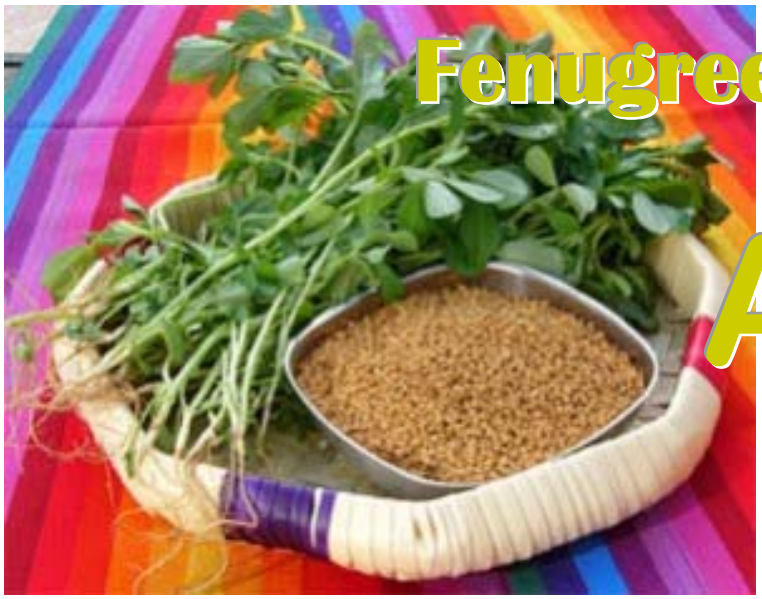
Science Tech ENTREPRENEUR
December 2006



Fenugreek Gum

Among agricultural plants useful as human-food, legumes stand next only to the grasses such as wheat, rice, maize and sugarcane. Food carbohydrates, produced from legumes, are more variable than those from grasses. The grasses mainly produce glucose polymers i.e. the starches and cellulose, besides hemicelluloses and sugars. Many legume seeds additionally produce complex carbohydrates or the gums, e.g. those based on galactomannans and other hetero-polysaccharides, which form their endosperm reserve polysaccharides. Because of the unique industrial applications, in food as well as non-food industries, legume galactomannans e.g. guar and locust bean gums have acquired great commercial value. There are many underutilized, tropical legume galactomannans that could be exploited as future resources, in developing countries. Fenugreek is one such annual legume crops, whose strongly scented seeds are source of a unique galactomannan gum. Other than fenugreek, cassia tora is another, emerging gum producing legume, which shall be covered by the authors, later in this magazine in another article.

Factors favoring commercialization of plant gums

A newly investigated polysaccharide gum is likely to be adopted for industrial production and use when -

- It has some useful functional properties such as, being a good viscosity builder or, a good gelling agent, for which it is being considered for commercialization.
- Gum cost is low and it is likely to be reasonably constant for several years to come. Regarding cost factor, the galactomannans from annual crops are cheaper compared to those from full-grown trees and their supply is more sustainable.
- The supply of high quality product gum is well assured, particularly when there is an increased world demand. This again is true of gums from land-cultivated annual crops.
- When a gum is meant for human consumption, consideration for its acceptance as a food, cosmetics or drug additive by the government agency's act e.g. "Food and Drug Act" or the FDA in USA, becomes an important consideration.

About a decade ago, only three legume-seed gums namely,

1. Guar gum (from *Cymoposis teteragonnolobous*, annual crop),
2. Locust bean gum (LBG, from *Ceratonia siliqua*, tree) and
3. Tara gum (from *Caesalpinia spinosa*, shrub),

produced commercially, were approved as food additives.

Whole fenugreek (botanical name *Trigonella **f**oenum-graecum,* Hindi name ***Methi)*** seed is edible, and hence its isolated gum is the latest addition to the list of edible galactomannan gums, allowed as food additives. Guar and fenugreek are two annual crops, mainly cultivated in the Indian subcontinent. Locust bean and tara seed gums are derived from pods of evergreen, perennial trees or shrubs, which are grown in the costal Mediterranean regions of Europe and Africa, and costal Peruvian Andes mountain range of South America respectively.

Fenugreek Galactomannan (FG-gum): An Emerging Industrial Polysaccharide

In his famous monogram on "Industrial Gums" (1993, 3rd Ed. Academic Press N.Y.) R.L. Whistler, mentioned that "Fenugreek seed-endosperm galactomannan was not in industrial production till 1990", but he suggested "There exist strong incentive to make dual use the seed by removing the spice and other components and separate the unique galactomannan, for which there is a good demand, as well as for the herbal products from fenugreek and its steroidal saponin, disogenin, which are in good demand for making sex hormone, cortisone used in making oral contraceptive". Like many other prophecies, made by Professor Whistler, regarding the future prospects of many underutilized plant polysaccharides, this prediction was soon to be fulfilled. Currently some industries have started producing and marketing a sizable

amount of fenugreek gum, and other fenugreek based herbal products are finding increasing applications.

Since fenugreek is a widely grown annual agriculture crop, its sustainable supply is well assured. Besides the gum, fenugreek seed also contains fatty and spicy oils, saponins (Disogenin) and good quality of lysine rich, edible protein; thereby making it a cost-effective agricultural crop. According to the Ayurvedic and Unani Systems of Medicine, fenugreek seed has been used in condiments and as a spice component of food in India and the Middle- and Far-East for centuries. Non-toxic and innocuous nature of fenugreek seed has been used traditionally as a food additive and hence no fresh FDA approval, for its isolated gum use, is required. Considering these factors, the Research Branch of Agriculture Canada started a project to produce fenugreek crop of an improved seed yield. A breeding program to produce seeds yielding higher levels of saponins (diosgenin) from fenugreek seed was also undertaken in England. For India there is a need to start a breeding program to improve gum yield from fenugreek seed and this can be undertaken by any of the Indian Agriculture Research Council lab. Any improvement of seed quality and its yield can result in increased yield of most of the seed components and value of the crop.

Like many other legume seeds, fenugreek seed endosperm is composed of a galactomannan polysaccharide, which is variably referred by the terms ‘fenugreek gum’, ‘fenugreek galactomannan’ and ‘fenugreek polysaccharide’, used interchangeably for its endosperm powder.

Scope for Production of Fenugreek Gum

Fenugreek is an annual legume plant, native to the Mediterranean region, but from ancient times, it has also been grown in the near and Middle East, Asia and Africa. It is now grown all over the world including Europe, Canada and the USA. It is an annual legume crop of India and the country is an important exporter of fenugreek seeds. In India it is used for food and the medicinal purposes. Fenugreek seed has a long history of use as a spice food in India and its medicinal applications are well known in the Ayurveda System of Medicine. Its health benefits, as a dietary fiber for regulating blood sugar and controlling blood lipids (LDL and cholesterol, which can result in hypertension), is well recognized, even by the Western, Allopathic System of Medicine.

Whole seed powder of fenugreek has been used to regulate blood sugar in healthy, obese, as well as for non-insulin dependent or the type-2 diabetic persons. Yet there

have been reports of patient's poor compliance in use of whole fenugreek seed powder on long-term use, which is particularly true of person in the western countries and this has been attributed to the bitter taste and spicy odor as well as the large and effective quantity (10-15g) of its required dose. This has necessitated isolation of pure fenugreek gum, free from bitter taste and spicy odor.

Fenugreek Crop

Fenugreek is an old cultivated spice-bean crop in India, and the country is a major fenugreek seed exporter in the world, followed by France, Egypt and Argentina. It is an erect annual plant, 30-60 cm high **(figure-1)**. The plant grows in well-drained soil under mild climate. The seed crop matures in 3-4 months and yields 300-400 kg seeds per acre. The plant bears thin, 10-15 cm long and sword-shaped pods, each containing 10-20 seeds. The oblong, yellow-brown seeds (2-3 mm long) are hard with an outer, wrinkled seed coat.

Fig.1 Fenugreek Plant, showing seed bearing pods

The strongly scented fenugreek seeds are used to as spice to flavor curries, pickles, chutneys in the east and for imitation maple syrup in Canada. In India, besides the seed, green fenugreek leaves are used as a vegetable.

Manufacturing of Fenugreek Galactomannan Gum

Important commercial galactomannan gums e.g. guar and locust bean gums are produced by stepwise, dry grinding of the respective seeds, which results in separation of nearly pure endosperm (gum) from the husk (seed coat) and the protein rich part or the germ. This is followed by further grinding of separated endosperm into powder of desired particle (mesh) size. Such dry processing has generally kept the processing cost of these gums low.

The technology of processing of guar gum, being currently used in India, was developed in the USA, but because of economic considerations, this technology and

guar gum manufacturing was out-sourced to India, for which now India has now gained full mastery. This technology know-how can be helpful in developing similar manufacturing technology for other seed gum e.g. FG-gum.
In case of fenugreek, the current and patented and industrial production methods have described only the wet-method of manufacturing. Such methods are generally adopted from the general laboratory method of extraction of seed polysaccharides and are costly.

Dry *verses* wet methods of extraction of seed Galactomannans

Major portion of any dry plant material consists of polysaccharides. The cost of raw material and process-cost of extraction of a commercially pure polysaccharide from a plant material can vary considerably. Thus the manufacture of many seaweed and microbial gums and pectin polysaccharides involve their extraction into water followed by filtration and precipitation with alcohol, which is recovered by fractional distillation for reuse. Drying and grinding follow this, when necessary. In such wet-methods, energy consumption is high and there is an overall high process cost involved. In contrast to such wet methods, most legume endosperm polysaccharide gums, which are galactomannans of commercial purity, are generally separated by differential grinding, sifting and sieving, starting from the seed. These, purely mechanical operations, keep the process cost, and hence the final product cost low. In case of fenugreek both dry and wet extraction of galactomannan seems to be feasible, but as mentioned the patented methods are generally based on wet extraction.

Need to develop dry processing method for manufacturing Fenugreek gum

There is a need to develop suitable dry process of extraction of fenugreek galactomannan, as has been done in case of other legume seeds. Morphological structure of dicotyledonous fenugreek seed suggests that by mild heat treatment, it should be possible to pop-up the husk, as has been done in case of other seed galactomannans. This can be followed by coarse grinding, which hard endosperm can stand, while more fragile husk and germ portions, get powdered and easily removed from intact endosperm by sifting.

Neglect in developing technology for dry processing of fenugreek seed into its gum, appears to be due to its smaller seed size. It is thought that compared to guar gum, the separation of industrially pure endosperm from the husk and germ in fenugreek

seed may not be achieved effectively. However in case of another legume seed, *Sesbenia bispinosa* (Daincha), which is also a seed of size much smaller than guar, successful separation of seed endosperm has been achieved by employing machines slightly modified from those being used in making guar split.

In case of fenugreek another problem, which can be visualized, shall be due to its characteristic smell of the spicy oil content and bitter tasting component of the seed, getting mixed into the endosperm gum, making it unpalatable. However, these problems can be solved. Solvent washing of split, to remove any bitter and odorous substances before grinding, can solve such a problem. It may be noted that the gum-yield, recovered from fenugreek seed by wet processing is around 20% or even less, whereas a suitable dry process can give better yield of >25% as in case of other legume seeds.

Fig.2. Fenugreek Endosperm (split), separated by dry grinding processed

We have developed a method to produce, highly pure fenugreek-endosperm split by a differential grinding in a dry process, which is based on modification of the currently used method for producing guar gum split. The product fenugreek split, which is shown in **Figure-2**, is completely odorless product and without any bitter taste. The yield of gum is >25%, which is better compared to that in a wet process.

Commercially produced FG-gum shall have specifications shown in **Table-1.**

Table 1

Specifications of Commercial Fenugreek Gum being marketed

Constituents	Amount (%)
Acid insoluble matter	3-5
Water insoluble matter	2-3
Loss on drying (Moisture)	8-10
Protein	3-5
Starch	Nil
Soluble galactomannan (Dietary fiber)	70-85
Calorie	1 kcal/g
Ash	1-2
Ether extract	1-2
Viscosity (Brookfield), 1.0% solution	3000-3500 cps
Particle size	70-100 mesh

Composition of Fenugreek Seed

Dicotyledonous fenugreek seed consists of a wrinkled brown-yellow seed coat or the husk, enclosing two whitish translucent endosperm halves mainly composed of a soluble galactomannan polysaccharide. Between the two endosperm halves is sandwiched, a yellowish germ portion, which is mainly composed of good quality of edible protein, besides ether extractables, which are- 7-9%, fatty oil and flavoring essential oil. After ether extraction, alcohol extraction of germ produce about 5-7% fraction, consisting of saponin (chiefly disogenin), a yellow pigments, alkaloid trigonelline, free amino acids, vitamins of B-complex group and flavonoids, which are antioxidants. All these non-galactomannan constituent of fenugreek are valued as herbal products and are marketable. Fibrous material, mainly from the husk, contains insoluble cellulosic fiber, while the endosperm is a soluble galactomannan gum

The average composition of the seed is given in the **Table-2**

Table 2
Major constituents of Fenugreek Seed

Component	Amount (%)
Moisture	3- 5
Protein	25-30
Lipids (ether extractable)	7-9
Steroidal saponins	5-7
Galactomannan	25-30
Insoluble fiber	20-25
Ash	3-4

In the legumes, endosperm galactomannans are the reserve seed polysaccharides, which are used up during the germination and growth of the plant embryo, till it starts photosynthesis. Germinating legume seeds including the FG-seeds produce β-mannase and α-galactase enzymes, which can cleave mannan backbone and galactose grafts respectively to degrade galactomannan polysaccharides. All galactomannan gums have a strong, but variable tendency to bind and hold water. Solvent defatted and protein freed fenugreek gum is whitish and odorless. It is effective in lowering blood sugar and blood lipid level, just like the whole seed

powder. Additionally it promotes growth of probiotic intestinal flora and acts as a soluble dietary fiber.

Chemical Structure of Fenugreek Gum

Legume seed galactomannans generally consists of a β, (1→4)-linked linear mannan backbone, to which single galactose grafts are linked randomly by an α, (1→6)-glycoside bond. Fenugreek galactomannan has this common structural feature. Galactomannans from different legume seeds differ in their M: G ratio, molecular weight and mode of placement of the galactose grafts, which are generally not spaced regularly but placed randomly and in blocks on the linear backbone. Fenugreek galactomannan is unique in having mannose and galactose in nearly 1: 1 ratio, and it is more cold water-soluble than any other galactomannans including guar gum.

Since the M: G ratio in fenugreek gum is close to 1; it makes FG-gum as one of the highest galactose (~ 48%; M: G, 1.02:1) containing galactomannan. Besides fenugreek, Lucerne (*Medicago sativa*) and clover (*Trifolium pratense*) are two other, though less common galactomannans, which have ~48 percent galactose. The linear mannan backbone of FG-gum thus have, α, (1→6) linked single galactose grafts on nearly all the mannose groups of the main chain. Molecular weight of FG-gum is ~30,000 Daltons, corresponding to an average presence of 180-190 monosaccharide (mannose + galactose) units in a molecule. On an average, the linear mannan backbone of fenugreek polysaccharide is built up of 90-95, β, (1→4) linked mannopyranosyl units and each backbone monomer carries an α, (1→6) linked galactopyranosyl group as shown in **Fig. 3**.

(Man-β 1→4 Man)$_n$

|α 1_--->6 |α 1_--->6

Gal Gal

Fig.-3. Structure of fenugreek Gum

Surface activity and emulsifying property

Most of the soluble polysaccharides have a certain degree of emulsion stabilizing action, which has been attributed to enhancement of viscosity, which imparts

increased stability to emulsified oil droplets. There is not much reduction of interfacial or surface tension by the soluble polysaccharides. In contrast to this, fenugreek gum solution shows unique property of large reduction interfacial and surface tension, which is comparable to that from gum arabic. Gum arabic action as an emulsifier in solution has been attributed to its composition, which constitutes the strongly hydrophobic carbohydrate portion, present as a composit with a hydrophobic protein portion.

This is not the case with fenugreek galactomannan, because highly purified (protein < 1%) polysaccharide also is as good emulsifier as gum Arabic. It has been suggested that, completely galactose substituted mannan backbone of the fully extended polysaccharide molecules are deposited on emulsified oil droplet in water protecting them against coalescence and flocculation. This property, coupled with its moisture holding capacity opens up interesting possibility of using of fenugreek gum in cosmetics and there is a need to explore FG-gum as a cheaper substitute of gum arabic.

FG-gum as a 'Nuteraceutical' with pharmaceutical benefits

FG-Gum, which has been stabilized by and removal of fats, oleoresin and proteins according to the patented methods, can be obtained from fenugreek seed powder. Effective removal of these constituents makes it odorless and bitterness free.

The following MNC-companies and their agents are marketing FG-gum in most of the European and American countries-

1. Adumim Food Ingredients Natura R&D division, (USA Patent No. 5,84,109, December 8, 1998), Mishor Adumim, 90610, Israel. Product name **Fenu-Pure**, Agent in France- Seah International. USA, http://www.plthomas.com/fenupure/fenupure.htm
2. KBC Inc. USA, (US Patent 5658571, 1997). http://www.kbcincusa.com/Naturally/Naturally98-01-01.htm, Product name **Fenuber**, (it is manufactured in India), Call- 480-763-5539, fax- 603-754-8396, admin@kbcincusa.com
3. Acatris Inc. Belgium/ USA, (USA-Patent No. 5,997,877, December, 7, 1999) www.acatris.com, Fax (952) 920-7704, Product name **FenuLife**

The process (Patents referred above) used in production of fenugreek galactomannan by these companies is based on removal of the bitter and spicy constituents, present in the seed, by organic solvent extraction of the whole seed

powder, followed by aqueous extraction of soluble polysaccharide along with some proteins. After filtration of insoluble material including cellulosic fiber, soluble polysaccharide was obtained from aqueous extract by repeated alcohol precipitation in 15-20% yield only.

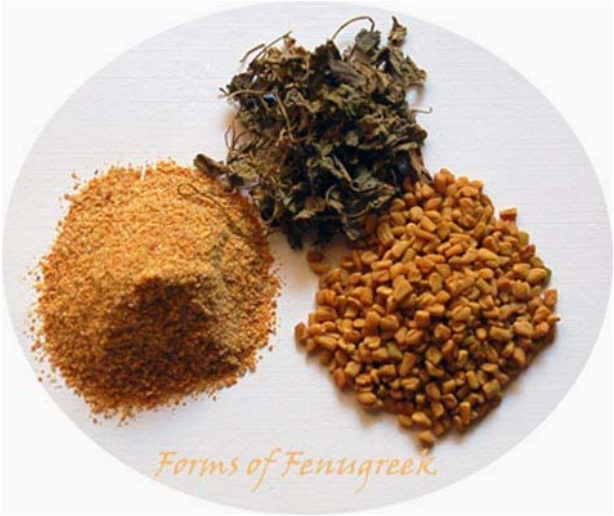
Medicinal Applications of Fenugreek Seed

It is now well established that fenugreek seed powder owes its blood sugar and blood lipid controlling action due to the presence of a unique galactomannan polysaccharide gum (a soluble dietary fiber) as the major component of its seed endosperm. Purified fenugreek gum is a completely odorless and tasteless, substance. The whole seed powder owes its bitter taste and odor to certain constituents, present in its germ portion and not due to its polysaccharide.

Fenugreek gum thicken ingested food to form a gel in stomach trapping fat, sugars and starch hydrolyzing, amylase enzymes to slow down sugar absorption. Thus, it is good for obese and diabetic persons. The gel, which appears like 'fat' inside the body, signals the gall bladder to empty bile into the stomach. The gel then irreversibly traps lipid-emulsifying bile salts and prevents their reabsorption. Thus, emulsification and absorption of lipids including cholesterol results in lowering of blood lipid. This in turn reduces hypertension and chance of heart attack.

It has been confirmed by animal experiments and clinical tests on humans that ingesting the food compounded with fenugreek gum lowers the sugar level in the blood. It also lowers the level of cholesterol and fat in the blood and restrains biosynthesis of cholesterol in the liver. The results of many researches have discovered that these effects are caused by galactomannan contained in seeds albumen. Complex polysaccharides (gums), or dietary fibers, generally have the effect of lowering the blood of cholesterol, and fenugreek is distinctive for having the effect of lowering the level of sugar in the blood as well.

Besides its use for making dose form of tablets and capsules, fenugreek gum is also being used in weight control formulations and other diet food as a functional ingredient.



Conclusion

Purified fenugreek gum is now commercially available and its production is best carried by dry grinding process, the technology of which is available with the author of this article. Purified FG-gum is particularly recommended for those, who are unable to take whole seed powder due to its odor and bitter taste. The byproduct in the process are the seed germ (proteins) and husk, which are also useful for extraction of neutracceuticals e.g. fenugreek oleo-resin, saponins and the latest edition to fenugreek product is an amino acid, 4-hydroxy-isoleucine (4-HIL), which is known to increase insulin secretion (insulinotropic), when carbohydrate rich diet is ingested. It catabolizes sugars by depositing it as muscle glycogen. Thus fenugreek whole seed powder has two constituents (gum + 4-HIL), which act in synergy to regulate sugar metabolism.

✍ **Dr. N.K. Mathur**

54, Devnagar,
Jodhpur, 342008,
Rajasthan

&

✍ **Dr. G.M. Mathur**

Rajasthan Agriculture University,
Experimental Station,
Sriganganagar,
Rajasthan