

## Review Article

# Phytochemical, Nutritional and Pharmacological Potentialities of Carob (*Ceratonia siliqua* L.): A Review

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## Abstract

Carob tree (*Ceratonia siliqua* L.) belongs to the leguminosae family and it is mainly cultivated in Mediterranean regions. It is well accepted by the people for its nutritional, pharmacological, phytochemical and therapeutic functions in the human body. Seeds and pulp of *Ceratonia siliqua* are eaten by humans or to animals, which contain carbohydrates, fibers, polyphenol, minerals and many other phytochemicals. This review aims to represent the nutritional and pharmacological activities of *Ceratonia siliqua* L. To have a better understanding, we have discussed the nutritional status of *Ceratonia siliqua* L., its available phytochemicals and their functional properties. The availability of various important phytochemicals along with their functional properties makes *Ceratonia siliqua* L. valuable for pharmaceuticals and industry.

**Keywords:** *Ceratonia siliqua* L.; Pharmacological; Phytochemicals

## Introduction

*Ceratonia siliqua* L. is an endemic, aromatic and medicinal plant which is found to be currently among the most successful forest fruit and fodder trees that exist in the Morocco (Say, 2008). It is a xerophytic tree showing some special characteristics such as hardiness, resistance to drought, soil fertilization and the fight against soil erosion. It has been exploited for a very long time, in particular thanks to its qualities fodder and food. Thanks to its biological and ecological peculiarity, it has been included in the national list of priority as a forest resource for conservation. Indeed, it is an agro-sylvopastoral species that can be used for the rehabilitation of degraded soils, thanks to its capacity adaptation to different edaphoclimatic conditions (Say, 2008). This evergreen tree presents very high economic profitability compared to other fruit species. In Morocco, it covers an area exceeding 30000ha, more than half of which is in the domain forestry, which favors a very important national production of carob pods (AitChitt et al., 2007).

The carob tree has, in addition, a great socio-economic interest since its pods, more rich in sugars than sugar cane and sugar beet, and which are used in industry food and pharmacological (Batlle and Tous, 1997; Gharnit et al., 2001). Carob is an essential reservoir of nutritional and pharmaceutical compounds. More specifically the locust bean seeds are generally used for the production of locust bean gum. All the parts of this tree are useful and exploited for their great wealth and their added value in several areas. The leaves are a popular fodder and have dietetic and medicinal properties. In addition, the bark and leaves were used in the traditional medicine as a laxative, diuretic, antidiarrheal and for the treatment of gastroenteritis (El Bouzdoudi et al., 2017). These leaf extracts contain multiple medicinal properties: cytotoxic and antimicrobial (Meziani et al., 2015; Meziou-Chebouti et al., 2015), antioxidants (Custodio et al., 2011; Rtibi et al., 2016) and antifungals (Fadel et al., 2011); Inhibitors of proliferation of tumor cells (Corsi et al., 2002; Custodio et al., 2011) and hepatoprotective (Ibrahim et al., 2012).

The present review aims to summarize and discuss the nutritional and phytochemicals and pharmacology of this useful and unexploited part of carob tree.

## Phytochemicals

The carob pods have high amounts of carbohydrates (40-60%), polyphenolic compounds especially tannins (18-20%), dietary fibers (27-50%) (Marakis, 1996), minerals (potassium, sodium, iron, copper manganese and zinc) (Karki et al., 2007; Gulay et al., 2012) and low amounts of protein (3-4%) and lipids (0.4-0.8%) (Biner et al., 2007; Özcan et al., 2007; Vekiari et al., 2011). This fruit is known especially, for its richness in sugars which are essentially composed of sucrose (32-38%), fructose (5-7%) and glucose (5-6%) (Rtibi et al., 2017), but their relative proportions are variable (Marakis, 1996). The pods also contain a high amount of dietary fiber and phenolic compounds (Avallone et al., 1997). There are many data about the chromatography methods performed by HPLC (High-Performance Liquid Chromatography) for determining polyphenols in carob pods which revealed the presence of condensed tannins (proanthocyanidins), had flavan(3-ol groups and their galloyl esters, gallic acid, (+)-catechin, epicatechingallate and quercetin glycosides (Ghenemi et al., 2017; Custodio et al., 2011; Corsi et al., 2002; Ortega et al., 2009) and several authors referred also to the presence of hydrolysable tannins (Gallotannins and ellagitannins) in carob pods (Avallone et al., 1997). It had polyphenols astannins, flavonoids (26%) and phenolic acids (such as gallic acid, cinnamic acid and p-coumaric acid), flavone glycosides (such as quercetin-3-a-L-rhamnopyronoside) and hydroxytyrosol (Owen et al., 2003). In addition, the carob juice is rich in electrolytes such as potassium, sodium, iron, copper, manganese and zinc. The chemical substances in carob pods differ widely according to carob species, climate and the stage of maturity as well as to different parts of tree. Indeed, the HPLC analysis showed that the principal compounds are: pyrogallol (3.55%), catechin (19.10%) and tannic acid (9.01%) in mature carob pods. However, this technique revealed the pyrogallol (48.02%), catechin (16.52%), gallic acid (15.12%),

chlorogenic acid 15.01%) and epicatechin (12.26%) in immature carob pods (Rtibi et al., 2016). In addition, this technique detected many phenolic compounds in leaves as kaemferol (77%), tannin acid (13%) catechin hydrate (4.30%) and polydatin (0.85%). Likewise, it was found that carob tree leaves are richer in fiber than the carob pod. However, the carob extract is richer in total and reduced sugars compared to leaves (El Bouzdoudi et al., 2017; Ghanemi et al., 2017, Owen et al., 2003; Rtibi et al., 2015; Rtibi et al., 2016).

## Biological Activities

Recently, it has been reported that the tree studied as having multiple biological activities, especially in digestive tract including antioxidant, anti-diarrheal, antibacterial, anti-ulcer, anticancer, anti-carcinogenic, anti-mutagenic and anti-inflammatory actions (Yamagishi et al., 2000; Greenspan et al., 2005; Lambert et al., 2005; Moreno et al., 2006; Song et al., 2007).

## Antioxidant Activity

Methanol extracts of the leaves and pulps (all sexes of the tree) were tested for radical scavenging (DPPH) and antioxidant (carotene-linoleate) activities and leaves extract found to be more active (El Hajjaji et al., 2010; Roseiro et al., 2013; Saoud et al., 2019; Ashande et al., 2019 et Oscar et al., 2020).

## Anti-inflammatory and Related Activities

Methanol extract of bark was tested for antioxidant (DPPH), acute toxicity (rats) and chemical (Carrageenan) or mechanical powder edema. It was analyzed for major compound families and flavonoids, tannins, sterols, quinones and mucilages were found. A galactomannan extracted from pods, authors refer to as Locust bean gum was used as contrast material in magnetic resonance enteroclysis (MRE) for imaging of Crohn's disease (bowels chronic inflammatory disease). It gave best results when used with water and mannitol. Leaves were extracted with dichloromethane: methanol 1:1v/v. The extract was tested for anti-inflammatory and cytotoxic activities and found inactive in both (Rtibi et al., 2017).

## Anti-Diabetic Effect

Ethanol/water (96%) extract of dry pods was tested for streptozotocin-induced diabetes in rats. It decreased blood glucose and lipids. Mixture of dried flowers of Roselle (*Hibiscus sabdariffa*) and dry pods of Carob was water extracted and administered to alloxan-induced diabetic rats. The extract was tested with or without Gamma radiation of the plants mixture powder. In both cases it was found active. Phenolic compounds may also have antioxidant effect used for managing oxidation stress-related chronic diseases such as diabetes and hypertension (Rtibi et al., 2018; Custodio et al., 2015).

## Anti-Obesity Effect

Obesity is undeniably one of the biggest medical problems of the 21st century due to dietary habit, sedentary lifestyle, and stress, which promotes various cardiovascular disease and pathologica conditions like hypertension, inflammation, and hepatosteosis (Kuzbicka and Rachon, 2013).

## Antimicrobial, Antifungal, Antiviral and Related Activities

Methanolic extract of *Ceratonia siliqua* was tested for antibacterial

activity, compared with methanolic extract of *Plantago major*, which was found more active for most bacteria. The extract of *Ceratonia siliqua* was more active of *Escherichia coli*, *Staphylococcus aureus* (Kivçak et al., 2002), the carob would also adsorb enterotoxins produced by certain strains of *Escherichia coli* and *Staphylococcus aureus* as well as by the chera *Vibrio*, and this adsorption mechanism could be explained by the presence of tannins in the insoluble and active part of the carob. In addition to his power nematocidal demonstrated by the work of El Allagui et al., (2007) which is due to its content of compounds phenolic, according to a recent study by Sanchez et al., 2010 the carob tree is a good source carbohydrate market for bioethanol production. Aqueous and methanolic extract were tested of antimicrobial activity, alone and in combination with other antibacterial agent (ampicillin, gentamicin, amikacin and clindamycin). The combination of extracts and antibacterial agents was more efficient than each separately. The extracts were analyzed and some pure compounds were isolated and characterized. Ethanolic and acetone extracts were tested of antibacterial activity against *P. atrosepticum* in Potato soft rot. Acetone extract was more active. Methanolic extract of leaves found to be active against *Listeria monocytogenes*. HPLC analysis of extracts yielded seven compounds with antibacterial activity, especially epigallocatechin-3-gallate. However, antifungal activity with ethyl-acetate and methanol has been observed against *Candida albicans*. The MICs of the aqueous extract of *Ceratonia siliqua* varied between 30 mg/ml for *Staphylococcus aureus* and 50 mg/ml for *E. coli* and *Candida albicans* (Singh et al., 2016; Al-Seeni, 2017, Aissani et al., 2012, Kivçak et al., 2002; Hsouna et al., 2015; Aissani et al., 2012).

Newcastle Disease, caused by Newcastle Disease Virus (NDV), is a serious threat to the global poultry industry due to its high mortality rate (Alexander, 2000). Ethanolic extract of *Ceratonia siliqua* leaves was tested against NDV and found partially active. The gradual concentrations of carob leaves extract (500, 240 and 50 µg/ml) showed 20, 40 and 80% mortality, respectively (Al-Hadid, 2016). These findings demonstrate a dose dependent manner of plant extract and mortality. Nevertheless, total inhibition of viral activity was not observed, suggesting the need to increase concentrations of the plant extract (Azab, 2017).

## Anticancer Activity

Ethanol and ethyl acetate extracts of propolis that was collected in an area (Morocco) with Carob as a major tree were prepared, and tested against three mammalian tumor cell lines. Medium activity was measured. Dry pods were extracted with ethanol, and it was analyzed for reductive components (very detailed), antioxidant, and anti-cancer and antipain activities. It was found moderately active for the three activities. Aqueous extracts of dry pods or leaves were tested against mouse hepatocellular carcinoma cell line, and both found active, but leaves extract was more active. Authors attribute this activity to the presence of gallic acid and some of its esters. Methanolic extracts of pods and leaves were prepared and tested for anti-proliferative and apoptotic activities in MDA-MB-231 human breast cancer cells, and found active, with higher activity of leaves extract. Authors relate these activities to the presence of phenolic compounds (Ghanemi et al., 2017).

## Other Usages

Several studies have shown that the use of soils associated with

polyethylene glycol (PEG) improves the digestibility and nutritional quality of the tannins contained in the leaves (Priolo et al., 2000), the latter were used in Turkey, in 'traditional' medicine to treat diarrhea and in the diet and in the treatment of obesity (Berrougui, 2007). The leaves were also referred to as being carries of cytotoxic, antimicrobial, antioxidant and antifungal activities (Kivçak and Mert, 2002; Custodio et al., 2011; Fadel et al., 2011; Meziani et al., 2015; MeziouChebouti et al., 2015). Corsi et al., (2002); Custodio et al., (2011) demonstrated the extraordinary ability leaf and pod extracts to inhibit tumor cell proliferation.

According to some authors, the soluble fibers of the pulp can have a preventive or curative effect on human and animal health, thanks to the reduction of the risk of thrombosis through the decrease in blood pressure and serum cholesterol level (Williams et al., 1995; Beaggar et al., 1996; Konate, 2007). In therapy, this essence is known for its cholesterol-lowering, antiproliferative, anti-diarrheal effect, and other digestive disorders, laxative and nourishing (Berrougui, 2007). In addition, it plays an effective role in the suppression of intestinal parasites (Min and Hart, 2003) and in the treatment of diarrhea (Serairi-Béji et al., 2000).

From research has shown that carob may be a good candidate for use as a functional food or as a food ingredient (Tsatsaragkou et al., 2014; Biernacka et al., 2017; Arribas et al., 2019; Salih and Jilal, 2020) because it can constitute a good source of antioxidant polyphenols (Owen et al., 2003).

Numerous clinical studies have highlighted the effectiveness of carob powder in the treatment of acute childhood diarrhea (Serairi-Béji et al., 2000), which was confirmed by the study clinic conducted by Loeb et al., (1989). The pulp is recommended against tuberculosis pulmonary and bronchial diseases. In decoction, however, it is antidiarrhoeal and slightly purifying. It is used for the treatment of certain diseases such as gastritis, enteritis, tonsillitis, colds, cancer... (Crosi et al., 2002).

## Conclusion

The carob tree may be considered as a valuable plant in both traditional and modern drugs development areas for its medicinal uses. Standardization of carob pods and extracts leaves extracts can be carried out for direct use against various above mentioned problems and further research can be undertaken for isolation, purification and pharmacological validation of active constituents responsible for particular pharmacological activity.

## References

- Ait Chitt M, M. Belmir et A. Lazrak, Production des plantes sélectionnés et greffés du caroubier. Transfert de technologie en Agriculture. N°153. IAV Rabat. 2007; 1-4.
- Aissani N, Coroneo V, Fattouch S, Caboni P. Inhibitory effect of carob (*Ceratonia siliqua*) leaves methanolic extract on *Listeria monocytogenes*. Journal of agricultural and food chemistry. 2012; 60(40): 9954-9958. doi:10.1021/jf3029623.
- Al-Hadid KJ. Evaluation of antiviral activity of different medicinal plants against Newcastle disease virus. Am. J Agric Biol Sci. 2016; 11(4): 157-163.
- Ashande C M, Lufuluabo G L, Mukiza J, Mpiana P T. A mini-review on the Phytochemistry and Pharmacology of the medicinal plant species *Persea Americana* Mill. (Lauraceae). Discovery Phytomedicine. 2019; 6(3): 102-111.
- Arribas C, Pereira E, Barros L, Alves MJ, Calhelha RC, Guillamón E, et al. Healthy novel gluten-free formulations based on beans, carob fruit and rice: Extrusion effect on organic acids, tocopherols, phenolic compounds and bioactivity. Food chemistry. 2019; 292: 304-313. doi:10.1016/j.foodchem.2019.04.074.
- Avallone R, Plessi M, Baraldi M, Monzani A. Determination of chemical composition of carob (*Ceratonia siliqua*): protein, fat, carbohydrates, and tannins. Journal of Food Composition and Analysis. 1997; 10(2): 166-172. doi:10.1006/JFCA.1997.0528.
- Azab A. Carob (*Ceratonia siliqua*): health, medicine and chemistry. Eur Chem Bull. 2017; 10: 456-469.
- Battle I, Tous J. Carob tree. *Ceratonia siliqua* L. Promoting the conservation and use of underutilized and neglected crops. 17. Institute of Plant Genetic and Crops Plant Research. Gatersleben/International Plant Resources Institute. Rome. Italy. 1997.
- Beaggar M, Andersen O, Neilsen J D, Rytting K L. Dietary fibre reduce blood pressure serum total cholesterol and platelet aggregation in rats. British J Nutr. 1996; 75: 483-493.
- Berrougui H. Le caroubier (*Ceratonia siliqua* L.), une richesse nationale aux vertus médicinales. Maghreb Canada Express. 2007; 5(9): 20.
- Biernacka B, Dziki D, Gawlik-Dziki U, Różyto R, Siastala M. Physical, sensorial, and antioxidant properties of common wheat pasta enriched with carob fiber. LWT. 2017; 77: 186-192.
- Biner B, H Gubbuk, M Karhan, M Aksu, M. Pekmezci. Sugar profiles of the pods of cultivated and wild types of carob bean (*Ceratonia siliqua* L.) in Turkey. Food Chemistry. 2007; 100: 1453-1455.
- Corsi L, R Avallone, F Cosenza, F Farina, C Baraldi, M Baraldi. Anti-proliferative effects of *Ceratonia siliqua* L. on mouse hepatocellular carcinoma cell line. Fitoter. 2002; 73(7-8): 674-684.
- Custódio L, Patarra J, Alberício F, Neng NR, Nogueira JMF, Romano A. In vitro antioxidant and inhibitory activity of water decoctions of carob tree (*Ceratonia siliqua* L.) on cholinesterases,  $\alpha$ -amylase and  $\alpha$ -glucosidase. Natural Product Research. 2015; 29(22): 2155-2159. doi:10.1080/14786419.2014.996147.
- Custodio L, Escapa A L, Fernandes E, Fajardo A, Aligué R, Alberício F, Romano A. In vitro cytotoxic effects and apoptosis induction by a methanol leaf extract of carob tree (*Ceratonia siliqua* L.). J Med Plant Res. 2011; 5(10): 1987-1996.
- Allagui NE, Tahrouch S, Bourijate M, Hatimi A. Action de différents extraits végétaux sur la mortalité des nématodes à galles du genre *Meloidogyne* ssp. Acta Botanica Gallica. 2007; 154(4): 503-509. doi:10.1080/12538078.2007.10516076.
- El Hajaji H, Lachkar N, Alaoui K, Cherrah Y, Farah A, Ennabili A, et al. Antioxidant properties and total phenolic content of three varieties of carob tree leaves from Morocco. Rec Nat Prod. 2010; 4: 193-204.
- Fadel F, Tahrouch S, Elmadidi S, Benddou Q, Hatimi A. Etude morphométrique et physicochimique comparative du caroubier forestier et celui d'une plantation privée. Biomatec-Echo. Maroc. 2011; 4(7): 3-10.
- Ghanemi F Z, Belarbi M, Fluckiger A, Nani A, Dumont A, De Rosny C, Hichami A. Carob leaf polyphenols trigger intrinsic apoptotic pathway and induce cell cycle arrest in colon cancer cells. J Funct Foods. 2017; 33: 112-121.
- Gharnit N, El Mtili N, ToubiEnnabili A, Ennabili A. Social characterization and exploitation of carob tree (*Ceratonia siliqua* L.) from Mokrisset and Bab Taza (NW of Morocco). Science Letters. 2001; 3: 10.
- Gulay MS, Yildiz-Gul O, Ata A, Balic A, Demirtas A. Toxicological Evaluation of Carob (*Ceratonia siliqua*) Bean Extracts in Male New Zealand White Rabbits. Journal of Animal and Veterinary Advances. 2012; 11(11): 1853-1857. doi:10.3923/JAVAA.2012.1853.1857.
- Hsouna AB, Trigui M, Jarraya, RM, Damak, M, Jaoua S. 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. J Med Plants Res. 2015; 9(14): 479-485.

23. Ibrahim AH, Mahmoud R, Abd El-baky, Desoukey SY, Abd-lateff A, Kamel MS. Bacterial Growth Inhibitory Effect of *Ceratonia siliqua* L. Plant Extracts Alone and in Combination with Some Antimicrobial Agents. *J Adv Biotech Bioeng*. 2012; 1: 3-13.
24. Karki A, Tiwari BR. Prevalence of acute diarrhoea in Kathmandu valley. *JNMA; journal of the Nepal Medical Association*. 2007; 46(168): 175-9. doi:10.31729/JNMA.261.
25. Kivçak B, Mert T, Öztürk H T. Antimicrobial and cytotoxic activities of *Ceratonia siliqua* L. extracts. *Turk J Biol*. 2002; 26(4): 197-200.
26. Konate I. Diversité Phénotypique et Moléculaire du Caroubier (*Ceratonia siliqua* L.) et des Bactéries Endophytes qui lui sont Associées. PhD thèse. Univ Mohammed V-Agdal. 2007; 196 p.
27. Archon. *Encyclopedic Dictionary of Archaeology*. 2021;83-83. doi:10.1007/978-3-030-58292-0\_10792.
28. Loeb H, Vandenplas Y, Würsch P, Guesry P. Tannin-rich carob pod for the treatment of acute-onset diarrhea. *Journal of pediatric gastroenterology and nutrition*. 1989; 8(4): 480-485. doi:10.1097/00005176-198905000-00010
29. Marakis S. Carob bean in food and feed: current status and future potentials a critical appraisal. *J Food Sci Technol*. 1996; 33(5): 365-383.
30. Meziani S, Oomah BD, Zaidi F, Simon-Levert A, Bertrand C, Zaidi-Yahiaoui R. Antibacterial activity of carob (*Ceratonia siliqua* L.) extracts against phytopathogenic bacteria *Pectobacterium atrosepticum*. *Microbial pathogenesis*. 2015;78:95-102. doi:10.1016/j.micpath.2014.12.001
31. Meziou-Chebouti N, Merabet A, Behidj N, Kirouani M, Aliouat S. Chemical composition and antibacterial activity of *Ceratonia siliqua* L. growing in Boumerdes (Algeria). In *New Developments in Biology, Biomedical & Chemical Engineering and Materials Science. Proc. Int. Conf. Chem. Engin. Mater. Sci. (CEMS 2015)*, Vienna, Austria. 2015; 15-17, 96-99.
32. Min BR, Hart SP. Tannins for suppression of intestinal parasites. *J Anim Sci*. 2003; 81: 102-109.
33. Oscar S, Antonio C, Marina G, Elsa R, Gabriel V. Phytochemical screening, antioxidant activity and in vitro biological evaluation of leaf extracts of *Hyptis suaveolens* (L.) from south of Mexico. *South African Journal of Botany*. 2020; 128: 62-66. doi:10.1016/j.sajb.2019.10.016.
34. Ortega N, Macià A, Romero M, Trullols E, Morello J, Anglès N, et al. Rapid determination of phenolic compounds and alkaloids of carob flour by improved liquid chromatography tandem mass spectrometry. *Journal of agricultural and food chemistry*. 2009; 57(16): 7239-7244. doi:10.1021/jf901635s.
35. Owen RW, Haubner R, Hull WE, Erben G, Spiegelhalter B, Bartsch H, et al. Isolation and structure elucidation of the major individual polyphenols in carob fibre. *Food and chemical toxicology : an international journal published for the British Industrial Biological Research Association*. 2003; 41(12): 1727-1738. doi:10.1016/S0278-6915(03)00200-X.
36. Özcan MM, Arslan D, Gökçalık H. Some compositional properties and mineral contents of carob (*Ceratonia siliqua*) fruit, flour and syrup. *International Journal of Food Sciences and Nutrition*. 2007; 58(8): 652-658. doi:10.1080/09637480701395549.
37. Priolo A, Waghorn GC, Lanza M, Biondi L, Pennisi P. Polyethylene glycol as a means for reducing the impact of condensed tannins in carob pulp: effects on lamb growth performance and meat quality. *Journal of animal science*. 2000; 78(4): 810. doi:10.2527/2000.784810X.
38. Roseiro LB, Tavares CS, Roseiro JC, Rauter AP. Antioxidants from aqueous decoction of carob pods biomass (*Ceratonia siliqua* L.): Optimisation using response surface methodology and phenolic profile by capillary electrophoresis. *Industrial Crops and Products*. 2013;44:119-126. doi:10.1016/J.INDCROP.2012.11.006.
39. Rtibi K, Selmi S, Grami D, Sebai H, Marzouki L. In vitro  $\alpha$ -amylase/ $\alpha$ -glucosidase inhibitory activities and in vivo improving glucose tolerance and hypoglycemic effect of *Ceratonia siliqua* leaves aqueous extract. *EC Nutrition*. 2018; 13(4): 171-179.
40. Rtibi K, Selmi S, Grami D, Amri M, Eto B, El-Benna J, et al. Chemical constituents and pharmacological actions of carob pods and leaves (*Ceratonia siliqua* L.) on the gastrointestinal tract: A review. *Biomedicine & pharmacotherapy = Biomedecine & pharmacotherapie*. 2017; 93: 522-528. doi:10.1016/j.biopha.2017.06.088.
41. Rtibi K, MA Jabri, S Selmi, A Souli, H Sebai, J El-Benna, et al. Carob pods (*Ceratonia siliqua* L.) inhibit human neutrophils myeloperoxidase and in vitro ROS-scavenging activity. *RSC Adv*. 2015; 5(102): 84207-84215.
42. Rtibi K, S Selmi, MA Jabri, G Mamadou, N Limas-Nzouzi, et al. Effects of aqueous extracts from *Ceratonia siliqua* L. pods on small intestinal motility in rats and jejunal permeability in mice. *RSC Adv*. 2016; 6(50): 44345-44353.
43. Salih G, Jilal A. Utilisation alimentaire de la pulpe de caroube: Formulation et test consommateur. *Rev Mar Sci Agron Vét*. 2020; 8(2): 249-252.
44. Saoud DH, Jelassi A, Hlila MB, Goudjil MB, Ladjel S, Jannet HB. Biological activities of extracts and metabolites isolated from *Anvillea radiata* Coss. & Dur. (Asteraceae). *South African Journal of Botany*. 2019; 121: 386-393. doi:10.1016/J.SAJB.2018.10.033.
45. Say H. Le caroubier au Maroc- Un arbre d'avenir. Centre de Recherche Forestière. Collection Maroc Nature. Haut-Commissariat des Eaux et Forêts et à la Lutte Contre la Désertification. 2008.
46. Serairi-Beji R, Mekki-Zouiten L, Tekaya-Manoubi L, Loueslati MH, Guemira F, Mansour AB. [Can carob powder be used with oral rehydration solutions for the treatment of acute diarrhea?]. *Medecine tropicale : revue du Corps de sante colonial*. 2000; 60(2): 125-8.
47. Tsatsaragkou K, Yiannopoulos S, Kontogiorgi A, Poulli E, Krokida M, Mandala I. Effect of Carob Flour Addition on the Rheological Properties of Gluten-Free Breads. *Food and Bioprocess Technology*. 2013; 7(3): 868-876. doi:10.1007/s11947-013-1104-x.
48. Vekiari S. A., G. Ouzounidou, M. Ozturk and G. Görk, Variation of quality characteristics in Greek and Turkish carob pods during fruit development. *Procedia – Social and Behavioral Sciences*. 2011; 19: 750-755.
49. Williams CL, Bollella M, Spack A, Puder D. Soluble fibre enhances the hypocholesterolemic effect and the step I diet in childhood. *J. Am. College Nutr*. 1995; 14(3): 251- 257.