

Medicinal and curative potential of fenugreek (*Trigonella foenum-graecum* L.) - A review

R.D. Meena*, S.S. Meena, M.D. Meena and P.K. Agrawal

ICAR-National Research Institute on Seed Spices, Ajmer-305206, (Raj.) India.

Abstract

Fenugreek also called methi is commercially cultivated worldwide due to its variety of uses. It has a long history as both a culinary, medicinal and therapeutic herb. The seeds of fenugreek are commonly utilized as a spice in food preparations due to the strong flavour and aroma. Fenugreek seed contains 45-60% carbohydrates, mainly mucilaginous fiber (galactomannan); 20-30% proteins high in lysine and tryptophan; 5- 10% fixed oils (lipids); pyridinetype alkaloids, mainly trigonelline (0.2-0.36%) choline (0.5%), gentianine and carpaine; flavonoids, free amino acids, such as 4- hydroxyisoleucine; arginine, histidine and lysine; calcium and iron; saponins (0.6 -1.7%); cholesterol and sitosterol; vitamins A, B 1, C and nicotinic acid; and 0.015% volatile oils. The fenugreek alkaloidal extract maintains blood glucose level and reduces lipid profile to almost normal and showed antioxidant effect on the tissues of liver and kidney. Ethanolic extract of fenugreek showed antineoplastic effect on the growth of cancer. Fenugreek defends ulcer formation in mouth and food duct. The main chemical constituents responsible the anti-inflammatory activity are alkaloids, saponins, and flavonoids. Fenugreek is also one of the candidates that have been tested for its activity against wide variety of microorganisms such as bacteria, virus, and fungus. Other than these fenugreek also known for various uses. In a number of studies, extracts of fenugreek seeds and some of their constituents have shown anticarcinogenic potency. In addition, fenugreek was reported to have gastroprotective consequence, antimicrobial behavior, anticancer effect, used in treatment of arthritis, increasing milk production, reducing weight and may regulate hyperthyroidism.

Keywords: Curative, disease, fenugreek, medicinal, therapeutic, *Trigonella foenum-graecum*

Introduction

Fenugreek is commercially significant seed spice crop due to its diverse uses. It belongs to the family Fabaceae. According to Meena *et al.*, (2020) fenugreek has wonderful importance in the life of human beings as rations as well as medicine and so it is cultivated for seeds, which can be used as condiments as well as flavoring agent food, pickles etc. There are two cultivated species of genus *Trigonella* viz. *foenum-graecum* (common fenugreek) and *corniculata* (Kasuri type fenugreek). Centre of origin of fenugreek is considered South-Europe, Mediterranean area and Western Asia. The major fenugreek producing nations are India, Argentina, Egypt, France, Morocco, Spain, Turkey and China. Fenugreek is a robustly scented annual herb, is recommended for the treatment of rheumatic in traditional medicine. Historical uses of fenugreek have a prolonged history as both a culinary and medicinal herb in the ancient world. Applications of fenugreek were documented in ancient Egypt, where it was used in incense and to embalm mummies (Morcos *et al.*, 1981). The Greeks and Romans people used it for cattle fodder. In ancient Rome, fenugreek was allegedly used to aid labor and delivery. In traditional

Chinese medicine, fenugreek seeds are used as a tonic, as well as a treatment for weakness and edema of the legs (Yoshikawa *et al.*, 1997). In India, fenugreek is commonly consumed as a condiment and used medicinally as a lactation stimulant (Patil *et al.*, 1997). Saponins, glycoside-D and trigofenoside-A are major components in the seeds (Conti *et al.*, 2010), while alkaloids, cardiac glycosides and phenols are found in the leaf extract (Ozbek *et al.*, 2003). The steroidal saponins present in the seeds as parent compounds for physiological steroid production could influence the local inflammatory response (Yoshikawa *et al.*, 1997, Ahmadiani *et al.*, 2001). Galactomannan, a guar gum comprising approx. 50% of the seed weight is postulated as another active ingredient in fenugreek seeds (Petit *et al.*, 1995). In high sucrose-fed rats, galactomannan feeding reduced appetite, body weight gain, glycemic response, plasma insulin concentrations and plasma triglycerides and total cholesterol concentrations (Sauvaire *et al.*, 1996). In human studies, galactomannan reduced post-prandial blood glucose concentrations (Raghuram *et al.*, 1994; Srichamroen *et al.*, 2008) and improved insulin sensitivity in both non-diabetic and diabetic subjects

(Raghuram and Rao, 1990). Feeding guar-galactomannan fibre reduced both total and LDL cholesterol concentrations in healthy and type 2 diabetic subjects (Fairchild *et al.*, 1996). The aim of this article is to review the literatures that investigate the various medicinal uses of fenugreek plant parts.

Medicinal and Pharmacological Properties of fenugreek

Antidiabetic effect

Diabetes mellitus occurs as a result of disordered metabolism of carbohydrates, lipids and proteins. Though numerous treatments of medications and injectable insulin available, but they have with certain side effects. Diabetes mellitus problem can be normalized through food habits which are not only economic but also rich in nutrition that would assist in maintaining glucose level in blood. Fenugreek (herbal plants) has been quite studied for diabetes management worldwide. Raju *et al.* (2001) has documented that seeds, leaves, and its extracts are a high-quality agent against diabetes. An investigator induced diabetes artificially by streptozotocin in rats and effect of fenugreek water seed extract was determined via diverse doses levels by intragastric intubation. It was also seen by other researchers that weight gained in fenugreek treated mice as compared to the cluster that received only streptozotocin. Similarly other researchers (Xue *et al.*, 2007) found that there was an add to in the body weight of rabbits that were supplemented with fenugreek as compared to the alloxan monohydrate induced diabetic rabbits. A group of scientists (Ramesh *et al.*, 2001) reported the effect of fenugreek seeds on alloxan stimulated diabetic rats. Histopathological analysis of pancreas of placebo controls was done in which normal acini and cytosol in the islets of Langerhans was observed. But there was an extensive damage to islets of Langerhans and reduced dimensions of islets in alloxan induced diabetes. Islets of Langerhans in diabetic rats that were treated with fenugreek extract were found to be restored. Moorthy *et al.* (2010) isolated GII from the aqueous extract of fenugreek seeds which was able to reduce blood glucose in glucose tolerance test in subdiabetic and moderately diabetic rabbits. This showed better consequences than the standard tolbutamide. In Egyptian folk medicine, fenugreek held a key place as a hypoglycemic agent. Gad *et al.* (2006) found the extract of fenugreek in a dose-dependent manner was able to inhibit -amylase activity. A further in vivo study showed repression of starch digestion and absorption in normal rats, suggesting that the hypoglycemic effect of the used plant extract was

mediated through insulin-mimetic effect. The effects on the human patients who had reduced blood glucose concentration after the utilization of either the fenugreek seeds or the leaves. Greater amount of reduction was observed while the whole seed followed by the gum isolated from cooked or uncooked seeds (Sharma, 1986). In different investigation it was observed that, on uninterrupted consumption of fenugreek seeds, serum total cholesterol, LDL and VLDL cholesterol, and triglycerides were drastically reduced (Sharma *et al.* 1990). The important ingredients that are found to be accountable for generating the antidiabetic effects are galactomannan rich soluble fiber part, saponin, and an amino acid called 4-hydroxyleucine which helps in increasing insulin in hyperglycemic rats and humans (Al-Habori *et al.*, 2001).

Antitumor and Anticarcinogenic Activity.

The chemical constituents of fenugreek possess anticancer activity those are phytoestrogens and saponins found in a study (Raju *et al.*, 2004). Saponins selectively inhibit cell division in tumor cells and also can activate apoptotic programs that can guide to programmed cell death called apoptosis (Francis *et al.*, 2002). In an in vivo study that was carried out on rats, azoxymethane was utilized to induce colon cancer. The effect of fenugreek seed powder along with its bioactive compound diosgenin was checked and it was experienced that both the crude extract and diosgenin were able to inhibit the formation of aberrant crypt foci (ACF) which observed as preneoplastic lesion. Following the positive response of the extract in vivo trial, anticancer potential of diosgenin was explored in in vitro experiments. HT-29 human colon cancer cells were used and it was seen that diosgenin repressed the proliferation of cells along with the induction of apoptosis. (Hibasami *et al.*, 2003). Scientists recorded diosgenin to have anti-cancer activity in bone cancer (Shishodia and Aggarwal 2006). Protodioscin, a furostanol saponin isolated from fenugreek, also induces apoptotic changes leading to death in a leukemic cell line (H. Hibasami *et al.*, 2003). Numerous studies on anticancer properties of fenugreek have been done and have revealed positive results. Some constituent of alkaloids, called "trigonelline," has revealed potential for use in cancer therapy (Bhalke *et al.*, 2009). In vivo cytostatic as well as cytotoxic effect of fenugreek seed extract was studied. Breast cancer in the mammalian model, that is, female Wistar rats, was induced by DMBA, a poly-cyclic aromatic hydrocarbon. Inhibition of the mammary hyperplasia and decrease in its occurrence were seen after aqueous seed extract of fenugreek was given every day to the rats at a dose of 200 mg/kg b.wt for 120 days.

(Amin *et al.*, 2005). The ethanolic seed extract reported the anti-neoplastic outcome against Ehrlich Ascites carcinoma cells within mice. The extract resulted in alter in number and growth pattern of ascites cells and tumor growth was also seemed to be considerably inhibited (Ardelean *et al.*, 2010). In artificial studies of the ethanolic seed extract exposed its cytotoxic effect on a number of cancer cell lines such as breast cancer cell lines, prostate cancer cell lines, and pancreatic cancer cell lines (Shabbeer *et al.*, 2009). Various researchers had seen the diosgenin inhibitory effect on the human osteosarcoma cell line, that is, 1547 cell line (Moalic *et al.*, 2001). The machinery of arrest cell cycle at G1 phase and the induction of apoptosis and chemomodulatory effect of fenugreek seed extract was assessed by Chatterjee *et al.* (2012) on two-stage mice skin carcinogenesis. DMBA and TPA were used to induce the skin tumor in mice which was suppressed by methanolic seed extract (Chatterjee *et al.*, 2012). Chloroform seed extract was showed the effective in killing of MCF-7 human immortalized breast cells all the way through induction of apoptosis (Khoja *et al.*, 2011). It was observed in fenugreek seeds during the diet an inhibitor of colon carcinogenesis by modulating the actions of -glucuronidase and mucinase (Devasena and Menon, 2007).

Antioxidant activities:

It has been documented in a variety of studies that fenugreek bears potential of a powerful antioxidant in which the presences of flavonoids and polyphenols have been found to be liable as antioxidants (Amin *et al.*, 2005). The disclosure of polyphenol rich extract of fenugreek seeds which showed defensive effects against hydrogen peroxide induced oxidation by protecting the erythrocytes since haemolysis and lipid peroxidation in a dose dependent manner (Raju *et al.*, 2004). Additional, fenugreek administration to diabetic animals showed a reversal of the disturbed antioxidant levels of enzymes such as catalase, superoxide dismutase and glutathione peroxidase and peroxidative harm in the tissues of heart and kidney (Dixit *et al.*, 2005). Supplementation of fenugreek seed powder to diabetic rats normalized the modifications in lipid peroxidation and oxidative stress (Kaviarasan *et al.*, 2004). In different green plant parts of fenugreek, maximum phenolic content and flavonoid contents were observed in distilled water extract followed by methanol and ethyl acetate. Cryogrinding techniques get better its antioxidant activity and retains medicinal properties by prevent molecules which good for human health (Genet *et al.*, 2002). The ability of fenugreek as functional food tested by determining the lipid peroxidation (LPO), and

cyclooxygenase enzyme (COX) inhibitory activities of hexane, ethyl acetate, methanolic and water extracts. The extracts repressed the LPO by 50-95%, CCOX-1 by 6-87 % and COX-2 by 36-70 % respectively (Anuradha and Ravikumar, 2001).

Anti ulcer activity

It is worth noting that fenugreek protects ulcer formation in rats via declining gastric volume, ulcer index value, total acidity, lesion formation and restorative ratio by markedly increasing the level of mucus secretion (Balaraman *et al.*, 2006). It may be due to the cytoprotective action of fenugreek can be attributed to the existence of flavonoids; which exert their anti ulcer effect.

Gastroprotective Effect.

In addition to different category of extracts, researchers have tried to extract oil from fenugreek seed which also possesses pharmacological characters. One such character is gastroprotective action observed in oil extracted from fenugreek seed. The occurrence of gastric ulceration, mean ulcer score, and ulcer index were found to be significantly decreased in a cluster of mice subjected to indomethacin to induce ulcer. The decrease in the gastric ulcer can be attributed to phytic acid, saponins, and trigonelline established in the essential oil of fenugreek (Kamel *et al.*, 2014). One of the studies exposed protective effect of aqueous extract of fenugreek seed against reflux esophagitis (RE) in rats and thus its potential to be used in clinical trial studies (Kheirandish *et al.*, 2013).

Anti-Inflammatory Activity

Fenugreek is utilized as a traditional remedy in several countries namely Iran, India, and African countries as a remedy for inflammation. The main chemical constituents responsible for the anti-inflammatory activity are alkaloids, saponins, and flavonoids. Sharififara *et al.* (2009) studied in vivo effect of methanolic extract using cream based system. Inflammation in terms was induced in Wistar rats using caseinogen and anti-inflammatory consequence was observed both by intraperitoneal administration and by the topical application in form of the cream. In a study the anti-inflammatory and antimelanogenic effect under artificial environmental (in vitro) system using human mono-cytic cell line (THP-1) were seen (Kawabata *et al.*, 2011). Production of inflammatory cytokines such as IL-1, IL-6, and TNF- was initiated using phorbol myristate acetate. Inhibitory action of fenugreek extract through methanol as a solvent system was observed with suppression in TNF- production. The inhibitory effects were concentration reliant. TNF-protein levels in the liver

and plasma of obese rats were found to be upregulated when fenugreek was orally consumed. This is an indicator of opposing activity of fenugreek seed on the production of TNF-. There are a few complex mechanisms (e.g., digestion, uptake, and metabolism) by which orally administered substance(s) can modulate biological mediators in vivo (Kawabata *et al.*, 2011). Sumanth *et al.* (2011) observed the anti-inflammatory effect in opposition to the ulcer production. Immersion stress and indomethacin were used to induce ulcer in rats. The aqueous extract of fenugreek seeds showed the antiulcer effect as calculated by the ulcer index (Raju and Bird, 2006). The defensive activity of the extract against ulcer was attributed to its known antioxidant activity. Not only seeds but also antipyretic and anti-inflammatory activity of the leaves of *T. foenum-graecum* has been reported (Sumanth *et al.*, 2011). Ravichandiran and Jayakumari (2013) compared the anti-inflammatory activity of fenugreek seed and leaves extract both in in vivo and in in vitro systems. It was observed that aqueous extract of leaves of fenugreek were effective against anti-inflammatory activity (Ahmadiani *et al.*, 2001). Fenugreek accelerates the wound healing procedure in rats injured in the posterior neck area due to its antioxidant potential (Ravichandiran and S. Jayakumari, 2013).

Obesity reducing action:

The beneficial effects of fenugreek fiber was investigated in healthy obese subjects which demonstrated that fenugreek administration showed marked boost in satiety (stopping eating food) and fullness and marked fall in hunger and prospective food consumption with reduced energy intake using visual analog scale which can act supportive for treating acute obesity patients. Galactomannan and unpalatably of the fenugreek fiber is understood to be responsible for promoting satiety by declining the rates of gastric emptying and decreased energy intake respectively (Mitra and Bhattacharya, 2006).

Hypertension activity

It has been explicated that the administration of fenugreek methanol extract and methanol fraction to rats shows antihypertensive. The essential oil obtained from fenugreek in mixture with other essential oils has been employed to reduce systolic blood pressure in spontaneously hypertensive rat (Sharififara *et al.*, 2009). The aqueous and benzene extract of fenugreek has been found to show diuretic activity in rats; which can be employed to cure hypertension (Abdullah *et al.*, 2007).

Anticholesterol activity

Fenugreek extracts has been examined not limited to the

rats and mice as they were also performed on various species of rabbits. Singhal *et al.* (1982) studied that the inclusion of fenugreek seeds as a diet constituent for the mice aided in reducing cholesterol level up to 42% and 58% equally in control group and in hypocholesterolemic group, respectively. An additional study was done to test the effects of fenugreek leaves on the cholesterol level. Reduction in total blood cholesterol, LDL, VLDL level, and triglycerides and there was an increase in HDL cholesterol level noticed after the consumption of dried fenugreek leaves in Albino rabbits (Hannan *et al.*, 2003). Presence of cholesterol in plasma is a sign of coronary heart disease. Fenugreek seed administration and its extracts drastically decreased plasma cholesterol, triglyceride, and LDL cholesterol. However, HDL cholesterol level was found to be stable; that is, no effect was registered on it (Chatterjee *et al.*, 2013). Isolation of a compound named GII from the seed extract of fenugreek with water and was GII able to decrease the total cholesterol level and increase HDL cholesterol which is an indicator of good cholesterol (Moorthy *et al.*, 2010).

Antigenotoxic Activity.

Investigators have examined the antigenotoxic effect of fenugreek. Root tip meristem cells of onion (*Allium cepa* L.) were treated with toxic chromium trioxide. Methanolic extract of the leaves of fenugreek (*Trigonell foenum-graecum*) showed dose-dependent decrease in chromosomal aberration in onion roots. Studies have been done in microbial systems to monitor the antimutagenic effect of fenugreek. Aqueous extract of fenugreek seeds inhibited the mutagenic activity of direct acting mutagens against *Salmonella typhimurium*, an infectious gram negative bacterium (Sharma *et al.*, 2012).

Antimicrobial Activity.

A lot of plants such as *Coriandrum sativum*, *Curcuma longa*, *Citrus lemon*, and *Ocimum sanctum* have been studied by the scientists who demonstrated antimicrobial action. Among them, fenugreek is also one of the candidates that have been tested for its activity against wide diversity of microorganisms such as bacteria, virus, and fungus (Dash *et al.*, 2011, Sheikhlar *et al.*, 2013, Chandra *et al.*, 2011, Moradi and Moradi, 2013). Dash *et al.* (2011) reported that sensitivity of the extracts against bacteria is dependent on the solvent system and the kind of microorganisms. Different approaches were employed to prepare the aqueous extract of fenugreek by Sheikhlar *et al.* (2013) and along with him co-workers; study was conducted on methanolic extract and aqueous extract against bacteria.

The methanolic extract showed activity, while the aqueous extract showed no activity at every concentrations. Chandra *et al.* (2011) made the aqueous extract of fenugreek seeds and employed disc diffusion method to study the antibacterial effect on three bacteria, namely, *Escherichia coli* (intestinal bacterium), *Pseudomonas putida*, and *Malassezia furfur* (skin fungus). The extract was found to be effective against *E. coli* and *M. furfur* but showed no reaction against *P. putida* (Chandra *et al.*, 2011). Crude extract of fenugreek seeds using methanol and acetone was tested against the four Gram-negative bacteria. The methanolic extract showed the wide range specificity towards various species, *S. typhi* showed resistance towards the acetonic extract. Also along with all the four different strains *E. coli* was found to show the highest sensitivity reaction towards acetonic extract. It is also recommended that sprouted or the germinated seeds had improved antimicrobial activity specifically against *H. pylori* (Moradi and Moradi 2013). Secondary metabolites in fenugreek seed extract possessed the anti-microbial activity as could be understood by various studies done by scientists. Similarly, these constituents can be found in the leaves of the fenugreek herb which can also exhibit the same property. Fungus being one of the abundant microorganisms has also shown its sensitivity towards one of the proteins called defensin extracted from fenugreek leaves. Defensin repressed the mycelial growth of *Rhizoctonia solani* (soil born fungus) and inhibited spore germination and consequential hyphal growth of leaf spot causing plant pathogen, *Phaeoisariopsis* (Olli and Kirti, 2006).

Other Disorders

Administration of fenugreek seed extract to together mice and rats revealed its effect on thyroid hormone that fenugreek restrains the synthesis of tri-iodothyronine concentration estimated by decrease in serum tri-iodothyronine concentration and T3/T4 ratio and consequently increased thyroxine levels which may be mediated through fenugreek-induced hypoglycaemia (Talpur *et al.*, 2005). It has been recorded that oral treatment with fenugreek reduced the quantity of calcium oxalate deposited in the kidneys stimulated by 3% glycolic acid in rats; which further supports its use in Saudi folk medicine (Rohini *et al.*, 2009). Fenugreek showed anti-cataract property in sodium selenite-induced cataract in rats by restoring the levels of glutathione, and additional antioxidant enzymes such as superoxide dismutase, catalase, etc, in the lens and inhibiting the lipid peroxidation (Sebastiana and Thampanb, 2007). The alkaloidal, ethanol and butanol extract of fenugreek has been established to possess

anti plasmodial activity against in vitro culture of chloroquine sensitive and resistant *Plasmodium falciparum* (Panda *et al.* 1999).

Anti-arthritic (Rheumatic) activity

Fenugreek is known since ancient time to treat and recommended for rheumatic (Arthritic) problems and joint pain (Asadi, 2014) in the body in traditional medicine. Saponins, glycoside-D and trigofenoside-A are major components in the seeds responsible for treating this problem

Conclusion

Fenugreek has an wide-ranging variety of actions which are probably to defend the human body against a variety of abuses and infections. Fenugreek has the potential to ameliorate diabetes mellitus exhibited through stimulating glycolytic enzymes, inhibiting gluconeogenesis. Moreover, the exaggerated action of fenugreek in treating cancer has been demonstrated all the way through various methods such as induction of apoptosis (cell death), inhibition of cell proliferation (increasing number of cells) and arachidonic acid pathway. Enhancing body of proof suggests that oxidative strain plays a vital role in the induction and progression of a variety of disorders such as Parkinson's disease, atherosclerosis, myocardial infarction, heart failure and Alzheimer's disease. However the promising antioxidant effect of fenugreek needs to be investigated in these diseases. In spite of an assortment of pleiotropic actions of fenugreek on chronic disorders such as obesity (fat body), inflammation, hypertension and ulcers, the related clinical applications of fenugreek is still in the queue of thir vicinity of research. Consequently, more focused research on specific experimental models, human trials and an understanding the instrument of action is essential.

Reference

- Abdullah, M.A., Al-Bayati, F.H., Ali, NAW and Baharuddin, N.A. 2007. Wound healing potential of *Ageratum conyzoides*, *Trigonella foenum-graceum* and *Ginkgo biloba* paste in rats. *Dentika Dental J.* 12:22-25.
- Ahmadiani, A., Javan, M., Semnianian, S., Barat, E. and Kamalinejad, M. 2001. Anti-inflammatory and antipyretic effects of *Trigonella foenum-graecum* leaves extract in the rat. *J. Ethnopharmacol.* 75:283-286.
- Al-Asadi, J.N. 2014. Therapeutic Uses of Fenugreek (*Trigonella foenum-graecum* L.). *American J. Social Issues and Humanities.* 21-36.
- Al-Habori, M., Raman, A., Lawrence, M.J. and Skett, P.

2001. In vitro effect of fenugreek extracts on intestinal sodium-dependent glucose uptake and hepatic glycogen phosphorylase A, *Inter. Journal of Experimental Diabetes Research*, 2(2):91–99.
- Amin, A., Alkaabi, A., Al-Falasi, S. and Daoud, S.A. 2005. Chemopreventive activities of *Trigonella Foenum Graecum* against breast cancer. *Cell Biol Intern* 29:687-94.
- Anuradha, C.V. and Ravikumar, P. 2001. Restoration on tissue antioxidants by fenugreek seeds (*Trigonella foenum -graecum*) in allox and iabetic rats. *Indian J Physiol Pharmacol*, 45:408-20.
- Ardelean, A., Pribac, G. and Hermenean, A. 2010. Cytostatic and cytotoxic effects of *Trigonella foenum-graecum* (fenugreek) seed extract, *Studia Universitatis Vasile Goldis, Seria S, tiint, ele Viet, ii*, 20(1):25–29.
- Balaraman, R., Dangwal, S. and Mohan, M. 2006. Antihypertensive effect of *Trigonella foenum-graecum* seeds in experimentally induced hypertension in rats. *Pharmaceut Bio*, 144:568-75.
- Bhalke, R.D., Anarthe, S.J., Sasane, K.D., Satpute, S.N., Shinde, S.N. and Sangle, V.S. 2009. Antinociceptive activity of *Trigonella foenum-graecum* leaves and seeds (Fabaceae), *Int. J. Pharmacy and Technology*, 8(2):57–59.
- Chandra, R., Dwivedi, V., Shivam, K. and Jha, A.K. 2011. Detection of Antimicrobial Activity of *Oscimum sanctum* (Tulsi) and *Trigonella foenum-graecum* (Methi) against some selected bacterial and fungal strains. *Research J Pharmaceutical, Biological and Chemical Sciences*, 2(4):809-812.
- Chatterjee, S., Goswami, N., Bhatnagar, P., Kumar, M. and Kumar, A. 2013. Antimutagenic and chemopreventive potentialities of fenugreek (*Trigonella foenum-graecum*) graecum seed extract,” *Oxidants and Antioxidants in Medical Science*, 2(1):45–53.
- Chatterjee, S., Kumar, M. and Kumar, A. 2012. Chemomodulatory effect of *Trigonella foenum-graecum* (L.) seed extract on two stage mouse skin carcinogenesis, *Toxicology International*, 19(3):287–294.
- Conti, B., Canale, A., Bertorli, A., Gozzini, F. and Piselli, L. 2010. Essential oil composition and larvicidal activity of six Mediterranean aromatic plants against the mosquito *Aedes albopictus* (Diptera: Culicidae). *Parasitol Res*, 107:1455-61.
- Dash, B. K., Sultana, S. and Sultana, N. 2011. Antibacterial activities of methanol and acetone extracts of Fenugreek (*Trigonella foenu-graecum*) and Coriander (*Corindrum sativum*). *Life Sciences and Medicine Research*, pp1–8.
- Devasena, T. and Menon, P.V. 2007. Fenugreek seeds modulate 1, 2-dimethylhydrazine-induced hepatic oxidative stress during colon carcinogenesis. *Ital J. Biochem*, 56:28–34.
- Dixit, P., Ghaskadbi, S., Mohan, H. and Devasagayam, T.P.A. 2005. Antioxidant properties of germinated fenugreek seeds. *Phytother Res*, 19:977-83.
- Fairchild, R.M., Ellis, P.R., Byrne, A.J., Luzio, S.D. and Mir, M.A. 1996. A new breakfast cereal containing guar gum reduces postprandial plasma glucose and insulin concentrations in normal-weight human subjects. *Br J Nutr*, 76:63-73.
- Francis, G., Kerem Z, Makkar, P.S. and Becker, K. 2002. The biological action of saponins in animals systems: a review, *British J. Nutrition*, 88:587–605.
- Gad, M.Z., El-Sawalhi, M.M., Ismail, M.F. and El-Tanbouly, N.D. 2006. Biochemical study of the anti-diabetic action of the Egyptian plants, fenugreek and balanites, *Molecular and Cellular Biochemistry*, 281:173–183.
- Genet, S., Kale, R.K. and Baquer, N.Z. 2002. Alterations in antioxidant enzymes and oxidative damage in experimental diabetic rat tissues: Effect of vanadate and fenugreek (*Trigonella foenum graecum*). *Molecular Cell Biochem*, 236:7-12.
- Hannan, J.M., Rokeya, B. and Faruque, O. 2003. Effect of soluble dietary fibre fraction of *Trigonella foenum-graecum* on glycemic, insulinemic, lipidemic and platelet aggregation status of Type 2 diabetic model rat. *J Ethnopharmacol*, 88:73–7.
- Hibasami, H., Moteki, H., Ishikawa, K., Katsuzaki, H., Imai, K., Yoshioka, K., Ishii, Y. and Komiya, T. 2003. Protodioscin isolated from fenugreek (*Trigonella foenum-graecum* L.) induces cell death and morphological change indicative of apoptosis in leukemic cell line H- 60, but not in gastric cancer cell line KATO III. *Int J. Mol Med.*, 11(1):23-26.
- Kamel, M.A., Hamza, R.Z., Abdel-Hamid, N.E. and Mahmoud, F.A. 2014, Anti-ulcer and gastro protective effects of fenugreek, ginger and peppermint oils in experimentally induced gastric ulcer in rats. *J. Chemical and Pharmaceutical Research*, 6(2):451-468.
- Kaviarasan, S., Vijayalakshmi, K. and Anuradha, C.V. 2004. Polyphenol rich extract of fenugreek seeds

- protect erythrocytes from oxidative damage. *Plant Foods Human Nut*, 59:143-47.
- Kawabata, T., Cui, M.Y. and Hasegawa, T. 2011. Anti-inflammatory and anti-melanogenic steroidal saponin glycosides from Fenugreek (*Trigonella foenum-graecum* L.) seeds. *Planta Med.*, 77:705–10.
- Kheirndish, R., Azari, O. and Shojaeepour, S. 2013. protective effect of Fenugreek (*Trigonella foenum-graecum*) seed extract on ex-perimental reflux esophagitis in rat,” *Iranian J. Veteri-nary Surgery*, 8(2):49–56.
- Khoja, K.K., Shafi, G. and Hasan, T.N. 2011. Fenugreek, a naturally occurring edible spice, kills MCF-7 human breast cancer cells via an apoptotic pathway,” *Asian Pacific J. Cancer Prevention*, 12(12):3299–3304.
- Meena, R.D., Meena, R.S., Sharma, Y.K., Meena, S.S. and Meena, N.L. 2020. Response of fenugreek varieties against *Rhizoctonia solani*, causing root rot. *International J. Seed Spices*, 10(1):73-75
- Mitra, A. and Bhattacharya, D.P. 2006. Effect of fenugreek in type 2 diabetes and dyslipidaemia. *Indian J. Practising Doctor*, 3:14-18.
- Moalic, S., Liagre, B. and Corbiere, C. 2001. A plant steroid, dios-genin, induces apoptosis, cell cycle arrest and COX activity in osteosarcoma cells,” *FEBS Letters*, 506(3):225–230.
- Moorthy, R., Prabhu, K.M. and Murthi, P.S. 2010. Antihypoglycemic compounds GII) from fenugreek (*Triginella foenum-graecum* L.) seed, its purification and effect in diabetes mellitus. *Indian J. Experimental Biology*, 48:1111-1118.
- Moradi, N. and Moradi, K. 2013. Physiological and pharmaceuti-cal effects of fenugreek (*Trigonella foenum-graecum* L.) as a multipurpose and valuable medicinal plant. *Global Journal of Medicinal Plant Research*, 1(2):199–206.
- Morcos, S.R., Elhawary, Z. and Gabrial, G.N. 1981. Proteinrich food mixtures for feeding the young in Egypt. 1. Formulation. *Z Ernahrungswiss*; 20:275-282.
- Olli, S. and Kirti, P.B. 2006. Cloning, characterization and antifungal activity of defensin Tfgd 1 from *Trigonella foenum-graecum* L. *J Biochem Mol Biol*, 39:278–83.
- Ozbek, H., Ugras, S., Dulger, H., Bayram, I., Tuncer, I., Ozturk, G. and Ozturk, A. 2003. Hepatoprotective effect of *F. vulgare* essential oil. *Fitoterapia*, 74:317-19.
- Tahiliani, P. and Kar, A. 1999. Inhibition of triiodothyro-nine production by fenugreek seed extract in mice and rats. *Pharmacological Research*, 40(5):405–409.
- Patil, S.P., Niphadkar, P.V. and Bapat, M.M. 1997. Allergy to fenugreek (*Trigonella foenum graecum*). *Ann Allergy Asthma Immunol*, 78:297-300.
- Petit, P.R., Sauvaire, Y.D., Hillaire-Buys, D.M., Leconte, O.M., Baissac, Y.G., Ponsin, G.R. and Ribes, G.R. 1995. Steroid saponins from fenugreek seeds: extraction, purification, and pharmacological investigation on feeding behavior and plasma cholesterol. *Steroids*, 60:674-680.
- Raghuram, T.C., Sharma, R.D., Sivakumar, B. and Sahay, B.K. 1994. Effect of fenugreek seeds on intravenous glucose disposition in non-insulin-dependent diabetic-patients. *Phytother Res*. 8:83-86.
- Raju, J. and Bird, R.P. 2006. Alleviation of hepatic steatosis accompanied by modulation of plasma and liver TNF-alpha levels by *Trigonella foenum-graecum* (fenugreek) seeds in Zucker obese (fa/fa) rats. *Int J Obese (Lond)*, 30:1298–307.
- Raju, J., Gupta, D., Rao, A.R., Yadava, P.K. and Baquer, N.Z. 2001. *Trigonella foenum graecum* (fenugreek) seed powder improves glucose homeostasis in alloxan diabetic rat tissues by reversing the altered glycolytic, gluconeogenic and lipogenic enzymes. *Mol. Cell.Biochem.*, 224:45–51.
- Raju, J., Patlolla, J.M.R., Swamy, M.V. and Rao, C.V. 2004. Diosgenin, a steroid saponin of *Trigonella Foenum Graecum* (fenugreek), inhibits azoxymethane-induced aberrant crypt foci formation in f344 rats and induces apoptosis in HT-29 human colon cancer cells, *Cancer. Epidemiol Biomarkers Prev*, 13:1392-98.
- Ramesh, H.P., Yamaki, K., Ono, H. and Tsushida, T. 2001. Two-dimensional NMR spectroscopic studies of fenugreek (*Trigonella foenum-graecum* L.) galactomannan without chemical fragmenta-tion. *Carbohydr. Polym.*, 45:69–77.
- Ravichandiran, V. and Jayakumari, S. 2013. Comparative study of bioactive fraction of *Trigonella foenum graecum* L. leaf and seed extracts for inflammation,” *Int. J. Frontiers in Science and Technology*, 1(2):128–148.
- Rohini, R.M., Nayeem, M. and Das, A.K. 2009. Diuretic effect of *Trigonella foenum- graecum* seed extracts. *Intern J Altern Med.*, 6:2.

- Sauvaire, Y., Baissac, Y., Leconte, O., Petit, P. and Ribes, G. 1996. Steroid saponins from fenugreek and some of their biological properties. *Adv Exp Med Biol*, 405:37-46.
- Sebastiana, K.S. and Thampanb, R.V. 2007. Differential effects of soybean and fenugreek extracts on the growth of MCF-7 cells. *Chemico-Biol Interactions*, 170:135-43.
- Shabbeer, S., Sobolewski, M. and Anchoori, R.K. 2009. Fenugreek: A naturally occurring edible spice as an anticancer agent. *Cancer Biol Ther*, 8:272-8.
- Shariffara, F., Khazaelia, P. and Allib, N. 2009. In vivo evaluation of anti-inflammatory activity of topical preparations from fenugreek (*Trigonella foenum-graecum* L.) seeds in a cream base. *Iranian J Pharmaceut Sci*, 5:157-62.
- Sharma, A., Kumar, M., Chandel, M. and Kaur, S.J. 2012. Modulation of chromium trioxide induced genotoxicity by methanol extract of leaves of *Trigonella foenum-graecum* L. *J. Experimental and Integrative Medicine*, 29(1):77-83.
- Sharma, R.D. 1986. Effect of fenugreek seeds and leaves on blood glucose and serum insulin responses in human subjects, *Nutrition Research*, 6 (12):1353-1364.
- Raghuram, T.C. and Rao, N.S. 1990. Effect of fenugreek seeds on blood-glucose and serum-lipids in type-I diabetes. *Eur J Clin Nutr.*, 44:301-306.
- Sheikhlar, A., Alimon, A.R., Daud, H.M., Saad, C.R. and Shanagi, H. 2013. screening of *Morus alba*, *Citrus limon* and *Trigonella foenum-graecum* extracts for antimicrobial properties and phy-tochemical compounds. *J. Biological Sciences*, 13(5) :386-392.
- Shishodia, S. and Aggarwal, B.B. 2006. Diosgenin inhibits osteoclastogenesis, invasion, and proliferation through the downregulation of Akt, I B kinase activation and NF- B-regulated gene expression. *Oncogene*, 25(10):1463-1473.
- Singhal, P.C., Gupta, R.K. and Joshi. L.D. 1982. Hypocholesterolemic effect of seeds. *Current Science*, 51:136-137.
- Srichamroen, A., Field, C.J., Thomson, A.B.R. and Basu, T.K. 2008. The modifying effects of galactomannan from Canadian-grown fenugreek (*Trigonella foenum-graecum* L.) on the glycemic and lipidemic status in rats. *J Clin Biochem Nutr*, 43:167-174.
- Sumanth, M., Kapil, P. and Mihir, P. 2011. Screening of aqueous extract of *Trigonella foenum graecum* seeds for its antiulcer activity, *Int.J.Research in Pharmaceutical and Biomedical Sciences*, 2(3):1085-1089.
- Talpur, N., Echard, B., Ingram, C. and Bagchi, D. 2005. Effects of a novel formulation of essential oils on glucose-insulin metabolism in diabetic and hypertensive rats: a pilot study. *Diab Obes Metab.*, 7:193-99.
- Xue, W.L., Li, X.S., Zhang, J., Liu, Y.H., Wang, Z.L. and Zhang, R.J. 2007. Effect of *Trigonella foenum-graecum* (fenugreek) extract on blood glucose, blood lipid and hemorheological properties in streptozotocin-induced diabetic rats. *Asia Pac. J. Clin. Nutr.*, 1:422-426.
- Yoshikawa, M., Murakami, T., Komatsu, H., Murakami, N., Yamahara, J. and Matsuda, H. 1997. Medicinal foodstuffs. IV. Fenugreek seed. (1): structures of trigoneosides Ia, Ib, IIa, IIb, IIIa, and IIIb, new furostanol saponins from the seeds of Indian *Trigonella foenum-graecum* L. *Chem Pharm Bull* (Tokyo), 45: 81-87.

Received : October 2020; Revised : November 2020;
Accepted : December 2020.