Biological Activities of the Doum Palm (*Hyphaene thebaica* L.) Extract and Its Bioactive Components

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Abstract

The doum palm (*Hyphaene thebaica*) is a type palm tree which has a wood texture and has edible oval fruits and the origin native to upper Egypt. The trunk of this small palm is dichotomous. It is one of the most important useful plants in the world. All parts of doum palm have a useful role such as fiber and leaflets which used to weave baskets and doum nuts which have antioxidants and secondary metabolites such as tannins, phenols, saponin, steroids, glycosides, flavonoid, terpenes and terpinoids. Also, roots, stems and leaves are used in medicine, ropes and baskets. Studies on anti-inflammatory, antioxidant, antimicrobial, anticancer and pharmacological potential of *Hyphaene thebaica* extracts and its major phytoconstituents like the phenolic, essential oil and flavonoid compounds are extensively discussed in this review.

Keywords: doum, antioxidant, antimicrobial, anticancer, phenolic compounds

1. Introduction

Hyphaene thebaica is commonly referred to as doum, and it is a type of palm tree with edible oval fruit which belongs to the mint family (Arecaceae). They have several vernacular names like doum palm, doom palm, gingerbread palm, zembaba, mkoma, arkobkobai and kambash [1, 2]. The doum palm is native to the northern half of Africa. It grows in the west from Mauritania and Senegal, and east to Egypt, Kenya and Tanzania. It tends to grow along the Nile River in Egypt and Sudan in the areas which contain groundwater. It is also native to the Levant and the Arabian Peninsula (Israel, Sinai, Yemen and Saudi Arabia). It grows in wadis and at oases, but it is considered as drought-tolerant and sometimes grows on rocky hillsides.

Also, it is very resistant to destruction by fire in scrub or a forest [3]. This chapter focuses on the biological activities and beneficial effects of the Doum palm extract and its bioactive components in humans.

2. Botanical description

The doum palm is a dioecious palm and grows up to 17 m (56 ft) high. The trunk, which can have a girth of up to 90 cm (35 in), the trunk divided into two branches, each branch divided again into two branches, and the ends of the branches contain tufts of large leaves. The bark is smooth, dark gray and contains the scars of fallen leaves. The petioles are about 1 m long, sheathing the branch at the base and contain curved claws. The leaves are fan-shaped and measure about 120 by 180 cm (47 by 71 in) (**Figure 1**). Male and female flowers are produced on separate trees. The inflorescences are similar in general appearance, up to about 1.2 m (3 ft. 11 in) long, irregular in the branching and have two or three spikes in each branch. Male flowers have a short-stalk, solitary in pits of the spadix, spathe-bracts encircling the spadix, pointed. Branches of female spadices become thicker in the fruiting stage. Woody fruits are produced in the female palm that continues on the tree for a long time. They are 6–10 × 6–8 cm, smooth, rectangular to cubical with rounded edges, shiny brown when ripe. Its fresh weight is about 120 g and dry weight is about 60 g and each one containing a single seed. The size of seeds about 2–3.5 × 3 cm, the color is ivory, truncate at the base and the apex is obtuse [4].

Figure 1. *Hyphaene thebaica* L. (Doum).

3. Traditional uses

H. thebaica tree is one of the most useful plants in the world [5]. Along the Nile, people used its fiber and leaflets to spin baskets. The fruits of doum palm are contained antioxidants [6]. Palms are used for firewood and charcoal. Leaves are probably the most important part of the palm, providing the raw material used in basketry, making mats, brooms, coarse textiles, ropes, thatching and string [7]. Leaves may also be used as fuel. The fibers of roots obtained after soaking in water for 2–3 days, and flogging of the roots are used for making fishing nets. Due to the high amounts of fibers in wood, it is difficult to cut them using an ax. Wood produced from the male palm is considered better than that of the female. It is often used for building, providing for support and rafters for houses, railway sleepers, planks, water ducts and wheels fence posts and raft construction. Dried bark is used to produce a black dye for leather wear [8]. Roots are used in the treatment of bilharzia, while fruit pulp is helped in the reduction control hypertension [9]. The hard seed inside the fruit, known as (vegetable ivory) is used to treat sore eyes in livestock using charcoal from the seed kernel as well as making buttons and small carvings, and artificial pearls [1]. In Turkey and Kenya, the powder made from the outer covering of the fruit is added to water and milk and left to stand to make a mild alcoholic drink; in other countries, the terminal meristem is tapped for making palm wine. The thin dried brown rind is used in the manufacture of sweetmeats, cakes, and molasses. In Egypt, the fruit is sold in herbalist shops and is popular among children. Apart from the use of the fruit as food, juice is extracted from the young fruit and palm wine is prepared from the sap [10]. Doum palm fruit in its powder form was applied in some food products as a source of fiber, stabilizer and minerals as well as for its potential healthy effect [11]. Research on the fruit pulp of *H. thebaica* showed that it contains nutritional trace minerals, proteins and fatty acids, in particular the nutritionally essential linoleic acid [12].

Also, aqueous doum palm extracts increased the viability and activity of some certain dairy starter cultures which used in the manufacture of some dairy products especially probiotics [13].

4. Chemical composition of doum fruit

Doum fruit has a high-quality protein varied between 2.86 and 5.01%, high proportion of lysine and cysteine of crude protein varied between 4.09–4.16% and 0.2–1.62%, respectively, the limited amino acid threonine, crude fat varied between 1.2 and 8.4%, crude fiber varied between 52.26 and 66.5%, the most important carbohydrates component was mannose varied between 13 and 75.9%, also the presence of calcium, magnesium, potassium, iron sodium and negligible amount of nickel, cobalt and molybdenum. Phytochemical compounds of doum fruit such as tannins, saponin, steroids, glycosides, flavonoid, terpenes and terpinoids were found at low and moderate concentrations [14].

5. Pharmacological activities of doum

Various extracts of *H. thebaica* (L) Mart are used in the treatment of hypertension, bilharzias and as a hematinic agent [15]. The water extract of doum fruits can reduce hyperlipidemia in nephrotic syndrome and leads to decrease the risk of glomerulosclerosis and atherosclerosis and consequently the natural, safe and nontoxic *H. thebaica* fruit could be of great merit for use as hypolipidemic drugs [16]. It is also good as hypocholesterolemic agent, hypolipidemic and hematinic suspensions lipidemic, and hematinic suspensions [17]. The identification of compounds by thin-layer chromatography showed that the doum fruit contains significant amounts of saponins, coumarins, hydroxyl cinnamates, essential oils and flavonoids [18]. It was found that the administration of flavonoid extracts to diabetic rats significantly increased adiponectin levels that stimulate the hypoglycemic action of insulin without altering the concentration of insulin in blood and decrease the weight and volume of contents of granuloma in inflammation [19]. Therefore, this might be its probable mechanism of anti-inflammatory action. Furthermore, the hypoglycemic effect of these herbs may be due to the increased level of serum insulin by increasing the pancreatic secretion of insulin from cells of islets of Langerhans or its release of bound insulin and also may be due to the enhancement of peripheral metabolism of glucose [20]. The decoction of doum fruits is well tolerated and no mortality or morbidity until the dose of 5 g/kg b. wt. Repeated oral administration of doum fruits at 0.5 g/kg b. wt. or 2 g/kg b. wt. was ineffective on the normal reproductive parameters. While the red blood corpuscles, packed cell volume, hemoglobin concentration and percent of phagocytic activity were significantly increased [21]. A significant decrease in blood glucose, cholesterol, triglycerides and total lipid levels was observed after 1 and 2 months of administration of the decoction of doum fruits [21]. The obtained results confirm the value of doum fruits as hematinic potentials, hypolipidemic, improve the hepato-renal functions and without side effects on the studied reproductive parameters.

Also, triglycerides were independently related to coronary heart disease and most of the anti-hypercholesterolemic drugs did not decrease triglycerides levels, but the aqueous extracts of doum fruits lower it significantly [22]. This effect may be related to the increase in endothelium bound lipoprotein lipase which hydrolyzes the triglycerides into fatty acids. Previously, the authors reported that the hypolipidemic properties of the aqueous pulp suspension of doum could be partly due to the presence of glycosides [23]. Saponins have been reported to form complexes with cholesterol and bile in the intestine thereby indirectly reducing the cholesterol level in the blood [24]. In addition, administration of 200, 400 and 800 mg/kg body weight of aqueous extracts of both stem and bark of *H. thebaica* (L) Mart showed no significant ($p > 0.05$) difference in feed intake, this may be due to the absence of tannin in both the stem and bark extracts. Decrease in feed intake was observed at the highest dose of 800 mg/kg of the methanolic fruit pulp extract of the same plant, this may be due to tannin content of the methanolic fruit pulp extract of the plant [25].

6. Bioactive compounds of doum palm

6.1. The chemical structure of volatile components

Doum fruit yielded a yellowish color volatile oil with a fragrant aromatic odor at a yield of 0.5% (fresh wt). Physical constants measured include: specific gravity (0.168) and refractive index (1.383). The result of analysis of essential oil of doum by GC and GC–MS techniques revealed the presence of a total 57 compounds (**Figure 2**). Monoterpenes represented 15.97% including compounds such as sabinene (0.82%), ß-pinene (1.97%), limonene (2.42%), terpinen

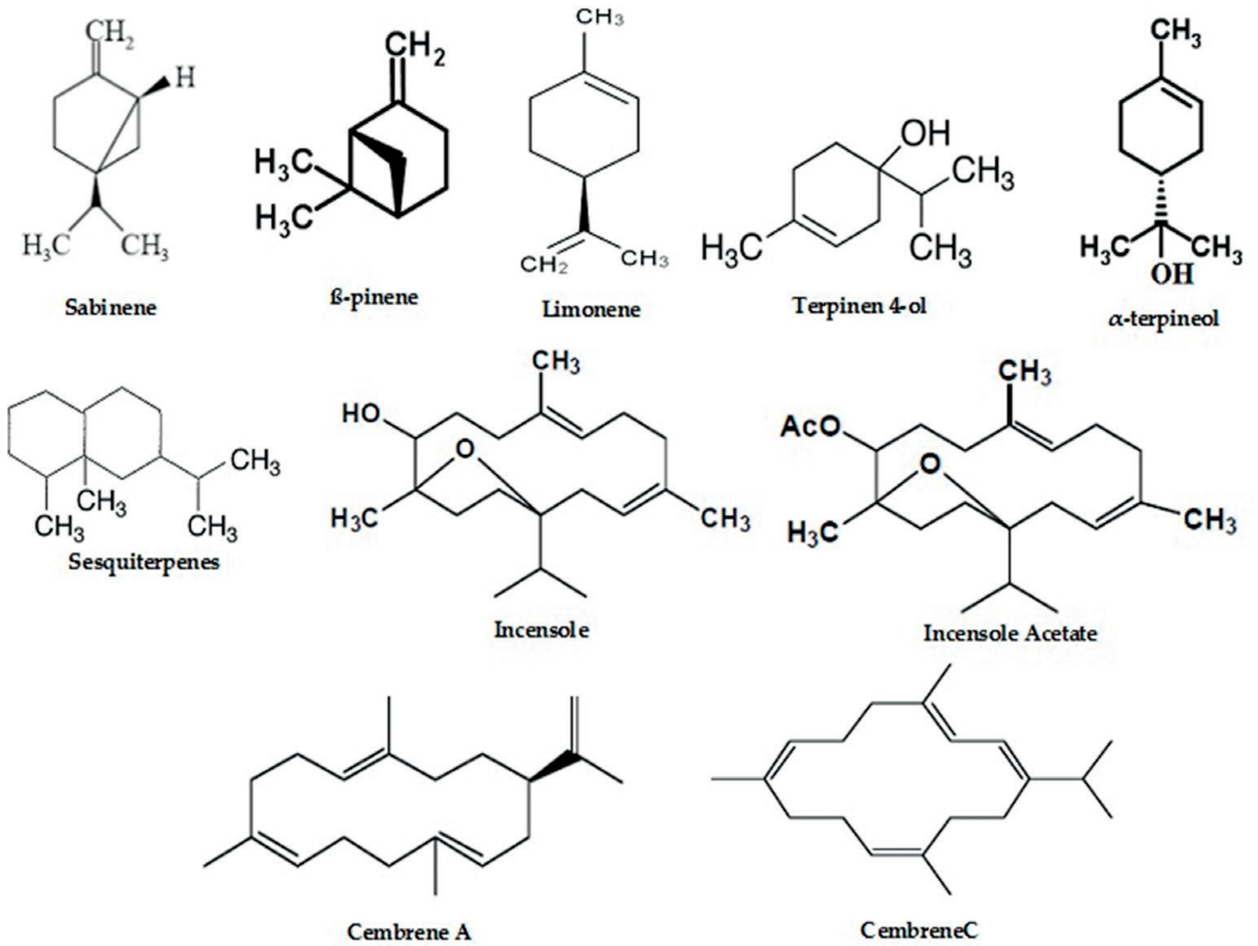

Figure 2. Chemical structures of doum fruit essential oil.

4-ol (1.77%), α-terpineol (0.95%), sesquiterpenes (3.2%), diterpenes represent 40.49%, of which incensole (19.81%) and incensole acetate (17.52%) were found to be the main components, non-terpenoidal components amount to 15.21% of which octylacetate (9.38%) was found to be the major and fatty acid (8.55%) with the main component palmitic acid (5.90%). Oxygenated compounds constituted 66.78% of the total compounds identified which indicated the economic value of this oil. Fruit of doum oil was found to contain volatile diterpenes especially cembrene A which showed cytotoxic activity, and this revealed the medical importance of the volatile oil of doum which could be utilized medicinally [26].

6.2. Chemical structure of doum fruit phenolic compounds

6.2.1. Total soluble phenols content and compounds

Different total soluble phenols values in doum were published in different studies; it ranged from 45.08 to 64.90 mg GAE/g DW [27]. While it recorded the highest values in pitted doum fruit extracts varied from 116.26 to 139.48 mg GAE/g DW [16]. The bioactive potential of fruits and vegetables attributed to their high content of polyphenols [28].

The most abundant phenolic compounds recorded in doum were metoxicinnamic acid, sinapic acids (hydroxycinnamic acids), chlorogenic acid, catechin, p-hydroxybenzoic acid, vanillic acids, 3,4 di hydroxycinnamic acid, caffeic acid, 2-hydroxycinnamic acid, Epicatechinand cinnamic acid, respectively (**Figure 3**) [29]. Doum pulps exhibited higher caffeic acid contents in comparison to the domestic fruits [30]. The highest four concentrations of phenolic compounds in doum fruit aqueous extracts were found to be 3-OH tyrosol, E-vanillic acid, catechin and chlorogenic acid, while the lowest were of alpha-coumaric acid, cinnamic acid, p-coumaric acid and coumarin [31].

6.2.2. Total flavonoids content and compounds

The total flavonoids content in different extracts of doum fruit extracts varied widely ranging from 24.04 to 47.17 mg rutin/g DW [16]. Similar results found that the content of flavonoids (mg/g) of fruits of *H. thebaica*, in the quercetin equivalent was 46.28 mg/g DW [27]. HPLC analysis of aqueous doum fruit extracts showed 11 flavonoid compounds (**Figure 4**). The highest concentrations were quercetin, hesperetin, naringin and rutin compounds [18]. Five flavone glycosides were isolated and identified from doum fruits namely, luteolin 7-*O*-*ß*-glucuronoide, apigenin 7-*O*-*ß*-glucuronoide, luteolin *O*-*ß*-glycoside, luteolin 7-*O*-rutinoside

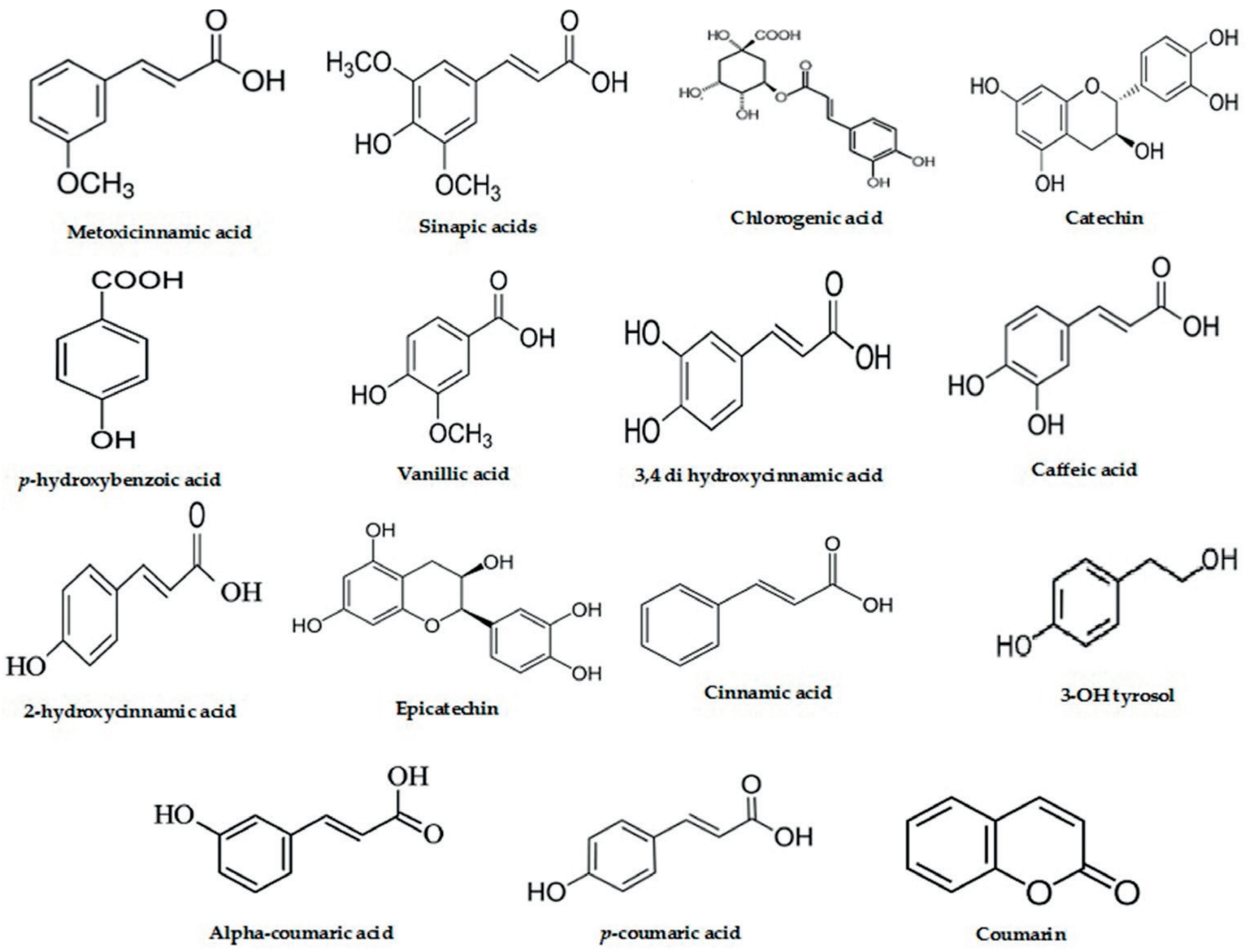

Figure 3. Chemical structures of doum fruit phenolic compounds.

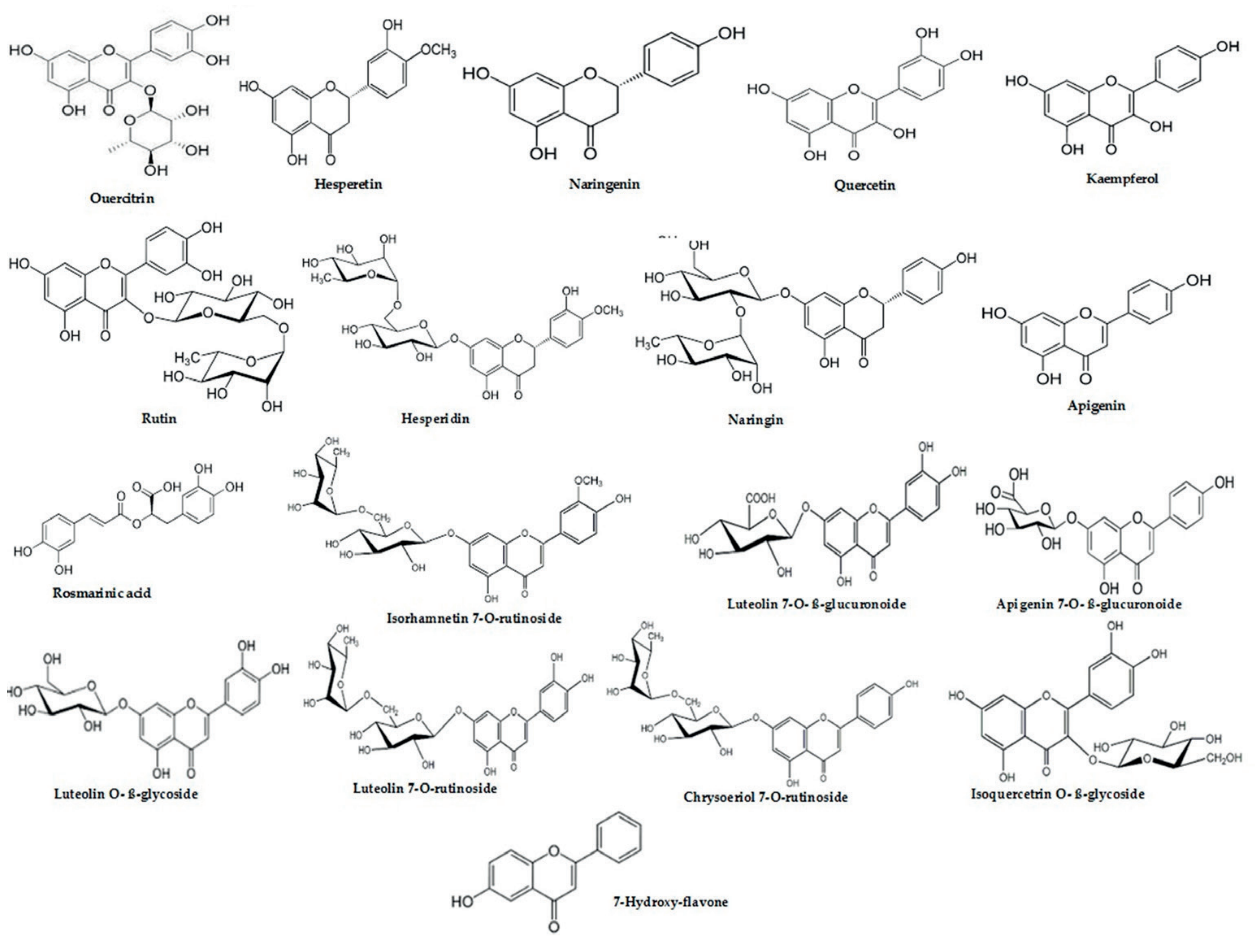

Figure 4. Chemical structures of doum fruit flavonoid compounds.

and chrysoeriol 7-*O*-rutinoside [32]. Glycosides of luteolin and chryseriol flavones previously isolated from doum fruit were identified. In addition, isoquercetrin and isorhamnetin rutinoside are reported for the first time in *H. thebaica* [33].

6.2.3. Chemical structure of doum palm leaves phenolic compounds

Doum leaves were extracted in 80% ethanol and filtrate. The aqueous ethanolic extract used to scavenge reactive oxygen species (ROS). The phenolic content of doum was determined by using HPLC and recorded the presence of four major compounds correspond to Gallic acid, Quercetin glucoside, Kaempferol rhamnoglucoside, Dimethyoxy quercetin rhamnoglucoside, respectively. An in-depth phytochemical investigation showed the presence of 14 compounds (**Figure 5**): 8-*C*-*ß*-D-glucopyranosyl-5, 7, 4′-trihydroxyflavone (vitexin), 6-*C*-*ß*-D-glucopyranosyl-5, 7, 4′-trihydroxyflavone (iso-vitexin) [34, 35]. Quercetin 3-*O*-*ß*-4C1-D-glucopyranoside, gallic acid [36], quercetin 7-*O*-*ß*- 4C1-D-glucoside [37], luteolin 7-*O*-*ß*-4C1- D-glucoside, tricin 5-*O*-*ß*-4C1-D-glucoside [38], 7, 3′ dimethoxy quercetin 3-O-[6″-O-*α*-L-rhamnopyranosyl]-*ß*-*D*-glucopyranoside (rhamnazin 3-O-rutinoside) [39] (kaempferol-3-*O*-[6″-*O*-*α*-L-rhamnopyranosyl]-*ß*-D-glucopyranoside (nicotiflorin) [40], apigenin, luteolin, tricin, quercetin and kaempferol. All these compounds were isolated and identified for the first time in doum leaves [41].

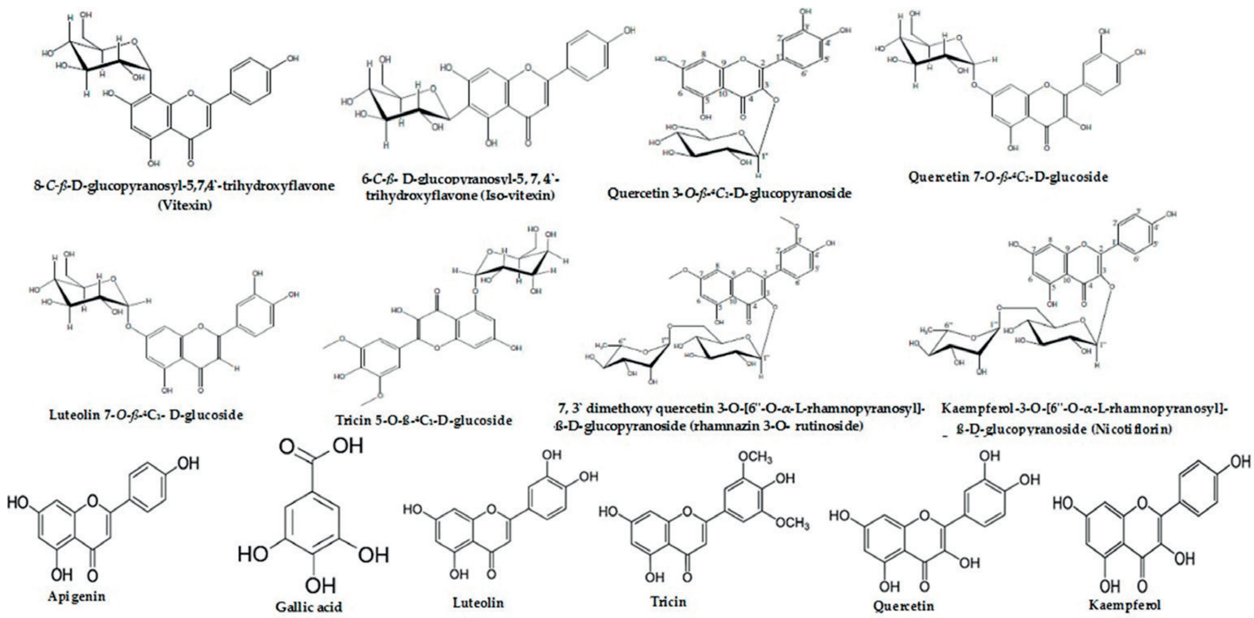

Figure 5. Chemical structures of doum leave phenolic compound.

7. Biological activities of doum fruit extracts

7.1. Antioxidant activity of doum fruit extracts

Doum is one of the commonly consumed traditional beverages in Egypt and is rich in polyphenolic compounds. Several studies have recorded that doum fruit extracts contain high amount of flavonoids, phenols and used as antioxidant and antibacterial activities (**Table 1**), which can alleviate the adverse effects of oxidative stress and prevent diseases caused by pathogenic bacteria [16]. It is well-known that plant phenolic compounds are highly effective free radical scavengers (**Figure 6**). Phenolic compounds antioxidant activity is associated with the presence of functional groups in the ring and the annular structure of the molecule, conjugated double bonds [42]. The antioxidant activity increased with the increase in concentration and the consumption of doum plant which would exert several beneficial effects by the value of its antioxidant and antimicrobial activities [27].

2,2-Diphenyl-1-Picrylhydrazyl (DPPH) is a free radical that received an electron or hydrogen radical and become a stable diamagnetic molecule [43]. DPPH was determined by the decrease in its absorbance at 517 nm, which was induced by antioxidants. The ability of hydrogen donating in the polyphenolic compounds in the doum fruit extracts helps in the scavenging ability of DPPH. The antioxidant activity measured from doum extracts was 343.4 μ moles trolox equivalents/g DW in hydrophilic extract and 42.67 μ moles trolox equivalents/g DW in lipophilic extract when using DPPH [29]. In addition, the IC_{50} values of doum extracts varied from 107.6 to 172.7 μg/ml [16]. These results are lower than the results reported by Abou–Elalla [44] who found that the aqueous doum extract exhibited 50% antioxidant activity (IC_{50}) at the concentration of 1000 μg/ml, also 1500 μg/ml extract exhibited 80% antioxidant activity. Also, the aqueous ethanolic extract of doum leaves appeared to be a potent scavenger of reactive oxygen species [41]. Strong correlation between total phenolics content and total

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Doum part	Method used	Extract type	Antioxidant activity/ IC_{50} Inhibition values	References
Fruit	DPPH	Dichloromethane	343.4 μ moles trolox /g	Salih and Yahia [29]
Fruit	DPPH	Hexane	42.67 μ moles trolox /g	Salih and Yahia [29]
Fruit	DPPH	Ethanol	IC_{50} = 172.7 μg/ml	Aboshora et al. [16]
Fruit	DPPH	Methanol	IC_{50} = 107.6 μg/ml	Aboshora et al. [16]
Fruit	DPPH	Water 12 h	40.77%	Aamer [18]
Fruit	DPPH	Methanol	64.55%	Mohamed et al. [27]
Bark	DPPH	Methanol	90.7%	Fayad et al. [52]
Fruit	FRAP	Methanol	28.93%	Sani et al. [47]
Fruit	FRAP	Distilled water	31.91%	Sani et al. [47]
Fruit	FRAP	Methanol	24.3%	Mohamed et al. [27]
Fruit	FRAP	Dichloromethane	13.57 μmoles trolox /g	Salih and Yahia [29]
Fruit	FRAP	Hexane	7.69 μmoles trolox /g	Salih and Yahia [29]
Leaves	Superoxide anion radical	Ethanol	IC_{50} = 1602 μg/ml	Eldahshan et al. [41]

Table 1. Antioxidant activity/ IC_{50} Inhibition values of doum part by different methods.

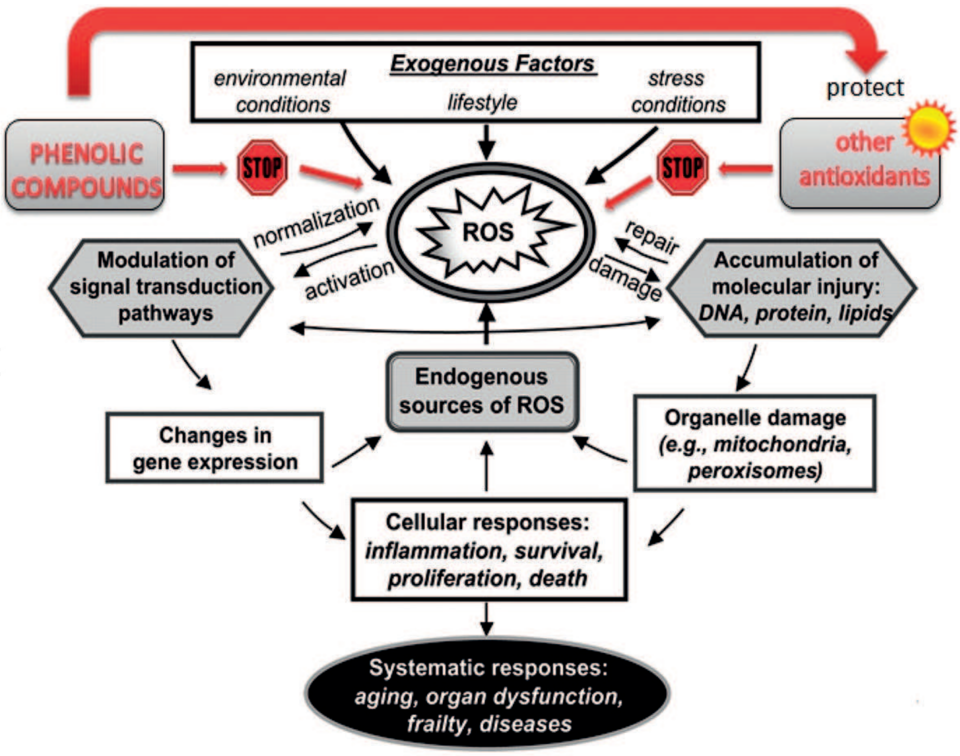

Figure 6. The scheme of factors involved in the formation of free radicals and a cellular response to reactive oxygen species (ROS). The red arrow and the text in red emphasize the importance of phenolic compounds, other reactive oxygen species (ROS). The red arrow and the text in red emphasize the importance of phenolic compounds, other antioxidants and the relationship between them. The sun signifies protection of other antioxidants by phenolic compounds.

antioxidant activity reported in many studies concluded the significant role that total phenols can play in antioxidant activity [29].

Iron is known as an essential transition metal element in the human body for the activity of many enzymes and for some important proteins participated in cellular respiration, O_2 transport, and redox reactions. However, because its transition metal, it contains one or more unpaired electrons that enable them to share in one-electron transfer reactions. Hence, its potent catalysts of autoxidation reactions, such as involvement in the production of OH^- from H_2O_2 in the Fenton reaction and in the decay of alkyl peroxides to alkoxyl and hydroxyl radicals [45]. Because of this property, transition metal chelation to shape low redox potential complexes is significant antioxidant property and measuring chelation of iron (II) is one method for estimating this property [46]. The reaction is based on the relationship of an antioxidant toward iron (II) in relation to ferrozine, the assay is affected by both concentration of antioxidant and binding constant and thus only powerful iron antioxidant chelator is detected. With this assay, many plant phenolic compounds have been described as antioxidants due to their chelating ability to iron ions. *H. thebaica* fruit has antioxidant activity of 28.93 ± 0.23% and 31.91 ± 0.14% for methanol and aqueous extract respectively [47]. The extracts of doum fruits showed an antioxidant potential, and this is due to the substantial amount of their water-soluble phenolic content [6]. The percentage of metal scavenging capacity at 200 μg/ml of tested methanol extracts *H. thebaica* and was found to be 24.3%. The antioxidant activity increased when extract concentration increased [27].

It displayed the Fe^{2+} chelating effect in a concentration-dependent manner. The antioxidant activity measured from doum extract was 13.57 μmoles trolox equivalents/g DW in hydrophilic extract and 7.69 μmoles trolox equivalents/g DW in lipophilic extract when using FRAP assay [29]. These results are in agreement with previous study, who found that doum fruit contained contain iron (II) chelating activity [6].

Superoxide radical is harmful to the body because it is a portent of the hydroxyl radical in the Fenton reaction and is the part of lipid peroxidation as an allylic hydrogen abstractor. Phenazine methosulphate/ß-NADH/nitro blue tetrazolium (PMS/NADH/NTB) system is used to determine superoxide radical [6]. Again, an antioxidant activity can come about by antioxidant donation of hydrogen or electron to superoxide or by direct reaction with it. Using this assay, doum fruit was found a very poor activity toward superoxide; it contains 0.02 mmol gallic acid equivalents/g extract. In addition, the significant inhibition percentage of superoxide generation was shown at 300 μg/ml concentration of *H. thebaica* as 63.22% [27]. The Doum extract is found to be an efficient scavenger of superoxide radicals generated in a PMS-NADH system in vitro and its activity is comparable to that of quercetin.

7.2. Anticancer activity of doum fruit extracts

Free radicals can react with biomolecules, causing extensive damage to DNA, protein, and lipid, which are considered to be related to aging, degenerative diseases of aging, cancer [48, 49]. Antioxidants play an important role in the later stages of cancer development. The oxidative stress is defined as the imbalance between oxidants and antioxidants in favor of the oxidants potentially leading to damage in human cells. Physiologically, antioxidants play a major role in preventing the formation of free radicals, which are responsible for many harmful oxidative processes [50]. Antioxidants may be synthetic or of natural source [51]. Antioxidants play an important role in the later stages of cancer development. The methanol extract of *H. thebaica* bark showed high cytotoxicity against human cancer cells and free radical scavenging activities, but showed no cytotoxic effect on human normal immortalized fibroblast cells (BJ- 1) [52]. *H. thebaica* extract showed cytotoxicity against A549 (lung carcinoma) and MCF-7 (breast adenocarcinoma) (87% and 89% respectively). Others reported that the fruit extract of *H. thebaica* had antioxidant and anticancer activities against acute myeloid leukemia [43]. It found that the incubation of tumor cells with doum extract significantly reduced the viability of these cells and the dead cells were significantly increased with high extract concentration. At concentration of 2 μg/ml, the extract reduced the viability from 98 to 83% (17% death). The dead cells produced by extract reached to 50% by 3 μg/ml when compared to control (2% death). Also, doum extract reduced the viability from 98 to 60% (61% death at 4 μg/ml and the dead cells reached to 92% dead by 8 μg/ml). This anticancer activity may be due to the antioxidant activity of doum extract. This is due to the substantial amount of their water-soluble phenolic compounds [6]. Plants extract which combines antioxidant and anticancer activities and at the same time safe to healthy cells is a promising cancer chemopreventive candidate.

The logic behind this is that the antioxidant will reduce, if not prevent, the DNA mutations and adducts caused by cytosolic free radicals and consequently prevent the initiation of cancer through induction of mutations. The anticancer activity will be useful in early eliminating any newly formed neoplastic cells that are not clinically detectable. However, these cancer cytotoxic agents should be with minor or no side effects as they are planned to be used for prolonged time preventing cancer formation [52].

7.3. Anti-inflammatory activity of doum fruit extracts

Ulcerative colitis (UC) and Crohn's disease (CD) are two major categories of inflammatory bowel diseases (IBDs). Familiar drugs that are administrated for the management of IBD include glucocorticoids and sulfasalazine. Antibiotics, monoclonal antibodies (Infliximab) and immunosuppressants are also sometimes used for difficult disease conditions [53]. These medicinal agents have side effects, and they could not suitably cure IBD patients [54]. In many studies, it has been reported that antioxidants show useful effects in experimental colitis [55]. The effect of various herbal drugs on experimental models of inflammatory bowel diseases (IBD) has been reported earlier with the antioxidant potential as the main mechanism of action against IBD [56]. As the plant *H. thebaica* is thought to possess anti-inflammatory and antioxidant properties, proving its role in the management of experimentally induced IBD [27]. It showed significant amelioration of experimentally induced IBD, which may be attributed to its antioxidant and anti-inflammatory properties [57]. The previous studies found that the weight and volume of contents of granuloma in inflammation were decreased after treatment with doum extract. This may be due to the presence of flavonoids, coumarins and saponins in doum extract which has anti-proliferative activity [58]. Therefore, this might be its probable mechanism of anti-inflammatory action. Also, flavonoids and coumarin derivatives have been reported as protective products to prevent and treat intestinal inflammatory processes induced by different chemical indictors of experimental colitis [59]. In addition, diet supplementation with doum has a promising anti-inflammatory influence on attenuating the complications associated with the renal dysfunction. Moreover, anti-inflammatory status of animals injected with cyclo sporine and supplemented with doum showed a significant amelioration in the kidney functions as compared to animals injected with the cyclosporine only [60]. The anti-inflammatory activity of doum was possibly due to its saponin content which acts against the oxidative damage and suppresses the serum transforming growth factor-ß1 (TGF-beta1) expression [61]. Therefore, doum administration declines the oxidative damage and the renal interstitial fibrosis in rats [60]. The significant increase in white blood cells caused by crude mesocarp extract of *H. thebaica* could be due to stimulation of bone marrow stem cells to produce these cells, which is an indication of immune—modulatory effect as was observed by other researchers exhibited by some plants [62]. The presence of phytochemicals such as glycosides and reducing sugars could be the reason for the leukocytosis [63]. Flavonoids protect both the hematopoietic committed stem cells and the formed blood cells from the attack of the reactive free radicals hence improving leucocytic production [64]. In *H. thebaica*, flavonoid conjugates, oxygenated fatty acids, and sphingolipids enriched in fruits are likely to mediate for its anti-inflammatory effect [65, 66].

Doum extracts treatments inhibited the activity of cyclooxygenase (COX-1), an enzyme known to be involved in inflammation [33].

7.4. Antimicrobial activity of doum fruit extracts

Methanol and aqueous extracts of doum fruit showed higherantibacterial activity against Gram-positive bacteria and Gram-positive bacteria except for *Listeria monocytogenes*, where only a slight inhibition was observed [27]. Moreover, the ethyl acetate extract of doum fruit was active against five pathogenic bacteria, ***Staphylococcus aureus***, *Escherichia coli*, *Bacellussubtilis*, *Pseudomonas aeruginosa* and *Klebsiella pneumonia* while methanol extract was active against *Pseudomonas aeruginosa* and *Klebsiella pneumonia*. Penicillium sp. growth was slightly affected by high concentration of methanolic extract [67]. *H. thebaica* fruit extracts reduced the growth of Erwiniacarotovora and produced inhibition zones up to 38 mm in diameter [68]. All doum extracts showed strong antibacterial activity against *Staphylococcus aureus* and Salmonella typhi, while methanol/ultrasonic (MU) extract inhibited the growth of all pathogenic bacteria used in the study. However, all doum fruit extracts demonstrated no antibacterial activity against *E. coli* colonies except the methanol/ultrasonic (MU) extract, which had slight activity [16]. The antibacterial activities against both Gram-positive and Gram-negative bacteria may indicate the presence of broad spectra antibiotic compounds or simply metabolic toxins in plant extracts [69]. Doum fruits showed antimicrobial and antihypertensive activities, and these activities were attributed to the presence of flavonoids [70]. The mechanism of polyphenol toxicity against microbes may be related to inhibition of hydrolytic enzymes (proteases) or other interactions that inactivate microbial adhesins, cell envelope transport proteins, and non-specific interactions with carbohydrates [71]. Also, the methanolic extract of *H. thebaica* showed stronger antifungal and anti-yeast activities than aqueous extracts [27]. Similar results were observed in previous studies, which showed that polar solvent extract of H. Tobacco has high antifungal activity against a wide range of fungal isolates, including *Aspergillus niger*, *Microsporum gypseum*, *Trichlorophyton rubrum*, *Mucor* sp., *Fusarium solani* and *Candida albicans* [72]. Antimicrobial activity may involve complex mechanisms, like the inhibition of the synthesis of cell walls and cell membranes, nucleic acids and proteins, as well as the inhibition of the metabolism of nuclide acids [73].

8. Conclusion

Hyphaene thebaica, a well-known plant for its antioxidant, anticancer and anti-Inflammatory potential because of its phenolic and flavonoid content was explored for its antimicrobial potential against various Gram-positive and Gram-negative bacteria and fungal pathogens. This chapter evidently reveals that the doum (leaf and fruit) extracts are effective antimicrobial and pharmacological agents. Further detailed study on its mechanism and safety profile may develop them as good candidates for food preservation or functional foods, as well as for pharmaceutical and natural plant-based products.

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