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Carob Beans (*Ceratonia siliqua* L.):Uses, Health Benefits, Bioactive And Aroma Compounds

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Abstract
Carob (*Ceratonia siliqua* L.) belongs to *Leguminosae* family and is mostly cultivated in the Mediterranean and Mediterranean-like areas. Carob fruit is constituted mainly by the pulp and seeds. Carob beans are used as food with great industrial interest for both human and animals. The beans are processed into essential oils, gums, molasse, syrup confectionery products, biscuits, cakes and juice. The beans have high nutritional value as they contain a considerable amount of protein, fat, carbohydrates, minerals dietary fiber and vitamins. They are rich in sugar and contain essential bioactives such as phenolic acids, proanthocyanins and tannins. The extracts of carob demonstrated strong antioxidant and antimicrobial activities. Indeed, they are used to prevent or to heal ailments such as asthma attacks, bronchitis, flu, coughing, diarrhea, cancer, cholesterol and cardiovascular diseases. The volatile compounds which provide the overall odor of carob beans are mainly aliphatic acids, alcohols, aldehydes, esters, ketones, lactones,furans, phenols, pyrroles, pyridines, pyrazines and terpenes. This paper highlighted the multipurpose uses, phytochemical and aroma compounds of carob beans that could be used as a nutritional supplement into other foods.

Keywords: Carob; *Ceratonia siliqua* L.; Aroma; Medicinal properties; Phytochemical

INTRODUCTION

Ceratonia siliqua L. also kown as carob is an evergreen tree which can be grown cultivated or uncultivated. It is mostly found in the Mediterranean and Mediterranean-like areas and thrives easly in the arid climate and poor soils. *Ceratonia siliqua* L. is one of the species of the subfamily of *Caesalpinaceae* and the family of *Leguminoseae* (*Fabaceae*) [1] and [2]. The scientific name of carob tree (*Ceratonia siliqua* L.) derives from Greek *keras*, horn, and Latin *siliqua*, referring to the hardness and shape of the pod. The common name is diversely appealed according to the dialects as it is called *kharuv* in Hebrew, *kharrub* in Arabic, *algarrobo* or *garrofero* in Spanish, *carrubo* in Italian, *caroubier* in French, *Karubenbaum* in German, *alfarrobeira* in Portuguese, *charaoupi* in Greek [3] and *harnup* or *keçiboynuzu* in Turkish. The carob fruit is an indehiscent pod, elongated, compressed, straight or curved, thickened at the sutures, 10-30 cm long, 1.5-3.5 cm wide and about 1 cm thick. The pulp is the main constituent of the pod ranging between 73 to 95 percent. The pod is constituted of about 90% pulp, 8% kernels (seeds) and 2% other materials [4]. The leaves are 10-20 cm long, alternate, pinnate and may possess or not a terminal leaflet [3].

According to the database of Food and Agriculture Organisation, in 2017, the production of carob is led by Portugal, followed by Italy, Morocco, Turkey and Greece, which have produced 41909, 28910, 21983, 15016 and 12528 tonnes, respectively (Fig. 1). The pulp is used for many purposes, especially for its sugar. However, the beans are the most demanded for the production of the high quality gum. The carob is processed in many food products including syrup, molasses and juice. In Turkey, carob molasses (pekmez) is one of the most consumed foods due to its nutritional and health benefits. The pekmez is produced by crushing carob into fine granules. These carob granules are then soaked in water (1:1 w/v) for three days, filtered and the juice is then heated up to a concentrated of 72°Brix [5]. It is used to enhance the nutritional and sensory quality of some foods. The carob is also employed for its health benefits, as it is applied for asthma attacks, bronchitis, grippe infections, coughing, cancer, cardiovascular diseases and diarrhea. These nutritional and health benefits have resulted from the beneficial effects of thousands of phytochemical compounds present in carob [6], [7], [8], [9] and [10].

This study will focus not only on the general uses of carob in more detail, but also on its phytochemical and aroma compounds.

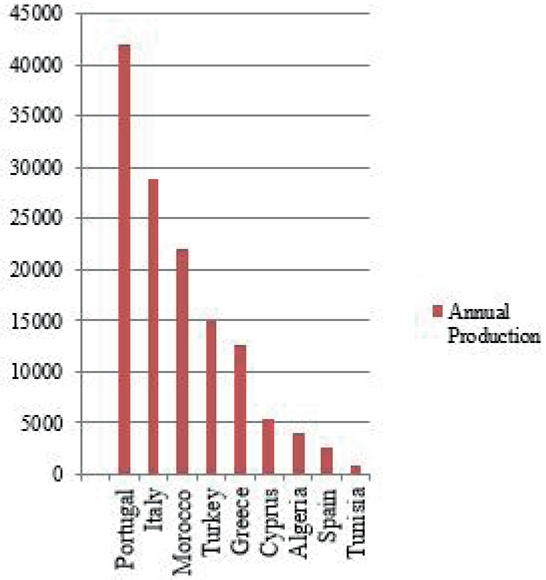

Fig. 1. Carob worldwide production in 2017 (FAOSTAT, 2019).

General uses

Food products

The pod consisting of the pulp and seed, is processed into juice, syrup, essence, molasses, unroasted and roasted carob powder. The of kibbles of the pulp can be extracted and purified to obtain the molasses and sugar. The kibbles can also be subjected to the fermentation and distillation to obtain alcohol or used as source of protein [3]. The pulp can be roasted or not and transformed to a powder which is used in confectioneries, biscuits, cakes and beverages. Increasingly, carob powder is considered as a substitute for cocoa, as it has been revealed to be suitable for the production of caffeine-free and theobromine-free products [11]. The caffeine has shown stimulant and antioxidant activity. Thus, the consumption of caffeine-based products may contribute to decrease the risk of several chronic diseases, including diabetes, liver disease, cancer and immune disorders as well. However, the excessive intake of caffeine (more than 300-400 mg per day) may induce the risk for developing coronary artery, osteoporosis, gastritis, anemia diseases as well as nutrient depletion [12] and [13]. The carob powder is made for its application in the preparation of dietary and pharmaceutical products. The powder is incorporated in the ingredients during the manfacturing of cakes, bread, sweets, ice creams or drinks to enhance their nutritional quality and to improve their flavor, as carob releases a unique and pleasant aroma. The seed is ground and used for their various functions in food, pharmaceutical and cosmetic industries. Likewise, the seed is employed as food additive (stabilizer and thickener), dietary fiber, pet food, pharmaceuticals and cosmetics [3].

The gum is one of the most important byproducts of carob used in food industry. Known as carob bean gum (CBG) or locust bean gum (LBG), the carob gum is made from the endosperm of the seed and is coded as E410 by European Codex. This gum is a polysaccharide named galactomannan. The Moroccan carob beans have yielded 60.63-72.49% of gum [14], while the Italian carob beans have displayed a yield of 38.5-52.2% of gum [15]. The gum is characterized by 6.36-8.63% of moisture, 0.36-0.99% of ash, 3.0-6.0 of pH and 0.52-0.62% of protein [14] and [15]. It contains a total sugar ranged between 62.6 and 81.5%. The sugar of carob bean gum is mainly constituted of xylose, rhamnose, fructose, galactose, mannose, glucose and sucrose [15]. The gum is used as food additive, especially for its strong capacities of thickeness, stabilization, emulsification and gelling. This gum has been successfully used for the production of many commodities, including ice creams, soups, sauces, cheese, fruit pies, canned meats, confectioneries, bakery products and pet foods [3].

Other usages

Traditionally, the leaves, pod and seed of carob are used as fodder to feed animals. The wood is used as firewood or can also transform to charcoal. The gum has other multifold benefits in parmaceutical industry as ingredients of anti-coeliac products, pomades, pills and toothpaste, in cosmetic industry as emilsifier, in textile industry as coloring agent and thickener, in paper industry as flotation agent and thickener, and in chemical, mining and explosive industries [3]. Furthermore, the pod is processed in essential oil which has an important value in cosmetic and pharceutical industries.

Health benefits

In addition to its potential for food industry, the carob is applied to prevent and to releive many ailments encompassing asthma, bronchitis, infections, coughing, diarrhea, anemia, cancer, hyper cholesterol, cardiovascular diseases and immune system disorders. The water extracts of carob pod and leaves have demontrated strong antiproliferative effects on experimental rats [16]. Similarly, the supercritical fluid extract of carob kibbles have responded positively showing an antiproliferative activity on rat N1E-115 neuroblastoma cells, human HeLa cervical cancer cell lines as well as MCF-7 breast cancer cell lines [17]. Thus, the pod and leaves exhibit the ability to protect from cancer and to kill carcinogenic cells. On one hand, the n-hexane, methanol, ethanol, ethyl acetate and water extracts of carob leaves have shown antimicrobial effects on many microorganisms including *Escherichia coli*, *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Salmonella thyphimurium*, *Enterobacter cloacae*, *Enterococcus faecalis*, *Pseudomonas aeroginosa* and *Candida albicans*, and on another hand, these extracts demonstrated cytotoxic effect aganist brine shrimp [18]. Klenow et al. (2009) [19] have revealed that carob extracts are capable to prevent the oxidative stress, especially in human colon. The carob pod has displayed gastroprotective effect due to its strong antioxidant activity [20]. Interestingly, the essential oil of carob pod has shown not only antibacterial and antifungal activity on some species of bacteria (including foodborne pathogens) and fungi, but also cytotoxic effects on the tumor induced-cells [21]. Likewise, the carob seeds have revealed a convincing antioxidant and hepatoprotective activities during the experimentation performed on rats [22]. Rtibi et al. (2016) [23] have investigated the efficacy of the aqueous extract of carob pod on the gastrointestinal transit and intestinal epithelium permeability of mice. They concluded that the aqueous extract of carob pod had health protective properties of laxative and anti-diarrhea. Furthermore, it has been indicated that the whole plant and its individual parts have health benefits including anti-inflammatory, antimicrobial, anti-diarrhea, antioxidant, anti-ulcer, anti-constipation and anti-absorptive of glucose activities [17], [24] and [25].

Phytochemical compounds

The carob is an important source of nutrients with an abundance in hydrocarbons, vitamins, minerals and polyphenol but poor in protein and fat. The carob pods with 6.01 % of moisture are revealed to contain 18.1-60% of sugars (especially glucose, fructose and sucrose), 9.69-50% of fibers, minerals (potassium, calcium, sodium, iron, phosphorus, copper, manganese and zinc), 3-4.71% of protein and 0.23-0.8% of lipids [2], [6], [7], [9] and [25]. This fruit is rich in sugars containing mainly sucrose (32-38%), fructose (5-7%) and glucose (5-6%) [25]. The carob flour and syrup contain 41.55-63.88% of sugars, 1.4-5.34% of protein, 0.15% of lipid, 3.34-11.66% of crude fibers, 2.16-2.92% ash and minerals (potassium, calcium, sodium, iron, phosphorus, copper, manganese and zinc) [6]. The powder of carob roasted at 150 °C for 60 min with 150 µm of particle size has found to contain 9%, 38.7% , 7.24%, 5.82%, 2.84%, 0.74% and 3.75% of moisture, total sugar, fiber, protein, ash, fat and tannins, respectively [26].

The carob has high amounts of polyphenol compounds, especially tannins estimated between 18 and 20%. The phytochemicals of carob with health benefits are summarized in Table 1. The total phenolic compounds and tannins have been determined to be 19-40.8 mg/g and 3.7-19.18 mg/g in carob pod and germ, respectively [6]. In addition to tannins, flavonoids have been detected in the ethyl acetate and methanolic extracts of carob barks which have shown an immense antioxidant activity [27]. Likewise, carob and grape juices have been found to display similar amounts of phenolic compounds with comparable organoleptic characteristics [9]. More than 40 individual polyphenolic compounds have been identified in carob and byproducts. Gallic acid, epigallocatechin, prodelphinidin, procyanindin, myricetin, quercetin, kaempferol, as well as other flavonol-glycosides, isoflavonols and tannins have been figured out in carob fiber, kibbles, gum, syrup and roasted [28]. Furthermore, the antiproliferative compounds like gallic acid, (-) epigallocatechin-3-gallate as well as (-) epicatechin-3-gallate have been revealed in the aqueous extracts of carob leaves and pods [16]. The HPLC analysis performed on the immature carob pods showed that the main phenolic compounds are pyrogallol, catechin, gallic acid, epicatechin, vanillic acid, tannic acid and coumarin [23]. Similarly, coumaric acid, caffeic acid, ferulic acid, syringic acid, galic acid, eriodictyol, chrysoeriol, isorhamnetin, tricetin-3,5-dimethyl ether and quercetin-3-alpha-L-rhamnoside have been discovered in the carob kibbles extracted by supercritical fluid extraction method [17] and [28]. In terms of the extraction of bioactive compounds of carob kibbles, the supercrical fluid extraction has been revealed to be more efficient than ultrasonic and conventional (solid-liquid extraction) methods [17]. Moreover, the seed oil of carob is constituted by linoleic acid, oleic acid, palmitic acid, stearic acid, tocopherol (especially γ-tocopherol, α-tocopherol, δ-tocopherol and β-tocopherol) and sterols (mainly β-sitosterol, campesterol, stigmasterol, 7-avenasterol, 7-stigmasterol and chlerosterol) [8]. With regard to this chemical composition, it can be assumed that the seed oil of carob might have an important application for pharmaceutical, food and cosmetic industries. In addition, the essential oils of carob pods are characterized by nonadecane, heneicosane, naphthalene, 1,2-benzenedicarboxylic acid dibutylester, heptadecane, hexadecanoic acid, octadecanoic acid, 1,2-benzenedicarboxylic acid, eicosene, farnesol 3, camphor, nerolidol and n-eicosane [21]. These oils have demonstrated antimicrobial activity on pathogen microorgansims thanks to their phytochemical compounds.

Table 1: Some phytochemicals of carob and byproducts

Class	Chemical compounds	Amounts	Source	References
Phenolic acids	Gallic acid	233.7 mg/kg	Carob fiber	[28]
		174.1 mg/kg	Carob kibbles	[28]
		1012.6 mg/kg	Carob syrup	[28]
		423.3 mg/kg	Carob flours	[28]
		4.30 mg/g	Carob leave	[16]
		1.20 mg/g	Carob pod	[16]
		423.3 mg/kg	Roasted carob	[28]
		15.12%	Carob pulp	[23]
		1.01%	Carob seed	[23]
	Vanillic acid	5.33%	Carob pulp	[23]
		3.02 %	Carob seed	[23]
	Caffeic acid	2.5 mg/kg	Carob syrup	[28]
	Cinnamic acid	24.2 mg/kg	Carob syrup	[28]
	Coumaric acid		Carob kibbles	[29]
		9.9 mg/kg	Carob syrup	[28]
	Chlorogenic acid	15.01%	Carob pulp	[23]
	Ferulic acid	14.6%	Carob syrup	[28]

Flavonoids	Catechin	14.8 mg/kg	Carob kibbles	[28]
		9.0 mg/kg	Carob syrup	[28]
		23.8 mg/kg	Carob gum	[28]
		0.01 mg/g	Carob pod	[16]
		16.52 %	Carob pulp	[23]
		6.51 %	Carob seed	[23]
		5.5 mg/kg	Roasted carob	[28]
	Epigallocatechin	41.9 mg/kg	Carob fiber	[28]
		8.6 mg/kg	Roasted carob	[28]
		0.06 mg/g	Carob pod	[16]
	Prodelphinidin dimer	5.7 mg/kg	Carob fiber	[28]
		5.8 mg/kg	Roasted carob	[28]
	Epigallocatechin-3-gallate	1.51 mg/g	Carob leave	[16]
		0.01 mg/g	Carob pod	[16]
	Procyanindin dimer	4.2 mg/kg	Carob fiber	[28]
		21.2 mg/kg	Roasted carob	[28]
	Epicatechin-3-gallae	0.47 mg/g	Carob leave	[16]
		0.08 mg/g	Carob pod	[16]
	Myricetin	171.1 mg/kg	Carob kibbles	[28]
		11.2 mg/kg	Carob syrup	[28]
		839.9 mg/kg	Carob fiber	[28]
		98.8 mg/kg	Carob flours	[28]
	Epicatechin	12.26 %	Carob pulp	[23]
	Procyanindin trimer	114.3 mg/kg	Carob fiber	[28]
	Quercetin	53.3 mg/kg	Carob kibbles	[28]
		0.9 mg/kg	Carob syrup	[28]
		1114.5 mg/kg	Carob fiber	[28]
		116.2 mg/kg	Carob flours	[28]
	Kaempferol	8.6 mg/kg	Carob kibbles	[28]
		255.7 mg/kg	Carob fiber	[28]
		4.5 mg/kg	Roasted carob	[28]
		6.6 mg/kg	Carob flours	[28]
Tocopherols	α-tocopherol	69.09-70.39 mg/100g	Carob seed oil	[8]
	α-tocopherol 3	1.78-4.94 mg/100g		
	β-tocopherol	1.85-2.30 mg/100g		
	γ-tocopherol	101.15-114.29 mg/100g		
	δ-tocopherol	8.70-10.66 mg/100g		
Tannins	Hydrolyzable tannins	26.3 mg/kg	Carob kibbles	[28]
		1506.8 mg/kg	Carob fiber	[28]
		330.3 mg/kg	Carob flours	[28]
	Tannic acid	4.23 %	Carob pulp	[23]
		18.81 %	Carob seed	[23]
	Condensed tannins	14.8 mg/kg	Carob kibbles	[28]
		9.0 mg/kg	Carob syrup	[28]
		191.8 mg/kg	Carob fiber	[28]
		18.7 mg/kg	Carob flours	[28]
Sterols	β-sitosterol	72.04-78.62 mg/kg	Carob seed oil	[8]
	Stigmasterol	0.58-11.43 mg/kg		
	Campesterol	5.32-5.33 mg/kg		
Coumarin	Coumarin	1.24%	Carob pulp	[23]

Aroma and aroma-active compounds

The different products of carob such as carob pods, leaves, seeds, kibbles and flowers have been investigated for their aromatic profile using various extraction methods. Vacuum distillation method [30] and [31], simultaneous distillation extraction [1] and [32], head space-solid-phase microextraction [33], [34], [35], [36] and [37], and dynamic headspace (in tube extraction) method [11] have been used to obtain the aromatic extracts of carob and derivatives. The overall aroma compounds of carob are mainly classified as aliphatic fatty acids, alcohols, aldehydes, esters, ketones, lactones, furans, phenols, pyrroles, pyridines, pyrazines and terpenes (Table 2). The carob aroma is affected by maturing stage, origin, processing conditions (roasting and powering) as well as flower satge and sex.

Volatile fatty acids. The volatile fatty acids provide the major volatile substances which contribute mostly to the total scent of carob. Butanoic acid, acetic acid, methyl propanoic acid, isobutyric acid, hexanoic acid, n-butyric acid, 2-methyl butanoic acid and 2-methyl butyric acid are the most powerful volatile fatty acids discovered in carob [11], [30], [32], [36] and [37]. Furthermore, hexanoic acid has been found as the most attracitve aroma compound to *Oryzaephilus surinamensis*. Likewise, acetic acid, propanoic acid, 2-methyl (isobutyric acid), butanoic acid and hexanoic acid were detected as aroma-active compounds carob fruit, while, isobutyric acid was detected as aroma-active compound in carob powder [37].

Alcohols. With respect to amount and number, alcohols were found among major volatile participants in carob. The main alcohols in carob were determined to be isoamyl alcohol, followed by isobutyl alcohol, 2-methyl-1-propanol, *n*-amyl alcohol, 2-furanmethanol, benzyl alcohol, ethanol and isopropyl alcohol [1], [11], [32] and [37]. Alcohols have been reported to be more abundant in the roasted carob [1].

Terpenes. The terpenes are predominated in carob flowers with monoterpenes and sesquiterpenes as main components. Linalool, α-pinene, limonene, *trans*-linalool oxide, *cis*-linalool furan oxide, β-pinene, β-myrcene, *cis*-ocimene, α-farnesene, γ-terpinene and δ-cadinene were detected as the most important terpenes in carob flowers [33], [35] and [37]. Similarly, limonene, 1,4-cineole, α-cubebene as well as farnesene and its isomers were detected in carob beans [32] and [36].

Esters. Several esters have been identified in carob, providing a pleasant odor to carob, especially to carob flower. The most powerful esters in carob flowers were found to be ethyl benzoate, 3-methylbutyl-(*E*)-2-methyl-2-butenoate, methyl salicylate, ethyl salicylate, acetic acid methyl ester and ethyl nonanoate [33], whereas, dimethyl propanoate, ethyl butanoate, ethyl methyl propanoate, methyl 2-methyl butanoate, acetic acid methyl ester, ethyl acetate, methyl propionate, 2-methyl propanoic acid methyl ester, butanoic acid methyl ester, butanoic acid ethyl ester, hexanoic acid ethyl ester, glycolic acid acetate and methyl butyrate were revealed as the major esters in carob pod [32], [36] and [37].

Aldehydes. The aroma compounds which belong to the group of aldehydes are responsible for the green odor. Together with volatile fatty acids and alcohols, aldehydes represent more than 94% of the overall aroma compounds in carob [1]. Decanal is only aldehyde detected carob in flowers [33], while, a myriad of aldehyde compounds mostly benzaldehyde, nonanal, myrtenal, ethanal, 2-butenal, 2-methyl-2-butenal, vanillin, methyl propanal, butanal, 3-methy butanal, 2-methyl butanal, pentanal, hexenal, acetaldehyde, propanal, (*E*)-cinnamaldehyde and benzeneacetaldehyde were identified in carob pod [1], [11], [32], [36] and [37].

Ketones. An important amount of ketones was figured out in the raw and roasted carob [1]. The major ketones detected in carob were 2-nonanone, 2-heptanone, 2-undecanone, 2-pentanone, 2,4-pentanedione, 2-methyl-3-pentanone, acetoin, 2-octanone, non-3-en-2-one and phenylbutanone [1], [32], [37] and [37]. Furthermore, 2-nonanone and 2-undecanone were revealed to provide an attractive effect on insects, especially *Ahasverus advena* [38].

Furans. The volatile compounds of furans participate also to the carob scent. They have been detected in the raw and roasted carob with an increased amount during the roasting [1]. Furans are known to be mainly formed during the heating process. The major furans in carob are 2-furaldehyde, furfural, 2-acetylfuran, α-methylfurfural, 2-methyl furan and 2-ethyl furan [1], [11], [31], [32] and [37]. 2- Furaldehyde was revealed as one of the aroma compounds of carob, as it has exerted an attractancy on *Oryzaephilus surinamensis* [31].

Volatiles phenols, lactones, pyrans, pyrroles, pyrazines and hydrocarbons. Beside above cited aroma compounds, many other volatile compounds have found as small contributors in carob. They belong to the aromatic groups of volatile phenols, pyrans, lactones, pyrroles, pyrazines and hydrocarbons as well. Among these aroma compounds, guaiacol, eugenol, 2-methoxy-4-vinylphenol, *p*-allylphenol, phenol, 3(4)-methyl phenol, *p*-vinylguaiacol, *γ*-valerolactone, *γ*-butyrolactone, γ-hexalactone, γ-octalactone, *γ*-decalactone, 2H-pyran-2-one tetrahydro-6-methyl, 1-ethyl-1*H*-pyrrole-2-carboxaldehyde, 2-acetylpyrrole, 1*H*-pyrrole-2-carboxaldehyde, 2-ethyl-3-methyl pyrazine, 2,6-dimethylpyrazine, 2-ethylpyrazine, 2-ethyl-3,5-dimethylpyrazine and 2-acetyl-3-ethylpyrazine have been detected in the raw, flowers as well as roasted carob [1], [32], [33] and [37].

Table 2: Aroma compounds of carob

Class	Compounds	Source	Reference
Acids			
	Acetic acid	Carob powder, fruit, beans and kibbles	[30], [32] and [37]
	Butanoic acid	Carob powder, fruit and kibbles	[11], [32], [36] and [38]
	Methyl propanoic acid	Carob beans	[32]
	2-Methyl propanoic acid	Carob powder and fruit	[11] and [37]
	Isobutyric acid	Carob powder, beans, fruit and kibbles	[30] and [37]
	Hexanoic acid	Carob powder and fruit	[32], [35] and [37]
	n-Butyric acid	Carob beans	[30]
	2-Methyl butanoic acid	Carob beans, powder and fruit	[11], [32] and [37]
	2-Methyl butyric acid	Kibbles	[30]
Alcohols			
	Isoamyl alcohol	Carob fruit and roasted	[1]
	Isobutyl alcohol		
	2-Methyl-1-propanol		
	n-Amyl alcohol		
	2-Furanmethanol	Carob powder	[11]
	Benzyl alcohol	Carob fruit, roasted and flowers	[1] and [37]
	Ethanol	Carob fruit, powder and flowers	[37]
	Isopropyl alcohol	Carob powder	[37]
Terpenes			
	Linalool	Carob beans and flowers	[32], [33], [35] and [37]
	α-Pinene	Carob flowers	[33], [35] and [37]
	Limonene		[33]
	cis-Ocimene		
	trans-Linalool oxide		[33], [35] and [37]
	cis-Linalool furan oxide		[35]
	β-Pinene		[35] and [37]
	β-Myrcene		[33] and [35]
	δ-Cadinene		[33] and [35]
	α-Farnesene	Carob flowers and pods	[35] and [36]
	γ-Terpinene	Carob, beans, flowers and pods	[32], [33] and [35]
Esters			
	Ethyl benzoate	Carob flowers	[33]
	3-Methylbutyl-(*E*)-2-methyl-2-butenoate		
	Methyl salicylate		
	Ethyl salicylate		
	Acetic acid, methyl ester		
	Ethyl nonanoate		
	Ethyl butanoate	Carob pods	[32]
	Ethyl methyl propanoate		
	Acetic acid, methyl ester	Carob fruit, powder and flowers	[37]
	Ethyl acetate	Carob fruit and powder	
	Methyl propionate		
	Butanoic acid, methyl ester		
	Butanoic acid, ethyl ester		
	Hexanoic acid ethyl ester		
	2-Methyl propanoic acid, methyl ester	Carob beans, fruit and powder	[32] and [37]
	Glycolic acid acetate	Carob pods	[36]
	Methyl butyrate		
Aldehydes			
	Decanal	Carob flowers	[33]

	Benzaldehyde	Carob fruit, roasted and powder	[1], [11], [36] and [37]
	Nonanal	Carob fruit, beans, flowers and powder	[31] and [37]
	3-Methy butanal		
	Myrtenal	Carob fruit and roasted	[1]
	2-Butenal		
	2-Methyl-2-butenal		
	Vanillin		
	Methyl propanal	Carob beans	[32]
	Hexenal		
	Pentanal		
	Butanal	Carob beans and powder	[32] and [37]
	2-Methyl butanal	Carob fruit, beans and powder	
	Acetaldehyde	Carob powder	[37]
	Propanal		
	(*E*)-Cinnamaldehyde	Carob fruit and roasted	[36]
	Benzeneacetaldehyde		
Ketones			
	2-Nonanone	Carob fruit, roasted, kibbles and powder	[1], [37] and [38]
	2-Heptanone		[1], [11] and [37]
	2-Undecanone	Carob fruit and kibbles	[1] and [37]
	2-Pentanone	Carob fruit, roasted and powder	[1] and [37]
	2,4-Pentanedione	Carob fruit and roasted	[1]
	2-Methyl-3-pentanone		
	Acetoin	Carob fruit, roasted and powder	[1], [33] and [37]
	2-Octanone	Carob fruit	[37]
	Non-3-en-2-one	Carob beans	[32]
	Phenylbutanone		
	1-(1H-pyrrol-2-yl) Ethanone	Carob powder	[36]
Furans			
	Furfural	Carob fruit, powder and roasted	[1], [11], [36] and [37]
	2-Furaldehyde	Kibbles	[31]
	2-Acetylfuran	Carob fruit and roasted	[1]
	α-Methylfurfural		
	2-ethyl furan	Carob fruit	[37]
	2-Methyl furan	Carob fruit, flowers and powder	
Volatiles phenols			
	Guaiacol	Carob fruit, roasted and powder	[1], [32], [33] and [37]
	Eugenol		
	2-Methoxy-4-vinylphenol		
	p-Allylphenol		
	Phenol		
	3(4)-Methyl phenol		
	p-Vinylguaiacol		
Lactones			
	γ-Valerolactone	Carob fruit and roasted	[1]
	γ-Butyrolactone		
	γ-Hexalactone		
	γ-Octalactone		
	γ-Decalactone		
Pyrans			
	2H-pyran-2-one, tetrahydro-6-methyl	Carob flowers	[36]

Pyrroles			
	1-Ethyl-1*H*-pyrrole-2-carboxaldehyde	Carob fruit, beans and roasted	[1] and [32]
	2-Acetylpyrrole	Carob fruit and roasted	
	1*H*-pyrrole-2-carboxaldehyde		
Pyrazines			
	Ethyl-3-methyl pyrazine	Carob beans	[31]
	2,6-Dimethylpyrazine	Carob fruit and roasted	[1]
	2-Ethylpyrazine		
	2-Ethyl-3,5-dimethyl pyrazine		
	2-Acetyl-3-ethylpyrazine		

CONCLUSION

The carob is a Mediterranean tree with multifold benefits. It is used in food industry for many purposes as it can be processed into juice, syrup, molasses, confectineries and gum. This plant is used in the traditional medicine to relieve several ilnesses such as asthma attacks, bronchitis, grippe infections, coughing, cancer and diarrhea. The carob is also used in the textile, pharmaceutical, consmetic as well as explosive industries. It contains many bioactive compounds which contribute to the strenghening of the human health. The unique odor of the carob is characterized by the volatile compounds which belong mainly to the aromatic groups of fatty acids, alcohols, terpenes, esters, aldehydes, ketones and furans. Further studies are needed to figured out the aroma-active compounds carob and its derived products.

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