Chemical Composition and Biological Uses of *Crocus sativus* L. (Saffron)

7

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Abstract

Crocus sativus L. (Iridaceae) is a stemless herb produced in Iran, Afghanistan, Turkey, Spain, Greece, and India. It is commonly known as saffron and used since historical times as an important crop of food and nutraceuticals and for its therapeutic importance. The main use of this plant comes from yellow-coloured dried stigmas having a bitter taste and intense aroma. Saffron contains aroma-yielding compounds and volatiles (150) of different chemical natures such as terpenes, terpene alcohol, and their esters. Around 135 bioactive molecules have been isolated including chemical markers (crocin, crocetin, picrocrocin, and safranal) from *C. sativus*. The picrocrocin and safranal are major contributors for its bitter taste and hay fragrance. *Golden herb* possesses a variety of therapeutic potentials such as antimicrobial including antiparasitic and antibacterial, antioxidant, hypotensive, hypolipidemic, anxiolytic, antidepressant, anticonvulsant, antinociceptive, anti-inflammatory, diuretic, cytotoxic, etc. In addition, saffron also possesses various health-promoting properties like treating asthma, menstrual cramps, depression, and many more. Many ayurvedic and herbal formulations have been prepared from saffron which includes skincare and health-care products. Saffron is an expensive spice with a price of for 1 kg stigmas around 600–1000$. The high cost and demand of the golden spice encourage the scientific community to made efforts for its large-scale production. Hence, quality insurance of saffron needs to be certified as per ISO/FDA. The overview of the background, phytochemistry, pharmacological activities,

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substitutes, adulterants, toxicity, and formulations has been discussed along with quality and standardization methods of saffron.

Keywords

Crocus sativus · Iridaceae · Phytochemistry · Standardization · Saffron

Abbreviations

CIE	International Commission on Illumination
FDA	Food and Drug Administration
HPLC	High-performance liquid chromatography
MDA	Malondialdehyde
TLC	Thin layer chromatography

7.1 Introduction

Crocus sativus L. (Iridaceae) is a stemless high-value medicinal and aromatic plant found in Europe, Asia, and America. The saffron word originated from Safran, a French word that means "yellow" (Evans 1997; Harper 2001; Mozaffarian 1996). Etymologically, *Crocus* is derived from the Greek word *Croci* meaning thread and *Sativus* meaning cultivation (Deo 2003). The plant has different names region-wise, e.g. in Arab it is known as Zahafaran, and in India Saffron [Keshar (Hindi), Kumkuma (Sanskrit), and Kungumapu (Tamil)]. *C. sativus* in addition to dye, perfume, and medicine has also been considered in culinary since ages (Abrishami 1997). It is the world's most valuable spice because of short flowering season of fewer than 3 weeks and effortful harvesting and 1 kg of stigmas can cost up to 1000$ (USDA 2009). Saffron has a strong fragrance, bright yellow-orange colour, and bitter taste. For this reason, saffron is often used in the aroma as well as in colour industry (Wani et al. 2011; Saeidnia 2012).

7.2 Origin and History

Saffron has a historical background of use and cultivated since antiquity. It has been cultivated for use as a dye and was the most loved and high-value spice crop of ancient Greeks, Romans, and Egyptians. The evidences for the use of saffron are around from 2400 BC, and more proofs for its use in colouring tunics exist in Spain. The saffron became popular in Mesopotamia with the civilization of Babylonian culture. Ancient scripts talk about utilization as a flavouring agent during the rule of Hammurabi (1800–1700 BC) and are also found in the text of Kashmir (fifth century BC). Iran, India (J&K), and Spain are the highest growers of saffron in the global

Fig. 7.1 Pictorial representation of *Crocus sativus L. (saffron)*

market. In Persian text, the use of saffron for paper production as well as for the preparation of ink of different shades has been mentioned. Saffron ink was used to write the holy prayers and scripts by the rulers and royal peoples. There is also evidence of saffron use by Sumerians around 5000 years ago which signifies its silver past.

7.3 Morphology

Saffron is a perennial herb with purple-coloured flowers having three stamens and a corm of 2 in. diameter. Each corm produces 5–9 small leaves (Fig. 7.1). The plant propagates through corms by sprinkling the roots at the base and circumference of the corms. The flowering occurs in late winters and spring (Evans 1997). In the first year, the corms did not produce flower buds due to lack of proper nourishment. The flower contains three indistinguishable sepals and petals. From the centre of flowers is located an ovary which ends up in a yellow-coloured style that gives rise to orange-red coloured stigmas, the main source of saffron. Flowers are sterile and hence don't provide any seeds. Hence, the mode of propagation is through corms, and a single corm produces one to seven flowers (Srivastavan et al. 2010).

7.4 Classification

Kingdom—Plantae	**Family**—Iridaceae
Division—Magnoliophyta	**Species**—*sativus*
Class—Liliopsida	**Genus**—*Crocus*
Order—Asparagales	

7.5 Traditional Uses

Saffron has been used in European culinary since ages for colour and flavour and also as important ingredients of Gugelhupf which is a German cake. Additionally, dairy items incorporate it to impart colour and flavour. Romanians used saffron for relieving hangovers. It has excellent antispasmodic properties and is used for pain relief (sixteenth to nineteenth centuries; Schmidt and Betti 2007). It has expectorant, aphrodisiac, sedative, and anxiolytic effects. The Egyptian mentions saffron for kidney and liver problems and in dysentery, measles, gallbladder, and urinary tract infections (Baumann 1960; Grisolia 1974). However, a higher dosage of saffron may act as an abortifacient and also lead to temporary paralysis (Malairajan et al. 2006).

7.5.1 Phytochemistry of *C. sativus*

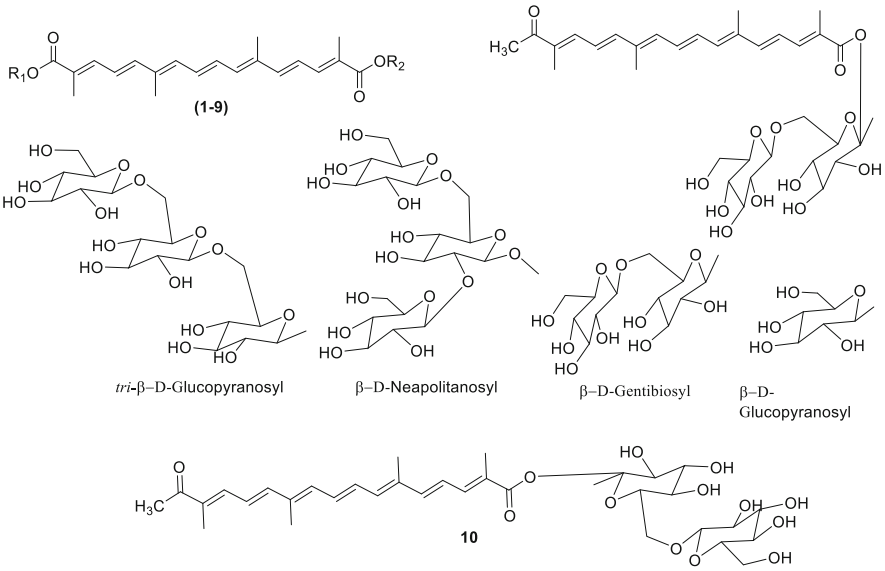
It is the most explored and well-known species of the genus *Crocus*. Crocetin and its esters, safranal and picrocrocin, are the quality control chemical markers of saffron. Major classes of compounds isolated from saffron include diterpenes, triterpenes, tetraterpenes, monoterpenoids, flavonoids and phenolics, carboxylic acids, sterols, nitrogen-containing compounds, and other classes. Detailed descriptions are discussed below.

7.5.1.1 Apocarotenoids and Their Derivative

It is the most characteristic class of phytochemicals that are reported in *C. sativus* stigmas. Crocetin (**1**) and its glycosidic esters crocins (**2–10**) are major water-soluble apocarotenoids, whereas phytoene, zeaxanthin, beta-carotene, and lycopene (**11–14**) are fat-soluble carotenoids present in saffron (Mykhailenko et al. 2019; García-Rodríguez et al. 2017; Figs. 7.2 and 7.3; Table 7.1). In saffron, the crocin is about 6–16% of dry weight and can further be increased to 30% by its cultivation and processing practices (Hu et al. 2015; Gregory et al. 2005; Kyriakoudi et al. 2012; Liorens et al. 2015). A novel xanthone, mangicrocin **(15)**, has also been reported from *C. sativus* stigmas (Ordoudi and Tsimidou 2004; Fig. 7.4).

7.5.1.2 Monoterpenoids

Picrocrocin (**16**) is a major chemical compound of volatile oil responsible for saffron essence, whereas safranal (**17**) constitutes over 60% of the oil and contributes to its bitter taste (Tarantilis and Polissiou 1997). Maggi and team provided the information that β-isophorone (**19**), isophorone isomer (**20**), α-pinene (**21**), 1,8-cineole (**22**), and β-ionone (**23**) are also the main components of essential oil, in addition to **16** and **17** (Maggi et al. 2010; Mykhailenko et al. 2019). (4*R*)-4-hydroxy-2,6,6-trimethylcyclohex-1-enecarbaldehyde4-O-[β-D-glucopyranosyl (1 → 3)-β-D-glucopyranoside] (**24**), a safranal glycoside, was reported from the alcoholic extract of saffron (Mykhailenko et al. 2019). Red saffron stigmas contain β-cyclocitral (**25**) and 4-oxoisophorone (**26**; Tarantilis and Polissiou 1997), whereas crocusatins (A-L; **27-38**) were isolated and reported from stigmas, petals, and pollens (Li and Wu



S.No	R1	R2
1.	H	H
2.	triglucocoside	gentiobioside
3.	nepolitanoside	gentiobioside
4.	gentiobioside	glucoside
5.	gentiobioside	gentiobioside
6.	gentiobioside	glucoside
7.	gentiobioside	H
8.	glucose	glucose
9.	glucose	H
10.	-	gentiobioside

Fig. 7.2 Diterpenes and triterpenes

2002a; Mykhailenko et al. 2019). The main monoterpenoids (**16-38**) from saffron are depicted in Fig. 7.5 and Table 7.1.

7.5.1.3 Flavonoids

Flavonoids are accumulated in all the tissues of *C. sativus*. The structure of flavonoids and their derivatives from *C. sativus* (compounds **39–89**) are depicted in Table 7.1 and graphed in Figs. 7.6, 7.7, 7.8, and 7.9. Flavonoids are further classified into different classes and discussed below in detail.

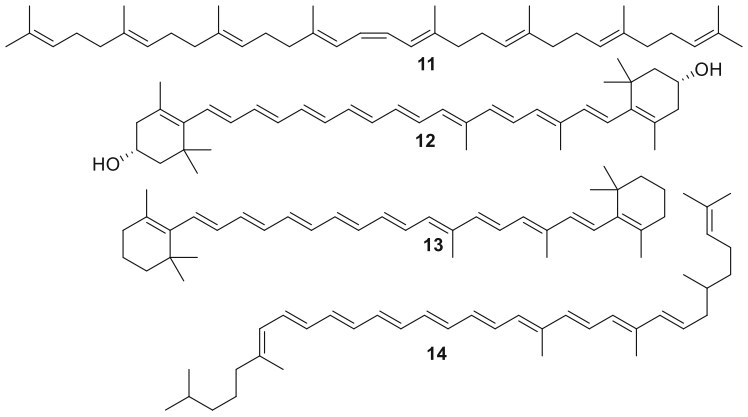


Fig. 7.3 Tetraterpenes

7.5.1.4 Flavone Derivatives

Flavones are the second most abundant class found in saffron. The compounds **39–70** fall under this category and are distributed in various tissues of the plant. The compounds are discussed in Table 7.1 and Fig. 7.6. The chromatographic studies based on mass fragmentation pattern detected the kaempferol (**39**), kaempferol 3-O-sophoroside-7-O-β-D-glucopyranoside (**40**), sophoraflavonoid (**41**), and kaempferol 7-O-β-D-sophoroside (**44**) in abundance (Mykhailenko et al. 2019) while kaempferol 3,7,4′-tri-O-β- glucopyranoside (**43**), kaempferol-3-dihexoside (**44**), astragalin (**45**; Li et al. 2004; Tung and Shoyama 2013), populin (**46**; Straubinger et al. 1997; Moraga et al. 2009a, 2009b), **47**, **48**, **49**, and their synthetically prepared derivatives such as **50 and 51** in low levels (Carmona et al. 2007;Vignolini et al. 2008; Montoro et al. 2008; Li et al. 2004). Similarly, quercetin, isorhamnetin, and their derivatives (**55–68**; Montoro et al. 2008, 2012; Norbeak et al. 2002), myricetin (**70**; Gismondi et al. 2012) and rhamnetin (**78**), were also reported in *C. sativus* stigmas (Fig. 7.6).

7.5.1.5 Flavonone Derivatives

Compounds (**71–75**) are categorized as flavonone derivatives and distributed in stigmas, petals, stamens, and leaves. The dihydrokaempferol (**71**; Mykhailenko et al. 2019), dihydrokaempferol 3-O-hexoside (**72**; Mykhailenko et al. 2019), and taxifolin 7-O-hexoside (**73**) were isolated, whereas naringenin 7-O-hexoside naringenin (**74–75)** were detected from stigmas **(**Mykhailenko et al. 2019; Fig. 7.7).

7.5.1.6 C-Flavone Derivatives

Compounds (**76–80**) are categorized as C-flavone derivatives and distributed mainly in leaves and tepals. Kaempferol 8-C-glycosides (**76-77**) were reported only in the leaves, whereas isoorientin (**78**), vitexin (**79**), and orientin (**80**) were noticed in the leaves and petals (Fig. 7.8; Mykhailenko et al. 2019).

Table 7.1 Phytochemicals from different parts of saffron

S. No	Identity	Part	References
Diterpenes and triterpenes			
1	Crocetin	Stigma; corms	Tarantilis and Polissiou (1997), Zhou et al. (2011)
2	*trans-/cis-crocetin* (tri-β-D-glucosyl)-(β-D-gentibiosyl) ester	Stigma	Zhou et al. (2011), Carmona et al. (2007)
3	*trans-/cis*-crocetin (β-D-neopolitanosyl)-(β-D-gentiobiosyl) ester	Stigma; flowers	Carmona et al. (2007)
4	*trans-/cis-crocetin* (β-D-neopolitanosyl)-(β-D-glucosyl) ester	Stigma	Carmona et al. 2007
5	*trans-/cis*-crocetin di-(β-D-gentiobiosyl) ester	Stigma; petals	Carmona et al. (2007), Pfander and Schurtenberge (1982), Straubinger et al. (1997)
6	*trans/cis*-crocetin (β-D-glucosyl)-(β-D-gentiobiosyl) ester)	Stigma; petals	Carmona et al. (2007), Montoro et al. (2012)
7	*trans/cis*-crocetin (β-D-gentiobiosil) ester	Stigma; petals	Pfander and Schurtenberger (1982), Montoro et al. (2012)
8	*trans/cis*-crocetin di-(β-D-glucosyl) ester	Stigma; petals	Pfander and Schurtenberger (1982), Carmona et al. (2007), Zhou et al. (2011)
9	*trans/cis*-crocetin (β-D-glucosyl) ester	Stigma; petals	Zhou et al. (2011)
10	*trans*-crocetin-1-al 1-O-β-D-gentiobiosyl ester	Stigma	Tung and Shoyama (2013)
Tetraterpenes			
11	Phytoene	Stigma	Grosso (2016)
12	Zeaxanthin	Stigma	Grosso (2016), Pfander and Schurtenberger (1982)
13	β-Carotene	Stigma	Grosso (2016), Pfander and Schurtenberger (1982)
14	Lycopene	Stigma	Grosso (2016), Pfander and Schurtenberger (1982)
Xanthone-carotenoid glycosidic conjugate			
15	Mangicrocin	Stigma	Ordoudi and Tsimidou (2004)
Monoterpenoids			
16	Picrocrocin	Stigma; petals	Zhou et al. (2011), Moraga et al. (2009a, b), Montoro et al. (2012)
17	Safranal	Stigma; flowers	Tarantilis and Polissiou (1997)
18	Safranal isomer	Stigma	Tarantilis and Polissiou (1997)
19	β-Isophorone	Stigma	Lage et al. (2015)
20	Isophorone isomer	Stigma	Tarantilis and Polissiou (1997)
21	α-Pinene	Stigma	Lage et al. (2015)
22	1,8-Cineole	Stigma	Lage et al. (2015)
23	β-Ionone	Stigma	Lage et al. (2015)

(continued)

Table 7.1 (continued)

S. No	Identity	Part	References
24	(4*R*)-4-Hydroxy-2,6,6-trimethylcyclohex-1-enecarbaldehyde 4-O-[β-D-glucopyranosyl(1 → 3)-β-D-glucopyranoside]	Stigma	Tung and Shoyama, (2013)
25	β-Cyclocitral	Stigma	Moraga et al. (2009a, b), Montoro et al. (2012), Lage et al. (2015)
26	4-Oxoisophorone	Stigma	Lage et al. (2015)
27	Crocusatin A	Pollen	Li and Wu (2002a)
28	Crocusatin B	Pollen	Li and Wu (2002a)
29	Crocusatin C	Stigma; petals; pollen	Li and Wu (2002a)
30	Crocusatin D	Petals; pollen	Li and Wu (2002a)
31	Crocusatin E	Stigma; pollen	Li and Wu (2002a)
32	Crocusatin F	Stigma; pollen	Li and Wu (2002a)
33	Crocusatin G	Stigma	Li and Wu (2002a)
34	Crocusatin H	Stigma	Li and Wu (2002a)
35	Crocusatin I	Petals	Li et al. (2004)
36	Crocusatin J	Stigma; petals	Li and Wu (2002a)
37	Crocusatin K	Petals	Li et al. (2004)
38	Crocusatin L	Petals	Li et al. (2004)
Flavonoids			
Flavon derivatives			
39	Kaempferol	Stigma; petals	Li et al. (2004), Montoro et al. (2012), Gismondi et al. (2012)
40	Kaempferol 3-O-sophoroside-7-O-β-D-glucopyranoside	Stigma	Straubinger et al. (1997), Carmona et al. (2007), Vignolini et al. (2008)
41	Sophoraflavonolosid (kaempferol-3-O-β-D-glucopyranosyl-(1 → 2)-β-D-glucopyranoside; kaempferol-3-O-β-D-sophoroside)	Stigma; tepals; pollen; leaves	Carmona et al. (2007), Vignolini et al. (2008), Moraga et al. (2009a, b)
42	Kaempferol 7-O-β-D-sophoroside	Stigma	García-Rodríguez. et al. (2017)
43	Kaempferol 3,7,4′-tri-O-β-glucopyranoside	Stigma	Carmona et al. (2007), Vignolini et al. (2008), Moraga et al. (2009a, b)
44	Kaempferol-3-dihexoside	Stigma	Carmona et al. (2007)
45	Astragalin	Stigma; petals	Li et al. (2004), Tung and Shoyama (2013)

(continued)

Table 7.1 (continued)

S. No	Identity	Part	References
46	Populin	Stigma; petals	Montoro et al. (2008), Straubinger et al. (1997)
47	Kaempferol 3-O-β-D-glucopyranosyl-(1 → 2)-O-β-D-glucopyranosid-7-O-β-D-glucopyranoside	Stigma	Li et al. (2004)
48	Kaempferol 3-O-α-L-(2-O-β-D-glucopyranosyl)rhamnopyranoside-7-O-β-D-glucopyranoside	Stigma	Li et al. (2004)
49	Kaempferol 3-O-β-D-(2-O-β-D-glucopyranosyl)glucopyranoside	Petals	Li et al. (2004), Montoro et al. (2012)
50	Kaempferol 3-O-β-D-(2-O-β-D-6-O-acetylglucosyl)glucopyranoside	Stigma; petals	Montoro et al. (2008), Li et al. (2004)
51	Kaempferol 3-O-α-L-(2-O-β-D-glucopyranosyl)rhamnoperanoside-7-O-β-D-(6-O-acetyl) glucopyranoside	Stigma	Li et al. (2004)
52	Kaempferol 3,7-di-O-β-D-glucopyranoside	Pollen; petals; stamens	Li et al. (2004), Montoro et al. (2012), Li and Wu (2002a)
53	Kaempferol 3-O-α-L-(2-O-β-D-glucopyranosyl)rhamnopyranosides	Tepals	Sánchez-Vioque et al. (2016)
54	Kaempferol 3-O-β-D-sophoroside-7-O-α-L-rhamnopyranoside	Tepals	Sánchez-Vioque et al. (2016)
55	Quercetin	Stigma	Li et al. (2004), Gismondi et al. (2012)
56	Helichrysoside	Tepals	Ordoudi and Tsimidou (2004), Zhou et al. (2011)
57	Tamarixetin 3-O-bihexoside	Sepals; stamens	Montoro et al. (2012)
58	Quercetin 3,4′-di-O-β-D-glucopyranoside	Tepals	Sánchez-Vioque et al. (2016)
59	Quercetin-3,7-di-O-β-D-glucopyranoside	Petals; stamens; flowers	Montoro et al. (2012)
60	Quercetin 3-O-β-D-sophoroside	Tepals	Montoro et al. (2012)
61	Quercetin 3-O-β-D-glucopyranoside	Stamens; petals	Montoro et al. (2012)
62	Quercetin 3-O-β-D-glucopyranosyl-(1 →2)-*α*-L-rhamnopyranoside-7-O-β-D-glucopyranoside	Flowers	Sánchez-Vioque et al. (2016)
63	Rhamnetin	Stamens; petals	Montoro et al. (2012), Termentzi and Kokkalou (2008)
64	Isorhamnetin	Petals	Montoro et al. (2012)
65	Crosatoside A	Pollen	Montoro et al. (2012)

(continued)

Table 7.1 (continued)

S. No	Identity	Part	References
66	Isorhamnetin 3,4′-di-O-β-D-glucopyranoside	Pollen; petals	Li and Wu (2002b), Montoro et al. (2008)
67	Isorhamnetin 3,7-di-O-β-D-glucopyranoside	Stamens; petals	Montoro et al. (2012)
68	Isorhamnetin-3-O-β-D-glucopyranoside	Pollen ; stigma; stamens; petals	Montoro et al. (2012); Li and Wu (2002b), Baba et al. (2015a, b)
69	Isorhamnetin-3-O-robinobioside	Pollen	Li and Wu (2002b)
70	Myricetin	Stigma	Gismondi et al. (2012)
Flavonon derivatives			
71	Dihydrokaempferol 7-O-β-D-glucopyranoside	Stigma	García-Rodríguez. et al. (2017)
72	Dihydrokaempferol 3-O-hexoside	Stigma; petals	Baba et al. (2015a, b), Montoro et al. (2008)
73	Taxifolin 7-O-hexoside	Stigma; petals; stamens	Baba et al. (2015a, b), Montoro et al. (2008, 2012)
74	Narinrenin 7-O-hexoside	Petals	Montoro et al. (2008)
75	Naringenin	Petals; stamens; leaves	Termentzi and Kokkalou (2008), Montoro et al. (2012), Baba et al. (2015a, b)
C-flavon derivatives			
76	Kaempferol-8-C-β-D-glycopyranosyl-6,3-di-O-β-D-glucopyranoside	Leaves	Sánchez-Vioque et al. (2016)
78	Isoorientin	Tepals	
79	Vitexin	Tepals; leaves	
80	Orientin	Tepals; leaves	
Anthocyanin			
81	Delphinidin 3,7-di-O-β-glucopyranoside	Petals	Lotfi et al. (2015), Nørbæk et al. (2002)
82	Petunidin 3,5-di-O-β-D-glucopyranoside	Tepals	
83	Petunidin 3,7-di-O-β-glucopyranoside	Tepals	
84	Petunidin 3-O-β-D-glucopyranoside	Tepals	
85	Myrtillin	Tepals	
86	Petunidin	Tepals	
87	Callistephin	Tepals	
88	Pelargonin	Tepals	
89	Cyanin	Tepals	

(continued)

Table 7.1 (continued)

S. No	Identity	Part	References
Phenols and phenol carboxylic acids			
90	Caffeic acid	Stigma; corms	Gismondi et al. (2012)
91	Chlorogenic acid	Stigma	Gismondi et al. (2012)
92	Ferulic acid	Corms	Esmaeili et al. (2011)
93	*p*-Coumaric acid	Corms; petals	Esmaeili et al. (2011)
94	Sinapic acid	Corms; petals	Termentzi and Kokkalou (2008), Baba et al. (2015a, b)
95	Gallic acid	Stigma; corms	Gismondi et al. (2012)
96	Protocatechuic acid	Petals	Li et al. (2004)
97	Vanillic acid	Petals	Li et al. (2004)
98	*p*-Hydroxybenzoic acid	Corms; petals; pollens	Li et al. (2004); Esmaeili et al. (2011)
99	3-Hydroxy-4-methoxybenzoic acid	Petals	Li et al. (2004)
100	Syringic acid	Corms	Esmaeili et al. (2011)
101	Gentisic acid	Corms	Esmaeili et al. (2011)
102	Salicylic acid	Corms	Esmaeili et al. (2011)
103	Benzoic acid	Pollen	Li and Wu (2002b)
104	Cinnamic acid	Corms	Esmaeili et al. (2011)
105	Protocatechuic acid methyl ester	Petals; pollen	Li et al. (2004)
106	Methylparaben	Petals; pollen; stigma	Li et al. (2004), Li and Wu (2002a, b)
107	(3*S*),4-Dihydroxybutyric acid	Petals	Li et al. (2004)
Phytosterols			
108	β-Sitosterol	Stigma; corms; flowers; pollen	Feizy and Reyhani (2016)
109	Stigmasterol	Stigmas; corms; flowers; stamens	Feizy and Reyhani (2016)
110	Fagasterol	Flowers	Feizy and Reyhani (2016)
111	Fucosterol	Flowers	Feizy and Reyhani (2016)
112	Campesterol	Corms	Feizy and Reyhani (2016)
Vitamins			
113	Riboflavin	Stigma	Lim (2014)
114	Thiamine	Stigma	Lim (2014)
115	Piridoxal	Stigma	Lim (2014)

(continued)

Table 7.1 (continued)

S. No	Identity	Part	References
Nitrogen-containing compounds			
116	Tribulusterine	Petals; stigma	Li et al. (2004), Li and Wu (2002a), Termentzi and Kokkalou (2008)
117	Adenosine	Petals; pollen; stigma; sprouts	Li et al. (2004), Li and Wu (2002a), Termentzi and Kokkalou (2008)
118	Harman	Petals; stigma	Li et al. (2004), Li and Wu (2002a)
119	Nicotinamide	Petals; pollen; stigma	Li et al. (2004), Li and Wu (2002a)
120	Uracil	Pollen; stigma	Li and Wu (2002a, b)
121	Thymine	Pollen; stigma	Li and Wu (2002a, b)
Furan derivatives			
122	(4*R*)-4-Hydroxy-dihydrofuran-2-one-O-β-D-glucopyranoside	Stigma	Li and Wu (2002a, b)
123	(4*S*)-4-Hydroxy-dihydrofuran-2-one-O-β-D-glucopyranoside	Stigma	Li and Wu (2002a, b)
124	2-Formyl-5-methoxyfuran	Stigma	Li and Wu (2002a 2002b)
Triterpenoid saponins			
125	Azafrin 1	Corms	Rubio-Moraga et al. (2011)
126	Azafrin 2	Corms	Rubio-Moraga et al. (2011)
Acetophenones			
127	2,3,4-Trihydroxy-6-methoxyacetophenone-3-O-β-D-glucopyranoside	Sprouts	Gao et al. (1999a)
128	2,4-Dihydroxy-6-methoxyacetophenone-2-O-β-D-glucopyranoside	Sprouts	Gao et al. (1999a)
Anthraquinones			
129	Emodin	Sprouts	Gao et al. (1999b)
130	2-Hydroxyemodin	Sprouts	Gao et al. (1999b)
131	1-Methyl-3-methoxy-8-hydroxyanthraquinone-2-carboxylic acid	Sprouts	Gao et al. (1999b)
132	1-Methyl-3-methoxy-6,8-dihydroxyanthraquinone-2-carboxylic acid	Sprouts	Gao et al. (1999b)
Others			
133	Crosatoside B β-(phydroxyphenyl)ethanol-α-O-L-rhamnopyranosyl (1 → 2)-β-D-glucopyranoside	Pollen	Li and Wu (2002a)

(continued)

Table 7.1 (continued)

S. No	Identity	Part	References
134	Sodium(2*S*)-(O-hydroxyphenyl) lactate	Stigma	Li and Wu (2002a)
135	3-(*S*)-3-β-D-glucopyranosyloxybutanolide	Sprouts	Gao et al. (1999a)

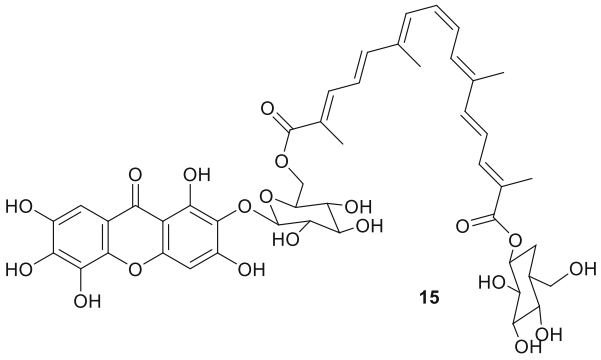


Fig. 7.4 Xanthones

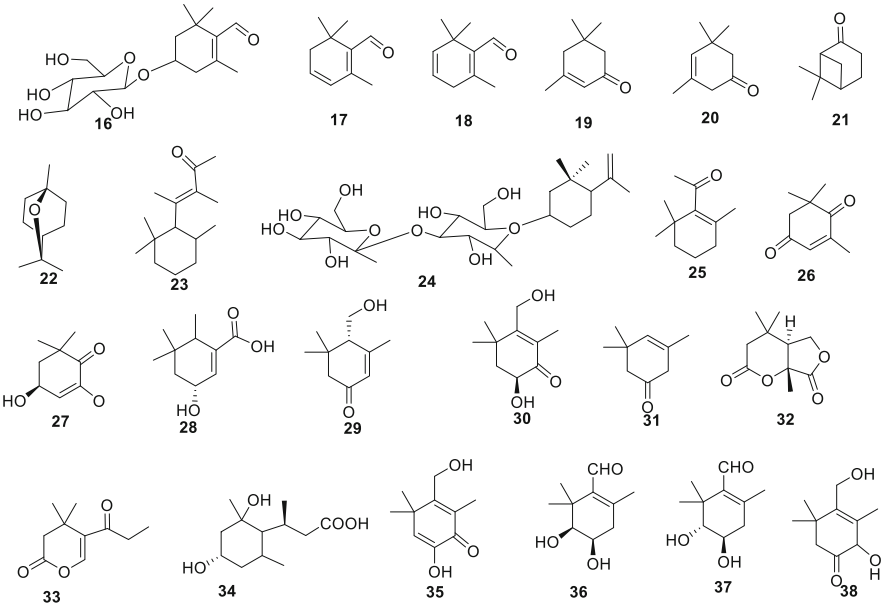
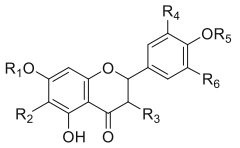


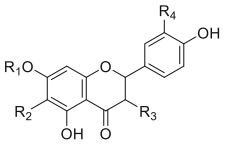
Fig. 7.5 Monoterpenoids and cyclohexane/hexene derivatives



(39-70)

	OR_1	R_2	R_3	R_4	OR_5	R_6
39.	H	H	OH	H	OH	H
40.	*β*-Glc	H	*O*-*β*-Glc-1 → 2-O-*β*-Glc	H	OH	H
41.	OH	H	*O*-*β*-Glc-1 → 2-*β*-Glc	H	OH	H
42.	*β*-Glc-1 → 2-*β*-Glc	H	OH	H	OH	H
43.	*O*-*β*-Glc	H	*O*-*β*-Glc	H	*O*-*β*-Glc	H
44.	H	H	O-hex-hex	H	OH	H
45.	H	H	*O*-*β*-Glc	H	OH	H
46.	*β*-Glc	H	OH	H	OH	H
47.	*β*-Glc	H	*O*-*β*-Glc-1 → 2-O-*β*-Glc	H	OH	H
48.	*β*-Glc	H	O-*α*-(2-O-*β*-Glc-Rha)	H	OH	H
49.	H	H	*O*-*β*-Glc-(2-O-*β*-Glc)	H	OH	H
50.	H	H	*O*-*β*-Glc-(2-O-*β*-acetyl)	H	OH	H
51.	*β*-(6-O-acetyl-Glc)	H	O-*α*-(2-O-*β*-Glu-Rha)	H	OH	H
52.	*β*-Glc	H	*O*-*β*-Glc	H	OH	H
53.	H	H	O-*α*-(2-O-*β*-Glu-Rha)	H	OH	H
54.	*α*-Rha	H	*O*-*β*-Glc-1 → 2-*β*-Glc	H	OH	H
55.	H	H	OH	OH	OH	H
56.	H	H	O-*p*-coumaroyl-Glc	OH	OH	H
57.	H	H	O-hex-hex	OH	OCH_3	H
58.	H	H	*O*-*β*-Glc	OH	*O*-*β*-Glc	H
59.	*β*-Glc	H	*O*-*β*-Glc	OH	OH	H
60.	H	H	*O*-*β*-Glc-1 → 2-O-*β*-Glc	OH	OH	H
61.	H	H	*O*-*β*-Glc	OH	OH	H
62.	*β*-Glc	H	*O*-*β*-Glc-1 → 2-O-*α*-Rha	OH	OH	H
63.	CH_3	H	OH	OH	OH	H
64.	H	H	OH	OCH_3	OH	H
65.	H	H	OH	OCH_3	*O*-*α*-Rha-(1→)-*β*-Glu	H
66.	H	H	*O*-*β*-Glc	OCH_3	*O*-*β*-Glc	H
67.	Glc	H	*O*-*β*-Glc	OCH_3	OH	H
68.	H	H	*O*-*β*-Glu	OCH_3	OH	H
69.	H	H	*O*-*β*-Rob	OCH_3	OH	H
70.	H	H	OH	OH	OH	OH

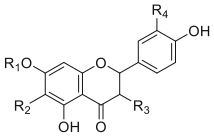
Fig. 7.6 Flavone derivatives



(71-75)

	R1	R2	R3	R4
71.	*β*-D-Glc	OH	OH	H
72.	H	OH	O-hex	H
73.	H	OH	O-hex	OH
74.	hex	OH	H	H
75.	H	OH	H	H

Fig. 7.7 Flavanone derivatives



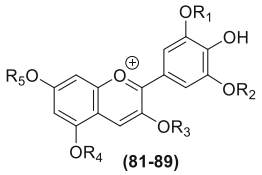
(76-80)

	R1	R2	R3	R4
76.	*C*-*β*-Glc	*O*-*β*-Glc	*O*-*β*-Glc	H
77.	*C*-*β*-Glc	*O*-*β*-Glc	OH	H
78.	H	*C*-*β*-Glc	H	OH
79.	*C*-*β*-Glc	H	H	H
80.	*C*-*β*-Glc	H	H	OH

Fig. 7.8 *C*-flavone derivatives

7.5.1.7 Anthocyanins

Compounds (**81–89**) are categorized as anthocyanins and distributed mainly in tepals and petals of violet saffron (Lotfi et al. 2015). Nine anthocyanin derivatives, namely, 3,7-di-O-β-glucoside of delphinidin (**81**) and petunidin (**83**), 3,5-di-O-β-glucoside of petunidin (**82**), 3-O-β-D-glucosides of petunidin (**84**) and delphinidin (**85**), petunidin (**86**), pelargonidin 3-O-β-D-glycopyranoside (**87**), pelargonidin 3,5-glycosides (**88**), and 3,5 cyanidin-diglycoside (**89**) were identified using HPLC (Fig. 7.9; Norbeak et al. 2002).



(81-89)

	R1	R2	R3	R4	R5
81.	H	H	*β*-glucoside	*H*	*β*-glucoside
82.	CH_3	H	*β*-glucoside	*β*-glucoside	H
83.	CH_3	H	*β*-glucoside	*H*	*β*-glucoside
84.	H	CH_3	*β*-glucoside	H	H
85.	H	H	*β*-glucoside	H	H
86.	H	CH_3	H	H	H
87.	-	-	*β*-glucoside	H	H
88.	-	-	*β*-glucoside	*β*-glucoside	H
89.	*H*	-	*β*-glucoside	*β*-glucoside	H

Fig. 7.9 Anthocyanins

7.5.1.8 Phenols and Their Derivatives

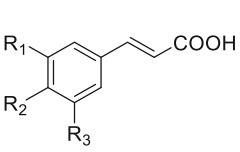
Stigmas of *C. sativus* were studied in-depth for its aromatic compounds (**90-107**). The distribution of these compounds among the different tissues was categorized under this class. The hydroxycinnamic acids, caffeic acid (**90**), chlorogenic acid (**91**; Gismondi et al. 2012), ferulic acid (**92**), *p*-coumaric acid (**93**), and sinapic acid (**94**), were reported in *C. sativus*. (Fig. 7.10 and Table 7.1). Several isolated and identified hydroxybenzoic acids and carboxylic acid, namely, gallic acid (**95**; Mykhailenko et al. 2019), protocatechuic acid(**96**), vanillic acid (**97**), *p*-hydroxybenzoic acid (**98**), 3-hydroxy-4-methoxybenzoic acid (**99**), syringic acid (**100**), gentisic acid (**101**), salicylic acid (**102**), benzoic acid (**103**), cinnamic acid (**104**), protocatechuic acid methyl ester (**105**), methylparaben (**106**; Li and Wu 2002a), and (3*S*),4-dihydroxybutyric acid (**107**), were reported (Fig. 7.10).

7.5.1.9 Phytosterols

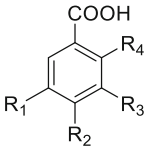
Phytosterols (**108–112**) were detected in stigma, petals, and corms (Feizy and Reyhani 2016; Fig. 7.11 and Table 7.1).

7.5.1.10 Vitamins

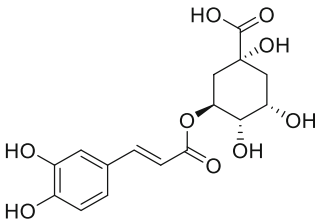
Three vitamins, namely, riboflavin (**113**; Hashemi and Erim 2016), thiamine (**114**), and pyridoxal (**115**; Lim 2014), were detected in stigma.



(90-94)



(95-103)



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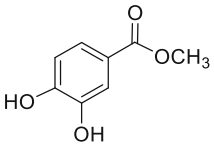

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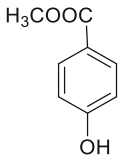

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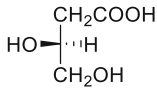

107

	R1	R2	R3	R4
90.	OH	OH	H	
91.	H	H	H	
92.	OCH_3	OH	H	
93.	H	OH	H	
94.	OCH_3	H	H	
95.	OH	OH	OH	H
96.	H	OH	OH	H
97.	H	OH	OCH_3	H
98.	H	OH	H	H
99.	H	OCH_3	OH	H
100.	OCH_3	OH	OCH_3	H
101.	OH	H	H	OH
102.	H	H	H	OH
103.	H	H	H	

Fig. 7.10 Phenolics and carboxylic acids

7.5.1.11 Nitrogen-Containing Compounds

Tribusterine (**116**), adenosine (**117**), harman (**118**), nicotinamide (**119**), uracil (**120**), and thymine (**121**; Fig. 7.12) were detected in stigmas, petals, sprouts, and pollens (b; Li and Wu 2002a).

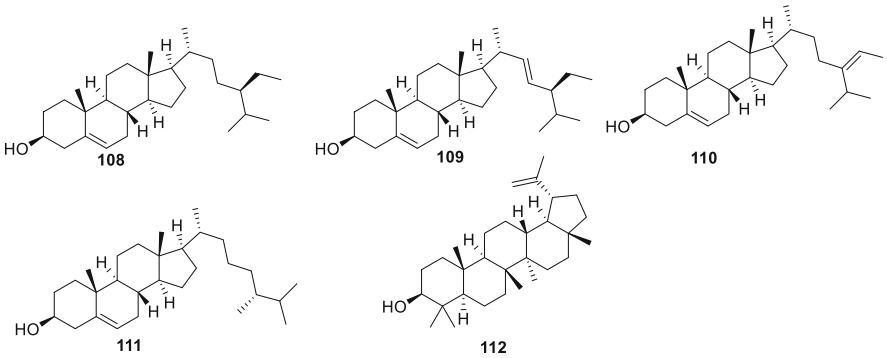

Fig. 7.11 Phytosterols

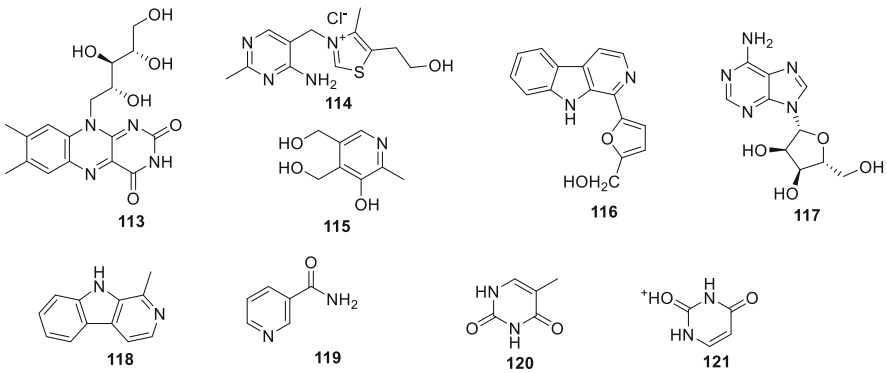

Fig. 7.12 Nitrogen containing compounds

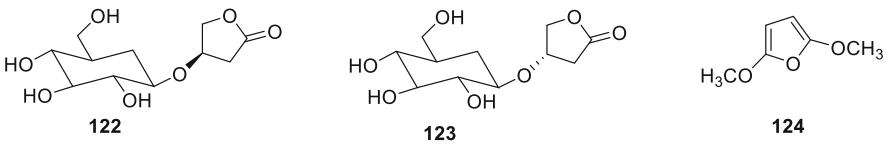

Fig. 7.13 Furans

7.5.1.12 Furan Derivatives

(4*R*)-4-Hydroxy-dihydrofuran-2-one-O-β-D-glucopyranoside (**122**), (4*S*)-4-hydroxy-dihydrofuran-2-one-O-β-D-glucopyranoside (**123**), and 2-Formyl-5-methoxyfuran (**124**) were detected in stigmas (Fig. 7.13; Li and Wu 2002a, b).

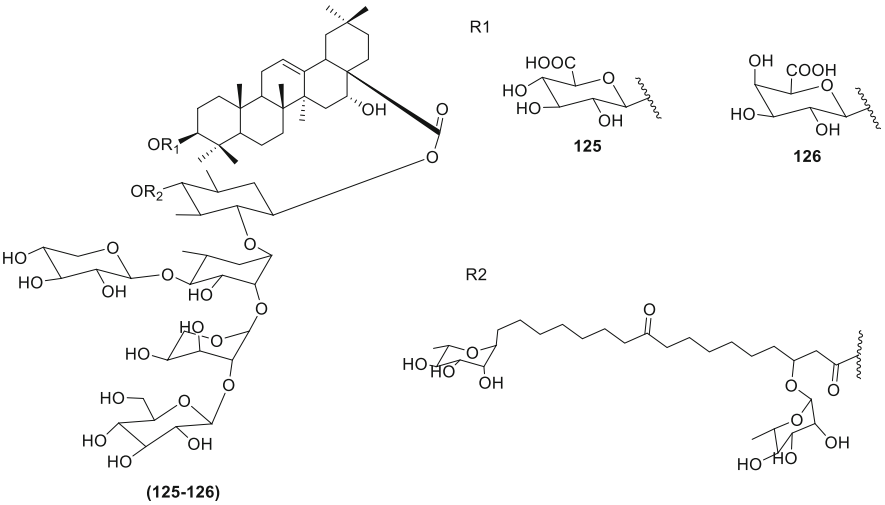

Fig. 7.14 Triterpenoid saponin

7.5.1.13 Triterpenoid Saponins

Two saponins, namely, azafrine1 (**125**) and azafrine2 (**126**), were reported from corms of saffron (Fig. 7.14; Mykhailenko et al. 2019).

7.5.1.14 Acetophenones and Anthraquinones

Acetophenones such as 2,3,4-trihydroxy-6-methoxyacetophenone-3-β-D-glucopyranoside (**127**) and 2,4-dihydroxy-6-methoxyacetophenone-2-β-D-glucopyranoside (**128**) and anthraquinones like emodin (**129**), 2-hydroxyemodin (**130**), 1-methyl-3-methoxy-8-hydroxyanthraquinone-2-carboxylic acid (**131**), and 1-methyl-3-methoxy-6,8-dihydroxyan- thraquinone-2-carboxylic acid (**132**) were isolated sprouts of *C. sativus* (Fig. 7.15; Gao et al. 1999a, b).

7.5.1.15 Others

γ-Lactone type of glucoside [3-(*S*)-3-β-D-glucopyranosyloxybutanolide] was isolated and characterized from sprouts of saffron (Gao et al. 1999a). Furthermore, macro- and micronutrients (Fe, Cu, Mn, Zn, Ca; Mykhailenko et al. 2019), amino acids, and saturated fatty acids were also detected in saffron (Table 7.1; Lim 2014; USDA 2013).

7.5.2 Pharmacological Activities

7.5.2.1 Antiparasitic and Antibacterial Activity

Several studies are reported on *C. sativus* for these activities. The isolated compounds from saffron (safranal and crocin) and semi-synthetic safranal derivatives were assessed against *Helicobacter pylori* for antibacterial and

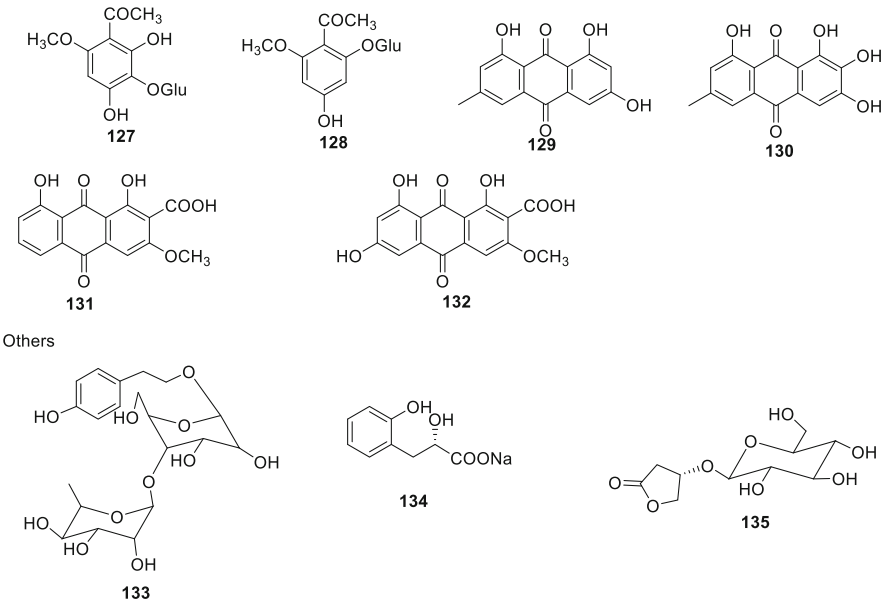

Fig. 7.15 Acetophenones and anthraquinones

plasmodia and leishmania for antiparasitic potential, respectively (De Monte et al. 2015). The MIC_{50} of safranal against *H. pylori* was observed at 32.0 μg/mL, while its two synthetic derivatives (thiosemicarbazonic) at 4–8 μg/mL, exceeding the values of reference drugs metronidazole and clarithromycin (>32 μg/mL). Hydrazothiazole was the most active compound (2–4 μg/mL). The synthetic derivatives showed lower activity against malaria, but high antileishmanial potential against *L. infantum* and *L. tropica* (IC_{50}, 6–16 μg/mL) was observed when compared to amphotericin B antibiotic (IC_{50}, 0.07–0.11 μg/mL). The highest antimalarial potential of crocin (IC_{50}, 18.93 μg/mL) and safranal (IC_{50}, 20 μg/mL) was found against the sensitive strain of chloroquine. Later, in vivo antimalarial activity of saffron stigmas was carried out against *Plasmodium berghei*. Chloroquine was used as a reference standard for accessing water and ethyl acetate extracts. The extracts moderately suppressed the parasitic count, but the combination of ethyl acetate fraction and chloroquine showed enhanced activity which further increases the survival percent of the mice as compared to treated with individual drug (Pestechian et al. 2015). Saffron leaves do not have any antimicrobial activity, while petals showed the activity against *S. aureus*, *S. enteric*, and *S. dysenteriae* (Jadouali et al. 2019).

7.5.2.2 Antioxidant Activity

Phenolics, crocetin, crocin, and safranal exhibited antioxidant activity in free radical scavenging assay (Hu et al. 2015). Saffron extract (300 μg/mL) showed 68.2% and 78.9% inhibition in the scavenging and reducing assays, respectively (Karimi et al.

2010). *C. sativus* leaves, petals, and flowers were also assessed for the concentration-dependent antioxidant potential, whereas petals showed highest while leaves were negligible in activities. Further, β-carotene oxidation inhibition and Cu^{2+}-chelating capacity determined the antioxidant potential of leaves, tepals, and corms of saffron. The finding indicated that tepals and leaves reduced the oxidation of β-carotene, while corms were found as poor antioxidant with slight Cu^{2+}chelating potential (Mykhailenko et al. 2019).

7.5.2.3 Hypotensive Activity

The hydro-alcoholic extract (200 mg/kg) of saffron stigmas were studied in normotensive and L-NAME-induced hypertensive rats (Nasiri et al. 2015), and it was observed that extract prohibited the rise in blood pressure and aortic reconstruction ($^*P < 0.001$). In another study, intravenous administration of safranal (1 mg/kg) and crocin (200 mg/kg) caused the reduction in the mean arterial blood pressure of the rats (60 ± 8.7, 50 ± 5.2, and 51 ± 3.8 mmHg, respectively) (Imenshahidi et al. 2010). Thus, both molecules of saffron showed excellent potential to treat hypertension.

7.5.2.4 Antidepressant Activity

Both stigmas and corms of the saffron have antidepressant potential that may be attributed due to the presence of crocin (Wang et al. 2010). Moreover, the saffron petals showed moderate activity at a dose of 30 mg/day (Moshiri et al. 2006).

7.5.2.5 Anxiolytic

Crocin was evaluated to assess its role to produce anxiolytic effects in light/dark model of rodents. The crocins (50 mg/kg) and diazepam (1.5 mg/kg) showed increase in latency time to enter the dark area and increased the time spent in the light compartment, while lower doses of crocins (15–30 mg/kg) did not modify the animal's behaviour. These findings clearly indicated the anxiolytic potential of crocin (Pitsikas et al. 2008).

7.5.2.6 Anticonvulsant

The anticonvulsant potential of saffron (safranal and *crocin)* was investigated in pentylenetetrazol-induced epileptic model of rodents. The safranal at a dose of 0.15 and 0.35 ml/kg body weight, *i.p.*, reduced the time interval of seizure, delayed onset of tonic seizures, and also protected the mice from death, while crocin (22 mg/kg, i.p.) did not show any antiepileptic activity (Hosseinzadeh and Talebzadeh 2005). But later, Tamaddonfard and his group reported that the crocin and diazepam combination has antiepileptic activities in rats at an effective dose of crocin (50 μg) with an ineffective dose of diazepam (2.5 μg). The study revealed that crocin potentiated the anticonvulsants of diazepam through GABAA-benzodiazepine receptor-mediated mechanism.

7.5.2.7 Memory-Enhancing and Anti-Alzheimer's Activity

The saffron extract and its active constituents were evaluated to know the effect to prevent Alzheimer's disease. The saffron extract (30 mg/day) showed better outcome on cognitive function than placebo after 16 weeks (Akhondzadeh et al. 2010a). In another study, it was observed that use of same dose for 6 months produced equivalent effect as that of donepezil (10 mg/day; Akhondzadeh et al. 2010b).

7.5.2.8 Antitumor Activity

Saffron and its chemical compounds have been evaluated for the therapeutic potential against the variety of cancers. The crocin-, picrocrocin-, and safranal-containing saffron stigma extracts reported to inhibit the growth of human tumor cells (Bhandari 2015; Escribano1996). Anti-proliferative activity on HCT-116, SW-480, and HT-29 (colorectal cancer) cell lines revealed that saffron and its major constituents restricted the proliferation of cancerous cells (Aung et al. 2007).

7.5.2.9 Cardiovascular Effect

Saffron and its bioactives exhibited cardioprotective characteristics in the evaluation of preclinical studies. Aqueous extract of *C. sativus* (20, 40, 80, and 160 mg/kg) and safranal (25, 50, 75 mL/kg) were reported to reduce the level of MDA content lipid peroxidation and level of MDA in the heart. CK-MB and LDH activities were reduced in serum of Wistar rats due to the effects of saffron and its bioactives (Mehdizadeh et al. 2013). Moreover, crocetin (50 mg/kg/day) prevents the inflammations and protects MIRI in rats by inhibiting ROS production. It has also shown reduction in myocardium apoptosis (Wang et al. 2014).

7.5.2.10 Antinociceptive and Anti-Inflammatory Activities

The petal and stigma of saffron have antinociceptive as well as anti-inflammatory potentials. These effects were might be due to the presence of bioactive agents of *C. sativus* (Hosseinzadeh and Younesi 2002).

7.5.2.11 Hypolipidemic and Hypoglycemic Activities

Crocin (100 mg), an important constituent of *C. sativus*, was found effective for patients with metabolic syndrome. The treatment for 1.5 months has shown reductions in the content of triglycerides and total cholesterols. This suggests the hypolipidemic potential of saffron. Further, the water extract of stigmas relieves cognition skills in the diabetic encephalopathy rats. It was observed that at a dose of 20, 40, and 80 mg/kg/day, the reduction in glucose levels was started at fourth, second, and first week of the extract administration, respectively (Kermani et al. 2017; Samarghandian et al. 2014).

7.5.2.12 Diuretic Activity

The diuretic activity of crocin and aqueous extract of saffron stigmas (60, 120, and 240 mg/kg) was reported by Shariatifar and workers (2014a, b). The results were calculated based on urine volume, electrolyte concentrations, creatinine, and urea. Thus, saffron extracts showed dose-dependent increment in the excretion of

electrolytes, while crocin significantly increases the content of creatinine and urinary nitrites in urine of the rats (Hassanin 2015).

7.5.2.13 Cytotoxic Activity

In cytotoxic studies, saffron extracts (100, 200, 400, and 800 μg/mL) reduced the VEGF-A and VEGFR-2 gene expression in MCF-7 cell lines in comparison to control. The decline in VEGF-A (17%) and VEGFR-2 (20%) in gene expression at 800 and 400 μg/mL, respectively, was noted (Mousavi and Baharara 2014). Saffron extract and combination of crocin and safranal gave IC_{50} values at 71 μg/mL and 39 μM for the antiproliferative activity against lymphoblastic T-cell leukaemia (Makhlouf et al. 2016). The saffron extract, crocin, and picrocrocin have shown cytotoxic and apoptogenic effects in malignant TC-1 and non-malignant COS-7 cell lines (Mykhailenko et al. 2019). The crocin (0.05–4 mM) and safranal (0.2–3.2 mM) showed significant cytotoxic effects against oral squamous cell carcinoma KB cells as well as NIH/3 T3 cells with the IC_{50} 2.8 and 0.3 mM, respectively (Mykhailenko et al. 2019). The safranal also inhibited the proliferation of neuroblastoma cells with IC_{50} value of 11.1 and 23.3 μg/mL after 24 and 48 h, respectively. Moreover, the saffron corms bioactive combination (carbohydrates and protein) was found cytotoxic against human cervical epithelioid carcinoma cells (IC_{50}, 7 mg/mL; Escribano et al. 1996, 2000). The triterpenoid saponins from corms were also active against HeLa tumoural cells (Mykhailenko et al. 2019).

7.5.2.14 Toxicity

C. sativus is considered safe even at a dose of more than1.5 g/day (Milajerdi et al. 2016). In animals, its lethal dose is 20.7 g/kg and no toxicity up to a dose of 5 g/kg was noticed. Isolated compounds crocin and dimethyl-crocetin were not found toxic in the Ames/Salmonella assay (Lari et al. 2015; Mykhailenko et al. 2019).

7.5.3 Standards and Criteria

7.5.3.1 Collection Period

The flowering of saffron remains only for 3–4 days and should be collected on the appearing of first flower. As the quality of flowers is affected by wind, sunlight, or heat, the best collection period is between October and November and should be done at dawn (Evans 1997; Kafi 2002).

7.5.3.2 Collection Method

Collection of flowers should be done by hand. Flowers have to be opened on the same day of collection. Opening of flowers before collection may lead to the destruction of stigmas and ultimately mixing with petals which will decrease the quality (Evans 1997; Hemmati Kakhki 2001).

7.5.3.3 Drying Methods

Stigmas must be dried for storage purposes. Quality and hence cost of saffron are mainly affected by drying process. Traditionally, stigmas were dried by putting them in baskets containing holes and hanging them on the roof at an appropriate temperature. Drying completes when the colour of stigmas changed to dark red. But this method was long and took around 10 days for drying. In the last few decades, the use of electric ovens is in trend. The recent method employed the use of a sterile silk net placed in the oven at 50–60 °C which gives high quality and fast drying (Dadkhah et al. 2003).

7.5.3.4 International Standards of Plant Material

The chemical characteristics of dried saffron as per ISO 3632-1 are depicted in Table 7.2. One of the main quality parameters is the measurement of colouring power through crocin, picrocrocin, and safranal) using ultraviolet-visible (UV-Vis) spectrophotometry. The colouring power of three quality categories for saffron threads at 440 nm should be 190, 150, and 100 units, respectively. In addition, the moisture content and maximum non-soluble ash content were also specified, and details are depicted in Table 7.2 (ISO/TS 2003).

7.5.3.5 Food and Drug Administration Criteria

Based on the FDA (Hemmati Kakhki 2001), the material must have the following properties:

- Stigmas must be yellow and foreign matter should not be >10%.
- The volatiles and humidity must not be >14% when the saffron dried at 100 °C.
- The total ash not >1% while soluble ash should not >1%.

Table 7.2 Chemical characteristics of dried saffron on the basis of ISO 3632-1

Main characteristics	Saffron powder (%)	Saffron thread (%)
Volatile substances and humidity content	10	12
Crude ashes (mass percentage) in dry matter	8	8
Non-soluble ashes in HCl (mass percentage) in dry matter		
For Grades 1 and 2	1	1
For Grades 3	1.5	1.5
Maximum picrocrocin absorption value at 257 nm		
Grade 1	70	70
Grade 2	55	55
Grade 3	40	40
Maximum safranal absorption value at 330 nm	20–50	20–50
Maximum crocin absorption value at 440 nm		
Grade 1	190	190
Grade 2	150	150
Grade 3	110	110

7.5.3.6 Adulterants

To reduce the cost of saffron, mixing is observed with beet, pomegranate, and red dyed silk fibres (Hagh-Nazari and Keifi 2007). In addition, the stamens of saffron are often adulterated with *Carthamus tinctorius* (safflower), *Calendula officinalis* (marigold), arnica, and tinted grasses to increase the product mass. Turmeric and paprika are combined with saffron powder. The labeling of *Curcuma longa* as "Indian saffron", "American saffron", or "Mexican saffron" also misleads the people. Besides, artificial colourants are another common way of adulteration (Kafi 2002).

7.5.3.7 Purity Check

Chemical Test

- Saffron shouldn't include yellow styles.
- When pressed between filterpaper, it should not leave an oily stain.
- When chewed, it should give a deep orange-yellow colour to the saliva.
- When soaked in water, it should immediately dissolve and give a distinct yellow colour.
- No colour is imparted to benzene when agitated with saffron.
- Saffron extract gives a purple-blue colour when comes in contact with sulphuric acid.

7.5.3.8 Other Methods

Other methods include microscopic studies, colorimetric reactions, chromatographic techniques, TLC, and HPLC. HPLC is considered the most reliable technique (Hagh-Nazari and Keifi 2007). A colorimetric reflection method is based on CIE system where L* is brightness, a* redness-greenness, and b* yellowness-blueness, and correlated with the colouring power on samples (Alonso et al. 2003).Also, the atmospheric chemical ionization-mass spectrometry technique is a sensitive and easy method for quantitative analysis of volatile compounds (Taylor and Linforth 2003). Fourier transform near-infrared spectroscopy technique is also introduced for quality analysis of saffron that does not require any sample treatment (Zalacaín et al. 2003).

7.5.4 Commercialized Formulation

- The topical polyherbal formulation (itch cream) for xerotic and pruritic skin disorders has been prepared with the ingredients (v/w basis): *Curcuma longa* (16.0%), *C. sativus*(0.025%), *Santalum album* (8.0%), vetiver (0.5%), *A. moschatus* (0.1%), *Lawsonia inermis* (3%), *Ocimum sanctum* (3%), and *Glycyrrhiza glabra* (0.5%) extracts, curcuma oil (6.1%), Surasar (0.5%), and Swarna Bhasma (0.00032%) in a non-greasy cream base q.s. (Chatterjee et al. 2005).
- Scar removal skin cream (100 g) ingredients: wheat germ oil (3.5 mL), turmeric (20 g), neem (2 mL), sandal wood (1 mL), orange (2 g), rosemary oil (5 mL), *A. vera* gel (2 mL), saffron (1 g), cream base q.s. (Kalia 2005).

- Tincture dose—5–20 min.
- Saffron tea 1 in 80 (infusion).

7.5.5 Conclusion and Future Prospects

C. sativus is an important medicinal as well as food crop widely cultivated for nutritional and flavour purposes. In this book chapter, we tried to summarize the traditional claims, standardization methods, phytochemistry, pharmacological potential, and commercialized products of all parts of saffron. Besides, various physical parameters like temperature, humidity, wind, and methods that affect quality (flavour and colour) of saffron were also discussed. The main challenge is to meet the raw product demands that make it expensive in international market. Carotenoids, phenolics, and flavonoids are the main classes of secondary metabolites that are found in saffron. The main active constituents crocin, crocetin, and safranal are potential antitumor, anti-inflammatory, antiparasitic, and antibacterial agents. However, the effects have been slightly evaluated in humans. It would be interesting to see these effects in clinical trials.

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