

REVIEW



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Recent insight on nutritional value, active phytochemicals, and health-enhancing characteristics of fig (*Ficus craica*)

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Abstract

The current review highlights the nutritional values, phytochemical profile, and health-enhancing characteristics of figs (*Ficus carica* L., family Moraceae). *Ficus carica* is one of the oldest fruit trees. The fruit has been appreciated as food and for its biomedical properties since ancient times. *Ficus carica* contains essential bioactive compounds that enhance health. The plant is characterized by unique compounds in all parts (peel, pulp, leaves, seed, and latex) besides primary nutrients (fatty acids, carbohydrates, vitamins, and minerals). *Ficus carica* is rich in bioactive secondary products such as flavonoids, furanocoumarin, anthocyanin, pectin, and phytosterols, contributing to many health benefits. Bioactive phytonutrients found in fig are used as antioxidant and antidiabetic agents due to the presence of specific functional groups that control diabetes. The health-enhancing effects of fig, including anti-tumor, anti-inflammatory, and anti-osteoporosis, are related to high levels of minerals essential to bone health and their benefits on Alzheimer's disease. All parts of *Ficus carica* have been used in cosmetics and pharmaceutical products, especially wound healing. In addition, *Ficus carica* has many uses in food items as a colorant and a preservative. To the best of knowledge, there is a lack of reports discussing the biochemistry, bioactivity, and medicinal traits of *Ficus carica* and the plant parts. This review gathered scientific information regarding the chemical profile, biological traits, and different uses of *Ficus carica*.

KEYWORDS

Alzheimer disease, antioxidants, ficin, food applications, furanocoumarin, health, nutrition, phytotherapy, wound healing

1 | INTRODUCTION

The food industry is always searching for natural bioactive molecules high in health-promoting effects associated with preventative and therapeutic use. Fig (*Ficus carica*) is one of the oldest fruits that is

consumed all over the world. The fruit meets the food industry's criteria for processing and manufacturing juices, syrups, and jams. *Ficus carica*, commonly called "fig", in Arabic teen or ten, is considered one of the first plants humans cultivated. The *Ficus carica* tree typically grows to 15–20 feet, with multi-spread branches and a stem

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seldom measuring seven or more inches across. *Ficus carica* milky-white latex mostly comprises the protein hydrolytic enzyme ficin (Badgujar, 2011).

Carica is the species name term for “having leaves resembling a papaya”. The fig is an important crop grown globally for fresh and dry consumption. Its most frequently eaten portion is fruit, which is hollow, fleshy, and receptacle-like (Duenas et al., 2008; Ramadan, 2023). It had been mentioned in the Holy Quran as a divine oath in the word of God Almighty “By the Fig and the Olive, and by Mount Sinai” “Surat Al-Tin: 1–2” as we have already seen in many surahs of this thirtieth part of the Quran (Ramadan, 2023).

Ficus carica (Moraceae family) appears in over 800 species and is one of the 37 genera. It is considered a seasonal fruit and generates two crops in 1 year. The most important one is figs produced during the growing season and obtained at the end when the crop is harvested (Ayuso et al., 2022). A nutritious diet rich in vitamins (such as riboflavin and thiamin), minerals, carbs, sugars, and organic acids is produced using fruits to produce novel food, drinks, and beverages. Fruits are readily available on the market for consumption in fresh or dried forms and are regarded as a unique source of fiber and phenolics, particularly furanocoumarins, proanthocyanidins, and phenolic acids (Badgujar et al., 2014; Ramadan, 2023).

Ficus carica's different parts, such as pulp, leaves, seeds, peels, and latex, could be used for unique uses (Palmeira et al., 2019), but the main parts used are peels and leaves. The peels represent 27% of the total weight of *Ficus carica* (Mahmoudi et al., 2018), and its importance is oriented due to having high amounts of bioactive substances with potential for nutrition, such as tocopherols, organic acids, flavonoids, triterpenoids, and phenolic acids.

This review aimed to discuss and highlight information about *Ficus carica* nutrients and bioactive compounds and their health impacts. In addition, this review discusses the novel applications of *Ficus carica* in edible products, cosmetics, nutraceuticals, and pharmaceuticals.

2 | THE ECONOMY OF *FICUS CARICA*

According to FAOSTAT, the highest fig producers in the world are Turkey, Egypt, and Algeria. On the other hand, only Spain was among the top 10 fig producers in Europe (Ayuso et al., 2022; Ramadan, 2023). According to recent statistics from FAOSTAT (2022), the global harvested area of *Ficus carica* is 281522 ha, and the global production is 1264943 tonnes (Ramadan, 2023).

During processing, a fresh fig may be discarded because of over-ripening, inadequate ripening, or spoilage that makes the fig unable to be used due to high bioactive compounds that accelerate the perishability of figs, and as a result, it will increase the economic loss. Bioactive compounds could be extracted and added to many products and ingredients to solve this problem, improving the economy, specifically in the Mediterranean region (Barolo et al., 2014). According to the International Nut and Dried Fruit Council Foundation,

the fig is best consumed dry, with Iran, the United States, Germany, India, France, and Italy having the highest consumption rates (Bey et al., 2013).

Figs cannot be kept and stored for long periods without losing quality and nutrients (Mat Desa et al., 2019). Thus, the best method to keep up its high quality as long as possible and increase the fig shelf life is by processing using salting, dehydration, and fermentation techniques (Martins et al., 2019; Ramadan, 2023). Nevertheless, in countries with low infrastructure and investment, it will be difficult to process and preserve the nutrients and quality of figs, which will cause economic loss.

3 | CHEMICAL PROFILE AND NUTRITIONAL VALUE OF FIG (*FICUS CARICA*)

Figs (*Ficus carica*) contain micro- and macro-nutrients at varied concentrations depending on the state of the fig (fresh or dried), climate, geographic location, and type of soil (Al-Snafi, 2017; Chauhan & Tanwar, 2015; Pal, 2020; Ramadan, 2023; Sadia et al., 2014; Verma et al., 2015; Vora et al., 2017).

The nutritional composition of dried and fresh fig in Table 1 shows that the dried fig contains high carbohydrate (65.2–73.5 g/100g) ranging from 65% to 73%, while the fresh fig contained 7.60–20.0 g/100g ranging from 8% to 20%. Glucose, fructose, and sucrose comprise most carbs in figs; dietary fiber, insoluble cellulose in the skin, and soluble pectin comprise the remainder (Pal, 2020; Ramadan, 2023). The fig's edible peel and pulp, which have been shown to have sufficient nutritional potential, make up its nutritional profile (Mahmoudi et al., 2018). However, fig pulp has a lower calorie value than peel because it contains more ash, lipids, and carbohydrates. Moisture and protein contents do not alter significantly (Ajmal et al., 2014; Palmeira et al., 2019; Ramadan, 2023).

Minerals including Ca, Fe, P, K, and Na are abundant in figs and necessary for the body's regular physiological operation (Al-Snafi, 2017; Chauhan & Tanwar, 2015; Mahmoudi et al., 2018; Pal, 2020; Ramadan, 2023). Iron is the most abundant mineral found in fig. Moreover, the figs contain a high amount of strontium that helps to maintain good bone health (Pal, 2020).

The nutritional value of the fig and its growing conditions make it available all year round, so it could be used as a natural edible supplement to provide energy (Khan et al., 2011). Besides, the dried fig's concentration of nutrients makes it a rich energy source; thus, it might be consumed as a snack (Vora et al., 2017).

3.1 | Fatty acids

Twenty-three different fatty acids (FAs) given in Table 2 are found in *Ficus carica*. Linolenic is the most abundant fatty acid in fresh fig (up to 35.0%), followed by oleic and palmitic acids (Badgujar et al., 2014; Ramadan, 2023). In the dried fig, the main fatty acid is linolenic acid (53.0%), followed by linoleic (21.0%), palmitic (14.0%), and oleic

TABLE 1 Nutritional composition (g/100 g) of fresh and dried fig fruit.

Component	Fresh fig	Dried fig	Reference
Moisture	79.9–88.1	12.9–25.9	Al-Snafi (2017), Chauhan and Tanwar (2015), Khan et al. (2011), Pal (2020), Sadia et al. (2014), and Vora et al. (2017)
Ash	0.60–4.00	0.89–4.65	Al-Snafi (2017), Chauhan and Tanwar (2015), Khan et al. (2011), Pal (2020), Sadia et al. (2014), and Vora et al. (2017)
Protein	0.53–1.30	1.80–8.60	Al-Snafi (2017), Chauhan and Tanwar (2015), Khan et al. (2011), Pal (2020), Sadia et al. (2014), Verma et al. (2015) and Vora et al. (2017)
Lipid	0.20–0.53	0.14–2.70	Al-Snafi (2017), Chauhan and Tanwar (2015), Khan et al. (2011), Pal (2020), Sadia et al. (2014), Verma et al. (2015), and Vora et al. (2017)
Crude fiber	2.10–2.20	3.68–69.4	Al-Snafi (2017), Khan et al. (2011), Pal (2020), Sadia et al. (2014), and Vora et al. (2017)
Carbohydrate	7.60–20.0	65.2–73.5	Al-Snafi (2017), Chauhan and Tanwar (2015), Khan et al. (2011), Pal (2020), Sadia et al. (2014), Verma et al. (2015), and Vora et al. (2017)
Energy (kcal/100g)	37.0	308.5–332.7	Al-Snafi (2017), Pal (2020), Sadia et al. (2014), and Verma et al. (2015)

TABLE 2 Fatty acid composition of *Ficus carica* peel and pulp.

Fatty acid	Peel	Pulp
Caproic acid	0.002–0.583	-
Caprylic acid	0.02–0.38	0.004–0.093
Capric acid	0.002–0.970	0.001–0.179
Undecanoic acid	-	0.009–0.233
Lauric acid	0.07–0.96	0.004–0.085
Myristic acid	0.06–3.06	0.05–0.50
Myristoleic acid	0.003–0.099	-
Pentadecanoic acid	0.05–0.53	0.03–0.30
Palmitic acid	0.1–23.9	0.30–11.2
Palmitoleic acid	0.02–0.30	0.001–0.121
Heptadecanoic acid	0.03–0.53	0.005–0.214
Stearic acid	0.1–6.0	0.04–3.91
Oleic acid	0.1–12.2	0.1–8.8
Linoleic acid	0.1–12.6	0.2–19.9
α -Linolenic acid	0.7–28.0	0.4–51.8
Arachidic acid	0.09–4.39	0.03–0.84
Eicosenoic acid	0.001–0.129	0.01–0.14
cis-11,14-Eicosadienoic acid	-	0.006–0.153
Heneicosanoic acid	0.01–0.15	0.006–0.084
Behenic acid	0.01–2.184	0.07–0.82
cis-13,16-Docosadienoic acid	0.002–0.267	-
Tricosanoic acid	0.001–0.263	0.008–0.139
Lignoceric acid	0.01–2.184	0.004–0.386
Saturated fatty acids	0.6–46.5	0.5–19.0
Monounsaturated fatty acids	0.2–12.7	0.1–9.1
Polyunsaturated fatty acids	0.5–40.8	0.6–71.9

Note: Adapted from Palmeira et al. (2019), and Ramadan (2023).

(10.0%) acids. Meanwhile, Pande and Akoh (2010) mentioned that linoleic (28.0%) was the main fatty acid in the whole fruit, followed by oleic, palmitic, and linolenic acids.

3.2 | Carbohydrates

According to Table 3, the main sugar found in *Ficus carica* peel and pulp is glucose, followed by fructose, sucrose, and trehalose in traces. By analyzing the different types of figs, the major sugar was fructose and glucose, while sucrose was found in lower amounts (Wojdyło et al., 2016). Additionally, with the total sugar content ranging from 44 to 74 g/100 g, the peel showed higher levels of different measured sugars. As a result, it had a 1.35-fold higher total free sugar content (43.4 g/100 g fw) than the pulp (Palmeira et al., 2019; Ramadan, 2023).

3.3 | Vitamins and minerals

Minerals, including Sr, Ca, Mg, Ph, and Fe, are abundant in figs (Table 4). According to studies, calcium helps reduce osteoporosis and the accompanying fractures. Magnesium is essential for preventing cardiovascular disorders. Phosphorus is also necessary for the growth and upkeep of cells and body structures. Iron is also necessary to produce enzymes and red blood cells (Soni et al., 2014).

3.4 | Phytochemicals and bioactive compounds of *Ficus carica*

Ficus carica phytochemical studies reported sterols, proanthocyanidins, anthocyanins, organic acids, amino acids, fatty acids, hydrocarbons, phenolics, aliphatic alcohols, volatiles, and a few additional types of secondary metabolites (Table 5). In *Ficus carica*, phytochemicals are mostly included in the latex, followed by leaves, fruit,

TABLE 3 Free sugars (g/100 g FW) of *Ficus carica* peel and pulp.

Sugar	Peel	Pulp
Fructose	0.1–17.4	0.09–13.1
Glucose	0.2–21.0	0.1–15.7
Sucrose	0.02–4.83	0.002–2.975
Trehalose	0.01–0.21	0.001–0.161
Total sugars	0.4–43.4	0.2–32.0

Note: Adapted from Palmeira et al. (2019), and Ramadan (2023).

TABLE 4 Vitamins and minerals profile of *Ficus carica* (g/100g).

Vitamin	Quantity	% DV
Vitamin A	7 µg	1%
Thiamine (B1)	0.06 mg	5%
Riboflavin (B2)	0.05 mg	4%
Niacin (B3)	0.4 mg	3%
Pantothenic acid (B5)	0.3 mg	6%
Vitamin B6	0.1 mg	8%
Folate (B9)	6 µg	2%
Vitamin C	2 mg	2%
Vitamin E	0.11 mg	1%
Vitamin K	4.7 µg	4%
Minerals	Quantity	%DV
Calcium	35 mg	4%
Iron	0.4 mg	3%
Magnesium	17 mg	5%
Manganese	0.13 mg	6%
Phosphorus	14 mg	2%
Potassium	232 mg	5%
Sodium	1 mg	0%
Zinc	0.15 mg	2%

Note: Adapted from Uddin and Shahab Uddin (2021) and Ramadan (2023).

TABLE 5 Occurrence of phytochemicals in different parts of *Ficus carica*.

Plant part	Type	Reference
Fruit	Anthocyanin	Solomon et al. (2006), Duen˜as et al. (2008), and Yemis et al. (2012)
Leaves	Flavonoids	Vaya and Mahmood (2006) and Vallejo et al. (2012)
	Phenolic compounds	Oliveira et al. (2009) and El-Shobaki et al. (2010)
	Organic acids	Oliveira et al. (2009)
	Triterpenoids	Saeed and Sabir (2002)
Latex	Fatty acids	Oliveira et al. (2010)
	Amino acids	Oliveira et al. (2010)
	Sterols	Rubnov et al. (2001); Oliveira et al. (2010)
	Volatile compounds	Oliveira et al. (2010)

and roots (Badgujar et al., 2014; Ramadan, 2023). In addition, dried fruits of *F. carica* are a rich source of organic acids and phenolic constituents (Oliveira et al., 2009; Rahmani & Aldebasi, 2017; Ramadan, 2023; Slatnar et al., 2011).

From the aqueous extract of *F. carica* leaves, phenolic acids such as 5-O- and 3-O-caffeoylquinic acids, quercetin-3-O-glucoside, quercetin-3-O-rutinoside, bergapten, psoralen, ferulic acid, and other organic (malic, oxalic, citric, shikimic, quinic, and fumaric) acids have been detected. The leafy parts of *F. carica* contain volatile chemicals, which are categorized and distributed according to different chemical categories. These compounds include aldehydes, such as hexanal, methyl-butanal, 2-methyl butanal, (E)-2-pentanal, and (E)-2-hexanal, alcohols, such as heptanol, 1-penten-3-ol, 2-methyl butanol, 3-methyl-1-butanol, monoterpenes: limonene and menthol, and sesquiterpenes (Debib & Menadi, 2023; Oliveira et al., 2010; Ramadan, 2023).

Fig fruit and bark were used for fifteen separate anthocyanin dyes, which mostly include pelargonidin derivatives plus cyanidin as an aglycone (Slatnar et al., 2011). Pentane extracts from *F. carica* contain volatiles, including benzyl alcohol, benzyl aldehyde, linalool, eugenol, furanoid, pyranoid (*trans*), indole, cinnamic aldehyde, cinnamic alcohol, and *trans*-caryophyllenes (Debib & Menadi, 2023).

Fresh and dried *F. carica* skins were analyzed to isolate specific phenolic components. Due to the contribution of the dry skin, dry figs had higher levels of phenolic compounds than the pulp of fresh fruit. The main phenolics were quercetin and rutinoside (Debib & Menadi, 2023; Vallejo et al., 2012; ˆalıřkan & Aytekin Polat, 2011).

Terpenoids, sterols, carotenoids, phenolic acids, volatile compounds, and flavonoids, including flavonols, anthocyanins, flavan-3-ols, and flavanones, are the primary bioactive components (Figure 1) in fig fruits and fig biowastes (Debib & Menadi, 2023; Pereira et al., 2017). The antioxidant effects of phenolic compounds are largely responsible for their health benefits (Debib & Menadi, 2023; Shahidi et al., 2019). These activities are linked to the chemical diversities of phenolics, particularly the hydroxyl groups on the aromatic rings. Furthermore, the structure of the hydroxyl groups connected to the phenolic constituent affects their bioactivity (Debib & Menadi, 2023; Vuolo et al., 2019).

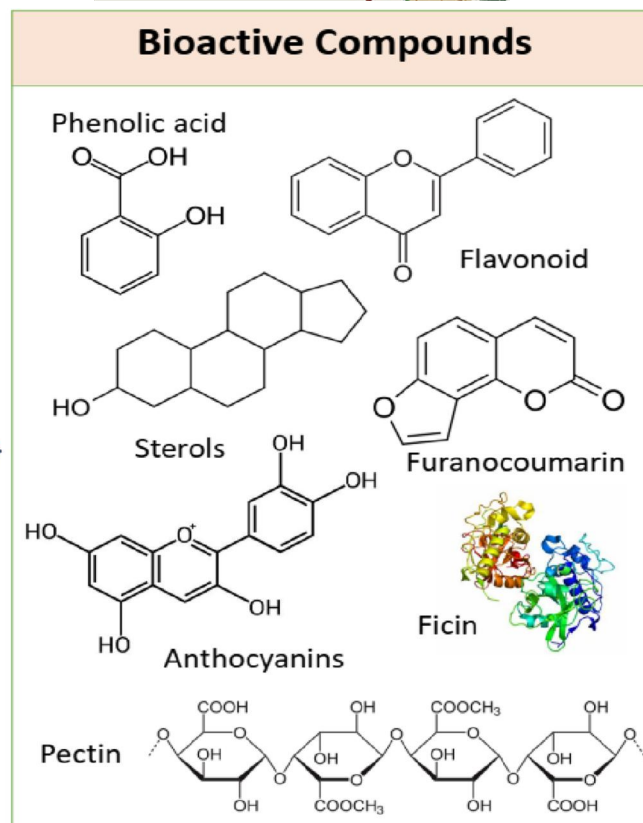


FIGURE 1 Major bioactive compounds in fig.

3.5 | Phenolic acids

Phenolics are essential to fruit quality because they contribute to taste, color, and characteristics (Kamiloglu & Akgun, 2023). The two subclasses of phenolic acids are hydroxycinnamic and hydroxybenzoic acids. The C6-C1 structure of hydroxybenzoic acids includes *p*-hydroxybenzoic, gallic, vanillic, protocatechuic, and syringic acids. Ferulic, caffeic, ellagic, *p*-coumaric, and chlorogenic acids are examples of hydroxycinnamic compounds, which are aromatic compounds with a 3-carbon side chain (C6-C3) (Arvaniti et al., 2019; Kamiloglu & Akgun, 2023). In addition to phenolic acids described above, figs have also been shown to contain coumarins such as bergapten, umbelliferon, psoralen, and angelicin (Debib & Menadi, 2023; Veberic & Mikulic-Petkovsek, 2016). Furthermore, fig methanol extract had high quantities of bergapten, methoxy psoralen, and psoralen (Ammar et al., 2015; Debib & Menadi, 2023; Kamiloglu & Akgun, 2023; Oliveira et al., 2010).

3.6 | Flavonoids

Quercetin is the most abundant flavanol found in *F. carica* leaves, latex, and pulp phytoextracts (Abdel-Aty et al., 2019; Ammar et al., 2015; Kamiloglu & Akgun, 2023; Palmeira et al., 2019; Sedaghat & Rahemi, 2018), while (–) epicatechin and (+)-catechin are the primary flavan-3-ols reported in the latex,

leaves, and pulp phytoextracts (Kamiloglu & Akgun, 2023; Pereira et al., 2017).

Flavonoid phytochemicals called anthocyanins are interesting because of the variety of colors they may take on, often ranging from red to purple and blue. Besides, their coloring potential and multiple multifunctional health-promoting qualities make anthocyanins viable natural food colorants (Lama et al., 2020). Meanwhile, figs are rich in anthocyanins, now used in food processing as a sustainable source of natural colorants. These bioactive compounds have additional health-enhancing traits that might help prevent diabetes, cancer, obesity, infection, and cardiovascular diseases. To create beneficial colorants with improved durability for the food sector, more investigations into the kinetics and biochemical stability of anthocyanin color deterioration over time are necessary (Ayuso et al., 2022; Ramadan, 2023).

3.7 | Furanocoumarin

Furanocoumarins are tricyclic aromatic constituents with a furan ring bonded to α -benzopyrone. The primary furanocoumarin compounds identified in the leaves and unripe fruit of *F. carica* are psoralen, isopsoralen, and bergapten. Furanocoumarins are found in entire fig fruit and fig latex, and they exhibit anticancer, antipyretic, anti-inflammatory, and antibacterial activities (Belguith-Hadriche et al., 2017; Debib & Menadi, 2023; Irudayaraj et al., 2016). They have also been used with UV radiation to treat autoimmune skin

disorders like vitiligo, psoriasis, and eczema. Meanwhile, their ability to interact with DNA nucleobases when exposed to UV radiation, which raises the risk of skin cancer, is connected to this phototoxic feature (Son et al., 2017).

3.8 | Ficin

F. carica produces a milky juice (latex) recovered from its different plant parts, including stems, fruits, and seeds, which contain a variety of secondary metabolites such as organic acids, terpenoids, alkaloids, fatty acids, amino acids, tannins, enzymes, and phytosterols. This juice is secreted in significant quantities, and its primary function is to protect and cure plants from external assaults. In addition, many latex metabolites are responsible for latex extracts' biological features, such as antioxidant, cytotoxic, and wound healing traits (Abdel-Aty et al., 2019; Barolo et al., 2014; Boyacioglu et al., 2021; Ramadan, 2023).

3.9 | Pectin

The units of a polysaccharide, galacturonic acid, mostly comprise pectin (Ramadan, 2023). It has unique chemical, physical, and biological traits and is widely distributed in the cell walls of fig peels. It is a high-value-added, useful thickener, colorant, emulsifier, gelling agent, and stabilizer. Using a hybrid ultrasound/microwave aided extraction (UMAE) technology, the researchers extracted a pectin-rich extract from fig peels. The average molecular weight of the 14.0% pectin they obtained ranged from 6.890 to 103.0 kDa. Hepatocellular carcinoma (HepG2) and human non-small cell lung cancer (A549) cells were both sensitive to the antioxidant and cytotoxic impact of the pectin-rich phytoextracts (Gharibzadeh et al., 2019a; Ramadan, 2023).

3.10 | Sterols

Triterpene analogs of cholesterol present in plants are called phytosterols. They are well-known for lowering the risk of cardiovascular and metabolic illnesses by reducing intestinal cholesterol absorption (Bai et al., 2021). For example, the fatty acid glycosides-6-O-acyl-D-glucosyl-sitosterols, stigmasterol, lupeol acetate, and oleandiene found in fig fruit latex extracts are all steroidal substances (Ghanbari et al., 2019).

3.11 | Volatile compounds

Volatile organic compounds (VOCs) are a variety of organic chemicals that are present in the roots, fruits, stems, flowers, seeds, leaves, bark, and other distinctive storage organs of plants (Nawade et al., 2020). They have recently become important quality

assessment indicators in medicine, agriculture, pharmaceutical, and environmental sciences. In a highly complex chemical environment, different insects use them to locate resources for survival, such as food, mates, prey, and predators (Nawade et al., 2020; Tiwari et al., 2020). For instance, the aroma of fresh figs has been predominantly attributed to aldehydes, ethers, monoterpenes, and ketone groups. Villalobos et al. (2018) looked into the temporal evolution of volatile compounds in various passively controlled air environments. Aldehydes (14), esters (6), hydrocarbons (5), furans (5), alcohols (5), and ketones (4) were the most common of the 48 compounds found in fig (Ayuso et al., 2022; Ramadan, 2023).

4 | HEALTH BENEFITS OF *FICUS CARICA* INGREDIENTS AND BIOACTIVE COMPOUNDS

Ficus carica contains several phytonutrients, including flavonoids and phenolic constituents, which have significant health impacts (Liu et al., 2011; Samtiya et al., 2021). Table 6 and Figure 2 present the health benefits of *Ficus carica* ingredients and bioactive compounds. Phenolics are well-known active constituents in *Ficus carica* that may protect against cancers, cardiovascular diseases, and other diseases. In addition, fig biowastes are good sources of structurally diverse active compounds with distinct antidiabetic, anti-inflammatory, immunomodulatory, anti-tumor, cardioprotective, and wound healing traits (Ayuso et al., 2022).

4.1 | Antidiabetic activity

Fig extracts inhibit glucose absorption in the intestinal tract via α -amylase and α -glucosidase inhibition, enhance glucose uptake via regulating glucose homeostasis via protein kinase (AMPK) activation and glucose transporter type 4 (GLUT4)-phosphatidylinositol-3 kinase PI3K- serine/threonine protein kinase (Deepa et al., 2018; Paramanya et al., 2023). Meanwhile, in alloxan-induced diabetic animals, *F. carica* fruit and leaf demonstrated high antidiabetic action via raising antioxidant potential. In streptozotocin-induced diabetic rats, methanol extracts from fruits, aqueous leaves, and leaf decoction prevented diabetic sequelae (El-Shobaki et al., 2010). In addition, *Ficus carica* extracts improve blood glucose level and insulin secretion (Perez et al., 2003). Recent in vivo studies showed that the hydro-ethanol extract of *F. carica* has anti-obesity effects. The findings were mainly demonstrated by decreased serum amounts of low-density lipoprotein (LDL) and animal body mass (Arafa et al., 2020; Paramanya et al., 2023).

4.2 | Anti-inflammatory potential

Inflammation is the body's response to pathogens and toxic materials. Many natural compounds are effective anti-inflammatory agents without severe side effects (Paramanya et al., 2023;

TABLE 6 Health benefits of *Ficus carica*.

Health benefit	Effect	Reference
Antidiabetic activity	Fig extracts inhibit glucose absorption in the intestinal tract, enhance glucose uptake, and regulate glucose homeostasis.	(Deepa et al., 2018)
Anti-inflammatory activity	TNF (tumor necrosis factor) inhibition was investigated on <i>ficus carica</i> branches' ethanolic extract and showed a 70% inhibition.	(Park et al., 2013).
Anti-tumor and immunomodulatory properties	<i>F. carica</i> showed inhibition of the viability of different cell lines. These results also demonstrated a relation between anti-tumor properties and antioxidant activity caused by inhibiting certain enzymes, including tyrosinase and α -glucosidase.	(Meziant et al., 2021).
Antioxidant activity	Flavonoids have an antioxidant action that attenuates ROS by enhancing antioxidant enzymes or inhibiting enzymes that employ a prooxidant effect on oxidative stress.	(Yan et al., 2013; Zhang et al., 2022).
Antimicrobial activity	Effect of high flavonoid and tannin levels. Their ability to combine with extracellular and soluble proteins and bacterial cell walls is probably the cause of their activity.	(Ramadan, 2023).
Antispasmodic activity	Spasmolytic activity in the ripe dried fruit, which could be mediated by the activation of K ⁺ ATP channels	(Gilani et al., 2008).
Anti-osteoporotic potential	Raw <i>F. carica</i> extract solution showed potential against osteoporosis in ovariectomized rats.	(Mohammad et al., 2018; Park et al., 2009)
Effect on Alzheimer's disease	Dietary supplementation of figs may help improve cognitive and behavioral deficits in Alzheimer's disease.	(Subash et al., 2016).
Cardioprotective and neuroprotective activity	<i>F. carica</i> lowered blood pressure levels, contraction force, and heart rate in normal and hypertensive rats.	(Alamgeer et al., 2017).
Wound healing	Proteolytic enzyme preparation for oral administration of trypsin and chymotrypsin has been employed. When compared to many currently available enzyme formulations, it provides improved relief of inflammatory symptoms and promotes faster healing of acute tissue injury.	(Chandanwale et al., 2017).
Antidiuretic	Leaf extracts of <i>ficus carica</i> . The extracts showed a dose-dependent increase in urine excretion.	(Munteanu et al., 2016)
Anti-neurodegenerative	<i>Ficus carica</i> fruit and leaf extracts showed potent inhibitory activities against acetylcholinesterase and butyrylcholinesterase enzymes.	(Subash et al., 2014; Sumanth & Mamatha, 2014).
Anti-lipidemic/Cholesterol	The administration of a hydroethanolic extract of <i>ficus carica</i> fruit reduced cholesterol, triglycerides, low-density lipoprotein (LDL), and very-low-density lipoprotein (VLDL) while increasing the protective benefits of high-density lipoprotein (HDL) (HDL).	(Birari & Bhutani, 2007).
Hepatoprotective	<i>F. carica</i> reduces the severity of hepatic and renal damage, most likely through antioxidant and antiapoptotic effects	(Fouad et al., 2019).
Antihypertensive	Fruit methanol extract in lowering hypertension in normotensive and glucose-induced hypertensive rats	(Alamgeer et al., 2017).

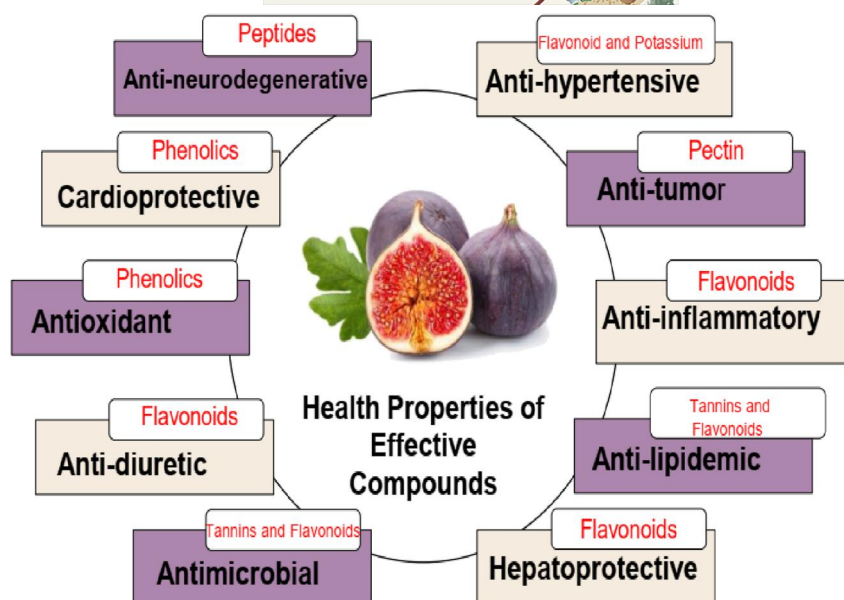
Ramadan, 2023). *Ficus carica* by-products, including barks, leaves, and latex, have been found to have anti-inflammatory activities (Lansky et al., 2008). TNF-(tumor necrosis factor) inhibition was investigated on *Ficus carica* branches ethanol extract and showed a 70% inhibition at 12.5 μ g/mL (Park et al., 2013). The methanolic dried fig fruit extract, at 38.07 mg/kg/day, protected rats from CCl₄-induced oxidative stress and hepatotoxicity. According to these findings, these hepatoprotective impact could be attributed to flavonoids' inhibition of free radical production because exogenous antioxidants might work with natural systems like protective enzymes or glutathione tocopherol to mitigate the negative

impacts of oxidative stress (Debib et al., 2016; Paramanya et al., 2023).

4.3 | Anti-tumor and immunomodulatory traits

Ficus carica has been considered as a possible treatment since ancient knowledge amassed multiple preparations of this plant that were taken into consideration for treating tumors. (Lansky et al., 2008; Paramanya et al., 2023). According to AlGhalban et al. (2021), *F. carica* leaf latex had a positive cytotoxic impact on breast cancer cells.

FIGURE 2 Health-enhancing traits of bioactive compounds found in fig.



Promising results were obtained in human prostate (PC3) and colon (HT-29) cancer cell lines, while it was claimed that ficin peroxidase-like activity was insufficient to clarify the findings (Boyacıoglu et al., 2021; Paramanya et al., 2023). Recent research has utilized the synergistic properties of *Ficus carioca* extracts and extra virgin olive oil to reduce the adverse effects of specific cancer therapy medications, including 5-fluorouracil and cisplatin (Elghareeb et al., 2021). The ethanol and acetone extracts of *F. carica* leaves inhibited the viability of different cell lines. These findings revealed a relationship between anti-tumor properties and antioxidant activity caused by inhibiting certain enzymes, such as tyrosinase and glucosidase (Meziant et al., 2021). Interferon (IFN), IL-6, IL-4, and TNF production was elevated when a fermented fig extract was tested in immunosuppressed mice given cyclophosphamide treatment (Paramanya et al., 2023; Zhao et al., 2020).

4.4 | Antioxidant potential

From a chemical perspective, antioxidants reduce aging-related degenerative processes by neutralizing metabolic waste products such as free radicals. Free radicals are well-known for causing damage to cells and their constituents, which can contribute to the development and progression of chronic degenerative disorders. Cellular metabolism produces reactive oxygen species (ROS) in equilibrium with the antioxidant defense system under a regular physiological system. The molecular basis of numerous diseases is disturbed when excessive ROS and oxidative stress disrupt this homeostasis. ROS could cause lipid peroxidation [for example, increased malondialdehyde (MDA)] and oxidative damage to DNA molecules (for example, cancer), membrane phospholipids, and proteins in this condition (Khutami et al., 2022; Niemann et al., 2017; Paramanya et al., 2023). By increasing antioxidant enzymes or blocking enzymes that have a prooxidant effect on oxidative stress (such as xanthine

oxidase, NADPH oxidase, and catalase), flavonoids have an antioxidant function that decreases ROS (Yan et al., 2013; Zhang et al., 2022). Strong correlations exist between skin color, total phenolic content, and antioxidant activity. As a result, figs from dark-colored cultivars had an antioxidant potential of 3–4 times greater than those from light-colored cultivars. These results were supported by numerous research findings (Faleh et al., 2012; Konak et al., 2015; Pereira et al., 2020). The sun-drying process positively impacted antioxidant potential, enhancing the antioxidant activities of dried figs compared to fresh ones, according to the impact of drying on antioxidant capacity (Chang et al., 2016; Paramanya et al., 2023).

4.5 | Antimicrobial potential

Several *Ficus carica* fruit types have been shown to have antibacterial activity (Debib et al., 2014; Ramadan, 2023). Azendjar and Taamriout, two types of Algerian figs, exhibited an antibacterial effect against some gram-positive bacteria and one yeast. These researchers speculate that the high flavonoid and tannin levels might be responsible for this impact. Their propensity to bind to soluble extracellular protein and the bacterial cell wall is most likely what makes them active. Furthermore, lipophilic flavonoids can potentially damage microbial membranes (Ramadan, 2023). The results of this study's inquiry into antimicrobial potential support the Algerian population's use of olive oil macerates from dried figs to combat infectious infections (Debib et al., 2018; Ramadan, 2023).

4.6 | Antispasmodic potential

The antispasmodic effect of a dried fig aqueous–ethanol extract was reported (Gilani et al., 2008; Ramadan, 2023), and the study discovered a spasmolytic potential in ripe dried fruits that might be

mediated by activation of the K^+ ATP channels. *Ficus carica*, when tested in isolated rabbit jejunum, produced relaxation of spontaneous and low K^+ (25 mM)-induced contractions with negligible effect on high K^+ (80 mM). Meanwhile, pretreatment of tissues with glibenclamide resulted in a rightward shift in the curves of low K^+ -induced contractions. In addition, *Ficus carica* inhibited adrenaline-induced human platelet aggregation and ADP (adenosine diphosphate).

4.7 | Anti-osteoporotic effect

The bone marrow-derived macrophages and RANKL-stimulated RAW264.7 cells responded favorably to the fig hexane extract as an inhibitor of osteoclast formation (Park et al., 2009; Ramadan, 2023). These results confirm earlier research showing that an extract at 50 mg/kg prevented osteoporosis in ovariectomized mice in a manner analogous to estrogen replacement treatment (Mohammad et al., 2018; Park et al., 2009).

4.8 | Effect on Alzheimer's disease

Alzheimer's disease mouse model APPsw/Tg2576 (Tg mice) memory, anxiety, and learning effects of 4% Oman-grown figs were described (Subash et al., 2016). The scientists evaluated four-month-old Tg and wild-type mice for their spatial memory and learning capacity, psychomotor coordination, and anxiety-related behavior. Mice fed a control diet without figs showed significant memory deficits, increased anxiety-related behavior, and severe impairment in spatial, position discrimination learning ability, and motor coordination compared to the wild-type control mice on the same diet after 15 months of testing using the Morris water maze and rotarod. Additionally, the study looked into how dietary supplements like pomegranate, figs, or dates affected the lowering of inflammatory cytokines. The researchers mentioned that taking the supplements lowered the activities of inflammatory cytokines and eotaxin (Essa et al., 2015). These data suggested that fig supplementation may aid in treating cognitive and behavioral abnormalities in Alzheimer's disease.

4.9 | Cardioprotective and neuroprotective activity

Different plants of *Ficus* spp. genus have demonstrated their effect as an anti-hypertensive agent. For example, using in vitro trials, fig ripe fruit methanol phytoextract lowered blood pressure levels, contraction force, and heart rate in normal and hypertensive animals. These benefits were attributed to the antioxidant properties of the phenolic compounds (Alamgeer et al., 2017). Additionally, anticoagulation, thrombosis, fibrinolysis, and platelet activity are pathologies concealed by cardiovascular illnesses (Shore-Lesserson, 2002).

4.10 | Wound healing properties

The healing traits of figs have sparked a greater interest in researching the role of the fruit's particular parts (Harish et al., 2008; Ramadan, 2023). Treatment with ficine reduces the time it takes for the wound to reach half closure by 2 days and expedites microbiological decontamination by 4 days (Baidamshina et al., 2020). Ficin, an enzyme derived from fig latex, effectively eliminates biofilms, which could be a significant barrier to wound treatment. Baidamshina et al. (2017) studied the antibiofilm and wound healing traits of the chitosan-immobilized ficin. Antibiotics cannot reach the microorganisms within those biofilms. Chitosan-immobilized ficin degraded staphylococcal biofilm in vitro and increased the efficacy of antimicrobial agents against biofilm-embedded bacteria. Besides, by treatment with ficin, the *S. aureus*-infected skin wound areas in animals were reduced twofold after four instead of 6 days. In wound treatment, one approach is to increase the antibiotic concentration by as much as a thousandfold. Bacteriophages, a popular antibacterial treatment, could operate within the biofilms. When compared to many available enzyme formulations, it provides improved relief of inflammatory symptoms and encourages faster healing of acute tissue damage (Chandanwale et al., 2017). It could be said that ficin is helpful for the treatment of biofilm-associated infections and speeds up wound healing and microbial decontamination.

4.11 | Antidiuretic traits

Diuretic medications treat various clinical conditions involving edema or volume overload, including hypertension, heart failure, ascites, nephrotic syndrome, and cirrhosis. They do this by regulating the volume and composition of body fluids (Ramadan, 2023). The diuretic effect of ethanol extract of *Ficus carica* whole plant was studied in rats at doses of 200 and 400 mg/kg body weight using measures such as total urine volume and urine concentrations of potassium (K^+), sodium (Na^+), and chloride (Cl^-). The administration of ethanol extract had a significant diuretic impact based on the increased urine volume and urinary excretion of electrolytes such as K^+ , Na^+ , and Cl^- (Sruthi et al., 2012).

Ficus carica aqueous and ethanolic leaf extracts have diuretic properties. The extracts increased urine excretion in a dose-dependent manner. The aqueous extract's uricosuric action (1.4 mg/kg) may benefit people with excessive blood uric acid levels. Flavonoids were found in the extracts due to their chemical makeup, which are assumed to be inhibitors (Munteanu et al., 2016).

4.12 | Anti-neurodegenerative effects

Neurodegenerative disorders (NDDs) are characterized by oxidative stress, neuroinflammation, abnormal RNA processing, DNA damage, protein oligomerization and aggregation, axonal transport deficit,

calcium deregulation, mitochondrial function and structure impairment, and abnormal neuron–glia interactions (Dugger & Dickson, 2017). *Ficus carica* fruit treatment increased learning and memory in experimental rat models (Sumanth & Mamatha, 2014). Treatment with *Ficus carica* alleviated memory-related behavioral abnormalities in Tg-mice while lowering oxidative damage and plasma A (1–40 and 1–42) levels (Ramadan, 2023; Subash et al., 2014). *Ficus carica* fruit and leaf phytoextracts showed potent inhibitory activities against acetylcholinesterases and butyrylcholinesterases, as shown in Table 7 (Subash et al., 2014; Sumanth & Mamatha, 2014). The acetyl- and butyryl-choline neurotransmitters' activity in the synapses is prolonged by the *Ficus carica*'s inhibitory influence on these enzymes (Breithaupt & Weigmann, 2004; Marshall, 2004; Orhan et al., 2011). Moreover, peptides may stimulate Ca^{2+} influx, enhancing the enzymes' activities and Ca^{2+} -mediated oxidative stress (Barbosa et al., 2002; Ramadan, 2023).

4.13 | Anti-lipidemic/cholesterol-limiting effects

Ficus carica leaf extracts have been shown to have antihyperlipidemic traits in both animals and humans (Perez et al., 1999; Serraclara et al., 1998). In type 2 diabetes mellitus with obesity as a risk factor, developed by a high-fat diet (HFD) and streptozocin, fig therapy may help reduce cholesterol levels (Arafa et al., 2020; Ramadan, 2023). As shown in Table 7, hydroethanol extract of *Ficus carica* fruit reduced triglycerides, cholesterol, LDL, and very low-density lipoprotein (VLDL) while increasing high-density lipoprotein (HDL) protective benefits. Additionally, *Ficus carica* fruit ethanol extracts inhibited pancreatic lipase, an enzyme that digests lipids and allows absorption into the intestinal lumen (Birari & Bhutani, 2007). According to these studies, *Ficus carica* prevents the buildup of cholesterol and

triglycerides and might be used to cure or prevent atherosclerosis and coronary heart disease. These investigations also support the traditional application of *Ficus carica* and its therapeutic advantages for illnesses linked to metabolic syndrome (Mawa et al., 2013). *Ficus carica* lipid-lowering impacts might be attributable to tannins and flavonoids, which are essential in lipid mobilization and metabolism (Rassouli et al., 2010). Further research into how fig mediates its antihyperlipidemic traits will report more pertinent knowledge (Ramadan, 2023).

4.14 | Hepatoprotective effect

Figs have been reported to protect organs, particularly the liver, against various chemical injuries such as ethanol, carbon tetrachloride, and rifampicin (Aghel et al., 2010; Gond & Khadabadi, 2008; Singab et al., 2010; Turan & Celik, 2016). The enhancement of liver marker enzymes, primarily alanine and aspartate transaminases, as well as antioxidant and anti-inflammatory capabilities, was suggested to be the mechanism behind the hepatoprotective effects. In a gamma-radiation toxicity animal model, daily injection of fig extract for 21 days reduced the extent of renal and hepatic injury, most likely due to its antioxidant and antiapoptotic traits (Fouad et al., 2019).

4.15 | Antihypertensive traits

The application of medicinal plants and fruits for treating life-threatening conditions is currently being investigated, and one such fruit is the fig. This is due to the high concentration of antioxidants in its leaves, fruits, and seeds (Badgujar et al., 2014; Olomon et al., 2006; Ramadan, 2023). The usefulness of fig fruit methanol extract in lowering hypertension in normotensive and glucose-

TABLE 7 Health benefits of *Ficus carica* bioactive compounds.

Bioactive compound	Health benefit	Reference
Furanocoumarin	Have been found to have anti-inflammatory, antipyretic, anticancer, and antibacterial activities and have been used with UV radiation to treat autoimmune skin diseases such as psoriasis, vitiligo, and eczema via multiple pathways	(Belguith-Hadriche et al., 2017; Irudayaraj et al., 2016; Son et al., 2017)
Anthocyanins	Health-promoting benefits that may effectively prevent cardiovascular disease, infection, cancer, diabetes, obesity, and other health challenges	(Ayuso et al., 2022).
Ficin	Biological properties of latex extracts, namely, antioxidant, cytotoxic, and wound healing effects	(Abdel-Aty et al., 2019; Boyacioglu et al., 2021).
Pectin	Antioxidant and cytotoxic effects against human non-small cell lung cancer and human hepatocellular carcinoma cells.	(Gharibzadeh et al., 2019)
Phytosterols	Lower the risk of cardiovascular and metabolic diseases	(Bai et al., 2021)
Volatile compounds	Resources for survival, such as food, mates, prey, and predators in a complicated chemical environment and have recently become crucial indicators for quality assessment in medicine, agriculture, pharmaceuticals, and environmental fields.	(Nawade, Shaltiel-Harpaz, Yahyaa, Kabaha, et al., 2020; Tiwari et al., 2020).

induced hypertensive rats was reported. The rich content of phenolic acids, composition and health-promoting benefits of *Ficus carica* extract flavonoid and potassium in the fruit were attributed to the efficiency of the fig extract. This shows the fig's promising possibilities in treating one of the world's top causes of mortality. Because different components of the fig tree exhibited possess high levels of antioxidants, the seeds, leaves, and bark should be investigated further in treating hypertension. Comparing the efficacies of extracts derived from various plant parts will also help identify and elucidate the specific constituents primarily responsible for antihypertensive potential (Alamgeer et al., 2017; Ramadan, 2023).

5 | POTENTIAL APPLICATIONS OF *FICUS CARICA*

There are many uses of *Ficus carica* in novel food, cosmetic, and pharmaceutical goods. Table 8 and Figure 3 present different food and non-food applications of *Ficus carica*. Differently, all parts of *Ficus carica* are extracted based on the products depending on the phenols and antioxidant traits. *Ficus carica* phytoconstituents produce sunscreen and coloring products (Chawla et al., 2012). *Ficus carica* also exhibits impressive pharmacological qualities such as anticancer, antioxidant, anti-inflammatory, cytotoxic, and hypolipidemic effects. Fig products are applied in traditional medicine to help treat several illnesses (Abbasi et al., 2017).

Moreover, studies have proved the effectiveness of fig products in treating and relieving atopic dermatitis and considered them an alternative to cortisones. Other studies proved the efficacy of fig products in preventing and treating skin warts and cancers such as cervical cancer (Ghanbari et al., 2019) due to anticancer properties from leaf extraction, which is used as a drug to inhibit cancer cell

growth. Therefore, another extraction is used to produce drugs for cardiovascular diseases due to having essential components such as flavone, rutine, and quercetin (Lianju et al., 2003). On the other hand, the high fiber concentration in fig helps relieve constipation, which functions as a laxative (Tabrizi et al., 2020; Teruel-Andreu et al., 2023). Therefore, *Ficus carica* is used in wound healing because it has high amounts of calcium, iron, and vitamin A.

Other applications used extraction from the peel as a colorant due to anthocyanin that makes the purple color (Backes et al., 2020). Furthermore, fig leaves are used as preservatives in food to prolong milk products' shelf life, especially pasteurized milk (El Dessouky et al., 2020). Moreover, the whole fig produces gum and syrup (Marvdashti et al., 2018) and as an alternative sugar in ice cream (Gençdag et al., 2021). Dried figs are available in multiple forms, including paste, nuggets, concentrate, and powder, and diced for industrial items (Rasool et al., 2023).

6 | CONCLUSION AND FUTURE ASPECTS

Ficus carica is a promising plant of functional food and health-promoting products. This work reviewed *Ficus carica* phytochemistry, nutritional value, functionality, and health-promoting traits. In addition, the potential food and nonfood applications are discussed. Fresh and dried *Ficus carica* are rich sources of phytochemicals, and their phytochemical levels are correlated with their biological potential. The long-term medical use of *Ficus carica* suggests that it could be considered safe. The majority of the medical studies carried out on *Ficus carica* used crude extracts. Therefore, it is not easy to reproduce those reports' outcomes and locate the precise bioactive metabolite. It is worth mentioning that ficin is of interest as a wound healing and antibiofilm

TABLE 8 Fig applications in the food industry.

Industry	Food product	Additive	Function	Reference
Food industry	Fig powder coproducts (FPC)	Peel and pulp	Peel FPC contains a higher level of antioxidant activity than pulp FPC.	(Viuda-Martos et al., 2015)
Food industry	Functional food	Leaves, pulp, peels, seeds, and latex	It adds high-value ingredients and their utilization in the food formulation.	(Rasool et al., 2023)
Food packaging	Fig-based chitosan film	Leaves	The incorporation of chitosan films and leaf extraction can be used to protect the food and increase its shelf life.	(Yilmaz et al., 2022)
Confectionery	Donut icing and pastry product "beijinhos."	Fig peels	Fig peel is used as a natural coloring agent.	(Backes et al., 2020)
Confectionery	Toffee	Fig fruit powder	Fig powder is added to toffee products to increase their physicochemical and sensory parameters.	(Khapre et al., 2011)
Baking	Cookies	Fresh fig fruit powder	The cookies prepared with fig powder have high nutrient value compared to market products.	(Khapre et al., 2011)
Dairy	Sugar-free milk-based dessert	Dried figs and CMC	Fig and CMC influence the dessert features.	(Jahromi & Niakousari, 2017)
Oil	Canola oil	Pulp and skin extract	Skin can increase oxidative stability because it contains a high value of phenolic compounds.	(Maghsoudlou et al., 2017)

Note: Adapted from Rasool et al. (2023), and Ramadan (2023).

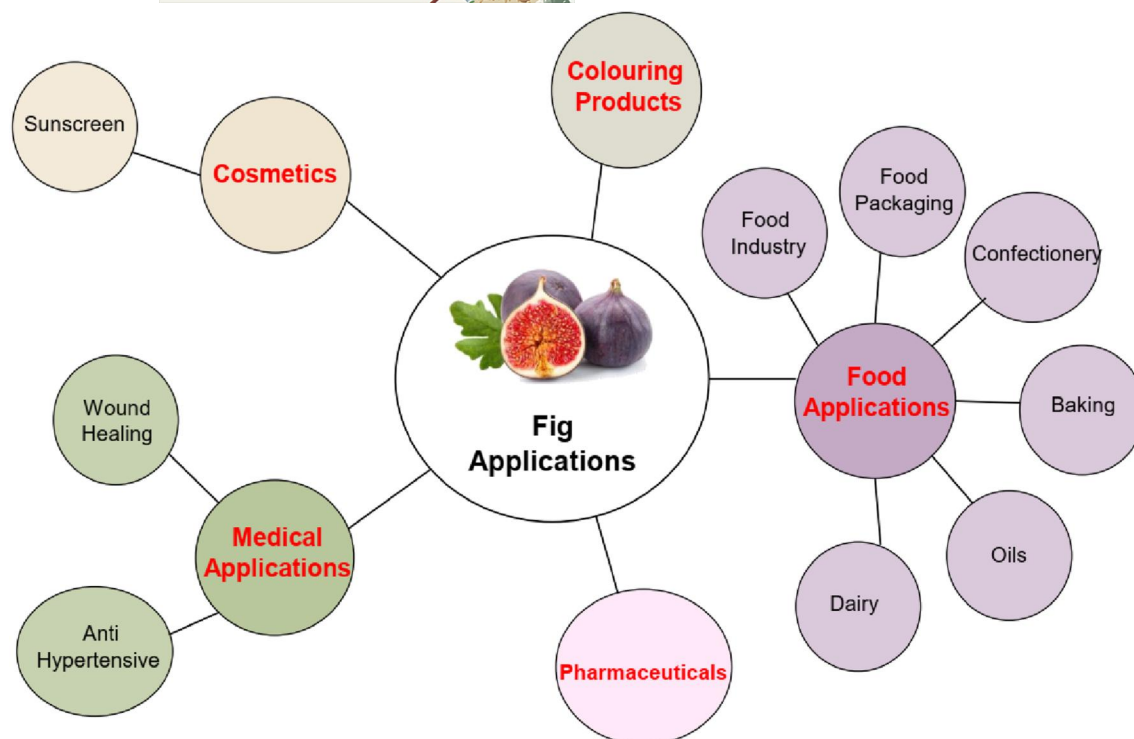


FIGURE 3 Food and nonfood applications of fig.

agent. In addition, the protective impact of *Ficus carica* leaf extracts against many diseases has been noted. Future nutritional and clinical trials could allow a deeper understanding of *Ficus carica* health-promoting traits. On the other hand, *Ficus carica* biowastes are structurally rich in various phenolic compounds. Meanwhile, in-depth research is needed to fully define all compounds in these biowastes and their corresponding biological potential to promote their use in foods, pharmaceuticals, and cosmetic applications.

AUTHOR CONTRIBUTIONS

Manar Yahya Alzahrani, Asmaa Ibrahim Alshaikhi, Jumanah Samir Hazzazi, and Jumanah Reda Kurdi: Writing-original draft. Mohamed Fawzy Ramadan: Supervision, writing-review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors confirm they have no known competing financial interests or personal relationships that could have influenced the manuscript.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

ETHICS STATEMENT

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