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A Recent Trend on Functional and Therapeutic Role of Carob Beans In Food Products

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ABSTRACT

Background: Carob (Ceratonia siliqua L.) is a nutritious and medicinal evergreen crop of the Leguminosae family, cultivated in Mediterranean regions of West Asia and North Africa. Although its sustaining worth has been recognized for prosperity, its therapeutic characteristics have only recently been investigated, regardless of that some of those facts have been employed in ancestral remedies for generations

Purpose: To study the different functional and therapeutic role of carob beans and its utilization in the food products

Conclusions: Carob products are high in fibre, carbohydrates, and beneficial components such as polyphenols and D-Pinitol. Because of their anti-hyperglycaemic, antioxidant, and an-ti-inflammatory properties, bioactive chemicals found in carob fruit and its derivatives help treat a variety of health issues, in-cluding diabetes, heart disease, and gastrointestinal disorders. The current review focuses on functional properties of carob beans and its potential in generating a wide range of health-beneficial food and formulations.

1. Introduction

Carob (Ceratonia siliqua) is a pine tree of the Fabaceae (Legumes) family. Its natural habitat is western Asia, but following domestication, it extended throughout the whole Mediterranean basin, as well as the western coastlines. Italy (23.11%), Turkey (10.39%) Portugal (28.83%), and Morocco (16.11%) were the biggest producers of carob globally from 2015 to 2018. The yield of carob pods is affected by many variables, including variety, location, cultural customs, and environmental conditions (Nasar Abbas et al., 2016). Carob pod has numerous uses in paints, polishes, adhesives, ceramics, cosmetics, film emulsions, oil drilling, and pharmaceuticals (Mudgil et al., 2014). Numerous studies support the utilization of carob produce and its derivatives as a useful food and food additives (Fidan et al., 2020). A presentation on carob pod commercial manufacturing and processing is detailed in Fig. 1. In the food sector, carob has a lot of promising benefits because of its many health advantages, (Goulas et al., 2016) which persists even after processing. Further, in numerous baked goods, milk formulas, it is used as a substitute for cocoa. Additionally, by fermenting carob pods with bacteria, fungi, and algae, various organic acids, alcohols, and enzymes can be produced (Tsatsaragkou et al., 2014; Srour et al., 2016; Custódio et al., 2015; Yatmaz et al., 2016). This unusual quality may be explained by the existence of biogenic volatile chemical substances, such as ketones/aldehydes, esters, and acids. Due to its positive impacts on health, carob pulp is receiving more and more attention as an ingredient in a variety of culinary products.

The majority of studies, however, focused on characterizing whole carob or seeds for their specific phytochemical elements. This study intends to examine and underline the carob's positive qualities as well as its potential to be used as an effective working component in the food sector, providing new insights into crop sustainability. The detailed functional characteristics of the carob bean and the food products derived from it are highlighted in this review article.

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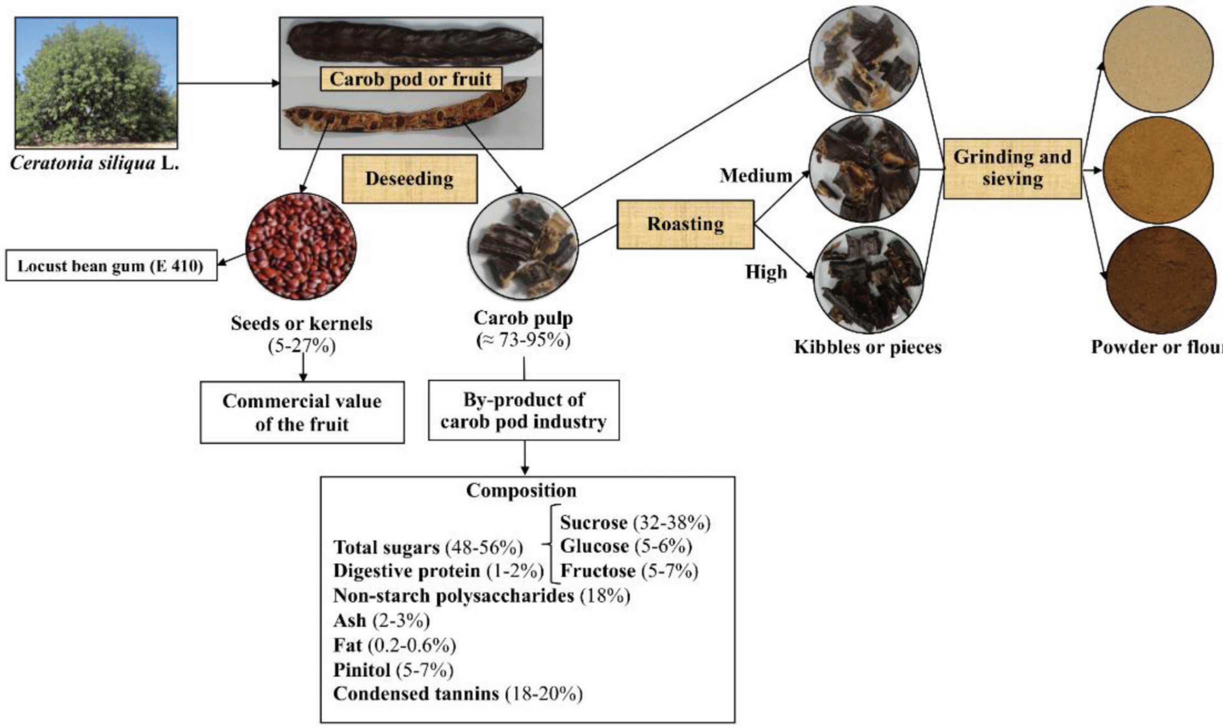

Figure 1: Commercial production of nutritional and functional by products of carob pod.

2. Carob beans as Functional Food

Functional food can be described as a food or beverage product which consist of nutraceutical or food-grade bioactive agents with therapeutic effects and above normal nutritional function.Recently, people are more interested in supplements derived from natural, traditional and non-traditional foods as possible sources of biologically active substances with proven health properties for inclusion in the human diet (Baumel et al., 2018). About that, carob (Ceratonia siliqua L.) holds potentially significant importance for the food industry due to its phytochemical constituents with functional properties as detailed in the following sections. We have discussed the chemical elements of carob and its biological features linked to their health benefits shown in (Table 1).

Table 1: Chemical elements of carob and biological features linked to health benefits.

S.No	Chemical Elements	Health Advantages/ Illness/ Biological Features	Target disease control	Carob fraction/ Part
1	Chlorogenic acid, Rutin Myricetin, Polyphenols	Inflammatory and Antitumoral activities, Neurogenerative disease	Abdominal obesity control	Powder of carob pulp
2	Epigallocatechin, Catechin, Syringic Acid	Antioxidant, Antibacterial, Antifungal	Help prevent heart and brain disease	Extract of carob pulp
3	Insoluble dietary fibre	Enhanced lipoprotein metabolism	Diabetes, heart disease and some type of cancer	Pulp of carob
4	D-pinitol	Anticancer/ Hepatoprotective	Improves liver	Pulp of carob
5	Flavonoids, condensed tannins	Antihypertensive activity, Antidepressant effect	Lower cholesterol	Peel of carob seed
6	Sugar, fibre, pyrogallol	Laxative and anti- diarrheal activities	Heart disease control	Carob pod
7	Galactomannan	Gastrointestinal effects		Seed endosperm

2.2. Anticancer and Related Activity

Carob is rich in phytochemicals and recent studies have shown that it has anti-cancer, anti-proliferative, and pro-apoptotic effects. The polyphenol quercetin promotes apoptosis (programmed cell death) in leukaemia cells by directly targeting the anti-apoptotic protein Bcl-x. It also works well in the tumour micro environment, shrinks tumours and prevents angiogenesis (formation of new blood vessels), as demonstrated in pancreatic and breast cancer xenograft models (Zhao et al., 2016). Carob fruit also contains gallic acid (phenolic acid), which inhibits the growth of osteosarcoma (bone cancer), Forester et al. investigated gallic acid and its derivatives involved in the antiproliferative activity of human colonic cell lines. Carob fibre extract and tannins are also anticancer agents and inhibit the growth of human colonic adenoma and adenocarcinoma cells by protecting these cells from oxidative stress. It has been demonstrated in the literature that the ethyl acetate fraction of carob leaves has a significant shielding result against induced hepatotoxicity and nephrotoxicity in rats (Hsouna et al., 2011).

2.3. Anti-hyperlipidaemic Activity

Coronary heart disease and stroke account for 38% of all deaths in the United States. Hyperlipidaemia, defined as increased levels of cholesterol, triglycerides, or both that are in the blood, which promotes atherosclerosis and can be a major cause of cardiovascular disease (Nelson et al., 2013). Eating a high-fibre diet lowered the risk of heart disease and mortality by lowering total serum and LDL concentrations in the blood. Carob fibre extract (CFE) reduced pancreatic lipase activity in rats, decreased fat digestion and absorption, and increased faecal fat excretion, thereby increasing postprandial fat excretion. Carob is rich in fibre and phenolic chemicals, both of which have antihyperlipidemic properties. Studies have shown that increasing the antioxidant content of carob showed hepatoprotective effects, reducing lipoproteins and oxidative stress in hypercholesterolemic rats (El-Rabey et al., 2017). The insoluble fibre contained in the pods attenuated the detrimental effects of hepatic dyslipidaemia by altering the SIRT1 and PGC-1 signalling pathways, which are crucial for cholesterol and triglyceride metabolism in the liver.

2.4. Anti-diabetic Effects

Diabetes is a chronic disease in which the pancreas either does not generate enough insulin or produces too much or does not use the insulin produced by the body. Uncontrolled diabetes causes hyperglycaemia and elevated blood sugar levels, which causes serious harm to kidneys, liver, blood vessels, and nerves. The number of people with diabetes is rapidly increasing. By 2025, the number of persons affected by diabetes is expected to grow by 300 million. Diabetes will be the sixth largest cause of mortality by 2030, according to the World Health Organization. Diabetic etiologies are treated with insulin or oral hypoglycaemic therapy. Controlling hyperglycaemia requires new drugs that reduce or limit glucose absorption (Chao et al., 2010). Due to their high flavonoid and polyphenol content, several herbs and extracts have been used as effective antidiabetic agents. Carob berries and extracts have also been implicated in anti-diabetic effects due to their complex phytochemical composition. These chemicals, which inhibit glucose transport and absorption in the intestine, can be used as dietary supplements to treat hyperglycaemia and diabetes. Carob leaves and bark is potent against α-amylase and β-glucosidase, two carbohydrate hydrolases that digest carbohydrates and cause postprandial hyperglycaemia in diabetic patients. Another study found that carob can be used to treat diabetes by improving glucose tolerance, inhibiting glucose absorption, and protecting rats from alloxan-induced diabetes (Hamza et al., 2015). Additionally, studies have shown that replacing sucrose with natural pinitol-rich sweeteners reduces glucose metabolic dysfunction in patients with impaired glucose tolerance (IGT) and normalizes dysfunctional glucose metabolism. Pancreatic cells can counteract insulin resistance in the early stages by increasing insulin production. Functional food enriched with locust bean fruit (CFE) extract ameliorate pancreatic cell dysfunction, resulting in increased insulin levels and decreased hyperglycaemia, making it a beneficial strategy for the treatment of type 2 diabetes in its late stages (Macho-González et al., 2020). Consumption of CFE-fortified meat increases lipoprotein metabolism and insulin signalling efficiency by lowering VLDL and plasma triglyceride levels through increased faecal fat excretion (Macho-González et al., 2020).

2.5. Prevent Obesity

Obesity is defined as the accumulation of triglycerides in adipose tissue as a result of increased adipocyte proliferation and adipocyte hypertrophy. Obesity due to abnormal adipocytokine secretion is a crucial contributor to the development of several chronic illnesses, including diabetes, cardiovascular disease, and cancer. In this condition, reactive oxygen species and oxidative processes are out of balance, leading to various metabolic abnormalities such as hyperinsulinemia, altered lipid metabolism, and increased triglyceride stores. The adverse health effects of weight loss drugs and surgery have shifted focus to the use of natural products, especially functional diets that aid weight loss while providing the nutrients the body needs (James et al., 2017). Carob is a superfood with strong antioxidant capacity that helps treat chronic lifestyle-related diseases. By feeding mice a high-fat diet and administering carob polyphenols (CPP), it was found that CPP functions as an anti-obesity chemical that inhibits adipocyte hypertrophy and increases in adipose tissue mass. The high antioxidant capacity of carob tree by-products makes them promising therapeutic agents for the treatment of metabolic syndrome (MetS). MetS is a multifactorial condition characterised by abdominal obesity, hyperglycemia, hypertension, and atherogenic dyslipidaemia (Rico et al., 2019) which raised the risk for heart disease and type 2 diabetes. MetS is more likely to occur due to poor diet, such as frequent snacking and consumption of high-energy foods. Healthy snacking behaviour, on the other hand, can control appetite, induce satiety, and reduce postprandial glycaemic responses while enhancing food quality. Rico et al., created a functional snack containing carob and wakame seaweed to address his NAFLD (non-alcoholic fatty liver disease), a liver symptom of MetS. According to Rico et al., functional snacks made from carob can cure fatty liver by increasing fat oxidation and decreasing oxidative stress. Carob contain significant amounts of dietary fibre, ttherefore, foods high in fibre have a low-calorie value, which helps with weight management (Lattimer et al., 2010).

2.6. Antioxidant Properties

ROS (reactive oxygen species) and RNS (reactive nitrogen species) are two forms of free radicals and ions. They are produced either locally by regular cellular metabolism (redox activities in cells) or outside (pollution, cigarette smoke, radiation, drugs, alcohol, cooking). These species function as both poisonous and helpful compounds. A precise balance between two conflicting effects is a fundamental component of life. At low to moderate quantities, ROS and RNS are advantageous to cellular responses and immunological function. At large concentrations, they create oxidative stress, a dangerous process that can kill all cell components. Cancer, arthritis, ageing, autoimmune disorders, cardiovascular and neurological diseases are all the influence of oxidative stress. The human body has several mechanisms to combat oxidative stress, including the production of antioxidants, which are classified as enzymatic antioxidants (superoxide dismutase, catalase, glutathione peroxidase, and glutathione reductase) or non-enzymatic antioxidants (lipoid acid, glutathione, L-ariginine, coenzyme Q10, lactoferrin, etc.). Endogenous and exogenous antioxidants act as “free radical scavengers,” preventing and repairing ROS and RNS damage (Graves, 2012; Lushchak, 2014; Pham-Huy et al., 2008). Saci et al. (2019) observed similar results, suggesting that unripe carob extract can act as a natural antioxidant and provide large amounts of secondary metabolites with neuroprotective effects in vitro. Several studies have demonstrated high antioxidant activity and improved developmental performance in rabbits (Abu Hafsa et al., 2017; Sadat et al., 2019; Lakkab et al., 2019; Rtibi et al., 2015a; Rtibi et al., 2015b)

3. Commercial Functional Food Products From Carob Beans

Great challenges for the food industry are the clear demonstration of the health benefits of natural ingredients sources before they can be successfully incorporated into functional food products with regulatory compliance and consumer acceptance. Several studies in recent years have demonstrated the versatility and functionality of different carob products used in the production of functional foods. The processing of whole carob fruit to obtain different carob products significantly affects physicochemical and functional properties. The carob products can be used as natural ingredients in the food industry due to flavouring or colouring effects and improved final products’ characteristics. Some examples of foodstuffs with the addition of carob products are presented in Table 2. The enhanced properties of the final products are highlighted.

3.1. As a Food Additive (Stabilizer/thickener)

LBG is used as a thickener and stabilizer as a food additive (E-410) in many dairy, meat and bakery products. Due to its excellent bioactive profile, it is also used in diet products and dietary supplements. However, dietary usage varies by application, with typical addition levels ranging from 0.2% to 0.5% (Mudgil et al., 2014). Few of its application in food industries include: binding water, controlling texture, affecting crystallization, preventing creaming or sedimentation, improving freeze-thaw behavior, synergizing starch products, preventing deterioration, maintaining turbidity in juices and soft drinks. Wielinga reported the technological role of LBG in extendong shelf-life of foods by foam stabilization (Wielinga et al., 2010). Additionaly, the texture of frozen foods, dairy products, and baked goods is determined by synergistic interactions between LBG and other biopolymers. Caseinate LBG biopolymers were found to exhibit significant emulsifying properties in oil-in-water emulsions at various pH value. Moreover, their emulsifying and stabilizing abilities are attributed to protein-polysaccharide interactions resulting from electrostatic interactions, hydrogen bonding, and van der Waals forces. LBG improves the rheological properties of goat milk yogurt while maintaining the microbiological longevity of yogurt cultures and probiotic bifidobacterial species.

Moreover, for frozen desserts, key concerns include product crystal size, viscosity, texture, and melting temperature. LBG contains galactomannan, a thickening agent which can be used to prevent ice crystal formation and improve the melting properties of ice cream. Chavez et al, (2018) found that LBG improved the mouthfeel, perceived viscosity, and melting properties of frozen goat milk desserts. Further research found that LBG reduced ice cream mix overflow, increased melting time, and improved the sensory properties of both animal and vegan ice cream. LBG can be used as a fat substitute to reduced-fat or low-fat dairy products and has a significant impact on the texture and organoleptic properties of the products. Furthermore, it can be used as a natural substitute for thickeners in the jam industry without affecting the organoleptic or physio-chemical properties of the jam (Mekhoukhe et al., 2021).

3.2. Cocoa Substitute

Coca is an important agricultural commodity as it is the main ingredient in chocolate-based products. It is also of great economic and social importance around the world. Several factors contribute to slowing coca supply growth, creating an imbalance between supply and demand, pushing up coca prices. To meet customer demand, sustainable alternative products are needed to overcome these problems. Carob is a natural, inexpensive coca substitute with many similarities that make it an ideal coca substitute. Carob powder is made by peeling, grinding and roasting the carob pulp. Carob is roasted at 120-180°C for 10-60 minutes, depending on the desired end result. Carob powder has a characteristic coca-like aroma, flavour and colour when roasted due to the caramelization of sugar and the Maillard process (Srour et al., 2016). Therefore, carob can be used as a cocoa substitute and offers a variety of benefits, including no caffeine and theobromine stimulants, high fibre supplementation, low fat content, and high antioxidant potential (Papageorgiou & Boublenza, 2017). Akdeniz et al. (2021) showed that carob is an excellent substitute for coca in dark and milk chocolate formulations, with no significant difference in organoleptic properties or consumer acceptability. Carob chocolate is also rich in nutritional value because carob has a low fat and high fibre content. Another study demonstrated the effective manufacture of chocolate using carob instead of cocoa, and the product is useful for conditions such as diabetes, celiac disease, caffeine intolerance, or calorie-conscious groups (Lanfranchi & Salem, 2012). Carob-based icings with excellent rheological and sensory properties have also been developed to replace chocolate icings and coatings in confectionery and bakery products. According to Pawowska et al. (2018) carob-based baked goods are more nutritious, have higher anti-radical properties, and have better sweet and sensory properties than cocoa-based baked goods, aldehydes, lactones, furans, pyrrole derivatives and other aromatic components, as well as retaining the appropriate texture and organoleptic properties.

3.3. Gluten-free Products

Due to their sensory and nutritional properties, grain-based baked goods are an important part of the human diet. However, due to the gluten content, these products are not suitable for celiac disease. Celiac disease is an autoimmune disease caused by the consumption of gluten proteins that cause an inflammatory response in the small intestine. Celiac disease patients should eat vegetables, raw meat, pasta, bread, cookies and other processed products (starches and gluten-free flours). There is only a limited range of products on the market that can be used as replacements for the standard celiac diet. In recent years, food manufacturers have taken an interest in producing products that meet the unique nutritional needs of customer groups suffering from food issues and allergies. Gluten-free foods (GF) fall into this category, particularly for weight management and disease prevention. Because it is healthier, it is in high demand not only among celiacs but also among non-celiacs (Papageorgiou et al., 2015). The production of gluten-free products presents many technological obstacles to the food industry. These include texture development due to gluten deficiency, low nutritional value, and bland taste. GF products require specific additives and ingredients to replicate the structural functions of gluten. Starches from legumes (beans) and cereals (rice and sorghum) are used for this. Carob is another legume with great potential for producing GF goods. Locust bean gum has rheological properties similar to wheat gluten and a superior nutritional profile (Arribas & Tsatsaragkou, 2012). Cervenka et al. (2019) and Sciammaro et al. (2018) reported locust bean flour biscuits as more nutritious than control biscuits. However, high amounts of locust bean gum have some negative effects on product taste, crispness, colour and aroma. According to the finding by Skaltsi et al. (2021), the most ideal formulation for producing high quality gluten-free biscuits with acceptable physical, textural, and sensory properties is dried apple pomace (32.6%–47.58%), locust bean gum (16.2%–29.2%), and water (29%-43%). Carob flour is also used to make new gluten-free fettuccine and noodles that are better cooked, more nutritious and more functional (Arribas & Altiner, 2020).

3.4. Fermented Products

Fermentation is a metabolic process in which bacteria convert carbohydrates into organic molecules such as acids, gases and alcohols. Both major and minor nutrients are required for this transformation. However, using pure food sources makes the industrial process expensive. Carob pods are an important source for fermentation due to their high nutritional value. Carob is processed to make various carob products such as CBG, carob juice and carob flour. After extracting all these fractions, the remaining sugar source can be used in fermentation processes to make specific organic molecules (Yatmaz & Haddarah, 2013). Citric acid, a tricarboxylic acid, is frequently utilized in the pharmaceutical, food, and beverage sectors as an acidulant and taste enhancer. Researchers are focused on making it from cheap sources. According to the literature, *Aspergillus niger* fermentation of carob extract produced significant levels of citric acid (Haider et al., 2014). Carob can also be used as a carbon source in the production of the industrial chemical lactic acid. Lactic acid is in high demand as it is used as a monomer in the production of biodegradable polylactic acid (PLA), a sustainable bioplastic. *Lactobacillus casein* and carob extract can be used as fermentation media to obtain higher concentrations of lactic acid. However, the carob extract must be treated with an invertase enzyme before sucrose can be converted to monosaccharides that can be successfully metabolized by *L. casein*. The highest concentration achieved using yeast extract as nitrogen source was 68.79% compared to other nitrogen sources which produced 66.70% (Turhan et al., 2010).

Due to rising prices and environmental concerns, conventional fuel supplies are being replaced by renewable fuels. Research in this area focuses on meeting the world's energy needs by producing clean fuels using simple and inexpensive technologies. Ethanol can be produced sustainably from food and waste. Due to their high sugar and mineral content, carob and its waste can be used to produce bioethanol (Bindal et al., 2019). Further, Bindal et al. (2019) demonstrated that carob can be efficiently used for large-scale ethanol production by using strain of *Saccharomyces sp*. The food industry faces major hurdles before it can demonstrate the health advantages of natural ingredient sources in order for them to be effectively incorporated into functional meals with regulatory compliance and customer acceptability (McClements & Xiao, 2014). Several recent studies have proved the flexibility and use of various carob products in the development of functional diets. The processing of whole carob kernels into various carob products has a significant impact on their physio-chemical and functional properties.

Carob products can be used as natural ingredients in the food industry due to their improved taste and colour characteristics. Table 3 shows some examples of different food category that have fortified carob products. Carob syrups (Brix 60, 70, or 80) were characterized by high antioxidant activity and emulsifying capacity, and high concentrations of reducing sugars. These improved qualities are attributed to the non-enzymatic browning process that occurs during juice cooking. The physio-chemical properties and acceptability of certain bread products may also be affected by the degree of roasting of the locust bean flour. This increased the hardness, elastic-like behaviour of cookie's dough indicating a more robust component interaction. In addition, in order to effectively use carob products as functional food ingredients, carob products must be understood in terms of their physical and chemical qualities, as well as their dependencies. Benkovic et al. (2017) investigated the physicochemical parameters of carob flour prepared with and without seeds and discovered that carob flour created with seeds had better cohesiveness indices and cake strength values than flour made without seeds. Furthermore, the cohesiveness and cake-forming ability of flour influenced the extraction efficiency of polyphenols and flavonoids, as well as the antioxidant capacity. In terms of carbohydrates, the carob seed-free sample contained more total sugars and soluble polysaccharides. These qualities give traditional dishes their nutritional and biological value, depending on the remaining ingredients. Papaefstathiou & Agapiou, (2018) compared the nutritional composition of 20 traditional carob foods with that of Cypriot carob meat. They concluded that carob fruits and powders can be recommended for inclusion in the daily human diet because they contain valuable nutrients and have a sweet taste yet are low in fat, whereas carob products can be recommended for their health and nutrition claims. Another important benefit of carob products is their use as gluten-free flours in the baked goods sector. Martin Diana et al. (2017) gluten-free crackers made from carob tree by-products (germ and seed coat) developed a snack. The polyphenols responsible for the product's antioxidant activity were anthocyanins, tannins, catechins, and flavanols (Albertos et al., 2015). Further, the germ and seed coats of carob processing-based by-products contributed to the protein and antioxidant activity of the engineered foods.

Table 3: Carob-based category of food and their primary advantages.

S.No	Food Category	Functional foods	Advantages
1.	Dairy Based	Carob spread	Colour and texture are both excellent. A great source of important mineral Total phenolic content is high
		Low lactose yoghurt with carob flour	Fibre content is high. Sweetness content is high

2.	Seed Based	Sesame pastes enriched with carob syrup	Enhanced emulsion stability and High nutritive value
3.	Cereal Based	Pasta enriched with carob flour	Colour, stiffness, and hardness are all excellent. High antioxidant activity and sucrose content and High total phenol content and glycaemic index
		Rice based extruded snacks like fortified with pea, bean and carob fruit	Phenolic chemicals in abundance, a high level of antioxidant activity, enhanced textural characteristics
		Muffin with carob powder	High level of water activity, High phytosterol and genistein concentration, Enhanced browning and FAST indexes
		Wafer cream with carob pod and chicory root powder	Caffeine content is low, High sugar content Improved physiochemical, rheological, and sensory qualities
		Bread with carob flour	Texture and sensory characteristics have been improved, Antibacterial action, Gluten aggregation is high
		Sponge cakes enriched with carob flour and carob syrup	High dietary fibre, protein, and carbohydrate content increased overall moisture content, A favourable impact on sensory properties

4. Conclusion and Future Trends

Health problems are increasing all over the world due to various causes such as modern lifestyles and large amounts of man-made materials. As a result, there is a great demand for articles that help reduce economic losses while providing many health benefits. The rich bioactivity profile and high fibre content of carob, as well as its effects on obesity, diabetes, oxidative stress, hyperlipidaemia and inflammation, make it an attractive food ingredient with potential for use in creating a wide range of health-promoting products. Additionally, locust bean (LBG) products improve rheology by imparting functional properties to foods, enhancing their nutritional profile, and prolonging the final product's shelf life when used as a food additive in recipes. Carob is undoubtedly beneficial not only for human health, but also for the economy and the environment. Further research is needed to analyse and investigate the neuroprotective effects of carob.

5. Competing Interests

None declared

6. References

Abd Razik, B. M., Hasan, H., Murtadha, A., K., & M. (2012). The study of antibacterial activity of Plantago major and Ceratonia siliqua. *Iraqi Postgraduate med J.*, *11*, 130–135.

Abu Hafsa, S. H., Ibrahim, S. A., Hassan, A. A., & Anim, J. (2017) [Ahead of print] Carob pods (Ceratonia siliqua L.) improve growth performance, antioxidant status and caecal characteristics in growing rabbits. *Journal of Animal Physiology and Animal Nutrition*, *101*(6), 1307–1315. https://doi.org/10.1111/jpn.12651

Agrawal, A., Mohan, M., Kasture, S., Foddis, C., Frau, M. A., Loi, M. C., & Maxia, A. (2011). Antidepressant activity of Ceratonia siliqua L. fruit extract, a source of polyphenols. *Natural Product Research*, *25*(4), 450–456.
https://doi.org/10.1080/14786419.2010.527447

Aissani, N., Coroneo, V., Fattouch, S., & Caboni, P. (2012). Inhibitory effect of carob (Ceratonia siliqua) leaves methanolic extract on Listeria monocytogenes. *Journal of Agricultural and Food Chemistry*, *60*(40), 9954–9958. https://doi.org/10.1021/jf3029623

Akdeniz, E., Yakışık, E., Rasouli Pirouzian, H., Akkın, S., Turan, B., Tipigil, E., Toker, O. S., & Ozcan, O. (2021). Carob powder as cocoa substitute in milk and dark compound chocolate formulation. *Journal of Food Science and Technology*, *58*(12), 4558–4566. https://doi.org/10.1007/s13197-020-04943-z

Akkaya, N. E., Ergun, C., Saygun, A., Yesilcubuk, N., Akel-Sadoglu, N., Kavakli, I. H., Turkmen, H. S., & Catalgil-Giz, H. (2020). New biocompatible antibacterial wound dressing candidates; agar-locust bean gum and agar-salep films. *International Journal of Biological Macromolecules*, *155*, 430–438.
https://doi.org/10.1016/j.ijbiomac.2020.03.214

Alali, F. Q., Tawaha, K., El-Elimat, T., Syouf, M., El-Fayad, M., Abulaila, K., Nielsen, S. J., Wheaton, W. D., Falkinham, J. O., & Oberlies, N. H. (2007).

Antioxidant activity and total phenolic content of aqueous and methanolic extracts of Jordanian plants: An ICBG project. *Natural Product Research*, *21*(12), 1121–1131. https://doi.org/10.1080/14786410701590285

Albertos, I., Jaime, I., Diez, A. M., González-Arnáiz, L., & Rico, D. (2015) Carob seed peel as natural antioxidant in minced and refrigerated (4 °C) Atlantic horse mackerel (Trachurus trachurus). *LWT – Food Science and Technology*, *64*(2), 650–656. https://doi.org/10.1016/j.lwt.2015.06.037

Al-Fawwaz, A. T., & Al-Khaza'leh, K. A. (2016). Antibacterial And Antifungal Effect Of Some Natural Extracts And Their Potential Use As Photosensitizers. *European Scientific Journal, ESJ*, *12*(6), 147–157. http://doi.org/10.19044/esj.2016.v12n6p147

Al-Hadid, K. J.. (2016). Evaluation of antiviral activity of different medicinal plants against Newcastle disease virus. *American Journal of Agricultural and Biological Sciences Sci*. 2016, *11*(4), 157–163. https://doi.org/10.3844/ajabssp.2016.157.163

Al-Qaraleh, S., Tarawneh, K. A., & Am-Euras, J. (2016). Agric. *Environmental Sciences*, *16*, 479–486. https://doi.org/10.5829/idosi.aejaes.2016.16.3.12847

Altiner, D. D. (2020). Physicochemical, sensory properties and in-vitro bioaccessibility of phenolics and antioxidant capacity of traditional noodles enriched with carob (Ceratonia siliqua L.) flour. *Food Science and Technology*, *41*(3), 587–595. https://doi.org/10.1590/fst.21020

Alvarez-Lorenzo, C., Blanco-Fernandez, B., Puga, A. M., & Concheiro, A. (2013). Crosslinked ionic polysaccharides for stimuli-sensitive drug Delivery. *Advanced Drug Delivery Reviews*, *65*(9), 1148–1171. https://doi.org/10.1016/j.addr.2013.04.016

Amagwula, I. O., Osuji, C. M., Omeire, G. C., Awuchi, C. G., & Okpala, C. O. R. (2022). Combined impact of freezing and soaking times on different cowpea varieties' flour functionality and resultant gel strength, sensory and product yield of moi-moi. *AIMS Agriculture and Food*, *7*(4), 762–776. https://doi.org/10.3934/agrfood.2022047

Amarenco, P., Goldstein, L. B., Messig, M., O'Neill, B. J., Callahan, A., Sillesen, H., Hennerici, M. G., Zivin, J. A., Welch, K. M. A., & SPARCL Investigators. (2009). Relative and cumulative Effects of Lipid and Blood Pressure Control in the Stroke Prevention by Aggressive Reduction in cholesterol Levels Trial. *Stroke*, *40*(7), 2486–2492. https://doi.org/10.1161/STROKEAHA.108.546135

Amessis-Ouchemoukh, N., Ouchemoukh, S., Meziant, N., Idiri, Y., Hernanz, D., Stinco, C. M., Rodríguez-Pulido, F. J., Heredia, F. J., Madani, K., & Luis, J. (2017). Bioactive metabolites involved in the antioxidant, anticancer and anticalpain activities of Ficus carica L., Ceratonia siliqua L. and Quercus ilex L. extracts. *Industrial Crops and Products*, *95*, 6–17. http://doi.org/10.1016/j.indcrop.2016.10.007

Anis, B. H., Mohamed, T., Raoudha, M. J., Mohamed, D., & Samir, J. (2015). Identification of phenolic compounds by high performance liquid chromatography/mass spectrometry (HPLC/MS) and in vitro evaluation of the antioxidant and antimicrobial activities of Ceratonia siliqua leaves extracts. *Journal of Medicinal Plants Research*, *9*(14), 479–485. https://doi.org/10.5897/JMPR2011.685

Arhire, L. I., Mihalache, L., & Covasa, M. (2019). Irisin: A hope in understanding and managing obesity and metabolic syndrome. *Frontiers in Endocrinology*, *10*, 524. https://doi.org/10.3389/fendo.2019.00524

Arribas, C., Cabellos, B., Cuadrado, C., & Guillamon. (2019a). Bioactive compounds, antioxidant activity, and sensory analysis of rice-based extruded snacks-like fortified with bean and carob fruit flours. E, and Pedrosa, *M.M. Foods*, *8*(381), 1–13.

Arribas, C., Cabellos, B., Cuadrado, C., Guillamón, E., & Pedrosa, M. M. (2019). Extrusion effect on proximate composition, starch and dietary fibre of ready-to-eat products based on rice fortified with carob fruit and bean. *LWT*, *111*, 387–393. https://doi.org/10.1016/j.lwt.2019.05.064

Arribas, C., Cabellos, B., Cuadrado, C., Guillamón, E., & Pedrosa, M. M. (2020) Cooking Effect on the Bioactive Compounds, Texture, and Color Properties of Cold-Extruded Rice/Bean-Based Pasta Supplemented with Whole Carob Fruit. *Foods, 9*(4), 415. https://doi.org/10.3390/foods9040415

Arribas, C., Cabellos, B., Cuadrado, C., Guillamón, E., & Pedrosa, M. M. (2019b) The effect of extrusion on the bioactive compounds and antioxidant capacity of novel gluten-free expanded products based on carob fruit, pea and rice blends. *Innovative Food Science and Emerging Technologies*, *52*, 100–107. https://doi.org/10.1016/j.ifset.2018.12.003

Arribas, C., Cabellos, B., Sánchez, C., Cuadrado, C., Guillamón, E., & Pedrosa, M. M. (2017) The impact of extrusion on the nutritional composition, dietary fiber and in vitro digestibility of gluten-free snacks based on rice, pea and carob flour blends. *Food and Function*, *8*(10), 3654–3663. https://doi.org/10.1039/c7fo00910k

Avallone, R., Cosenza, F., Farina, F., Baraldi, C., & Baraldi, M. (2002). Extraction and purification from Ceratonia siliqua of compounds acting on central and peripheral benzodiazepine receptors. *Fitoterapia*, *73*(5), 390–396. https://doi.org/10.1016/s0367-326x(02)00115-6

Awuchi, C. G., & Okpala, C. O. R. (2022). Natural nutraceuticals, especially functional foods, their major bioactive components, formulation, and health benefits for disease prevention – An overview. *Journal of Food Bioactives*, *19*. https://doi.org/10.31665/JFB.2022.18317

Awuchi, C. G., Morya, S., Dendegh, T. A., Okpala, C. O. R., & Korzeniowska, M. (2022). Nanoencapsulation of food bioactive constituents and its associated processes: A revisit. *Bioresource Technology Reports*, *19*, (101088). https://doi.org/10.1016/j.biteb.2022.101088

Aziz, H., & Hicham, E. L. B. (2014). Optimization of production of carob pulp syrup from different pop lations of Moroccan carob (Ceratonia siliqua L..). *International Journal of Emerging Technology and Advanced Engineering*, *4*(3), 855–863.

Babiker, E. E., Özcan, M. M., Ghafoor, K., Al Juhaimi, F., Ahmed, I. A. M., & Almusallam, I. A. (2020). Physico-chemical and bioactive properties, fatty acids, phenolic compounds, mineral contents, and sensory properties of cookies enriched with carob flour. *Journal of Food Processing and Preservation*, *44*(10), e14745. https://doi.org/10.1111/jfpp.14745

Bahry, H., Abdalla, R., Pons, A., Taha, S., & Vial, C. (2019). Optimization of lactic acid production using immobilized Lactobacillus rhamnosus and carob pod waste from the Lebanese food industry. *Journal of Biotechnology*, *306*, 81–88. https://doi.org/10.1016/j.jbiotec.2019.09.017

Bañuls, C., Rovira-Llopis, S., López-Doménech, S., Veses, S., Víctor, V. M., Rocha, M., & Hernández-Mijares, A. (2016). Effect of consumption of a carob pod inositol-enriched beverage on insulin sensitivity and inflammation in middle-aged prediabetic subjects. *Food and Function*, *7*(10), 4379–4387. https://doi.org/10.1039/C6FO01021K

Barak, S., & Mudgil, D. (2014). Locust bean gum: Processing, properties and food applications—A review. *International Journal of Biological Macromolecules*, *66*, 74–80. https://doi.org/10.1016/j.ijbiomac.2014.02.017

Barakat, N. A. M., Laudadio, V., Cazzato, E., & Tufarelli, V. (2013). Potential contribution of Retama Raetam (Forssk.) Webb and Berthel as a forage shrub in Sinai. Egypt. *Arid Land Research and Management*, *27*(3), 257–271. https://doi.org/10.1080/15324982.2012.756561

Barbosa, J. M., Ushikubo, F. Y., de Figueiredo Furtado, G., & Cunha, R. L. (2019). Oil in water emulsions stabilized by Maillard conjugates of sodium caseinate-locust bean gum. *Journal of Dispersion Science and Technology*, *40*(5), 634–645. https://doi.org/10.1080/01932691.2018.1476152

Baumel, A., Mirleau, P., Viruel, J., Bou Dagher Kharrat, M., La Malfa, S., Ouahmane, L., Diadema, K., Moakhar, M., Sanguin, H., & Médail, F. (2018). Assessment of plant species diversity associated with the carob tree (Ceratonia siliqua, Fabaceae) at the Mediterranean scale. *Plant Ecology and Evolution*, *151*(2), 185–193. https://doi.org/10.5091/plecevo.2018.1423

Ben Hsouna, A., Alayed, A. S., & Abdallah, E. M. (2012). *African Journal of Microbiology Research*, *6*, 3480–3484.

Ben Hsouna, A., Alayed, A. S., & Abdallah, E. M. (2012). Evaluation of antimicrobial activities of crude methanolic extract of pods of Ceratonia siliqua L. against some pathogens and spoilage bacteria. *African Journal of Microbiology Research, 6*(14), 3480–3484. https://doi.org/10.5897/AJMR11.1613

Benchikh, Y., & Louailèche, H. (2014). Effects of extraction conditions on the recovery of phenolic compounds and in vitro antioxidant activity of carob (Ceratonia siliqua L.) pulp. *Acta Botanica Gallica*, *161*(2), 175–181. https://doi.org/10.1080/12538078.2014.909325

Benkovíc, M., Belščak-Cvitanović, A., Bauman, I., Komes, D., & Srečec, S. (2017) Flow properties and chemical composition of carob (Ceratonia siliqua L.) flours as related to particle size and seed presence. *Food Research International*, *100*(2), 211–218. https://doi.org/10.1016/j.foodres.2017.08.048

Berk, E., Sumnu, G., & Sahin, S. (2017). Usage of carob bean flour in gluten free cakes. *Chemical Engineering Transactions*, *57*, 1909–1914.

Bindal, P., & Vishwanatha, T. (2019). Bioethanol production by sub merged fermentation from carob pod extract by using Saccharomyces ssp. *International Journal of biotech trends and technology*, *9*(1), 1–3. https://doi.org/10.14445/22490183/IJBTT-V9I1P601

Bissar, S., & Özcan, M. M. (2022). Determination of quality parameters and gluten free Macaron production from carob fruit and sorghum. *International Journal of Gastronomy and Food Science*, *27*, 100460. https://doi.org/10.1016/j.ijgfs.2021.100460

Boublenza, I., Lazouni, H. A., Ghaffari, L., Ruiz, K., Fabiano-Tixier, A. S., & Chemat, F. (2017). Influence of roasting on sensory, antioxidant, aromas, and physicochemical properties of carob pod powder (Ceratonia siliqua L.). *Journal of Food Quality*, 2017, 1–10. https://doi.org/10.1155/2017/4193672

Brassesco, M. E., Brandão, T. R. S., Silva, C. L. M., Pintado, M., & Bean, C. (2021). Carob bean (Ceratonia siliqua L.): A new perspective for functional food. *Trends in Food Science and Technology*, *114*, 310–322. https://doi.org/10.1016/j.tifs.2021.05.037

Braz, L., Grenha, A., Corvo, M. C., Lourenço, J. P., Ferreira, D., Sarmento, B., & Rosa da Costa, A. M. R. (2018). Synthesis and characterization of locust bean gum derivatives and their application in the production of nanoparticles. *Carbohydrate Polymers*, *181*, 974–985. https://doi.org/10.1016/j.carbpol.2017.11.052

Carbas, B., Salinas, M. V., Serrano, C., Passarinho, J. A., Puppo, M. C., Ricardo, C. P., & Brites, C. (2019). Chemical composition and antioxidant activity of commercial flours from Ceratonia siliqua and Prosopis spp. *Journal of Food Measurement and Characterization*, *13*(1), 305–311.

https://doi.org/10.1007/s11694-018-9945-7

Cepo, V., D., Mornar, A. (2014). Optimization of roasting conditions as an useful approach for increasing antioxidant activity of carob powder. Nigovi´c, B., Kremer, D., Radanovi´c, D., & Vedrina Dragojevi´c, I. Lebensmittel-Wissenschaft und -Technologie – *Food Science and Technology*, *58*(2), 578–586.

https://doi.org/10.1016/j.lwt.2014.04.004

Červenka, L., Frühbauerová, M., & Velichová, H. (2019). Functional properties of muffin as affected by Substituing wheat flour with carob powder. *Potravinarstvo Slovak Journal of Food Sciences*, *13*(1), 212–217. https://doi.org/10.5219/1033

Chan, D. C., Pang, J., Romic, G., & Watts, G. F. (2013). Postprandial hypertriglyceridemia and cardiovascular disease: Current and future therapies. *Coronary Heart Disease*, *15*(309), 1–9.

https://doi.org/10.1007/s11883-013-0309-9

Chao, E. C., & Henry, R. R. (2010). SGLT2 inhibition—A novel strategy for diabetes treatment. Nature Reviews. *Drug Discovery*, *9*(7), 551–559. https://doi.org/10.1038/nrd3180.

Chaves, M. A., Piati, J., Malacarne, L. T., Gall, R. E., Colla, E., Bittencourt, P. R. S., de Souza, A. H. P., Gomes, S. T. M., & Matsushita, M. (2018). Extraction and application of chia mucilage (Salvia hispanica L.) and locust bean gum (Ceratonia siliqua L.) in goat milk frozen dessert. *Journal of Food Science and Technology*, *55*(10), 4148–4158.

https://doi.org/10.1007/s13197-018-3344-2

Clark, M. J., & Slavin, J. L. (2013). The Effect of fiber on satiety and food intake: a systematic review. *Journal of the American College of Nutrition*, *32*(3), 200–211. https://doi.org/10.1080/07315724.2013.791194

Corsi, L., Avallone, R., Cosenza, F., Farina, F., Baraldi, C., & Baraldi, M. (2002). Antiproliferative effects of Ceratonia siliqua L. on mouse hepatocellular carcinoma cell line. Fitoterapia, 73(7–8), 674–684. https://doi.org/10.1016/s0367-326x(02)00227-7

Custódio, L., Fernandes, E., & Romano, A. (2009). Study of the antioxidant activity of extracts from carob tree (ceratonia siliqua l.). *Acta Horticulturae*, *841*, 507–510. https://doi.org/10.17660/ActaHortic.2009.841.70

Custódio, L., Fernandes, E., Escapa, A. L., López-Avilés, S., Fajardo, A., Aligué, R., Albericio, F., & Romano, A. (2008). Antiproliferative and apoptotic activities of extracts from carob tree (Ceratonia siliqua L.) in MDA-MB-231 human breast cancer cells. *Planta Medica*, *74*(9), PA48.

https://doi.org/10.1055/s-0028-1084046

Custódio, L., Fernandes, E., Escapa, A. L., López-Avilés, S., Fajardo, A., Aligué, R., Albericio, F., & Romano, A. (2009). Antioxidant activity and in vitro inhibition of tumor cell growth by leaf extracts from the carob tree (Ceratonia siliqua). *Pharmaceutical Biology*, *47*(8), 721–728.

https://doi.org/10.1080/13880200902936891

Custódio, L., Patarra, J., Albericio, F., Neng, N. R., Nogueira, J. M. F., & Romano, A. (2015). In vitro antioxidant and inhibitory activity of water decoctions of carob tree (Ceratonia siliqua L.) on cholinesterases, α-amylase and α-glucosidase. *Natural Product Research*, *29*(22), 2155–2159.

https://doi.org/10.1080/14786419.2014.996147

Dakia, P. A., Wathelet, B., & Paquot, M. (2007). Isolation and chemical evaluation of carob (Ceratonia siliqua L.) seed germ. *Food Chemistry*, *102*(4), 1368–1374. https://doi.org/10.1016/j.foodchem.2006.05.059

Dayani, O., Khezri, A., & Moradi, A. G. (2012). Determination of nutritive value of date palm by-products using in vitro and in situ measurements. *Small Ruminant Research*, *105*(1–3), 122–125. https://doi.org/10.1016/j.smallrumres.2012.01.015

Durazzo, A., Turfani, V., Narducci, V., Azzini, E., Maiani, G., & Carcea, M. (2014). Nutritional characterisation and bioactive components of commercial carobs flours. *Food Chemistry*, *153*, 109–113. https://doi.org/10.1016/j.foodchem.2013.12.045

Egbuna, C., Awuchi, C. G., Kushwaha, G., Rudrapal, M., Patrick-Iwuanyanwu, K. C., Singh, O., Odoh, U. E., Khan, J., Jeevanandam, J., Kumarasamy, S., Chukwube, V. O., Narayanan, M., Palai, S., Găman, M. A., Uche, C. Z., Ogaji, D. S., Ezeofor, N. J., Mtewa, A. G., Patrick-Iwuanyanwu, C. C., Chikwendu, C. J. (2021). Bioactive compounds effective against type 2 diabetes mellitus: A systematic review. *Current Topics in Medicinal Chemistry*, *21*(12), 1067–1095. https://doi.org/10.2174/1568026621666210509161059

Egbuna, C., Parmar, V. K., Jeevanandam, J., Ezzat, S. M., Patrick-Iwuanyanwu, K. C., Adetunji, C. O., Khan, J., Onyeike, E. N., Uche, C. Z., Akram, M., Ibrahim, M. S., El Mahdy, N. M., Awuchi, C. G., Saravanan, K., Tijjani, H., Odoh, U. E., Messaoudi, M., Ifemeje, J. C., Olisah, M. C., . . . Ibeabuchi, C. G. (2021). Toxicity of nanoparticles in biomedical application: Nanotoxicology. *Journal of Toxicology*, 2021, 9954443. https://doi.org/10.1155/2021/9954443

El Hajaji, H., Lachkar, N., Alaoui, K., Cherrah, Y., Farah, A., Ennabili, A., Bali, B., & Lachkar, M. (2010). *Records of Natural Products*, *4*, 193–204. http://www.acgpubs.org/RNP/2010/Volume%204/Issue%201/23_RNP_1001_181.pdf

El Rabey, H. A., Al-Seeni, M. N., & Al-Ghamdi, H. B. (2017). Comparison between the hypolipidemic activity of parsley and carob in hypercholesterolemic male rats. *BioMed Research International*, 2017, 3098745. https://doi.org/10.1155/2017/3098745

El-Baky, A. H., Abd El-Baky, R. M., Desoukey, S. Y., AbdLateff, A., & Kamel, M. S. (2013). Bacterial Growth Inhibitory Effect of Ceratonia siliqua L. Plant Extracts Alone and in Combination with Some Antimicrobial Agents. *Journal of Advanced Biotechnology and Bioengineering*, *1*, 3–13. https://doi.org/10.12970/2311-1755.2013.01.01.1

El-Beshbishy, H. A., Singab, A. N. B., Sinkkonen, J., & Pihlaja, K. (2006). Hypolipidemic and antioxidant effects of Morus alba L.(Egyptian mulberry) root bark fractions supplementation in cholesterol-fed rats. Life Sciences, *78*(23), 2724–2733. https://doi.org/10.1016/j.lfs.2005.10.010

El-Haskoury, R., Zizi, S., Touzani, S., Al-Waili, N., Al-Ghamdi, A., Abdallah, M. B., York, N., & Care, M. (2015). Diuretic activity of carob (Ceratonia siliqua L.) honey: Comparison with furosemide. *African Journal of Traditional, Complementary and Alternative Medicines*, *12*(4), 128–133. https://doi.org/10.21010/ajtcam.v12i4.19

El-Manfaloty, M. M., & Ali, H. M. (2014). The influence of carob powder on serum glucose and lipid profile in albino induced diabetic rats. *al-Iqti ād Al-manzilī*, *30*(30), 35–46. https://doi.org/10.21608/jhe.2014.59454

El-Sherif, G., El-Sherif, M. A., & Tolba, K. H. (2011). *Natural Science*, *9*, 108–115. http://connection.ebscohost.com/c/articles/69683741

Engin, S. P., & Mert, C. (2020). The effects of harvesting time on the physicochemical components of aronia berry. *Turkish Journal of Agriculture and Forestry*, *44*(4), 361–370. https://doi.org/10.3906/tar-1903-130

Ercan, Y., Irfan, T., & Mustafa, K. (2013). Optimization of ethanol production from carob pod extract using immobilized Saccharomyces cerevisiae Cells in a stirred tank bioreactor. *Bioresource Technology*, *135*, 365–371. https://doi.org/10.1016/j.biortech.2012.09.006

Ersan, P., & Sonmez, Ö., ¨ O., ¨ & Gozmen, ¨ B. (2020). Microwave – Assisted d – Pinitol extraction from carob: Application of box – Behnken design. *Journal of the Iranian Chemical Society*, *17*(4), 871–879. https://doi.org/10.1007/s13738-019-01824-x

Fantini, M., Benvenuto, M., Masuelli, L., Frajese, G. V., Tresoldi, I., Modesti, A., & Bei, R. (2015). In vitro and in vivo antitumoral effects of combinations of polyphenols, or polyphenols and anticancer drugs: Perspectives on cancer treatment. *International Journal of Molecular Sciences*, *16*(5), 9236–9282. https://doi.org/10.3390/ijms16059236

Fidan, H., Petkova, N. T., & Slavov, A. (2019). Carob syrup and carob flour (Ceratonia siliqua L.) as functional carob syrup and carob flour (Ceratonia siliqua L.). Carpathian *Journal of Food Science and Technology*, *11*(1), 71–82.

Fidan, H., Stankov, S., Petkova, N., Petkova, Z., Iliev, A., Stoyanova, M., Ivanova, T., Zhelyazkov, N., Ibrahim, S., Stoyanova, A., & Ercisli, S. (2020). Evaluation of chemical composition, antioxidant potential and functional properties of carob (Ceratonia siliqua L.) seeds. *Journal of Food Science and Technology*, *57*(7), 2404–2413. https://doi.org/10.1007/s13197-020-04274-z

Forester, S. C., Choy, Y. Y., Waterhouse, A. L., & Oteiza, P. I. (2014). The anthocyanin Metabolites gallic acid, 3-O- methylgallic Acid, and 2, 4, 6-trihydroxybenzaldehyde Decrease Human colon Cancer Cell Viability by Regulating Pro-oncogenic Signals. *Molecular Carcinogenesis*, *53*(6), 432–439. https://doi.org/10.1002/mc.21974

Foundation, R. W., & Der Aue, I. (1997). Effects of roasting temperature on the aroma components of carob

(Ceratonia siliqua L.). *Journal of Agricultural and Food Chemistry*, *8561*(96), 1345–1350. https://doi.org/10.1021/jf960468e

Fujita, K., Norikura, T., Matsui-Yuasa, I., Kumazawa, S., Honda, S., Sonoda, T., Kojima-Yuasa, A., & Loor, J. J. (2021). Carob Pod Polyphenols Suppress the Differentiation of Adipocytes through Post transcriptional Regulation of C/EBPβ. PLOS ONE, 16(3), e0248073. https://doi.org/10.1371/journal.pone.0248073

Góral, M., Kozłowicz, K., Pankiewicz, U., Góral, D., Kluza, F., & Wójtowicz, A. (2018). Impact of stabilizers on the freezing process, and physicochemical and organoleptic properties of coconut milk-based ice cream. *LWT*, *92*, 516–522. https://doi.org/10.1016/j.lwt.2018.03.010

Goulas, V, & Georgiou, E. (2020). Utilization of carob fruit as sources of phenolic compounds with antioxidant Potential: Extraction optimization and application in food models. *Foods*, *9*(20), 1–13.

Goulas, V., & Georgiou, E. (2019). Utilization of carob fruit as sources of phenolic compounds with antioxidant Potential: Extraction optimization and application in food models. *Foods*, *9*(1), 1–13. https://doi.org/10.3390/foods9010020

Goulas, V., & Hadjisolomou, A. (2019). Dynamic changes in targeted phenolic compounds and antioxidant potency of carob fruit (Ceratonia siliqua L.) products during in vitro digestion. *LWT*, *101*, 269–275. https://doi.org/10.1016/j.lwt.2018.11.003

Goulas, V., Stylos, E. K., Chatziathanasiadou, M. V., Mavromoustakos, T., & Tzakos, A. G. (2016). Functional components of carob fruit: linking the chemical and biological space. *International Journal of Molecular Sciences*, *17*(11), 1875. https://doi.org/10.3390/ijms17111875

Goulas, V., Stylos, E., Chatziathanasiadou, M. V., Mavromoustakos, T., & Tzakos, A. G. (2016). Functional components of carob Fruit: Linking the chemical and biological space. *International Journal of Molecular Sciences*, *17*(11), 1875. https://doi.org/10.3390/ijms17111875

Graves, D. B. (2012). The emerging role of reactive oxygen and nitrogen species in redox biology and some implications for plasma applications to medicine and biology. *Journal of Physics. Part D*, *45*(26), 1–42. https://doi.org/10.1088/0022-3727/45/26/263001

Griffin, K., & Khouryieh, H. (2020). Influence of electrostatic interactions on the formation and stability of multilayer fish oil-in-water emulsions stabilized by whey protein-xanthan-locust bean complexes. *Journal of Food Engineering*, *277*, 109893. https://doi.org/10.1016/j.jfoodeng.2019.109893

Guenaoui, M., Guemour, D. J., & Meliani, S. (2019). Evaluation of the use of carob pods (Ceratonia Silliqua) in rabbit nutrition; effect on growth performances and health status after weaning. *Livestock Research for Rural Development*, *31*, 85–87.

Haddarah, A., Ismail, A., Bassal, A., Hamieh, T., Ioannou, I., & Ghoul, M. (2013). Morphological and chemical variability of Lebanese carob varieties. *European Scientific Journal, ESJ*, *9*(18). https://doi.org/10.19044/esj.2013.v9n18p%p

Haider, M. M. (2014). Citric acid production from carob pod extract by Aspergillus niger. *IOSR Journal of Pharmacy and Biological Sciences*, *9*(3), 112–116. https://doi.org/10.9790/3008-0934112116

Hajaji, H. E., Lachkar, N., Alaoui, K., Cherrah, Y., Farah, A., Ennabili, A., Bali, B. E., & Lachkar, M. (2011). Antioxidant activity, phytochemical screening, and total phenolic content of extracts from three genders of carob tree barks growing in Morocco. *Arabian Journal of Chemistry*, *4*(3), 321–324. https://doi.org/10.1016/j.arabjc.2010.06.053

Hallagan, J. B., La Du, B. N., Pariza, M. W., Putnam, J. M., & Borzelleca, J. F. (1997). Assessment of cassia gum. *Food and Chemical Toxicology, 35*(6), 625–632. https://doi.org/10.1016/S0278-6915(97)00018-5

Hamza, R. G., & Al-Seeni, M. (2015). Effect of using gamma-irradiated mixture extract of carob and Roselle in diabetic rats. *International Journal of Pharmacy and Biological Sciences*, *6*(1), B951–B960.

Hamza, R. G., & Al-Seeni, M. N. (2015). International *Journal of Pharmacy and Biological Sciences*, *6*, 951–960. http://www.ijpbs.net/details.php?article=4022

Hellwig, M., Gensberger-Reigl, S., Henle, T., & Pischetsrieder, M. (2018). Food-derived 1,2-dicarbonyl compounds and their role in diseases. *Seminars in Cancer Biology*, *49* (November 2017), 1–8. https://doi.org/10.1016/j.semcancer.2017.11.014

Hsouna, A. B., Saoudi, M., Trigui, M., Jamoussi, K., Boudawara, T., Jaoua, S., & El Feki, A. E. (2011). Characterization of bioactive compounds and ameliorative effects of Ceratonia siliqua Leaf extract against CCl4 induced hepatic oxidative damage and renal failure in rats. *Food and Chemical Toxicology*, *49*(12), 3183–3191. https://doi.org/10.1016/j.fct.2011.09.034

Hussein, A. M., Shedeed, N. A., Abdel-Kalek, H. H., & El-Din, M. H. A. (2011). Antioxidative, Antibacterial and Antifungal Activities of Tea Infusions from Berry Leaves, Carob and Doum. *Polish Journal of Food and Nutrition Sciences*, *61*(3), 201–209. https://doi.org/10.2478/v10222-011-0022-8

Ibrahim, A. H., Abd El-Baky, R. M., Desoukey, S. Y., AbdLateff, A., & Kamel, M. S. (2013). Bacterial growth inhibitory effect of Ceratonia siliqua L. Plant extracts alone and in combination with some antimicrobial agents. *J. Adv. Biotechnol. Bioeng.*, *1*, 3–13.

James, B. (2017). Use of nutraceutical and natural compounds containing anti-obese properties for the prevention and treatment of obesity. *EC Nutrition*, *6*(5), 184–186.

Jamous, R. M., Zaitoun, S. Y., Husein, A. I., Qasem, I. B., & Ali-Shtayeh, M. S. (2015). Screening for Biological Activities of Medicinal Plants Used in Traditional Arabic Palestinian Herbal Medicine. *European Journal of Medicinal Plants*, *9*(1), 1–13. https://doi.org/10.9734/EJMP/2015/17429

Jana, S., Gandhi, A., Sheet, S., & Sen, K. K. (2015). Metal ion-induced alginate–locust bean gum IPN microspheres for sustained oral Delivery of aceclofenac. *International Journal of Biological Macromolecules*, *72*, 47–53. https://doi.org/10.1016/j.ijbiomac.2014.07.054

Kaity, S., Isaac, J., & Ghosh, A. (2013). Interpenetrating polymer network of locust bean gum-poly (vinyl alcohol) for controlled release drug Delivery. *Carbohydrate Polymers*, *94*(1), 456–467. https://doi.org/10.1016/j.carbpol.2013.01.070

Kanat, M., DeFronzo, R. A., & Abdul-Ghani, M. A. (2015). Treatment of prediabetes. *World Journal of Diabetes*, *6*(12), 1207–1222. https://doi.org/10.4239/wjd.v6.i12.1207

Kivcak, B., & Mert, T. (2002). *Turkish Journal of Biology*, *26*, 197–200. http://journals.tubitak.gov.tr/biology/issues/biy-02-26-4/biy26-4-2-0111-4.pdf

Kongor, J. E., Hinneh, M., de Walle, D. V., Afoakwa, E. O., Boeckx, P., & Dewettinck, K. (2016). Factors influencing quality variation in cocoa (Theobroma cacao) bean flavour profile—A review. *Food Research International*, *82*, 44–52. https://doi.org/10.1016/j.foodres.2016.01.012

Kumar, V. P., Chauhan, N. S., Padh, H., & Rajani, M. (2006). Search for antibacterial and antifungal agents from selected Indian medicinal plants. *Journal of Ethnopharmacology*, *107*(2), 182–188. https://doi.org/10.1016/j.jep.2006.03.013

Kumazawa, S., Taniguchi, M., Suzuki, Y., Shimura, M., Kwon, M. S., & Nakayama, T. (2002). Antioxidant activity of polyphenols in carob pods. *Journal of Agricultural and Food Chemistry*, *50*(2), 373–377. https://doi.org/10.1021/jf010938r

Lachkar, N., Al-Sobarry, M., El Hajaji, H., Lamkinsi, T., Lachkar, M., Cherrah, Y., & Alaoui, K. (2016). *Journal of Chemical and Pharmaceutical Research*, *8*, 202–210. http://www.jocpr.com/articles/antiinflammatoryand-antioxidant-effect-of-ceratonia-siliqua-l-methanol-barksextract.pdf

Lakkab, I., El, H., Lachkar, N., Lefter, R., Ciobica, A., El, B., & Lachkar, M. (2019). Ceratonia siliqua L. seed peels: Phytochemical pro fi le, antioxidant activity, and e ff ect on mood disorders, 54(January), 457–465. https://doi.org/10.1016/j.jff.201 9.01.041.

Lanfranchi, M., Zirilli, A., Alfano, S., Spiridione, F. S., Alibrandi, A., & Giannetto, C. (2019). The carob as a substitute for cocoa in the production of chocolate: Sensory analysis with bivariate association. *Calitatea*, *20*(168), 148–153.

Lattimer, J. M., & Haub, M. D. (2010). Effects of dietary fiber and its components on metabolic health. *Nutrients*, *2*(12), 1266–1289. https://doi.org/10.3390/nu2121266

Leidy, H. J., Todd, C. B., Zino, A. Z., Immel, J. E., Mukherjea, R., Shafer, R. S., Ortinau, L. C., & Braun, M. (2015). Consuming high-protein soy snacks affects appetite control, satiety, and diet quality in young people and influences select aspects of mood and cognition. *Journal of Nutrition*, *145*(7), 1614–1622. https://doi.org/10.3945/jn.115.212092

Liang, C. Z., Zhang, X., Li, H., Tao, Y. Q., Tao, L. J., Yang, Z. R., Zhou, X. P., Shi, Z. L., & Tao, H. M. (2012). Gallic acid induces the apoptosis of human osteosarcoma cells in vitro and in vivo via the regulation of mitogen-activated protein kinase pathways. *Cancer Biotherapy and Radiopharmaceuticals, 27*(10), 701–710. https://doi.org/10.1089/cbr.2012.1245

Lopez, S. (2018). D-pinitol, a highly valuable product from carob pods: Health-promoting effects and metabolic pathways of this natural super-food ingredient and its derivatives. ‘ ’ Anchez, J. I., Moreno, D. A., & García-Viguera, C. *AIMS Agriculture and Food*, *3*(February), 41–63. https://doi.org/10.3934/agrfood.2018.1.41

López-Sánchez, J. I., Moreno, D. A., & García-Viguera, C. (2021). Correction: D-pinitol, a highly valuable product from carob pods: Health-promoting effects and metabolic pathways of this natural super-food ingredient and its derivatives. *AIMS Agriculture and Food*, *6*(2), 752–753. https://doi.org/10.3934/agrfood.2021044

Loullis, A., & Pinakoulaki, E. (2018). Carob as cocoa substitute: A review on composition, health benefits and food applications. *European Food Research and Technology*, *244*(6), 959–977. https://doi.org/10.1007/s00217-017-3018-8

Lushchak, V. I. (2014). Free radicals, reactive oxygen species, oxidative stress and its classification. *Chemico-Biological Interactions*, *224*, 164–175. https://doi.org/10.1016/j.cbi.2014.10.016

Macho-Gonzalez, ´ A., Garcimartín, A., Lopez-Oliva, ´ M. E., Celada, P., Bastida, S., Benedí, J., & S´ anchez-Muniz, F. J. (2020). Carob-fruit-extract-enriched meat modulates lipoprotein metabolism and insulin signaling in diabetic rats induced by high-saturated-fat diet. *Journal of Functional Foods*, *64*, 103600.

Macho-González, A., Garcimartín, A., López-Oliva, M. E., Bertocco, G., Naes, F., Bastida, S., Sánchez-Muniz, F. J., & Benedí, J. (2017). Fiber purified extracts of carob fruit decrease carbohydrate absorption. *Food and Function*, *8*(6), 2258–2265. https://doi.org/10.1039/c7fo00166e

Macho-Gonzalez, A., Garcimartín, A., López-Oliva, M. E., Ruiz-Roso, B., Martín de la Torre, I., Bastida, S., Benedí, J., Sánchez-Muniz, F. J., Sánchez-Muniz, F. J. (2019) Can Carob-Fruit-Extract-Enriched Meat Improve the Lipoprotein Profile, VLDL-Oxidation, and LDL Receptor Levels Induced by an Atherogenic Diet in STZ-NAD-Diabetic Rats? *Nutrients*, *11*(2), I, & S´ anchez-Muniz. https://doi.org/10.3390/nu11020332

Macho-González, A., Garcimartín, A., Naes, F., López-Oliva, M. E., Amores-Arrojo, A., González-Muñoz, M. J., Bastida, S., Benedí, J., & Sánchez-Muniz, F. J. (2018). Effects of fiber purified extract of carob fruit on fat digestion and postprandial lipemia in healthy rats. *Journal of Agricultural and Food Chemistry*, *66*(26), 6734–6741. https://doi.org/10.1021/acs.jafc.8b01476

Macho-González, A., López-Oliva, M. E., Merino, J. J., García-Fernández, R. A., Garcimartín, A., Redondo-Castillejo, R., Bastida, S., Sánchez-Muniz, F. J., & Benedí, J. (2020). Carob fruit extract-enriched meat improves pancreatic beta-cell dysfunction, hepatic insulin signaling and lipogenesis in late-stage Type 2 diabetes mellitus model. *Journal of Nutritional Biochemistry*, *84*, 108461. https://doi.org/10.1016/j.jnutbio.2020.108461

Madigan, M. T., Martinko, J. M., & Parker, J. (2006). *Brock biology of microorganisms*, *11* p. 136. Pearson Prentice Hall.

Mahtout, R., Zaidi, F., Saadi, L. O., Boudjou, S., Oomah, B. D., & Hosseinian, F. (2016). *International Journal of Engineering and Techniques*, *2*, 168–177. http://www.ijetjournal.org/Volume2/Issue2/IJETV2I2P28.pdf

Malik, K., Arora, G., & Singh, I. (2011). Locust bean gum as superdisintegrant—Formulation and evaluation of nimesulide orodispersible tablets. *Polimery w Medycynie*, *41*(1), 17–28.

Mamone, G., Sciammaro, L., De Caro, S., Di, L., Siano, F., Picariello, G., & Cecilia, M. C. (2019). Comparative analysis of protein composition and digestibility of Ceratonia siliqua L. and Prosopis spp. seed germ flour. *Food Research International*, *120* (December 2018), 188–195. https://doi.org/10.1016/j.foodres.2019.02.035

Marti, A., & Pagani, M. A. (2013). What can play the role of gluten in gluten free pasta? *Trends in Food Science and Technology*, *31*(1), 63–71. https://doi.org/10.1016/j.tifs.2013.03.001

Martin, V. T., & Vij, B. (2016). Diet and Headache: Part 1. *Headache: The Journal of Head and Face Pain*, *56*(9), 1543–1552. https://doi.org/10.1111/head.12953

Martin-Diana, A. B., Izquierdo, N., Albertos, I., Sanchez, M. S., Herrero, A., Sanz, M. A., & Rico, D. (2017). Valorization of carob's germ and seed peel as natural antioxidant ingredients in gluten-free crackers. *Journal of Food Processing and Preservation*, *41*(2), article e12770. https://doi.org/10.1111/jfpp.12770

Martínez-Larrad, M. T., Corbatón-Anchuelo, A., Fernández-Pérez, C., Lazcano-Redondo, Y., Escobar-Jiménez, F., & Serrano-Ríos, M. (2016). Metabolic syndrome, glucose tolerance categories and the cardiovascular risk in Spanish population. *Diabetes Research and Clinical Practice*, *114*, 23–31. https://doi.org/10.1016/j.diabres.2016.02.003

Martínez-Rodríguez, R., Navarro-Alarcón, M., Rodríguez-Martínez, C., & Fonollá-Joya, J. (2013) Effects on the lipid profile in humans of a polyphenol-rich carob (Ceratonia siliqua L.) extract in a dairy matrix like a functional food; a pilot study. *Nutricion Hospitalaria*, *28*(6), 2107–2114. https://doi.org/10.3305/nh.2013.28.6.6952

Mazaheri, D., Shojaosadati, S. A., Mousavi, S. M., Hejazi, P., & Saharkhiz, S. (2012). Bioethanol production from carob pods by solid-state fermentation with Zymomonas mobilis. *Applied Energy*, *99*, 372–378. https://doi.org/10.1016/j. apenergy.2012.05.045

Mbue, N. D., Mbue, J. E., & Anderson, J. A. (2017). Management of Lipids in Patients with diabetes.

Nursing Clinics of North America, 52(4), 605–619. https://doi.org/10.1016/j.cnur.2017.07.009. [99] Tangvarasittichai, S. (2015). Oxidative Stress, insulin Resistance, dyslipidemia and type 2 diabetes mellitus. *World Journal of Diabetes*, *6*(3), 456–480. https://doi.org/10.4239/wjd.v6.i3.456

McClements, D. J., & Xiao, H. (2014). Excipient foods: Designing food matrices that improve the oral bioavailability of pharmaceuticals and nutraceuticals. *Food and Function*, *5*(7), 1320–1333. https://doi.org/10.1039/c4fo00100a

Medeiros, M. L., Lannes, S. C. D. S., & de Substitutos Do Cacau, P. F. (2010). *Food Science and Technology*, *30*, 243–253. https://doi.org/10.1590/S0101-20612010000500037

Medjekal, S., Bodas, R., Bousseboua, H., & López, S. (2018). Evaluation of carob (Ceratonia siliqua) and honey locust (Gleditsia triacanthos) pods as a feed for sheep. *Iranian Journal of Applied Animal Science*, *8*(2), 247–256.

Mekhoukhe, A., Kicher, H., Ladjouzi, A., Fatiha, L. M., De Biomathématiques, L., Medouni-Adrar, S., Madani, K., . . . Madani, K. (2018) Antioxidant activity of carob seeds and chemical composition of their bean gum by- products. *Journal of Complementary and Integrative Medicine*, *16*(1). https://doi.org/10.1515/jcim-2017-0158

Mekhoukhe, A., Mohellebi, N., Mohellebi, T., Deflaoui-Abdelfettah, L., Medouni-Adrar, S., Boulekbache-Makhlouf, L., & Madani, K. (2021). Jam processing: Effect of pectin replacement by locust bean gum on its characteristics. *Mediterranean Journal of Nutrition and Metabolism*, *14*(1), 13–24. https://doi.org/10.3233/MNM-200493

Meziani, S., Oomah, B. D., Zaidi, F., Simon-Levert, A., Bertrand, C., & Zaidi-Yahiaoui, R. (2015). Antibacterial activity of carob (Ceratonia siliqua L.) extracts against phytopathogenic bacteria Pectobacterium atrosepticum. *Microbial Pathogenesis*, *78*, 95–102. http://doi.org/10.1016/j.micpath.2014.12.001

Mokhtari, M., Sharifi, S., & Tabatabaee, M. S., Int. (2011). *Proceedings of the Chem. Biology and Environment Eng.*, *3*, 82–86. http://www.ipcbee.com/vol3/22-L10002.pdf

Moreira, da Silva, T. C., A. T., Fagundes, C., & Ferreira, S. M. R. (2017). Candido, ˆ L. M.B., Passos, M, and Krüger, C.C.H. Elaboration of Yogurt with Reduced Level of Lactose Added of Carob (Ceratonia siliqua L.). *LWT-Food Science and Technology*, *76*, 326–329.

Moreira, T. C., Transfeld da Silva, Á., Fagundes, C., Ferreira, S. M. R., Cândido, L. M. B., Passos, M., & Krüger, C. C. H. (2017). Elaboration of yogurt with reduced level of lactose added of carob (Ceratonia siliqua L.). *LWT – Food Science and Technology*, *76*, 326–329. https://doi.org/10.1016/j.lwt.2016.08.033

Morya, S., Awuchi, C. G., & Menaa, F. (2022). Advanced functional approaches of nanotechnology in food and nutrition. In P. Chowdhary, V. Hare & V. Kumar (Eds.), Environmental management technologies: Challenges and opportunities. CRC Press (pp. 257–272). *Taylor & Francis*. https://doi.org/10.1201/9781003239956-16

Mounce, F. S., Al-Saeed, M. H., & Bas. (2017). *Journal of Veterinary Research*, *16*, 219–242. http://www.basjvet.com/wp-content/uploads/2017/05/219-242.pdf

Mouse, H. A., Tilaoui, M., Jaafari, A., M'barek, L. A., Aboufatima, R., Chait, A., Zyad, A., & Rev. Bras. (2012). *Farmacogn*, *22*, 558–567. http://doi.org/10.1590/S0102- 695X2012005000030

Mudgil, D., Barak, S., & Khatkar, B. S. (2011). Guar gum: processing, properties and food applications—A Review. *Journal of Food Science and Technology*, *51*(3), 409–418. https://doi.org/10.1007/s13197-011-0522-x

Narin, B., Sungurlu, F., Balci, A., Arman, A., Kurdas, O. O., & Simsek, M. (2009). Comparison of MR enteroclysis with colonoscopy in Crohn's disease–first locust bean gum study from Turkey. *Saudi Journal of Gastroenterology*, *15*(4), 253–257. https://doi.org/10.4103/1319-3767.56104

Nasar-Abbas, S. M., E-Huma, Z., Vu, T., Khan, M. K., Esbenshade, H., & Jayasena, V. (2015). Carob Kibble: a Bioactive-Rich food ingredient. *Comprehensive Reviews in Food Science and Food Safety*, *15*(1), 63–72. https://doi.org/10.1111/1541-4337.12177

Nelson, R. H. (2013). Hyperlipidemia as a risk factor for cardiovascular disease. *Primary Care*, *40*(1), 195–211. https://doi.org/10.1016/j.pop.2012.11.003

Obeidat, B. S., Alrababah, M. A., Alhamad, M. N., Gharaibeh, M. A., & Ishmais, M. A. A. (2012). Effects of feeding carob pods (Ceratonia siliqua L.) on nursing performance of Awassi ewes and their lambs. *Small Ruminant Research*, *105*(1–3), 9–15. https://doi.org/10.1016/j.smallrumres.2012.01.001

Ozcan, M. M. (2009), ¨ M. M., Arslan, D., & Gokçalik, ¨ H. Some compositional properties and mineral contents of carob (Ceratonia siliqua) fruit , flour and syrup. *International Journal of Food Sciences and Nutrition*, *58*(8), 652–658. https://doi.org/10.1080/09637480701395549

Oziyci, H. R., Tetik, N., Turhan, I., Yatmaz, E., Ucgun, K., Akgul, H., Gubbuk, H., & Karhan, M. (2014).

Mineral composition of pods and seeds of wild and grafted carob (Ceratonia siliqua L.) fruits. *Scientia Horticulturae*, *167*, 149–152. https://doi.org/10.1016/j.scienta.2014.01.005

Papaefstathiou, E., Agapiou, A., Giannopoulos, S., & Kokkinofta, R. (2018). Nutritional characterization of carobs and traditional carob products. *Food Science and Nutrition*, May(8), 2151–2161. https://doi.org/10.1002/fsn3.776

Papageorgiou, M., & Skendi, A. (2015). Texture design of "free-from" foods—The case of gluten-free. *Modifying Food Texture*, 239–268.

Papageorgiou, M., Paraskevopoulou, A., Pantazi, F., & Skendi, A. (2020). Cake perception, texture and aroma profile as affected by wheat flour and cocoa replacement with carob flour. *Foods*, *9*(11), 1586. https://doi.org/10.3390/foods9111586

Papakonstantinou, E., Chaloulos, P., Papalexi, A., & Mandala, I. (2018). Effects of bran size and carob seed flour of optimized bread formulas on glycemic responses in humans: A randomized clinical trial. *Journal of Functional Foods*, *46*, 345–355. https://doi.org/10.1016/j.jff.2018.04.045

Park, Y. W., Oglesby, J., Hayek, S. A., Aljaloud, S. O., Gyawali, R., & Ibrahim, S. A. (2019). Impact of different Gums on textural and microbial properties of goat milk yogurts during refrigerated storage. *Foods*, *8*(5), 169. https://doi.org/10.3390/foods8050169

Pawłowska, K., Kuligowski, M., Jasińska-Kuligowska, I., Kidoń, M., Siger, A., Rudzińska, M., & Nowak, J. (2018). Effect of replacing cocoa powder by carob powder in the muffins on sensory and physicochemical properties. *Plant Foods for Human Nutrition*, *73*(3), 196–202. https://doi.org/10.1007/s11130-018-0675-0

Petit, M. D., & Pinilla, J. M. (1995). Production and purification of a sugar syrup from carob pods. *LWT – Food Science and Technology*, *28*(1), 145–152. https://doi.org/10.1016/S0023-6438(95)80027-1

Petitjean, M., & Isasi, J. R. (2022). Locust bean gum, a vegetable hydrocolloid with industrial and biopharmaceutical applications. *Molecules*, *27*(23), 8265. https://doi.org/10.3390/molecules27238265

Pettinelli, N., Rodríguez-Llamazares, S., Farrag, Y., Bouza, R., Barral, L., Feijoo-Bandín, S., & Lago, F. (2020). Poly(hydroxybutyrate-co-hydroxyvalerate) Microparticles Embedded in κ-carrageenan/locust Bean Gum Hydrogel as a dual Drug Delivery Carrier. *International Journal of Biological Macromolecules*, *146*, 110–118. https://doi.org/10.1016/j.ijbiomac.2019.12.193

Pham-Huy, L. A., He, H., & Pham-Huy, C. (2008). Free radicals, antioxidants in disease and health. *International Journal of Biomedical Science*, *4*(2), 89–96. https://doi.org/10.59566/IJBS.2008.4089

Pignataro, G., Di Prinzio, R., Crisi, P. E., Belà, B., Fusaro, I., Trevisan, C., De Acetis, L., & Gramenzi, A. (2021). Comparison of the therapeutic effect of treatment with antibiotics or nutraceuticals on clinical activity and the fecal microbiome of dogs with acute diarrhea. *Animals: An Open Access Journal from MDPI*, *11*(6), 1484. https://doi.org/10.3390/ani11061484

Polanowska, K., Varghese, R., Kuligowski, M., & Majcher, M. (2021). Carob kibbles as an alternative raw material for production of kvass with probiotic potential. *Journal of the Science of Food and Agriculture*, *101*(13), 5487–5497. https://doi.org/10.1002/jsfa.11197

Prajapati, V. D., Jani, G. K., Moradiya, N. G., Randeria, N. P., & Nagar, B. J. (2013). Locust bean gum: A versatile biopolymer. *Carbohydrate Polymers*, *94*(2), 814–821. https://doi.org/10.1016/j.carbpol.2013.01.086

Prajapati, V. D., Jani, G. K., Moradiya, N. G., Randeria, N. P., Maheriya, P. M., & Nagar, B. J. (2014). Locust bean gum in the development of sustained release mucoadhesive macromolecules of aceclofenac. *Carbohydrate Polymers*, *113*, 138–148. https://doi.org/10.1016/j.carbpol.2014.06.061

Prakash, O., Kumar, R., Srivastava, R., Tripathi, P., Mishra, S., & Ajeet, A. (2015). Plants explored with antidiabetic properties: A review. *American Journal of Pharmacological Sciences*, *3*(3), 55–66.

Primikyri, A., Chatziathanasiadou, M. V., Karali, E., Kostaras, E., Mantzaris, M. D., Hatzimichael, E., Shin, J. S., Chi, S. W., Briasoulis, E., Kolettas, E., Gerothanassis, I. P., & Tzakos, A. G. (2014). Direct binding of Bcl-2 family proteins by quercetin triggers its pro-apoptotic activity. *ACS Chemical Biology*, *9*(12), 2737–2741. https://doi.org/10.1021/cb500259e

Quiles-Carrillo, L., Mellinas, C., Garrigos, M. C., Balart, R., & Torres-Giner, S. (2019). Optimization of microwave-assisted extraction of phenolic compounds with antioxidant activity from carob pods. *Food Analytical Methods. AC*, *12*(11), 2480–2490.

https://doi.org/10.1007/s12161-019-01596-3

Ramstad, P. E. (1950). Amino acid compositions of wheat and carob gluten. *Cereal Chemistry*, *27*, 238–243.

Rached, I., Barros, L., Fernandes, I. P., Santos-Buelga, C., Rodrigues, A. E., Ferchichi, A., Barreiro, M. F., & Ferreira, I. C. (2016). Ceratonia siliqua L. hydroethanolic extract obtained by ultrasonication: Antioxidant activity, phenolic compounds profile and effects in yogurts functionalized with their free and microencapsulated forms. *Food and Function*, *7*(3), 1319–1328. https://doi.org/10.1039/c6fo00100a

Rahmoun, N. M., Ziane, H., & Boucherit-Otmani, Z. (2014). Antibacterial and antifungal screening of four medicinal plants. *Journal of Coastal Life Medicine*, *2*(12), 975–979.

Rahmoun, N. M., Ziane, H., & Boucherit-Otmani, Z. (2014). Antibacterial and antifungal screening of four medicinal plants. *Journal of Coastal Life Medicine*, *2*, 975–979. https://doi.org/10.12980/JCLM.2.2014APJTB-2014-0072

Ravat, T. H., Yardi, V., Mallikarjunan, N., & Jamdar, S. N. (2019). Radiation processing of locust bean gum and assessing its functionality for applications in probiotic and enteral foods. *LWT*, *112*, 108228. https://doi.org/10.1016/j.lwt.2019.05.126

Richane, A., Ismail, H. B., Darej, C., Attia, K., & Moujahed, N. (2022). Potential of Tunisian carob pulp as feed for ruminants: Chemical composition and in vitro assessment. *Tropical Animal Health and Production*, *54*(1), 58. https://doi.org/10.1007/s11250-022-03071-4

Rico, D., Martin-Diana, A. B., Lasa, A., Aguirre, L., Milton-Laskibar, I., De Luis, D. A., & Miranda, J. (2019). Effect of Wakame and carob pod snacks on nonalcoholic fatty liver disease. *Nutrients*, *11*(1), 86.(b. https://doi.org/10.3390/nu11010086

Rico, D., Martín-Diana, A. B., Martínez-Villaluenga, C., Aguirre, L., Silván, J. M., Dueñas, M., De Luis, D. A., & Lasa, A. (2019). In vitro approach for evaluation of carob by-products as source bioactive ingredients with potential to attenuate metabolic syndrome (mets) a. *Heliyon*, *5*(1), e01175. https://doi.org/10.1016/j.heliyon.2019.e01175

Román, L., González, A., Espina, T., & Gómez, M.., Espina, T., & Gomez, ´. (2017) Degree of roasting of carob flour affecting the properties of gluten-free cakes and cookies. *Journal of Food Science and Technology*, *54*(7), 2094–2103. https://doi.org/10.1007/s13197-017-2649-x

Rtibi, K., Jabri, M. A., Selmi, S., Souli, A., Sebai, H., El-Benna, J., Amri, M., & Marzouki, L. (2015a). Carob pods (Ceratonia siliqua L.) inhibit human neutrophils myeloperoxidase and in vitro ROS-scavenging activity. *RSC Advances*, *5*(102), 84207–84215. https://doi.org/10.1039/C5RA14719K

Rtibi, K., Jabri, M. A., Selmi, S., Souli, A., Sebai, H., El-Benna, J., Amri, M., & Marzouki, L. (2015b). Gastroprotective effect of carob (Ceratonia siliqua L.) against ethanol-induced oxidative stress in rat. *BMC Complementary and Alternative Medicine*, *15*(1), 292. https://doi.org/10.1186/s12906-015-0819-9

Rtibi, K., Jabri, M. A., Selmi, S., Souli, A., Sebai, H., El-Benna, J., Amri, M., & Marzouki, L. (2015). Carob pods (Ceratonia siliqua L.) inhibit human neutrophils myeloperoxidase and in vitro ROS-scavenging activity. *RSC Advances*, *5*(102), 84207–84215. https://doi.org/10.1039/C5RA14719K

Rtibi, K., Jabri, M. A., Selmi, S., Souli, S., H., Amri, M., ElBenna, J., & Marzouki, L. (2015). *RSC Advances*, *6*, 65483–65493. https://doi.org/10.1039/c6ra11297h

Rtibi, K., Marzouki, K., Salhi, A., & Sebai, H. (2021). Dietary supplementation of carob and whey modulates gut morphology, hemato-biochemical indices, and antioxidant biomarkers in rabbits. *Journal of Medicinal Food*, *24*(10), 1124–1133. https://doi.org/10.1089/jmf.2020.0185

Rtibi, K., Selmi, S., Grami, D., Saidani, K., Sebai, H., Amri, M., Marzouki, L., Marzouki, L., & Ceratonia Siliqua, L. (2017). Ceratonia siliqua L. (immature carob bean) Inhibits intestinal glucose absorption, improves glucose tolerance and protects against alloxan-induced diabetes in rat. *Journal of the Science of Food and Agriculture*, *97*(8), 2664–2670. https://doi.org/10.1002/jsfa.8091

Ruiz-Roso, B., Quintela, J. C., De La Fuente, E., Haya, J., & Pérez-Olleros, L. (2010). Insoluble carob fiber rich in polyphenols lowers total and LDL cholesterol in hypercholesterolemic sujects. *Plant Foods for Human Nutrition*, *65*(1), 50–56. https://doi.org/10.1007/s11130-009-0153-9

Saci, F., Bachir bey, M., Louaileche, H., Gali, L., & Bensouici, C. (2020). Changes in anticholinesterase, antioxidant activities and related bioactive compounds of carob pulp (Ceratonia siliqua L.) during ripening stages. *Journal of Food Measurement and Characterization*, *14*(2), 937–945. https://doi.org/10.1007/s11694-019-00344-9

Sadat, S. S., Mohammadi, S., Sazegar, G., Fazel, A., Ebrahimzadeh, A., Ghayour Mobarhan, M., Beheshti, F., Attari, S. S., & Tavallaei, S. (2019). Effects of carob fruit extract on spermatogenesis, antioxidant status, and apoptosis in adult male mice. *Pharmaceutical Sciences*, *25*(3), 184–189. https://doi.org/10.15171/PS.2019.28

Salem, E. M., & Fahad, A. O. (2012). Substituting of cacao by carob pod powder in milk chocolate manufacturing. *Aus. J. Bas. Appl. Sci.*, *6*(3).

Santilli, F., Guagnano, M. T., Vazzana, N., La Barba, S., & Davi, G. (2015). Oxidative stress drivers and modulators in obesity and cardiovascular disease: From biomarkers to therapeutic approach. *Current Medicinal Chemistry*, *22*(5), 582–595. https://doi.org/10.2174/0929867322666141128163739

Sassi, A., Bouhlel, I., Mustapha, N., Mokdad-Bzeouich, I., Chaabane, F., Ghedira, K., & Chekir-Ghedira, L. (2016). Assessment in vitro of the genotoxicity, antigenotoxicity and antioxidant of Ceratonia siliqua L. extracts in murine leukaemia cells L1210 by comet assay. *Regulatory Toxicology and Pharmacology*, *77*, 117–124.
http://doi.org/10.1016/j.yrtph.2016.02.009

Sayiner, M., Koenig, A., Henry, L., & Younossi, Z. M. (2016). Epidemiology of nonalcoholic fatty liver disease and nonalcoholic steatohepatitis in the United States and the rest of the world. *Clinics in Liver Disease*, *20*(2), 205–214.
https://doi.org/10.1016/j.cld.2015.10.001

Sciammaro, L. P., Ferrero, C., & Puppo, M. C. (2018). Gluten-free baked muffins developed with Prosopis A. Flour. *LWT*, *98*, 568–576.
https://doi.org/10.1016/j.lwt.2018.09.045

Sebai, H., Souli, A., Chehimi, L., Rtibi, K., Amri, M., ElBenna, S., & M. (2013). *Journal of Medicinal Plants Research*, *7*, 5–90.
https://doi.org/10.5897/JMPR12.915

Sęczyk, Ł., Świeca, M., & Gawlik-Dziki, U. (2016). Effect of carob (Ceratonia siliqua L.) flour on the antioxidant potential, nutritional quality, and sensory characteristics of fortified durum wheat pasta. *Food Chemistry*, *194*, 637–642.
http://doi.org/10.1016/j.foodchem.2015.08.086

Sengül, M., Fatih Ertugay, M., Sengül, M., & Yüksel, Y. (2007). Rheological characteristics of carob pekmez. *International Journal of Food Properties*, *10*(1), 39–46. https://doi.org/10.1080/10942910600627996

Sharaf, H. A., Shaffie, N., Morsy, F. A., Badawi, M., & Abbas, N. F. (2015b). Role of some phytoestrogens in recovering bone loss: histological results from experimental ovariectomized rat models. *Journal of the Arab Society for Medical Research (Print)*, *10*(2), 65. https://doi.org/10.4103/1687-4293.175880

Singh, R. S., Kaur, N., Rana, V., Singla, R. K., Kang, N., Kaur, G., Kaur, H., & Kennedy, J. F. (2020). Carbamoylethyl locust bean gum: Synthesis, characterization and evaluation of its film forming potential. *International Journal of Biological Macromolecules*, *149*, 348–358. https://doi.org/10.1016/j.ijbiomac.2020.01.261

Siriwongwilaichat, P., & Koedcharoenporn, J. (2019). Improvement of texture and gel stability of restructured frozen mango pulp by using xanthan gum and locust bean gum. *Sci. Eng. Health Stud.*, 59–72.

Skalli, S., Hassikou, R., & Arahou, M. (2019). An ethnobotanical survey of medicinal plants used for diabetes treatment in Rabat, Morocco. *Heliyon*, *5*(3), e01421.
https://doi.org/10.1016/j.heliyon.2019.e01421.

Skaltsi, A., Marinopoulou, A., Poriazi, A., Petridis, D., & Papageorgiou, M. (2022). Development and optimization of gluten-free biscuits with carob flour and dry apple pomace. *Journal of Food Processing and Preservation*, *46*(10), e15938.
https://doi.org/10.1111/jfpp.15938

Smith, B. M., Bean, S. R., Schober, T. J., Tilley, M., Herald, T. J., Aramouni, F., Dakia, P. A., Wathelet, B., Paquot, M., Bengoechea, C., Romero, A., Villanueva, A., Moreno, G., Alaiz, M., & Millan, ´ F., Guerrero, A. (2008). Composition and molecular weight distribution of carob germ protein fractions. Puppo, M.C., Lakkab. *Food Chemistry*, *102*(2), 675–683, I., El, H., … Ghoul, M.
https://doi.org/10.1016/j. foodchem.2007.08.069

Sonmez, & A. Y. D. I. N. O. L.; Ozcan, T. (2022). Assessment of structure and sensory characteristics of reduced fat yoghurt manufactured with carob bean gum polysaccharides. *Food Science and T Echnology*, 2021, 42. https://doi.org/10.1590/fst.61220

Sour, S., Chahinez, F., & Taif, A. (2019). Beneficial Effects of Carob Pulp (Ceratonia siliqua) on Lipids Profile and Oxidant/antioxidant Status in Obese Rats. *Revue Agrobiologia*, *9*(1), 1200–1206.

Srour, N., Daroub, H., Toufeili, I., & Olabi, A. (2016). Developing a carob-based milk beverage using different varieties of carob pods and two roasting treatments and assessing their effect on quality characteristics. *Journal of the Science of Food and Agriculture*, *96*(9), 3047–3057. https://doi.org/10.1002/jsfa.7476

Stankov, S., Dzhivoderova-Zarcheva, M., Dimitrova, E., Damyanova-Bakardzhieva, M., & Fidan, H. (2020). Rheological and sensory properties of glazes prepared with carob and cocoa powders. *Journal of Food Processing and Preservation*, *44*(8), e14580.
https://doi.org/10.1111/jfpp.14580

Suzek, H., Celik, I., & Dogan, A. (2017). Nephroprotective Hepatoprotective Potential and Antioxidant Role of Carob Pods (Cerotonia siliqua L.) against Carbon Tetrachloride-induced Toxicity in Rats. *Indian Journal of Pharmaceutical Education and Research*, *51*(2), 312–320. https://doi.org/10.5530/ijper.51.2.37

Talibi, I., Askarne, L., Boubaker, H., Boudyach, E. H., Msanda, F., Saadi, B., & Ben Aoumar, A. A. (2012). Antifungal activity of Moroccan medicinal plants against citrus sour rot agent Geotrichum candidum. *Letters in Applied Microbiology*, *55*(2), 155–161. https://doi.org/10.1111/j.1472-765X.2012.03273.x

Temiz, M. A., Temur, A., & Celik, I. (2015). *Journal of Food and Nutrition Research*, *3*, 57–61. https://doi.org/10.12691/jfnr-3-1-10

Tounsi, L., Karra, S., Kechaou, H., & Kechaou, N. (2017). Processing, physico-chemical and functional properties of carob molasses and powders. *Journal of Food Measurement and Characterization*, *11*(3), 1440–1448. https://doi.org/10.1007/s11694-017-9523-4

Tous, J., & Antoni, C. S. (2013). The carob tree: Botany, horticulture, and genetic resources. *Horticultural reviews* (1st ed), 41, 500 mm.

Tsatsaragkou, K., Gounaropoulos, G., & Mandala, I. (2014). Development of gluten free bread containing carob flour and resistant starch. *LWT – Food Science and Technology*, *58*(1), 124–129. https://doi.org/10.1016/j.lwt.2014.02.043

Tsatsaragkou, K., Kara, T., Ritzoulis, C., Mandala, I., & Rosell, C. M. (2017). Improving carob flour performance for making gluten-free breads by particle size fractionation and jet milling. *Food and Bioprocess Technology*, *10*(5), 831–841. https://doi.org/10.1007/s11947-017-1863-x

Tsatsaragkou, K., Papantoniou, M., & Mandala, I. (2015). Rheological, physical, and sensory attributes of gluten-free rice cakes containing resistant starch. *Journal of Food Science*, *80*(2), E341–E348. https://doi.org/10.1111/1750-3841.12766

Tsatsaragkou, K., Yiannopoulos, S., Kontogiorgi, A., Poulli, E., Krokida, M., & Mandala, I. (2012). Mathematical approach of structural and textural properties of gluten free bread enriched with carob flour. *Journal of Cereal Science*, *56*(3), 603–609. https://doi.org/10.1016/j.jcs.2012.07.007

Tsatsaragkou, K., Gounaropoulos, G., & Mandala, I. (2014). Development of gluten free bread containing carob flour and resistant starch. *LWT*, *58*(1), 124–129. https://doi.org/10.1016/j.lwt.2014.02.043.

Turfani, V., Narducci, V., Durazzo, A., Galli, V., & Carcea, M. (2017). Technological, nutritional and functional properties of wheat bread enriched with lentil or carob fl ours. *LWT*, *78*, 361–366. https://doi.org/10.1016/j.lwt.2016.12.030

Turhan, I., Bialka, K. L., Demirci, A., & Karhan, M. (2010). Enhanced lactic acid production from carob extract by Lactobacillus casei using invertase pretreatment. *Food Biotechnology*, *24*(4), 364–374. https://doi.org/10.1080/08905436.2010.524485

Uysal, S., Zengin, G., & Aktumsek, A. (2015). Studies on in vitro Antioxidant Activities of Nine Different Fruit Tree Leaves Collected From Mediterranean Region of Turkey. *Journal of Medicinal Herbs and Ethnomedicine*, *1*(1), 97–102. https://doi.org/10.5455/jmhe.2015.09.022

Valero-Munoz, M., Ballesteros, S., Ruiz-Roso, B., Pérez-Olleros, L., Martín-Fernández, B., Lahera, V., de Las Heras, N., de Las Heras, N., P´erez-Olleros, Martín-Fern´ andez. (2019) Supplementation with an insoluble fiber obtained from carob pod (Ceratonia siliqua L.) rich in polyphenols prevents dyslipidemia in rabbits through SIRT1/PGC-1α pathway. *European Journal of Nutrition*, *58*(1), 357–366. https://doi.org/10.1007/s00394-017-1599-4

Valero-Muñoz, M., Martín-Fernández, B., Ballesteros, S., Lahera, V., & de Las Heras, N. (2014). Carob Pod Insoluble Fiber Exerts anti-atherosclerotic Effects in Rabbits through Sirtuin-1 and peroxisome proliferator-activated receptor-γ coactivator-1α. *Journal of Nutrition*, *144*(9), 1378–1384. https://doi.org/10.3945/jn.114.196113

Verdile, G., Keane, K. N., Cruzat, V. F., Medic, S., Sabale, M., Rowles, J., Newsholme, P., Martins, R. N., Fraser, P. E., & Newsholme, P. (2015). Inflammation and oxidative stress: The molecular connectivity between insulin resistance, obesity, and Alzheimer's disease. *Mediators of Inflammation*, 2015, 1–17. https://doi.org/10.1155/2015/105828

Verma, A., Tiwari, A., Panda, P. K., Saraf, S., Jain, A., & Jain, S. K. (2019). Locust bean gum in drug Delivery application. In Natural polysaccharides in drug delivery and biomedical applications (pp. 203–222). Academic Press.

Vitali Čepo, D., Mornar, A., Nigović, B., Kremer, D., Radanović, D., & Vedrina Dragojević, I. (2014). Optimization of roasting conditions as an useful approach for increasing antioxidant activity of carob powder. *LWT – Food Science and Technology*, *58*(2), 578–586. https://doi.org/10.1016/j.lwt.2014.04.004

Wang, J., & Li, Q. X. (2011). Chemical composition, characterization, and differentiation of honey botanical and geographical origins. In Inadvances in food and nutrition research (1st ed., Vol. 62). *Elsevier Inc.*, 89–137. https://doi.org/10.1016/B978-0-12-385989

Wielinga, W., & Gums, S. (2010). In A. Imeson (Ed.). Food stabilizers, thickeners and gelling agents (pp. 167–179). Wiley-Blackwell.

Yatmaz, E., & Turhan, I. (2012). Optimization of mannanase production from Aspergillus sojae pyrG– transformed using response surface method. *Journal of Biotechnology*, *161*, 39. https://doi.org/10.1016/j.jbiotec.2012.07.122

Yatmaz, E., & Turhan, İ. (2018b). Carob as a carbon source for fermentation technology. *Biocatalysis and Agricultural Biotechnology*, *16*, 200–208. https://doi.org/10.1016/j.bcab.2018.08.006

Ydjedd, S., Bouriche, S., López-Nicolás, R., Sánchez-Moya, T., Frontela-Saseta, C., Ros-Berruezo, G., Rezgui, F., Louaileche, H., & Kati, D. E. (2017). Effect of in Vitro Gastrointestinal Digestion on Encapsulated and Nonencapsulated Phenolic Compounds of Carob (Ceratonia siliqua L.) Pulp Extracts and Their Antioxidant Capacity. *Journal of Agricultural and Food Chemistry*, *65*(4), 827–835. https://doi.org/10.1021/acs.jafc.6b05103

Yousif, A. K., & Alghzawi, H. M. (2000). Processing and characterization of carob powder. *Food Chemistry*, *69*(3), 283–287. https://doi.org/10.1016/S0308-8146(99) 00265-4.

Zhao, X., Wang, Q., Yang, S., Chen, C., Li, X., Liu, J., Zou, Z., & Cai, D. (2016). Quercetin inhibits angiogenesis by targeting calcineurin in the xenograft model of human breast Cancer. *European Journal of Pharmacology*, *781*, 60–68. https://doi.org/10.1016/j.ejphar.2016.03.063.

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