FENUGREEK NUTRACEUTICAL PROPERTIES AND UTILIZATION IN VARIOUS FOOD PRODUCTS

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Content

Summary

The present chapter reviews about nutraceutical properties of fenugreek (*Trigonella foenum graecum* L.) and its utilization in various product developments. Fenugreek is a medicinal herb with nutraceutical properties. It has been used globally as a spice to increase the organoleptic properties of foodstuffs. Nutraceutical properties of fenugreek owes to its bioactive compounds. Fenugreek has been observed to have hypoglycemic, anti-carcinogenic, anti-cholesterolemic effect and immunological properties. The antioxidant properties of fenugreek reduce the damage caused by reactive oxygen species. Besides its nutraceutical properties, fenugreek has been taken as a food. It has been used as an adhesive, stabilizer and emulsifying agent. Moreover, recently it has been used for the development of functional foods such as healthy nutritious extruded and bakery product.

1. Introduction

Fenugreek (*Trigonella foenum graecum* L.) leaves and seeds have been used in food as a spice. Fresh leaves are edible and have been used for culinary purpose (Figure 1). They have been used globally for enhancing the sensory acceptability of the food product. Although, fenugreek has slightly bitter and somewhat sweet kernels but they

have well acceptability as flavoring agent for foodstuff (Betty, 2008). Besides its utilization as spice, it has been consumed as a medicinal herb due to its beneficial health effects such as reducing the level of blood glucose in diabetics, controls the growth of cancer, lowers the level of cholesterol, prevents or delays oxidation by free radicals and improved immunological activities (Wani and Kumar, 2018). Among the beneficial health effects such as anti-diabetic and hypocholesterolemia are ascribed due to the intrinsic dietary fiber constituent (Srinivasan, 2006). Brilliant functional and medicinal properties of fenugreek are accredited to its chemical composition. Fenugreek is well recognized for its fiber, gum and bioactive compounds. Fenugreek have been used as an ingredient for the development of various food product (Wani and Kumar, 2015, 2016, Shirani and Ganesharanee, 2009), as an additive to foods such as emulsifying agent, adhesive and stabilizer (Meghwal and Goswami, 2012). Bioactive compounds including, trigonelline, 4-hydroxyisoleucine, diosgenin, polyphenols such as quercetin and galactomannan are responsible for biomedical activities of fenugreek. Beneficial physiological effects of fenugreek have been correlated to diabetes mellitus. It has been found to play an important role as dietary reformer on the metabolism and physiology and the influence on the biologic mechanisms action with respect to diabetes mellitus and various other biological diseases. Wonderful medicinal and functional properties of fenugreek are accredited to its chemical composition. Hence, fenugreek can be appraised among the wonder spices with the huge scope in endorsing it as an outstanding and worthy source of nutraceutical (Srinivasa and Naidu, 2021). Table 1 below shows the chemical composition of fenugreek seed and dried leaf powder. This review covers the updated version of nutraceutical features and possible food uses of fenugreek that has not been so far reviewed.

Figure 1. Fenugreek leaves and Seeds

Parameters	Fenugreek seed flour	Fresh fenugreek Leaves
Moisture (%)	7.38	86.0
Ash (%)	3.72	-
Crude protein (%)	27.7	4.4
Crude fat (%)	6.42	1.0
Crude fibre (%)	7.09	1.0
Total carbohydrate (%)	47.64	-
Total energy (kcal)	387.7	-
Calcium (mg/100g)	176	395 mg

Potassium (mg/100g)	770	31 mg
Sodium (mg/100g)	67	76 mg
Iron (mg/100g)	34	16.5 mg
Zinc (mg/100g)	3	-
Mg	160 mg	67 mg
P	370 mg	51 mg
Cu	33 mg	0.26 mg
S	16 mg	167 mg
Cl	165 mg	165 mg
Choline	50 mg	1.35 g
Vitamin C	43 mg	52 mg
β-Carotene	96µg	2.3 mg
Thiamine	340µg	40µg
Riboflavin	290µg	310µg
Nicotinic acid	1.1 mg	800µg
Folic acid	84µg	

Table 1. Chemical composition of fenugreek with values expressed per 100g. (Wani and Kumar, 2015; Srinivasan, 2006)

1.1 Bioactive Compounds in Fenugreek Seeds

The fenugreek seeds are a very good source of bioactive compounds. Main bioactive compounds found are diosgenin, trigocoumarin, trigonelline, nicotinic acid, trimethyl coumarin, steroids, alkaloids, flavonoids and sapogenins. Main volatile compoounds of fenugreek such as stallone and anethole too have bioactivity (Bahmani et al., 2016; Belguith-Hadriche et al., 2010; Nagulapalli Venkata et al., 2017; Sarwar et al., 2020; Kousalya et al., 2019). Presence of alkaloids, flavonoids and steroids in fenugreek make its usage as therapeutic and hormonal drug (Yadav and Baquer, 2014). Fenugreek seeds are also rich in caffeic acid and kaempferol (Benayad et al., 2014), galactomannan and 4-hydroxyisoleucine (Bano et al., 2016). Figure 2 shows the structure of some of the major chemical constituents of fenugreek identified with HPLC-QTOF MS/MS analysis (Singh et al., 2020). Percentage of some of the major bioactive compounds such as yamogenin based saponin (4.8%), volatile oil (1.24%), diosgenin (0.6 to 1.7%), trigonelline (0.2 to 0.38%), and C-glycosyl flavones of apigenin and luteolin (0.10%) (Yao et al., 2020). The health promising benefits of fenugreek and polyphenol attracted many researchers toward plant phenols like stilbenes. Resveratrol (3, 5, 4-trihydroxy-trans-stilbene) is one of the most popular polyphenols that work on obesity, cardiovascular preventive agents, anti-diabetic, and neuroprotective properties. Fenugreek diosgenin is a steroidal compound. Diosgenin is spriostanol saponins comprising a hydrophobic steroid aglycone which is linked to the hydrophilic sugar moiety sapogenin that is present in fenugreek seeds. Diosgenin is a major precursor used to produce synthetic steroids in the pharmaceutical industry (Raju and Chinthalapally, 2012). Fenugreek seeds are recognized as a potential source of diosgenin which is a basic compound in the synthesis of the steroid drugs like cortisone and sexual hormones (Marker et al., 1947).

Steroidal sapogenin is a class of secondary metabolites that belong to the biosynthetic forerunners are sterols especially cholesterol (Dangi et al., 2016) and are found as glycosides that are known as steroidal sapogenins. Fenugreek seed diosgenin (25R-spirost-en-3b-ol) is a plant-derived steroidal sapogenin that is extensively used to produce sex hormones, steroidal drugs, and oral contraceptives due to its wide pharmaceutical properties. Diosgenin has potential against various day to day life disorders like cardiovascular diseases, cancer, skin irritation, oxidative stress, obesity, hyperlipidaemia, osteoporosis, and neurological disorder (Deshpande and Sanjivani, 2014; Cai et al., 2020). The low solubility and less bioavailability of diosgenin made it difficult to delve into the medicinal and health promising properties of diosgenin (Cai et al., 2020). The bioactive potential of fenugreek also cures the damage caused by day-to-day life stress. It could be rectified by the consumption of an appropriate amount of phenolic, and anti-oxidant compounds that cause a delay in the oxidation of food as they eliminate oxygen and nitrogen reactive species that affect the DNA, protein, and lipid of the living system (Amarowicz and Fereidoon, 2017).

Major Chemical Compound	Chemical Compounds	Reference
Saponin	Fenugreekine, Trigofoenosides A-G, Fenugrin B	Kousalya et al., (2019)
Steroidal saponin	Diosgenin, apigenin, tigogenin, yamogenin, gitogenin, neogetigenin, smilagenin, sarsasapogenin, yuccagenin, hederagin	Ahmad et al., (2016)
Flavonoids	Luteloin, tricine, calycosin, orientin, quercetin, glycopyronaside, tricin-7-O-D, lilyn, kaempferol	Blumenthal et al., (2000)
Alkaloids	Trigonelline, choline, gentianine, carpaine	Rababah et al., (2011)
Amino acids	Arginine, Glycine, Histidine, Isoleucine, Leucine, Lysine, Methionine, Phenylalanine, Threonine, Tyrosine Valine	Yasothai, 2021
Lipids	Total lipids comprised of 84.1% neutral lipids, 5.4% glycolipids and 10.5% phospholipids. Among them neutral lipids comprised particularly of 86% of triacylglycerols, 6.3% diacylglycerols and minor amount of sterols, free fatty acids and monoacylglycerols. Glycolipids include Acylmonogalactosyldiacylglycerol and acylatedsterylglycoside, sterylglucoside, monogalactosylmonoacylglycerol and digalactosyldiacylglycerol. The phospholipids comprising of phosphatidylcholine, phosphatidylethanolamine, phosphatidylserine, lysophosphatidylcholine, phosphatidylinositol, phosphatidylglycerol, and phosphatidic acid. (Hemavathy and Prabhakar,1989) (Chatterjee, Variyar and Sharma, 2010)	

Vitamins	Vitamin C, Vitamin B1, Vitamin B2, Vitamin B6, Vitamin A, Niacin, Nicotinic Acid, β-carotene, Folic acid	(Srinivasan, 2006); Ahmad et al., 2016)
Coumarins	Methyl coumarin, trigocumarin, trimethyl coumarin	Raju et al. (2001)
Other	minerals, bitter fixed oil	(Yadav *et al*., 2014); Wani and Kumar, 2018)

Table 2. Fenugreek seeds contain important chemical compounds

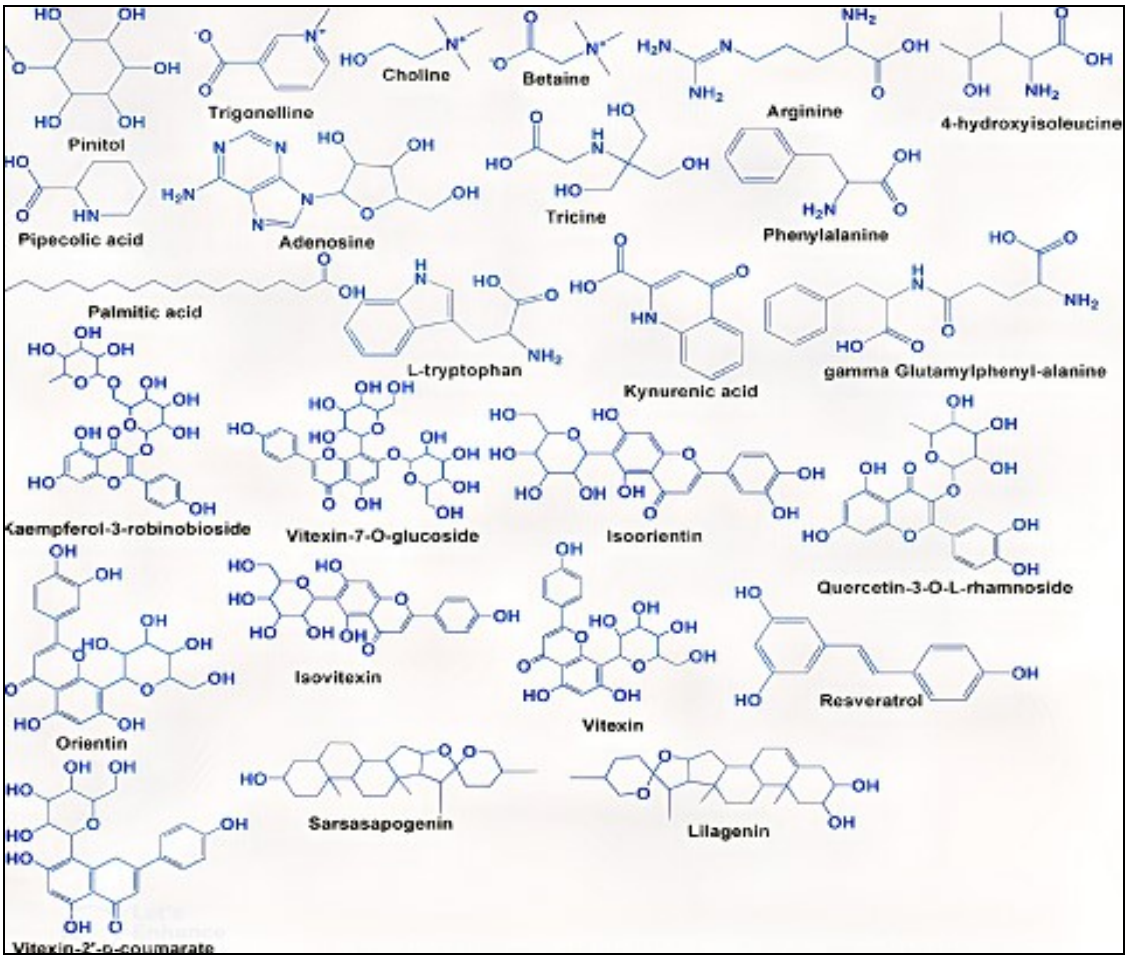

Figure 2. Structures of major constituents of fenugreek identified with HPLC-QTOF MS/MS analysis (Source: Singh et al., 2020).

For safety assurance and clinical efficacy, quality control is important as far as extracts of bioactive constituents are concerned. So it is essential to find out bioactive compounds for quality control. In past few decades, researchers have find out analytical methods with the help of technologies like spectro-photometry and chromatography to develop fast and precise method for the determination of bioactive compound,

structural characterization and identification of bioactive compound of fenugreek (Taylor et al. 1997; Chopra et al., 2006).

To date only small number of constituents, such as, isoxanthochymol, xanthochymol, garcinol and camboginol have been quantitatively find out by LC-MS/MS methods in fenugreek (Faeste et al., 2010). Fenugreek seeds have been wondered due to the existence of fiber content, alkaloids and steroid saponins. Using HPLC system, following five bioactive compounds have been detected and quantified, such as, isovitexin, vitexin, orientin, isoorientin and trigonelline (Singh et al., 2020). Figure 2 shows the HPLC chromatograms of standards (1) and seed extract of Trigonella foenum-graecum (2).

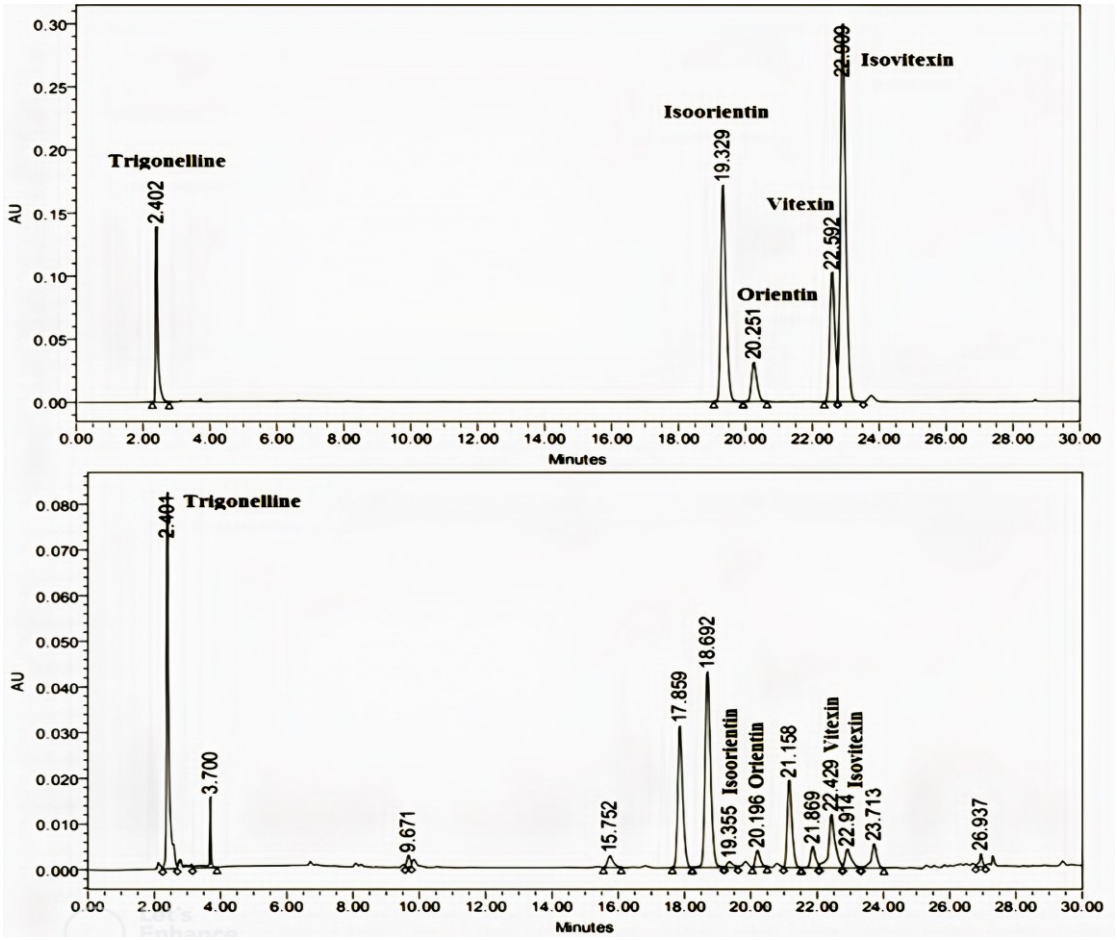

Figure 3. HPLC chromatograms of standards (1) and seed extract of *Trigonella foenum-graecum* (2) (Source: Singh et al., 2020).

2. Use of Fenugreek as Nutraceutical

Nutraceuticals are the compounds having beneficial physiological effect other than providing nutritional requirements. In addition to that nutraceuticals has been used to improve the well-being, provides defense against chronic ailment, defer the process of aging or helps in maintaining the functioning of the body. Importance is being given to present herbal nutraceuticals effective on tough therapeutic disorders associated with

oxidative stress such as Parkinson's diseases, inflammatory, immune, melanoma, eye, allergy, Alzheimer, heart diseases, diabetes and also obesity. These days, nutraceuticals have received attention because of promising nutritive, protective and therapeutic properties. Nutraceuticals marketplace is expanding worldwide (Hardy, 2000). Fenugreek is known to exhibit lot of beneficial physiological health effects such as thyroxin-induced hyperglycemia, nticancerous, hypocholesterolaemic and anti-diabetic etc. Fenugreek is one of the oldest medicinal herbs used in several African and Asian nations (Dixit et al., 2005). In this review fenugreek was studied extensively for its nutraceutical properties. Several claims made for its nutraceutical properties and beneficial physiological health effects have been well supported by earlier works and scientific studies.

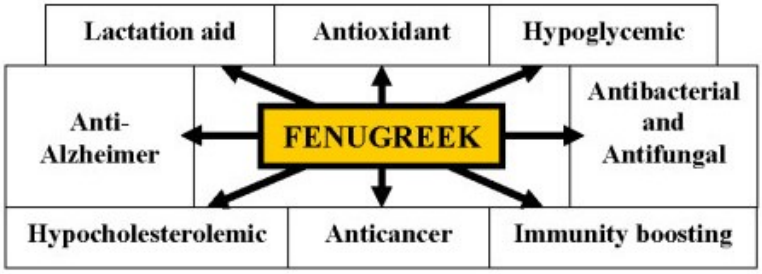

Figure 4. Multibeneficial physiological effects of fenugreek

2.1. Fenugreek and Hypoglycemic Effect

Foods rich in dietary fiber offer significant improvement to individuals with diabetes mellitus. As per Epidemiological reports occurrence of diabetes is less in people with high fiber consumptions as compared to the people with low fiber consumptions. Problems related to heart and diabetes is rare in Japan and India as compared to USA (Srinivasan, 2005). As the fenugreek seeds, generally used in India and Japan as a spice, are a rich source of dietary fiber and therefore, are beneficial as far as diabetes is concerned (Chatterjee and Prakashi, 1995). Though the mechanism of action of fenugreek in human beings is not well understood, but the animal studies have shown the effect of dietary fiber to curb the release of gastrointestinal inhibitory peptides and insulinotropic hormones and defer gastric emptying (Srinivasan, 2005). Reduced post-prandial glucose level was reported with the addition of dietary fiber is for an extended period of time.

Fenugreek seed extracts have shown improvement to the diabetic patients, suppression of the glycosuria in mild diabetes, and improvement in the severe diabetic condition (Srinivasan, 2005). Fenugreek is rich source of dietary fiber, also comprises of trigonelline, which is an alkaloid recognized to have an effect on glycosuria. As reported by National Institute of Nutrition, India, fenugreek have beneficial effects on both type-1 and type-2 diabetes. Number of studies on hypoglycemic effect of fenugreek seeds has been reported in rats (Mondal et al., 2004; Vats et al., 2002; Raju et al., 2001; Gupta et al., 1999; Ahmad et al., 1995; Ali et al., 1995; Khosla et al., 1995), mice (Ajabnoor and Tilmisany, 1988), diabetic rabbits (Moorthy et al., 1989, Moorthy et al., 1990) and in diabetic dogs (Ribes et al., 1986; Valette et al., 1984).

Animal Studies

Soluble dietary fiber portion of fenugreek has been reported to decrease the postprandial rise in blood glucose of type-2 diabetic rats by postponing the sucrose digestion. Soluble dietary fiber when administered orally two times a day at the rate of 0.5 g/kg for period of 28 days. Decrease in serum fructosamine level was reported without change in insulin level (Hannan et al., 2003). Defatted fenugreek, when fed to diabetic as well as normal dogs for pa period of 8 days, a decreased effect on glucose level were noticed (Ribes et al., 1986). Similarly, defatted fenugreek containing fiber and saponins have been reported to reduce cholesterolemia along with hyperglycemia in diabetic dogs Valette et al., 1984). Further, defatted fenugreek in Long Evans Rats has been reported to considerably check the increased fasting blood glucose following streptozotocin administration (Mondal et al., 2004). Extract from the fenugreek seed spice given to alloxan-diabetic rats and normal rats showed hypoglycemic effect (Vats et al., 2002) and also in mice (Zia et al., 2001). Alloxan diabetic rabbits were orally fed with fenugreek portion of 100 mg/kg for a period of 15 days, an improved glucose tolerance was observed (Murthy et al., 1990).

Although the health benefits of fenugreek seed has been known from many year, but now a day's interest is being given to its active components. Earlier, the anti-diabetic effect of fenugreek was ascribed to its alkaloid, which is trigonelline (Puri et al., 2002). Jain et al. (1987) reported maximum hypoglycemic activity in rabbits administered with alkaloid rich portion of fenugreek. Moorthy et al. (1989) reported a different bioactive compound from that of trigonelline. There are much evidences reported that hypoglycemic effect of fenugreek is due to gum and fiber, which constitute maximum portion of fenugreek seed. Main reason of hypoglycemic effect is that dietary fiber postpones gastrointestinal emptying. Irrespective of that dietary fiber which forms gel, decreases the discharge of insulinotropic hormones as well as gastrointestinal inhibitory polypeptides.

Abdel-barry et al., (1997) reported hypoglycemic and anti-diabetic effects of fenugreek leaves in both diabetic and normal rats. Fenugreek leaves supplementation have resulted in the reduction of hyperglycemia, glycosylated hemoglobin and hypoinsulinaemia in streptozotocin-induced diabetic rats (Devi et al., 2003).

Human Studies

Fenugreek of 15g each day given to diabetes mellitus patients (non-insulin dependent), result revealed that out of 21, 17 patients showed reduction in blood glucose with non-significant variation in insulin levels (Madar and Arad, 1989). Similarly, sixty diabetes mellitus patients (noninsulin dependent) were fed up with 25 g of fenugreek seed powder each day, twice with food for a period of 168 days. Results revealed lower blood glucose (Fasting) as well as glucose tolerance improved. Decrease in glucose was reported during excretion. Not only that a reduction in insulin level was also reported (Sharma et al., 1996).

Fenugreek seed powder of 25 was given to 2 insulin dependent diabetic patients each day, lower plasma glucose and glycosuria was noticed. Decrease in insulin requirement

was also reported. For longer duration of time, 100 g fenugreek was given to insulin dependent as well as noninsulin dependent diabetic patients (Sharma and Raghuram, 1990; Sharma et al., 1990). A decrease in blood glucose (Fasting) was reported after the intake of fenugreek. Glucose through urine, triglyceride as well as cholesterol was lowered. Diabetes mellitus was found to be under control under clinical observation.

Fenugreek whole seed powder or soluble portion of fiber when given to healthy persons revealed a decrease in blood glucose level (Nahar et al., 1992). Intake of 10 g of fenugreek for 3 hours before glucose load by 14 fasting persons both diabetic as well as normal lead to hypoglycemic effect in persons having diabetes (Pahwa et al., 1990). In normal persons, fenugreek had no effect on blood glucose as well as glucose tolerance.

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Biographical Sketches

Dr. Sajad Ahmad Wani is currently working as D.S. Kothari Post-doctoral fellow in the Division of Food Science and Technology, SKUAST, Kashmir, J&K, India. He has completed his Masters Degree in Food Technology from IUST, Awantipora, J&K, India and PhD from Sant Longowal Institute of Engineering and Technology, Punjab, India. Qualified National Eligibility Test (2015) (NET) conducted by Indian Council of Agricultural Research (ICAR) in Dec 2015. He has published more than 36 research/review articles, 10 book chapters and 4 book. He is also writing articles for the popular magazines *Food & Beverage News* (India's First Magazine for Food & Beverage Industry). He has attended 50 National and 20 International conferences, seminars and workshops throughout the world. Dr. Wani has participated in various faculty development programmes. Dr. Wani serves as Editorial Board Member of number of national and International Journals. He is Potential Peer Reviewer of reputed International Journals related to Food Science and Technology that belong to popular publishing house viz. Elsevier, Taylor-Francis, Wiley, Springer etc. He is also working as member of various associations like IFT, IFERP, International Association for Agricultural Sustainability, AFSTI, Asia Society of Researchers and Asian Council of Science Editors. Dr. Wani is the recipient of "D.S. Kothari post-doctoral fellowship" and "Maulana Azad National Fellowship (MANF-2013-14) from University Grant Commission, New Delhi, India.

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Prof. Haroon Rashid Naik is currently working as Director Planning and Monitoring SKUAST, Kashmir. He has been Prof. & Head Department of Food Technology and Dean of students in Islamic University of Science & Technology from 2007-2009.He is a graduate in agriculture from GNDU Amritsar (1987), Masters in Food Technology from CFTRI Mysore (1990) and Ph.D Food Technology from PAU Ludhiana (2000).He has been pioneer establishing department of Food technology at IUST Awantipura and creation of food tech programs in SKUAST. Till date he has supervised more than 20 MSc. Students and 10 Ph.D students. Presently 8 Ph.D scholars are pursuing their program under his supervision. He has published more than 100 research/review articles, 10 book chapters and 10 books. As the Principal investigator of the Project All India coordinated Research on PHET from 2002 to 2010 and from 2013-2016 many useful technologies for commercialization were developed particularly for temperate crops under his supervision. He has successfully established food processing labs and training centers through various funded projects from MOFPI Govt of India. He has more than 25 years of experience in teaching, research and extension education to his name.

Dr. Tariq Ahmad Ganaie is currently working as head Department of Food Technology, IUST, Kashmir. He has completed his M.Sc Chemistry in 2001 and M.Tech (Agriculture Processing and Food Engineering) from Aligarh Muslim University, Aligarh, UP in 2005. He has completed his PhD (Food Technology) from University of Kashmir. He has published many research as well as review papers in various reputed national and international journals with high impact factor. He has organized many national and international conferences, workshops and symposia. He has delivered many invited talks at national and international conferences, workshops and symposia. He is also the editorial board member

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Dr Basharat Nabi Dar is a graduate in Agricultural Sciences and did his MS and PhD in Food Technology. He started his professional career in 2012 as Assistant Professor of Food Technology at IUST, Awantipora, India. He has been a Visiting Scientist at the Institute of Food Science, Cornell University, USA under the CV Raman Fellowship of the University Grants Commission, India. He is the recipient of the UGC research Award 2014-16 in the field of Agricultural sciences. He is on the expert panel of Joint FAO/WHO Expert meeting on the prevention and control of microbiological hazards in fresh fruits and vegetables (JEMRA). He is the Coordinator of the Food Testing Laboratory sponsored by the Ministry of Food Processing and Industries, India. He is also associated with several research projects as a PI/Co-PI/member. Recognition of his contributions has provided ample opportunities to collaborate, present talks, interact with professionals and has an active presence in public policy discourse through his position as a technical expert to WHO/FAO, & the GOI. He has editorship of 5 books and has more than 90 publications in his field.