phytoconstituents identified so far. Especially the fruit of this species is the primary organ packed with bioactives. Fruit contains more than 300 reported phytochemicals belonging to all classes, including terpenes, phenolic compounds, carotenoids, and flavonoids (Table 27.2). The most common solvent system used to extract these compounds is a hexane/acetone/ethanol mixture. Some important phytoconstituents of goldenberry fruits include (−)-caryophyllene oxide,

TABLE 27.2 Distribution of phytoconstituents in selected parts of goldenberry (Kasali et al., 2021).

	Phytoconstituents	Aerial parts	Calyces	Fruits	Leaves	Roots	Seeds
1.	3α-Tigloylnxytropane	✓ (Kubwabo et al., 1993)				✓ (Kubwabo et al., 1993)	
2.	Physoperuvine	✓ (Kubwabo et al., 1993)				✓ (Basey et al., 1992; Kubwabo et al., 1993; Sahai & Ray, 1980)	
3.	(+)-*N*,*N*-Dimethylphysoperuvinium					✓ (Sahai & Ray, 1980)	
4.	Phygrine					✓ (Basey et al., 1992)	
5.	3β-Acetoxytropane	✓ (Kubwabo et al., 1993)				✓ (Kubwabo et al., 1993)	
6.	*N*-Methylpyrrolidinylhygrine isomers	✓ (Kubwabo et al., 1993)				✓ (Kubwabo et al., 1993)	
7.	Cuscohygrine	✓ (El-Gengaihi et al., 2013)				✓ (El-Gengaihi et al., 2013)	
8.	Physalolactone C					✓ (Ali et al., 1984)	
9.	Withaperuvin E, F, G, H					✓ (Bagchi et al., 1984; Chen et al., 2011; Neogi et al., 1986)	
10.	(*S*)-4-Iodo-1,2-epoxybutane			✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)
11.	1,1,1,5,7,7,7-Heptamethyl-3,3 bis(trimethylsiloxy) tetrasiloxane			✓ (Ertürk et al., 2017)		✓ (Ertürk et al., 2017)	
12.	1,2,3-Tri(t-butyl) cyclopropenylium tribromide-[71]					✓ (Ertürk et al., 2017)	
13.	1,2-Benzenedicarboxylic acid			✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)
14.	3,3-Dimethyl-hexane			✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)
15.	3,3-Dimethyl-octane			✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)
16.	3α-Tigloylnxytropane	✓ (Kubwabo et al., 1993)				✓ (Kubwabo et al., 1993)	

(Continued)

TABLE 27.2 (Continued)

	Phytoconstituents	Aerial parts	Calyces	Fruits	Leaves	Roots	Seeds
17.	3β-Acetoxytropane	✓ (Kubwabo et al., 1993)				✓ (Kubwabo et al., 1993)	
18.	Diethyl ester			✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)
19.	Dimethyl-flubendazole					✓ (Ertürk et al., 2017)	
20.	Docosane			✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)
21.	Eicosamethyl cyclodecasiloxane			✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)	
22.	Hygrine	✓ (Kubwabo et al., 1993)				✓ (Kubwabo et al., 1993)	
23.	*N*-Methylpyrrolidinylhygrine A	✓ (Kubwabo et al., 1993)				✓ (Kubwabo et al., 1993)	
24.	*N*-Methylpyrrolidinylhygrine B	✓ (Kubwabo et al., 1993)				✓ (Kubwabo et al., 1993)	
25.	Tropine	✓ (Kubwabo et al., 1993)				✓ (Kubwabo et al., 1993)	
26.	Dimethyl-flubendazole					✓ (Ertürk et al., 2017)	
27.	1,2,3-Tri(*t*-butyl) cyclopropenylium tribromide						✓ (Darwish & Shaker, 2021)
28.	Antheraxanthin	✓ (Yu et al., 2019)					
29.	Cuscohygrine	✓ (Kubwabo et al., 1993)				✓ (Kubwabo et al., 1993)	
30.	Lutein	✓ (Yu et al., 2019)					
31.	Neoxanthin	✓ (Yu et al., 2019)					
32.	Phytofluene	✓ (Yu et al., 2019)		✓ (Etzbach et al., 2018)			
33.	Violaxanthin	✓ (Yu et al., 2019)					
34.	Zeaxanthin	✓ (Yu et al., 2019)					

35.	*c*-Carotene	✓ (Yu et al., 2019)					
36.	Eicosamethyl cyclodecasiloxane						✓ (Ertürk et al., 2017)
37.	(all-*E*)-Lutein		✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)		
38.	(all-*E*)-Lutein 3-*O*-myristate		✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)		
39.	(all-*E*)-Neoxanthin		✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)		
40.	(all-*E*)-Neoxanthin palmitate		✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)		
41.	(all-*E*)-Taraxanthin		✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)			
42.	(all-*E*)-Taraxanthin ester		✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)			
43.	(all-*E*)-Violaxanthin		✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)			
44.	(all-*E*)-Violaxanthin or (all-*E*)-neoxanthin ester		✓ (Etzbach et al., 2018)				
45.	(all-*E*)-α-Carotene		✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)			
46.	(all-*E*)-α-Cryptoxanthin myristate		✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)			
47.	(*E*)-Vanillic acid		✓ (Abou Baker & Rady, 2020)				
48.	(*E*)-α-Carotene		✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)			
49.	(*Z*)-Lutein 1		✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)			
50.	(*Z*)-Lutein 2		✓ (Etzbach et al., 2018)				
51.	(*Z*)-Lutein ester		✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)			
52.	(*Z*)-Taraxanthin		✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)			

(*Continued*)

TABLE 27.2 (Continued)

	Phytoconstituents	Aerial parts	Calyces	Fruits	Leaves	Roots	Seeds
53.	(*Z*)-Taraxanthin-α-linolenic acid		✓ (Etzbach et al., 2018)				
54.	(*Z*)-β-Carotene		✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)			
55.	α-Copaeneol		✓ (Ballesteros-Vivas et al., 2019)		✓ (Ballesteros-Vivas et al., 2019)		
56.	13-Epimanool		✓ (Ballesteros-Vivas et al., 2019)		✓ (Ballesteros-Vivas et al., 2019)		
57.	16-B_1-PhytoP		✓ (Ballesteros-Vivas et al., 2019)		✓ (Ballesteros-Vivas et al., 2019)		
58.	16α-Methylpregnenolone		✓ (Ballesteros-Vivas et al., 2019)		✓ (Ballesteros-Vivas et al., 2019)		
59.	17,27-Dihydroxylated withaloid D isomer 1		✓ (Ballesteros-Vivas et al., 2019)		✓ (Ballesteros-Vivas et al., 2019)		
60.	2,3-Dihydro-17,27-hydroxylated withanolide D derivative		✓ (Ballesteros-Vivas et al., 2019)		✓ (Ballesteros-Vivas et al., 2019)		
61.	2,3-Dihydro-27-hydroxylated withanolide D isomer 1		✓ (Ballesteros-Vivas et al., 2019)		✓ (Ballesteros-Vivas et al., 2019)		
62.	2,3-Dihydro-27-hydroxylated withanolide D isomer 2		✓ (Ballesteros-Vivas et al., 2019)		✓ (Ballesteros-Vivas et al., 2019)		
63.	2,3-Dihydro-27-hydroxy-4β-hydroxywithanolide E isomer		✓ (Ballesteros-Vivas et al., 2019)		✓ (Ballesteros-Vivas et al., 2019)		
64.	2,3-Dihydro-4β-hydroxywithanolide E		✓ (Ballesteros-Vivas et al., 2019)		✓ (Ballesteros-Vivas et al., 2019)		
65.	2,3-Dihydro-hydroxylated 4β-hydroxywithanolide E derivative		✓ (Ballesteros-Vivas et al., 2019)		✓ (Ballesteros-Vivas et al., 2019)		

66.	2′,4′-Dimethoxy-3-hydroxy-6-methylflavone		✓ (Ballesteros-Vivas et al., 2019)		✓ (Wahdan et al., 2019)		
67.	2′,5′-Dimethoxyflavone		✓ (Wahdan et al., 2019)		✓ (Wahdan et al., 2019)		
68.	27-Hydroxy-4β-hydroxywithanolide E isomer		✓ (Ballesteros-Vivas et al., 2019)		✓ (Ballesteros-Vivas et al., 2019)		
69.	2-Hydroxy-2′,4′,6′-trimethoxychalcone		✓ (Wahdan et al., 2019)		✓ (Wahdan et al., 2019)		
70.	3-(3,4-Dimethoxyphenyl)-6-methyl-4-phenylcoumarin		✓ (Wahdan et al., 2019)		✓ (Wahdan et al., 2019)		
71.	3-(3,4-Dimethoxyphenyl)-7-hydroxy-4-methylcoumarin		✓ (Wahdan et al., 2019)		✓ (Wahdan et al., 2019)		
72.	3,2′,4′,5′,6-Pentamethoxyflavone		✓ (Wahdan et al., 2019)		✓ (Wahdan et al., 2019)		
73.	3,4,5-Methoxy cinnamic		✓ (Abou Baker & Rady, 2020)		✓ (Abou Baker & Rady, 2020)		
74.	3,5,3′,5′-Tetra-*tert*-butyldiphenoquinone		✓ (Wahdan et al., 2019)		✓ (Wahdan et al., 2019)		
75.	3,6,2′,3′-Tetramethoxyflavone				✓ (Wahdan et al., 2019)		
76.	3,6,3′,4′-Tetramethoxyflavone		✓ (Wahdan et al., 2019)		✓ (Wahdan et al., 2019)		
77.	3′-Benzyloxy-5,6,7,4′-tetramethoxyflavone		✓ (Wahdan et al., 2019)		✓ (Wahdan et al., 2019)		
78.	3-Hydroxy-7,8,2′-trimethoxyflavone		✓ (Wahdan et al., 2019)		✓ (Wahdan et al., 2019)		
79.	3-*O*-Caffeoylquinic acid		✓ (Medina et al., 2019)		✓ (Medina et al., 2019)		
80.	3-*O*-Feruloylquinic acid		✓ (Medina et al., 2019)		✓ (Medina et al., 2019)		
81.	3-*O*-*p*-Coumaroylquinic acid		✓ (Medina et al., 2019)		✓ (Medina et al., 2019)		
82.	4,4-Dimethyl-5-α-cholestane-3-one		✓ (Ballesteros-Vivas et al., 2019)		✓ (Ballesteros-Vivas et al., 2019)		

(*Continued*)

TABLE 27.2 (Continued)

	Phytoconstituents	Aerial parts	Calyces	Fruits	Leaves	Roots	Seeds
83.	4-Aminobenzoic acid		✓ (Abou Baker & Rady, 2020)		✓ (Abou Baker & Rady, 2020)		
84.	4-Hydroxy chalcone		✓ (Wahdan et al., 2019)		✓ (Wahdan et al., 2019)		
85.	4-*O*-Feruloylquinic acid		✓ (Medina et al., 2019)		✓ (Medina et al., 2019)		
86.	5-(7a-Isopropenyl-4,5-dimethyl-octahydroinden-4-yl)-3-methyl-pent-2-en-1-ol		✓ (Ballesteros-Vivas et al., 2019)		✓ (Ballesteros-Vivas et al., 2019)		
87.	5,6-Epoxy-β-carotene		✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)			
88.	5-*O*-Caffeoylquinic acid (chlorogenic acid)		✓ (Medina et al., 2019)				
89.	5-*O*-Feruloylquinic acid		✓ (Medina et al., 2019)				
90.	7-Hydroxycoumarin-3-carboxylic acid		✓ (Wahdan et al., 2019)				
91.	7δ-Ergosterol		✓ (Ballesteros-Vivas et al., 2019)				
92.	9-D_{1t}-PhytoP		✓ (Medina et al., 2019)				
93.	9-Epi-9-D_{1t}-PhytoP		✓ (Medina et al., 2019)				
94.	9-Epi-9-F_{1t}-phytoP		✓ (Medina et al., 2019)				
95.	9-F_{1t}-PhytoP		✓ (Medina et al., 2019)				
96.	9-L_1-PhytoP		✓ (Medina et al., 2019)				
97.	Acecetin		✓ (Abou Baker & Rady, 2020)				
98.	Ambrial		✓ (Ballesteros-Vivas et al., 2019)				
99.	Apg 6 arabinose 8 glucose		✓ (Abou Baker & Rady, 2020)				

100.	Apg 6 glucose 8 rhamnose		✓ (Abou Baker & Rady, 2020)				
101.	Apg 6 rhamnose 8 glucose		✓ (Abou Baker & Rady, 2020)				
102.	Apig-7-*O*-neohespiroside		✓ (Abou Baker & Rady, 2020)				
103.	Apigenin		✓ (Abou Baker & Rady, 2020)				
104.	Apigenin 7 glucose		✓ (Abou Baker & Rady, 2020)	✓ (Abou Baker & Rady, 2020)			
105.	Benzoic acid		✓ (Ballesteros-Vivas et al., 2019)	✓ (Etzbach et al., 2018)			
106.	Biotin		✓ (Wahdan et al., 2019)				
107.	Caffeic acid		✓ (Ballesteros-Vivas et al., 2019)	✓ (Al-Olayan et al., 2014)			✓ (Darwish & Shaker, 2021)
108.	Caffeine		✓ (Abou Baker & Rady, 2020)	✓ (El-Beltagi et al., 2019)			
109.	Catechol		✓ (Abou Baker & Rady, 2020)	✓(El-Beltagi et al., 2019)			
110.	Chlorogenic acid		✓ (Abou Baker & Rady, 2020)				
111.	Chlorophyll *a*		✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)			
112.	Chlorophyll *a* derivative		✓ (Etzbach et al., 2018)				
113.	Chlorophyll *b*		✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)			
114.	Chlorophyll *b* derivative 2		✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)			
115.	Cinnamic acid		✓ (Abou Baker & Rady, 2020)	✓ (El-Beltagi et al., 2019; Etzbach et al., 2018)			
116.	Coniferol		✓ (Ballesteros-Vivas et al., 2019)				
117.	Copalol isomer 1		✓ (Ballesteros-Vivas et al., 2019)				

(*Continued*)

TABLE 27.2 (Continued)

	Phytoconstituents	Aerial parts	Calyces	Fruits	Leaves	Roots	Seeds
118.	Copalol isomer 2		✓ (Ballesteros-Vivas et al., 2019)				
119.	Copalol isomer 3		✓ (Ballesteros-Vivas et al., 2019)				
120.	Coumarin		✓ (Abou Baker & Rady, 2020)				
121.	Cryptomeridiol		✓ (Ballesteros-Vivas et al., 2019)				
122.	Diepicedrene-1-oxide		✓ (Ballesteros-Vivas et al., 2019)				
123.	Dihydro-4β-hydroxywithanolide E		✓ (Ballesteros-Vivas et al., 2019)				
124.	Dihydromanoyl oxide 1		✓ (Ballesteros-Vivas et al., 2019)				
125.	Dihydromanoyl oxide 2		✓ (Ballesteros-Vivas et al., 2019)				
126.	Dihydromanoyl oxide 3		✓ (Ballesteros-Vivas et al., 2019)				
127.	Dihydromanoyl oxide 4		✓ (Ballesteros-Vivas et al., 2019)				
128.	Dihydromanoyloxide-7-carboxylic acid methyl ester		✓ (Ballesteros-Vivas et al., 2019)				
129.	Di-*O*-isobutanoyl-*O*-(2-methylbutanoyl)-*O*-pentenoylsucrose		✓ (Ballesteros-Vivas et al., 2019)				
130.	Di-*O*-isobutanoylsucrose		✓ (Ballesteros-Vivas et al., 2019)				
131.	Di-*O*-isobutanoyl-*O*-nonanoylsucrose		✓ (Ballesteros-Vivas et al., 2019)				
132.	Di-*O*-isobutanoyl-*O*-decanoylsucrose		✓ (Ballesteros-Vivas et al., 2019)				
133.	Di-*O*-isobutanoyl-*O*-octanoylsucrose		✓ (Ballesteros-Vivas et al., 2019)				
134.	Di-*O*-isobutanoyl-*O*-pentenoylsucrose		✓ (Ballesteros-Vivas et al., 2019)				

135.	Ellagic acid		✓ (Abou Baker & Rady, 2020)					
136.	Ent-16-B1-phytoP		✓ (Medina et al., 2019)					
137.	Ent-9-L1-phytoP		✓ (Medina et al., 2019)					
138.	Ent-16-epi-16-F1t-phytoP		✓ (Medina et al., 2019)					
139.	Ent-16-F1t-phytoP		✓ (Medina et al., 2019)					
140.	Epicatechin		✓ (Abou Baker & Rady, 2020)	✓ (Mier-Giraldo et al., 2017)				
141.	Epimanoyl oxide		✓ (Ballesteros-Vivas et al., 2019)					
142.	Eudesmadienol		✓ (Ballesteros-Vivas et al., 2019)					
143.	Farnesol acetate		✓ (Ballesteros-Vivas et al., 2019)					
144.	Ferulic acid-hexoside		✓ (Medina et al., 2019)					
145.	Feruloylquinic acid		✓ (Medina et al., 2019)					
146.	Friedelan-3-one		✓ (Ballesteros-Vivas et al., 2019)					
147.	Ferulic acid		✓ (Ballesteros-Vivas et al., 2019)	✓ (Al-Olayan et al., 2014; Darwish & Shaker, 2021)				
148.	Gallic acid		✓ (Ballesteros-Vivas et al., 2019)	✓ (El-Beltagi et al., 2019; Mier-Giraldo et al., 2017)				
149.	Gardenin		✓ (Wahdan et al., 2019)					
150.	Germacratrienol isomer 1		✓ (Ballesteros-Vivas et al., 2019)					
151.	Germacratrienol isomer 2		✓ (Ballesteros-Vivas et al., 2019)					

(*Continued*)

TABLE 27.2 (Continued)

	Phytoconstituents	Aerial parts	Calyces	Fruits	Leaves	Roots	Seeds
152.	Germacratrienol isomer 3		✓ (Ballesteros-Vivas et al., 2019)				
153.	Hesperetin		✓ (Abou Baker & Rady, 2020)				
154.	Hydroxylated 4β-hydroxywithanolide E derivative		✓ (Ballesteros-Vivas et al., 2019)				
155.	Isoaromadendrene epoxide		✓ (Ballesteros-Vivas et al., 2019)				
156.	Isoferulic acid		✓ (Abou Baker & Rady, 2020)				
157.	Isorhamnetin		✓ (Ballesteros-Vivas et al., 2019)				
158.	Isovitexin		✓ (Wahdan et al., 2019)				
159.	Kaempferol		✓ (Ballesteros-Vivas et al., 2019)	✓ (Al-Olayan et al., 2014; El-Beltagi et al., 2019)			
160.	Kaempferol-3-*O*-rhamnosyl (1⟶6)glucoside		✓ (Medina et al., 2019)				
161.	Kaempferol-3-*O*-rhamnosyl (1⟶6)glucoside-7-*O*-glucoside		✓ (Medina et al., 2019)				
162.	Kaempferol-hexoside		✓ (Ballesteros-Vivas et al., 2019)				
163.	Kaempferol-rutinoside		✓ (Ballesteros-Vivas et al., 2019)				
164.	Kamp3(2-*p*-manryl)glucose		✓ (Abou Baker & Rady, 2020)				
165.	Kamp3−7 di-rhamnoside		✓ (Abou Baker & Rady, 2020)				
166.	Khusiol		✓ (Ballesteros-Vivas et al., 2019)				
167.	Limonene		✓ (Ballesteros-Vivas et al., 2019)	✓ (Ballesteros-Vivas et al., 2019)			

168.	Luteo 6 glucose 8 arabinose		✓ (Abou Baker & Rady, 2020)				
169.	Luteo 7 glucose		✓ (Abou Baker & Rady, 2020)				
170.	Maalialcohol		✓ (Ballesteros-Vivas et al., 2019)				
171.	Methyl-3,7-bis(acetyloxy) cholestan-26-oate		✓ (Ballesteros-Vivas et al., 2019)				
172.	Methylprednisolone succinate		✓ (Wahdan et al., 2019)				
173.	Myricetin		✓ (Ballesteros-Vivas et al., 2019)				
174.	Naringin		✓ (Abou Baker & Rady, 2020)				
175.	Naringenin		✓ (Abou Baker & Rady, 2020)	✓ (El-Beltagi et al., 2019)			
176.	*O*-Butanoyl-di-*O*-isobutanoylsucrose		✓ (Ballesteros-Vivas et al., 2019)				
177.	*O*-Decanoyl-*O*-isobutanoylsucrose		✓ (Ballesteros-Vivas et al., 2019)				
178.	*O*-Isobutanoyl-*O*-(2-methylbutanoyl)-*O*-octanoylsucrose		✓ (Ballesteros-Vivas et al., 2019)				
179.	*O*-Isobutanoyl-*O*-(2-methylbutanoyl)-*O*-pentenoylsucrose		✓ (Ballesteros-Vivas et al., 2019)				
180.	*O*-Isobutanoyl-*O*-(2-methylbutanoyl)sucrose		✓ (Ballesteros-Vivas et al., 2019)				
181.	*O*-Isobutanoyl-*O*-octenoylsucrose		✓ (Ballesteros-Vivas et al., 2019)				
182.	*O*-Isobutanoylsucrose		✓ (Ballesteros-Vivas et al., 2019)				
183.	*p*-Coumaric acid		✓ (Abou Baker & Rady, 2020; Ballesteros-Vivas et al., 2019)				
184.	Pheophytin a		✓ (Etzbach et al., 2018)				

(*Continued*)

TABLE 27.2 (Continued)

	Phytoconstituents	Aerial parts	Calyces	Fruits	Leaves	Roots	Seeds
185.	*p*-Hydroxy benzoic acid		✓ (Abou Baker & Rady, 2020)	✓(El-Beltagi et al., 2019)			
186.	Phytoene		✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)			
187.	Phytol		✓ (Ballesteros-Vivas et al., 2019)		✓ (Peter et al., 2020; Ramadan & Mörsel, 2003)		
188.	Protocatechuic acid		✓ (Abou Baker & Rady, 2020; Ballesteros-Vivas et al., 2019)				
189.	Pyrogallol		✓ (Abou Baker & Rady, 2020)				
190.	Quercetin		✓ (Ballesteros-Vivas et al., 2019)				
191.	Quercetin-3-*O*-glucoside		✓ (Medina et al., 2019)				
192.	Quercetin-3-*O*-rhamnosyl (1⟶6)glucoside-7-*O*-glucoside		✓ (Medina et al., 2019)				
193.	Quercetin-hexoside		✓ (Ballesteros-Vivas et al., 2019)				
194.	Quercetrin		✓ (Abou Baker & Rady, 2020)				
195.	Rhamncetin		✓ (Abou Baker & Rady, 2020)				
196.	Rosmarinic acid		✓ (Abou Baker & Rady, 2020)				
197.	Quercetin-3-*O*-rutinoside		✓ (Ballesteros-Vivas et al., 2019; S. Medina et al., 2019)				
198.	Salicylic acid		✓ (Abou Baker & Rady, 2020)	✓ (El-Beltagi et al., 2019)			
199.	Sclareol		✓ (Ballesteros-Vivas et al., 2019)				

200.	Sclareol oxide		✓ (Ballesteros-Vivas et al., 2019)				
201.	Sesquichamene		✓ (Ballesteros-Vivas et al., 2019)				
202.	Sesquiterpeneol isomer		✓ (Ballesteros-Vivas et al., 2019)				
203.	Spironolactone		✓ (Wahdan et al., 2019)				
204.	*trans*-Geranylgeraniol		✓ (Ballesteros-Vivas et al., 2019)				
205.	Tyrosol		✓ (Ballesteros-Vivas et al., 2019)				
206.	Vanillic acid		✓ (Ballesteros-Vivas et al., 2019)	✓ (Ballesteros-Vivas et al., 2019)			
207.	Vanillin		✓ (Ballesteros-Vivas et al., 2019)	✓ (Ballesteros-Vivas et al., 2019)			
208.	Vitexin		✓ (Ballesteros-Vivas et al., 2019)				
209.	Withanolide D isomer		✓ (Ballesteros-Vivas et al., 2019)				
210.	Withanolide E isomer 1		✓ (Ballesteros-Vivas et al., 2019)				
211.	Withanolide E isomer 2		✓ (Ballesteros-Vivas et al., 2019)				
212.	Withanolide E isomer 3		✓ (Ballesteros-Vivas et al., 2019)				
213.	Xanthine		✓ (Wahdan et al., 2019)				
214.	α-13,13-Dimethylpodocarp-7-en-3□-ol		✓ (Ballesteros-Vivas et al., 2019)				
215.	α-Coumaric acid		✓ (Abou Baker & Rady, 2020)				
216.	α-Elemol		✓ (Ballesteros-Vivas et al., 2019)				
217.	α-Tocopherol		✓ (Ballesteros-Vivas et al., 2019)	✓ (Ballesteros-Vivas et al., 2019)			

(*Continued*)

TABLE 27.2 (Continued)

	Phytoconstituents	Aerial parts	Calyces	Fruits	Leaves	Roots	Seeds
218.	α-Tocopherol-β-D-mannoside		✓ (Ballesteros-Vivas et al., 2019)				
219.	β-Sitosterol		✓ (Ballesteros-Vivas et al., 2019)	✓ (Ramadan & Moersel, 2007; Ramadan & Mörsel, 2003)			
220.	β-Tocopherol		✓ (Ballesteros-Vivas et al., 2019)	✓ (Ramadan & Moersel, 2007; Ramadan & Mörsel, 2003)			
221.	δ-Cadinol		✓ (Ballesteros-Vivas et al., 2019)				
222.	δ-Terpineol		✓ (Ballesteros-Vivas et al., 2019)				
223.	δ-Tocopherol		✓ (Ballesteros-Vivas et al., 2019)				
224.	(−)-Caryophyllene oxide			✓ (Yilmaztekin, 2014)			
225.	(5a′)-Pregnane-3,20a′-diol			✓ (Al-Olayan et al., 2014)			
226.	(9*Z*)-β-Carotene			✓ (Etzbach et al., 2018)			
227.	(all-*E*)-Antheraxanthin myristate-palmitate			✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)		
228.	(all-*E*)-Lutein 3′-*O*-palmitate			✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)		
229.	(all-*E*)-Lutein 3-*O*-palmitate-3′-*O*-myristate			✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)		
230.	(all-*E*)-Lutein dimyristate			✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)		
231.	(all-*E*)-Lutein dipalmitate			✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)		
232.	(all-*E*)-Neoxanthin dipalmitate			✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)		
233.	(all-*E*)-Neoxanthin myristate			✓ (Etzbach et al., 2018)			
234.	(all-*E*)-Violaxanthin dimyristate			✓ (Etzbach et al., 2018)			

235.	(all-*E*)-Violaxanthin dipalmitate			✓ (Etzbach et al., 2018)			
236.	(all-*E*)-Violaxanthin myristate-palmitate			✓ (Etzbach et al., 2018)			
237.	(all-*E*)-Zeaxanthin dimyristate			✓ (Etzbach et al., 2018)			
238.	(all-*E*)-Zeaxanthin dipalmitate			✓ (Etzbach et al., 2018)			
239.	(all-*E*)-Zeaxanthin myristate-palmitate			✓ (Etzbach et al., 2018)			
240.	(all-*E*)-Zeinoxanthin			✓ (Etzbach et al., 2018)			
241.	(all-*E*)-α-Cryptoxanthin			✓ (Etzbach et al., 2018)			
242.	Palmitate			✓ (Etzbach et al., 2018)			
243.	(*E*)-2-Hexenol			✓ (Mayorga et al., 2001)			
244.	(*E*)-Non-2-enal			✓ (Majcher et al., 2020)			
245.	(*E*2,*Z*6)-Nona-2,6-dienal			✓ (Majcher et al., 2020)			
246.	(*Z*)-Neoxanthin- or (*Z*)-violaxanthin ester			✓ (Etzbach et al., 2018)			
247.	(*Z*)-Stigmasta-5,24(28)-dien-3β-ol			✓ (Majcher et al., 2020)			
248.	(*Z*)-*c*-Carotene			✓ (Etzbach et al., 2018)			
249.	Δ5-Avenasterol			✓ (Ramadan & Moersel, 2007; Ramadan & Mörsel, 2003)			
250.	Δ7-Avenasterol			✓ (Ramadan & Moersel, 2007; Ramadan & Mörsel, 2003)			
251.	(all-*E*)-Violaxanthin myristate-palmitate			✓ (Etzbach et al., 2018)			
252.	✓ (Etzbach et al., 2018)			✓ (Etzbach et al., 2018)			
253.	5,8-Epoxy-α-carotene			✓ (Etzbach et al., 2018)			
254.	Campesterol			✓ (Ramadan & Moersel, 2007; Ramadan & Mörsel, 2003)	✓ (Peter et al., 2020)		
255.	Decanoic acid			✓ (Ertürk et al., 2017)			

(*Continued*)

TABLE 27.2 (Continued)

	Phytoconstituents	Aerial parts	Calyces	Fruits	Leaves	Roots	Seeds
256.	Eicosanoic acid			✓ (Ertürk et al., 2017)			
257.	Eicosenoic acid			✓ (Ertürk et al., 2017)			
258.	Erucic acid			✓ (Ertürk et al., 2017)			
259.	Ergosterol			✓ (Ertürk et al., 2017)			
260.	Hexadecanoic acid			✓ (Medina et al., 2019)	✓ (Peter et al., 2020)		
261.	Homo-c-linolenic acid			✓ (Ramadan & Moersel, 2007)			
262.	Lanosterol			✓ (Ramadan & Moersel, 2007; Ramadan & Mörsel, 2003)			
263.	Linoleic acid			✓ (Ramadan & Moersel, 2007; Ramadan & Mörsel, 2003)	✓ (Peter et al., 2020)		
264.	Lutein ester			✓ (Etzbach et al., 2018)			
265.	Nervonic acid			✓ (Ramadan & Moersel, 2007; Ramadan & Mörsel, 2003)			
266.	Octadecanoic acid						
267.	Oleic acid			✓ (Ramadan & Moersel, 2007; Ramadan & Mörsel, 2003)			
268.	Palmitoleic acid			✓ (Ramadan & Moersel, 2007; Ramadan & Mörsel, 2003)			
269.	Stigmasterol			✓ (Peter et al., 2020)	✓ (Peter et al., 2020)		
270.	Tetradecanoic acid			✓ (Ramadan & Moersel, 2007; Ramadan & Mörsel, 2003)			
271.	Tetracosanoic acid			✓ (Ramadan & Moersel, 2007; Ramadan & Mörsel, 2003)			
272.	α-Linolenic acid			✓ (Medina et al., 2019)			

273.	β-Carotene			✓ (Ramadan & Moersel, 2007; Ramadan & Mörsel, 2003)			
274.	1,25-Dihydroxyvitamin D2			✓ (Ramadan & Moersel, 2007; Ramadan & Mörsel, 2003)			
275.	1,8-Menthadien-4-ol			✓ (Yilmaztekin, 2014)			
276.	1-Phenyl-1,2-propanediol			✓(Mayorga et al., 2001)			
277.	2,3-Diethyl-5-methyl pyrazine			✓ (Ramadan et al., 2015)			
278.	2,3-Dimethyl-1-butanol			✓ (Yilmaztekin, 2014)			
279.	2-Acetyl-1-pyrroline			✓ (Majcher et al., 2020)			
280.	2-Butanone			✓ (Yilmaztekin, 2014)			
281.	2-Heptanol			✓(Mayorga et al., 2001)			
282.	2-Heptanone			✓ (Yilmaztekin, 2014)			
283.	2-Methylbutanal			✓ (Yilmaztekin, 2014)			
284.	2-Methylbutanol			✓ (Yilmaztekin, 2014)			
285.	2-Methylbutanoic acid			✓(Mayorga et al., 2001)			
286.	2-Methylbutyl acetate			✓ (Yilmaztekin, 2014)			
287.	2-Methylpropanol			✓ (Mayorga et al., 2001)			
288.	2-Methylpropanoic acid			✓(Mayorga et al., 2001)			
289.	2-Methylpropanal			✓ (Majcher et al., 2020)			
290.	2-Methylpropenal			✓ (Yilmaztekin, 2014)			
291.	2-Nonadecanol			✓ (Yilmaztekin, 2014)			
292.	2-Norbornanone			✓ (Yilmaztekin, 2014)			
293.	2-Pentanone			✓ (Yilmaztekin, 2014)			
294.	2-Phenyl ethyl alcohol			✓ (Al-Olayan et al., 2014)			
295.	2-Phenylethanol			✓ (Majcher et al., 2020; Mayorga et al., 2001)			
296.	2-Phenylacetaldehyde			✓ (Majcher et al., 2020)			
297.	2-Propanone			✓ (Yilmaztekin, 2014)			

(*Continued*)

TABLE 27.2 (Continued)

	Phytoconstituents	Aerial parts	Calyces	Fruits	Leaves	Roots	Seeds
298.	2-Undecenal			✓ (Ramadan et al., 2015)			
299.	3,4-Dimethylbenzoic acid			✓ (Ertürk et al., 2017)			
300.	3,5-Octadienone			✓ (Ramadan et al., 2015)			
301.	3,7-Dimethyl-1-octene			✓ (Yilmaztekin, 2014)			
302.	3-Ethyl-4-heptanol			✓ (Yilmaztekin, 2014)			
303.	3-Hydroxy-2-butanone			✓ (Mayorga et al., 2001)			
304.	3-Methyl-1-hexanol			✓ (Yilmaztekin, 2014)			
305.	3-Methyl-1-penten-3-ol			✓ (Dymerski et al., 2016)			
306.	3-Methyl-3-vinyl-1-cyclopropene			✓ (Dymerski et al., 2016)			
307.	3-Methyl butyl butanoate			✓ (Yilmaztekin, 2014)			
308.	3-Octenol			✓ (Yilmaztekin, 2014)			
309.	3 Oxo-7,8-dihydro-α-ionol			✓ (Majcher et al., 2020)			
310.	3-Phenyl propanol			✓ (Yilmaztekin, 2014)			
311.	4-Hydroxy butyl acrylate			✓ (Ramadan et al., 2015)			
312.	4-Isopropyl-1-methyl-2-cyclohexen-1-ol			✓ (Yilmaztekin, 2014)			
313.	4-Methyl-1-pentanol			✓ (Yilmaztekin, 2014)			
314.	4-Nonanone			✓ (Yilmaztekin, 2014)			
315.	4-Octanol			✓ (Yilmaztekin, 2014)			
316.	4-Propyl guaiacol			✓ (Ramadan et al., 2015)			
317.	4-Terpineol			✓ (Yilmaztekin, 2014)			
318.	4-Vinylguaiacol			✓ (Mayorga et al., 2001)			
319.	4-Vinylphenol			✓ (Mayorga et al., 2001)			
320.	4-Vinylsyringol			✓(Mayorga et al., 2001)			
321.	4β-Hydroxywithanolide E			✓ (Ramadan et al., 2015)			

322.	5,8-Epoxy-α-carotene			✓ (Etzbach et al., 2018)			
323.	6-Methyl-2-heptanone			✓ (Yilmaztekin, 2014)			
324.	6-Methyl-5-heptene-2-one			✓ (Dymerski et al., 2016)			
325.	6-Methyl-hept-5-en-2-ol			✓ (Yilmaztekin, 2014)			
326.	9-(*Z*)-Octadecenoic acid			✓ (Mayorga et al., 2001)			
327.	Acetaldehyde			✓ (Yilmaztekin, 2014)			
328.	Acetic acid			✓(Mayorga et al., 2001)			
329.	Allyl caproate			✓ (Ramadan et al., 2015)			
330.	Apigenin			✓ (El-Beltagi et al., 2019)			
331.	Benzaldehyde			✓ (Yilmaztekin, 2014)			
332.	Benzyl acetate			✓ (Ramadan et al., 2015)			
333.	Benzyl alcohol			✓ (Yilmaztekin, 2014)			
334.	Betulin			✓ (Al-Olayan et al., 2014)			
335.	Butanal			✓ (Yilmaztekin, 2014)			
336.	Butane-2,3-dione			✓ (Yilmaztekin, 2014)			
337.	Butanoic acid			✓ (Yilmaztekin, 2014)			
338.	Butanol			✓ (Yilmaztekin, 2014)			
339.	Butanol-2-methyl			✓ (Ramadan et al., 2015)			
340.	Butyl 3-hydroxybutyrate			✓ (Dymerski et al., 2016)			
341.	Butyl acetate			✓ (Dymerski et al., 2016; Yilmaztekin, 2014)			
342.	Butyl butanoate			✓ (Yilmaztekin, 2014)			
343.	Butyl decanoate			✓ (Yilmaztekin, 2014)			
344.	Butyl dodecanoate			✓ (Yilmaztekin, 2014)			
345.	Butyl octanoate			✓ (Yilmaztekin, 2014)			

(*Continued*)

TABLE 27.2 (Continued)

	Phytoconstituents	Aerial parts	Calyces	Fruits	Leaves	Roots	Seeds
346.	Butyl-3-hydroxybutanoate			✓ (Yilmaztekin, 2014)			
347.	Camphene			✓ (Yilmaztekin, 2014)			
348.	Capric acid, methyl ester			✓ (Dymerski et al., 2016)			
349.	Carvacrol			✓ (Yilmaztekin, 2014)			
350.	Caryophyllene oxide			✓ (Dymerski et al., 2016)			
351.	Catechin			✓ (Mier-Giraldo et al., 2017)			
352.	Cedr-8-en-9-alpha-ol acetate			✓ (Ramadan et al., 2015)			
353.	Cedrenol			✓ (Ramadan et al., 2015)			
354.	Chlorophyll *b* derivative 1			✓ (Etzbach et al., 2018)			
355.	*cis*-3-Hexenol			✓ (Yilmaztekin, 2014)			
356.	*cis*-Myrtanol			✓ (Yilmaztekin, 2014)			
357.	*cis*-Piperitone oxide			✓ (Yilmaztekin, 2014)			
358.	*cis*-*p*-Mentha-1(7),8-dien-2-ol			✓ (Yilmaztekin, 2014)			
359.	*cis*-Verbenol			✓ (Yilmaztekin, 2014)			
360.	Citronellyl acetate			✓ (Ramadan et al., 2015)			
361.	Cyclooctatetraene			✓ (Yilmaztekin, 2014)			
362.	Cyclosativene			✓ (Ramadan et al., 2015)			
363.	Cymenene			✓ (Yilmaztekin, 2014)			
364.	Decanal			✓ (Yilmaztekin, 2014)			
365.	Decanoic acid			✓ (Yilmaztekin, 2014)			
366.	Dehydrosabinene			✓ (Yilmaztekin, 2014)			
367.	Diethylene glycol			✓ (Darwish & Shaker, 2021)			

368.	Dihomo-c-linolenic acid			✓ (Ramadan & Mörsel, 2003)			
369.	Dihydroactinidiolide			✓ (Yilmaztekin, 2014)			
370.	Dihydrocarveol			✓ (Ramadan et al., 2015)			
371.	Dimethylvinylcarbinol			✓ (Yilmaztekin, 2014)			
372.	Docosanoic acid			✓ (Rodrigues et al., 2009)			
373.	Dodecane			✓ (Dymerski et al., 2016)			
374.	Dodecanoic acid, methyl ester			✓ (Dymerski et al., 2016)			
375.	Endo-borneol			✓ (Yilmaztekin, 2014)			
376.	Ethanol			✓ (Yilmaztekin, 2014)			
377.	Ethyl 2-methyl propanoate			✓ (Majcher et al., 2020)			
378.	Ethyl acetate			✓ (Yilmaztekin, 2014)			
379.	Ethyl benzoate			✓ (Al-Olayan et al., 2014)			
380.	Ethyl butanoate			✓ (Yilmaztekin, 2014)			
381.	Ethyl caprate			✓ (Dymerski et al., 2016)			
382.	Ethyl caproate			✓ (Dymerski et al., 2016)			
383.	Ethyl decanoate			✓ (Yilmaztekin, 2014)			
384.	Ethyl dodecanoate			✓ (Yilmaztekin, 2014)			
385.	Ethyl hexanoate			✓ (Yilmaztekin, 2014)			
386.	Ethyl hexanol			✓ (Yilmaztekin, 2014)			
387.	Ethyl hydroxyl hexanoate			✓ (Dymerski et al., 2016)			
388.	Ethyl octanoate			✓ (Majcher et al., 2020; Yilmaztekin, 2014; Ramadan et al., 2015)			
389.	Ethyl pentanoate			✓ (Yilmaztekin, 2014)			
390.	Ethyl-2-butenoate			✓ (Yilmaztekin, 2014)			

(*Continued*)

TABLE 27.2 (Continued)

	Phytoconstituents	Aerial parts	Calyces	Fruits	Leaves	Roots	Seeds
391.	Ethyl-3-hydroxybutanoate			✓ (Mayorga et al., 2001)			
392.	Ethyl-3-hydroxyhexanoate			✓ (Mayorga et al., 2001)			
393.	Ethyl-3-hydroxyoctanoate			✓(Mayorga et al., 2001)			
394.	Ethyl-5-hydroxyoctanoate			✓ (Mayorga et al., 2001)			
395.	Eucalyptol			✓ (Yilmaztekin, 2014)			
396.	Farnesol			✓ (Yilmaztekin, 2014)			
397.	Fenchol			✓ (Yilmaztekin, 2014)			
398.	Furaneol			✓ (Majcher et al., 2020)			
399.	Geranaldehyde			✓ (Yilmaztekin, 2014)			
400.	Geraniol			✓ (Yilmaztekin, 2014)			
401.	Geranoic acid			✓ (Mayorga et al., 2001)			
402.	Geranyl acetone			✓ (Yilmaztekin, 2014)			
403.	Guaiacol			✓(Mayorga et al., 2001)			
404.	Heptan-2-ol			✓ (Yilmaztekin, 2014)			
405.	Heptanal			✓ (Yilmaztekin, 2014)			
406.	Heptanol			✓ (Yilmaztekin, 2014)			
407.	Hexadecanoic acid ester			✓ (Ramadan et al., 2015)			
408.	Hexanal			✓ (Majcher et al., 2020; Yilmaztekin, 2014; Dymerski et al., 2016)			
409.	Hexanoic acid			✓ (Mayorga et al., 2001; Yilmaztekin, 2014)			
410.	Hexanol			✓ (Yilmaztekin, 2014)			
411.	Hexyl butanoate			✓ (Yilmaztekin, 2014)			
412.	Hexyl ethanoate			✓ (Yilmaztekin, 2014)			
413.	Hexyl octanoate			✓ (Yilmaztekin, 2014)			
414.	Homofuraneol			✓ (Ramadan et al., 2015)			
415.	Hydrocinnamic alcohol			✓ (Yilmaztekin, 2014)			

416.	Isoamyl octanoate			✓ (Yilmaztekin, 2014)			
417.	Isobutyl acetate			✓ (Yilmaztekin, 2014)			
418.	Isobutyl alcohol			✓ (Yilmaztekin, 2014)			
419.	Isobutyl butanoate			✓ (Yilmaztekin, 2014)			
420.	Isobutyl decanoate			✓ (Yilmaztekin, 2014)			
421.	Isobutyl dodecanoate			✓ (Yilmaztekin, 2014)			
422.	Isobutyl octanoate			✓ (Yilmaztekin, 2014)			
423.	Isoeugenol			✓ (Ramadan et al., 2015)			
424.	Isophorone			✓ (Yilmaztekin, 2014)			
425.	Isopropenyl ethyl ketone			✓ (Yilmaztekin, 2014)			
426.	Isopulegol			✓ (Yilmaztekin, 2014)			
427.	Kaempferol 3-*O*-rutinoside			✓ (Al-Olayan et al., 2014)			
428.	Linalool			✓ (Yilmaztekin, 2014)			
429.	Linalool oxide			✓ (Yilmaztekin, 2014)			
430.	Lucenin-2			✓ (Al-Olayan et al., 2014)			
431.	Methional			✓ (Majcher et al., 2020)			
432.	Methyl acetate			✓ (Yilmaztekin, 2014)			
433.	Methyl benzoate			✓ (Dymerski et al., 2016)			
434.	Methyl butanoate			✓ (Yilmaztekin, 2014)			
435.	Methyl butene			✓ (Ramadan et al., 2015)			
436.	Methyl decanoate			✓ (Yilmaztekin, 2014)			
437.	Methyl heptenone			✓ (Yilmaztekin, 2014)			
438.	Methyl hexanoate			✓ (Yilmaztekin, 2014)			
439.	Methyl octanoate			✓ (Yilmaztekin, 2014)			
440.	Methyl salicylate			✓ (Yilmaztekin, 2014)			
441.	Methyl ß-methylcrotonate			✓ (Dymerski et al., 2016)			

(*Continued*)

TABLE 27.2 (Continued)

	Phytoconstituents	Aerial parts	Calyces	Fruits	Leaves	Roots	Seeds
442.	Methyl-11-cyclopentylundecanoate			✓ (Yilmaztekin, 2014)			
443.	Methyl-2-methoxyoct-2-enoate			✓ (Dymerski et al., 2016)			
444.	Methyl-3-hydroxybutanoate			✓ (Mayorga et al., 2001)			
445.	Myrcenol			✓ (Yilmaztekin, 2014)			
446.	Neric acid			✓ (Yilmaztekin, 2014)			
447.	Neryl acetate			✓ (Ramadan et al., 2015)			
448.	Nonanal			✓ (Yilmaztekin, 2014)			
449.	Nonanoic acid			✓ (Yilmaztekin, 2014)			
450.	Nonanol			✓ (Ramadan et al., 2015)			
451.	Nopol			✓ (Yilmaztekin, 2014)			
452.	*O*-Coumaric acid			✓ (El-Beltagi et al., 2019)			
453.	Oct-1-en-3-ol			✓ (Majcher et al., 2020)			
454.	Octadecanoic acid			✓ (Ramadan & Moersel, 2007; Ramadan & Mörsel, 2003)			✓ (Darwish & Shaker, 2021)
455.	Octanal			✓ (Yilmaztekin, 2014)			
456.	Octanoic acid			✓ (Yilmaztekin, 2014)			
457.	Octanoic acid, 3-methylbutyl ester			✓ (Dymerski et al., 2016)			
458.	Octanol			✓ (Yilmaztekin, 2014)			
459.	*p*-Anisaldehyde			✓ (Ramadan et al., 2015)			
460.	*p*-Cymen-8-ol			✓ (Yilmaztekin, 2014)			
461.	*p*-Cymene			✓ (Yilmaztekin, 2014)			
462.	Pentyl alcohol			✓ (Dymerski et al., 2016)			
463.	Phenethyl alcohol			✓ (Yilmaztekin, 2014)			

464.	Phenol			✓ (Mayorga et al., 2001)			
465.	Phenyl ethyl benzoate			✓ (Ramadan et al., 2015)			
466.	Phenyl ethyl acetate			✓ (Yilmaztekin, 2014)			
467.	Pheophytin *b*			✓ (Etzbach et al., 2018)			
468.	*p*-Menth-4(8)-ene-1,2-diol			✓(Mayorga et al., 2001)			
469.	Propyl decanoate			✓ (Yilmaztekin, 2014)			
470.	Propyl hexanoate			✓ (Ramadan et al., 2015)			
471.	Propyl octanoate			✓ (Yilmaztekin, 2014)			
472.	Quercetin 3,4′,7-trimethyl ether			✓ (Al-Olayan et al., 2014)			
473.	Rosoxide			✓ (Yilmaztekin, 2014)			
474.	*sec*-Butyl butyrate			✓ (Yilmaztekin, 2014)			
475.	Syringic acid			✓ (El-Beltagi et al., 2019)			
476.	Terpinen-4-ol			✓ (Dymerski et al., 2016)			
477.	Terpinolene			✓ (Dymerski et al., 2016)			
478.	*trans*-3-Hexenol			✓ (Yilmaztekin, 2014)			
479.	*trans*-Citral			✓ (Yilmaztekin, 2014)			
480.	Trimethyl phenyl butenone			✓ (Ramadan et al., 2015)			
481.	Verbenene			✓ (Yilmaztekin, 2014)			
482.	Verbenone			✓ (Yilmaztekin, 2014)			
483.	Vitamin B9 (folic acid)			✓ (Al-Olayan et al., 2014)			
484.	Vitamin E			✓ (Peter et al., 2021; Peter et al., 2020; Ramadan & Mörsel, 2003)	✓ (Peter et al., 2021)		
485.	Vitamin K_1			✓ (Ramadan & Mörsel, 2003)			

(*Continued*)

TABLE 27.2 (Continued)

	Phytoconstituents	Aerial parts	Calyces	Fruits	Leaves	Roots	Seeds
486.	α-Cubebene			✓ (Al-Olayan et al., 2014)			
487.	α-Linolenic acid			✓ (Yilmaztekin, 2014)			
488.	α-Pinene			✓ (Yilmaztekin, 2014)			
489.	α-Terpinene			✓ (Yilmaztekin, 2014)			
490.	α-Terpineol			✓ (Yilmaztekin, 2014)			
491.	α-Terpinolene			✓ (Yilmaztekin, 2014)			
492.	β-Bisabolol			✓ (Al-Olayan et al., 2014)			
493.	β-Citronellol			✓ (Yilmaztekin, 2014)			
494.	β-Cyclocitral			✓ (Yilmaztekin, 2014)			
495.	β-Ionone			✓ (Yilmaztekin, 2014)			
496.	β-Ionone-5,6-epoxide			✓ (Yilmaztekin, 2014)			
497.	β-Linalool			✓ (Majcher et al., 2020)			
498.	β-Myrcene			✓ (Yilmaztekin, 2014)			
499.	β-*trans*-Ocimene			✓ (Yilmaztekin, 2014)			
500.	*c*-Butyl-*c*-butyrolactone			✓ (Dymerski et al., 2016)			
501.	*c*-Caprolactone			✓ (Dymerski et al., 2016)			
502.	*c*-Ethylbutyrolactone			✓ (Yilmaztekin, 2014)			
503.	*c*-Linoleic acid			✓ (Ramadan & Moersel, 2007)			
504.	*c*-Octalactone			✓ (Mayorga et al., 2001; Ramadan et al., 2015)			
505.	*c*-Terpinene			✓ (Dymerski et al., 2016; Yilmaztekin, 2014)			
506.	*c*-Tocopherol			✓ (Ramadan & Moersel, 2007)			
507.	*c*-Undecalactone			✓ (Yilmaztekin, 2014)			

508.	δ-Muurolene			✓ (Ramadan et al., 2015)			
509.	δ-Octalactone			✓ (Yilmaztekin, 2014)			
510.	1,1,1,5,7,7,7-Heptamethyl-3,3			✓ (Ertürk et al., 2017)			
511.	Ethyl isoallocholate				✓ (Peter et al., 2021)		
512.	Hexahydrofarnesyl acetone				✓ (Peter et al., 2021)		
513.	Perulactone B				✓ (Fukushima et al., 2016)		
514.	Physalin B				✓ (Fukushima et al., 2016)		
515.	Physalin D				✓ (Fukushima et al., 2016)		
516.	Physalin F				✓ (Fukushima et al., 2016)		
517.	Withanolide E				✓ (Fukushima et al., 2016)		
518.	Withanolide F				✓ (Fukushima et al., 2016)		
519.	(all-*E*)-Lutein dimyristate			✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)		
520.	(all-*E*)-Neoxanthin myristate			✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)		
521.	(all-*E*)-Taraxanthin		etzb	✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)		
522.	(all-*E*)-Violaxanthin dipalmitate			✓ (Etzbach et al., 2018)			
523.	(all-*E*)-Zeaxanthin dimyristate			✓ (Etzbach et al., 2018)			
524.	(all-*E*)-Zeaxanthin myristate-palmitate			✓ (Etzbach et al., 2018)			
525.	(all-*E*)-α-Cryptoxanthin palmitate						

(*Continued*)

TABLE 27.2 (Continued)

	Phytoconstituents	Aerial parts	Calyces	Fruits	Leaves	Roots	Seeds
526.	(*Z*)-Lutein 1		✓ (Etzbach et al., 2018)	✓ (Etzbach et al., 2018)			
527.	(*Z*)-Neoxanthin- or (*Z*)-violaxanthin ester			✓ (Etzbach et al., 2018)			
528.	*c*-Linolenic acid						
529.	(S)-4-Iodo-1,2-epoxybutane			✓ (Ertürk et al., 2017)		✓ (Ertürk et al., 2017)	✓ (Ertürk et al., 2017)
530.	1,2,3-Tri(t-butyl) cyclopropenylium tribromide					✓ (Ertürk et al., 2017)	
531.	1,1,1,5,7,7,7-Heptamethyl-3,3 bis(trimethylsiloxy) tetrasiloxane						✓ (Ertürk et al., 2017)
532.	Diethylene glycol			✓ (Darwish & Shaker, 2021)			✓ (Darwish & Shaker, 2021)

(5a′)-pregnane-3,20a′-diol, (all-*E*)-lutein 3′-*O*-palmitate, (all-*E*)-lutein 3-*O*-palmitate-3′-*O*-myristate, (9*Z*)-β-carotene, (all-*E*)-antheraxanthin myristate-palmitate, (all-*E*)-violaxanthin dipalmitate, palmitate, acetaldehyde, (*E*)-2-hexenol, (*Z*)-*c*-carotene, Δ5-avenasterol, acetic acid, apigenin 7 glucose, benzaldehyde, betulin, butanoic acid, butanol, catechin, caffeic acid, caffeine, cinnamic acid, decanoic acid, eucalyptol, ferulic acid, and vitamins (B9, E, K1).

Seventeen important phytochemicals have been present in the ariel body part of goldenberry, including 3α-tigloyln-xytropane, 3β-acetoxytropane, hygrine, *N*-methyl pyrrolidinyl hygrine B, *N*-methyl pyrrolidinyl hygrine A, tropine, antheraxanthin, lutein, cuscohygrine, phytofluene, neoxanthin, violaxanthin zeaxanthin, and β-carotene. After fruit, calyces are the richest source of phytoconstituents. The various chemical classes make calyces necessary on nutraceutical and therapeutic bases. Goldenberry leaves contain perulactone B, campesterol, linoleic acid, physalin B, D & F, phytol, withanolide E and F, and vitamin E (Table 27.2).

A wide range of diverse biological principles and pharmaceutical activities are ascribed to goldenberry. Most importantly, goldenberry fruit's antiinflammatory, antioxidant, and anticancer properties can be the scientific basis for isolating active agents and developing new natural drugs/health supplements and nutra-pharmaceuticals (Fig. 27.1). The extract possesses remarkable antioxidant content, consisting of compounds that play a vital role in safeguarding against and repairing damage caused by free radicals. These free radicals are associated with aging and various diseases, including cancer. The natural antioxidants in the berry fruit protect against oxidative damage caused by free radicals and are strongly associated with reducing various diseases, including cancer and oxidative stress-related disorders. Extensive research has identified a list of distinct bioactives (functional compounds) potentially offering multiple health benefits (Yu et al., 2021).

The fruit extract has also shown cytotoxic and antiproliferative effects in SW480 and SW620 cells. The extract also induced apoptosis and increased the expression of TRAIL-DR4/-DR5 receptors and caspase-3 activation in both cell lines. In addition, the extract had an impressive level of antioxidant activity and also contained high levels of flavonoids and carotenoids (Mazo et al., 2013). Most importantly, withanolides from goldenberry include more than 300 natural C-28 steroidal lactones with antitumor properties against breast cancer (Yu et al., 2021) and hepatocellular carcinoma (Yen et al., 2010).

Withanolides-rich calyx extract possesses antiproliferative potential against HT-29 colon cancer cells (Barkaoui et al., 2023). Interestingly, these phytoconstituents can induce apoptosis-related genes and thus beneficially alter the expression of many genes associated with oxidative stress and oxidative damage. As a result, the extract reduced the incidence of HT-29 colon cancer cells without adverse effects against normal cells. The mechanism behind the action

FIGURE 27.1 Goldenberry fruit. *Photo by Iryna Riabchykova: https://www.pexels.com/photo/groundcherries-on-a-wooden-surface-14738069/.*

of such phytoconstituents may either be blocking the cell cycle in the S phase or altering cellular redox homeostasis and related metabolic processes. Foodomics data integration shows the altered pathway of protein synthesis due to the nonavailability of aminoacyl tRNA production and impaired fatty acid, amino acid, and pyridine metabolic pathways (Ballesteros-Vivas et al., 2019).

A natural compound in the goldenberry fruit, 4 β-hydroxy withanolide E (4HW), can inhibit the procoagulant effects of the inflammatory cytokine TNF-α. It has been revealed that this active compound (4HW) may potentially treat inflammation-derived cancer, pathological disorders, and autoimmune disease (Hsieh et al., 2021). Another study details 4HW as a potential chemotherapeutic agent against lung cancer cells (Yen et al., 2010). It also inhibits colon and breast cancer (Ramadan et al., 2015). In addition, this bioactive compound (4HW) present can treat oral cancer by selectively inducing apoptosis in oral cancer (Chiu et al., 2013).

P. peruviana−derived magnolin has antiproliferative potential against pancreatic cancer (against PANC-1). Magnolin limits PANC-1 to inhibit tumor cell migration. The *in silico* studies show that Magnolin inhibiting matrix metalloproteinase-3 has dose-dependent effects (Sayed et al., 2022). Similarly, an active compound in the fruit, namely, Nitrosamine, inhibits the tumor suppressor genes associated with reactive oxygen species (ROS) generation (El-Kenawy et al., 2015). The fruit extract affects the interleukin-6, interleukin-8, and monocyte chemo attachment protein-1 with dose-dependent behavior (Mier-Giraldo et al., 2017). Withanolide derivatives (4β-hydroxy withanolide E) (4), withaperuvin C (5), physalactone (6) present in aerial parts, and phyperunolide F (8) can block NF-kB transcription factor and thus have the potential to inhibit NO generation. Two compounds, namely, phyperunolide F (8) and physalactone (6), might be explored as effective pharmaceutical/drug leads (Chang et al., 2016).

Being effective natural antioxidants, phenolic compounds in golden can impede breast and colon cancer. In addition, phenolics, isolated from fresh and dehydrated goldenberries, can prolong cell lifespan and inhibit oxidative damage. As expected, the skin of goldenberries contains nearly three times the amount of antioxidants compared to their pulp, with antioxidant levels peaking when the fruits are fully ripe (Chang et al., 2016).

Physalin B (steroidal compound) in goldenberry juice can induce growth inhibition in breast cancer cells via p53 activation with dose-based effects. In addition, it impedes the phosphorylation of Akt and PI3K and increases the phosphorylation of GSK-3 β, thus reducing the incidence of human breast cancer (Wang et al., 2018).

Ripe *P. peruviana* fruit extractions in ethanol and isopropanol solvents have shown improved cytotoxic and immunomodulatory effects against human cervical cancer that can be linked to the presence of ursolic acid, gallic acid and rosmarinic acid and flavonoids (quercetin, and epicatechin) in these extracts. The high antioxidant contents in *P. peruviana* additionally contribute to various medicinal properties, including antiasthmatic and antiseptic effects, strengthening of the optic nerves and treatment of throat infection as well as elimination of intestinal parasitic pathogens (parasites and amebas) and removal of albumin from the kidneys. In addition, the fruit has demonstrated antiulcer activity and effectiveness in lowering cholesterol levels (Ramadan et al., 2015).

These berries contain a variety of polyphenols that effectively inhibit the release of specific inflammatory immune markers (Mier-Giraldo et al., 2017). The husk of goldenberries exhibited antiinflammatory properties in mice with inflammatory bowel disease. In addition, the mice treated with this extract showed reduced inflammation due to decreased contents of inflammatory markers in the tissues. Goldenberry juice has also demonstrated a promising hepatoprotective effect in rats with hepatitis, making it a viable natural additive for manufacturing functional yogurt drinks (Shahein et al., 2022).

Goldenberry possesses significant potential for antihypertensive and antidiabetic effects (Bernal et al., 2018; Pinto et al., 2009). Their extracts from this species have an antidiabetic effect. In Chinese folk medicine, *P. peruviana* fruits have been used to treat diabetes mellitus. This fruit's antidiabetic effects and antihyperglycemic properties can be linked to its ability to inhibit intestinal carbohydrase enzymes (Abd El-Gwad et al., 2018). As a dietary component, goldenberry fruit and its peel (to the diet at 5% and 10% levels) resulted in notable reductions in elevated blood glucose levels, increased insulin concentration, and improved lipid profile.

Goldenberry fruit supplementation showed positive effects on the liver and kidneys of diabetic rats preventing diabetes-related complications like hepatotoxicity (Zakaria et al., 2020). Juice extract can provide nutritional support for individuals with type 2 diabetes mellitus with decreased blood glucose levels, higher insulin levels, and improved insulin resistance (Kinasih et al., 2020). The phytoconstituents may help mitigate the complications of diabetes by exerting an impact on the reduction of free radicals within the pancreatic β-cells (Darwish et al., 2020). The fruit juice was also found to improve lipid and glucose metabolism in rats with alloxan-induced diabetes and lowered the amount of total cholesterols, blood glucose, and triglycerides compared to positive control. Consuming *Physalis*-infused Rusk, which exhibits high antioxidant potential, mainly improves blood lipid levels. These findings strongly suggest that *Physalis* Rusk consumption possesses significant hypoglycemic activities in rats with alloxan-induced diabetes (Shalaby et al., 2016).

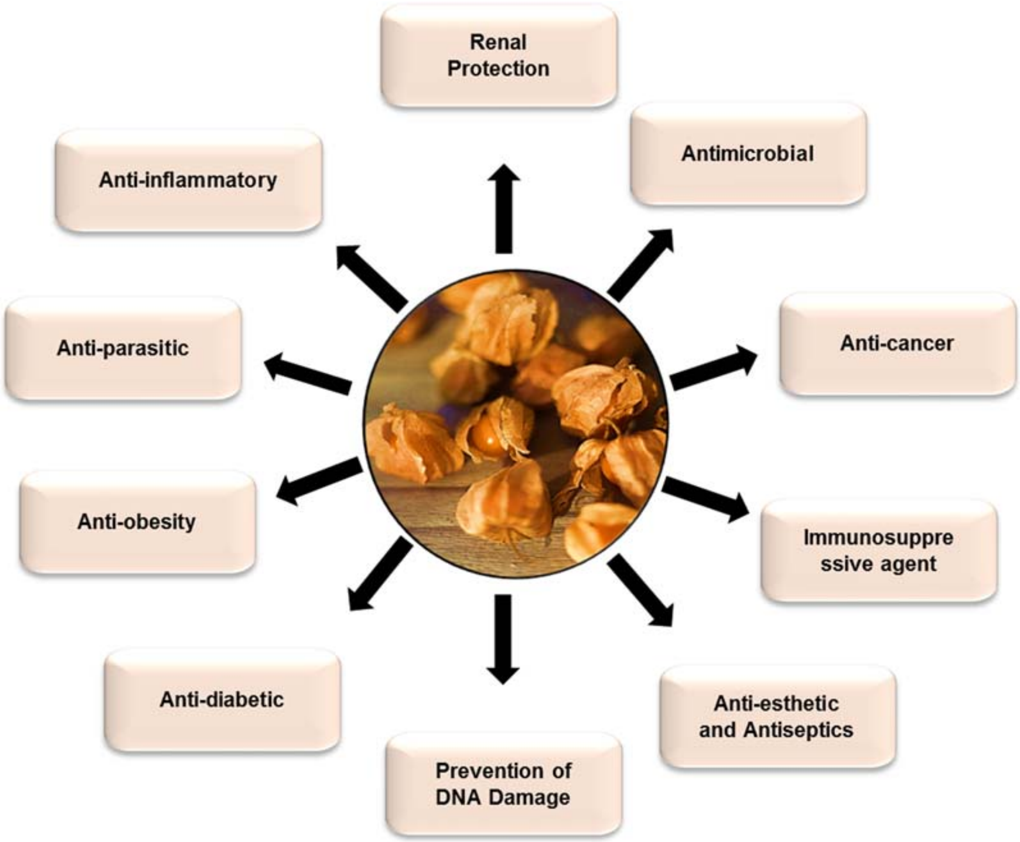

FIGURE 27.2 Pharmaceutical potential of goldenberry.

The flavonoids, particularly quercetin, in goldenberry juice, have been found to stimulate glucose uptake in the skeletal and muscular tissue by improving and increasing the translocation of GLUT4 (glucose transporter 4). When employed as antidiabetic agents, these compounds minimize the production of advanced glycation end products and glucose oxidation, which cause ROS generation. These ROS further contribute to β-cell damage and reduced insulin sensitivity.

Consuming goldenberry fruit appears to be linked to biological networks related to insulin function. The consumption/ingestion of goldenberries affects signaling pathways linked with insulin, thus providing a basis for proposing hypotheses about how *P. peruviana* may exert its observed biological activities. However, additional clinical trials need to be made to assess the mechanistic effects of goldenberries regarding glucose and insulin metabolism in healthy subjects/individuals compared with those with prediabetic and diabetic conditions (Vaillant et al., 2021). It was suggested that *Physalis* fruit extracts could be used as an alternative treatment for chronic inflammation and as a potential anticancer and immunomodulatory agent for developing innovative functional products (Mier-Giraldo et al., 2017). Identifying volatile compounds can also help develop food flavorings and fragrances with nutraceutical effects (Ramadan et al., 2015). In fact, *P. peruviana* is an emerging fruit crop with impressive medicinal benefits and thus has significant potential to play a key role in treating multiple health disorders based on a rich and rare combination of diverse phytochemicals and bioactives. However, there is still a need for efforts to be directed towards the isolation and characterization of a wide array of individual bioactive compounds using state-of-the-art technologies along with elucidating the mode of action of such phytochemicals distributed in this food cum medicinal plant (Fig. 27.2).

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