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Chemical and Physical Characterization of Dehydrated Functional Fenugreek Leaf Powder

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Fenugreek (*Trigonella foenum-graecum)* is a popular and most ancient recorded medicinal herb. Leaves and seeds of which are used as important ingredient in Indian cuisine. Even after harvesting of leaves, respiration and transpiration continues and affect quality during post harvest handling operations. Shape of leaf being as infinite slab having enormous exposed surface area to volume ratio, the enhanced respiration and transpiration losses are reported to be extremely high and losses the quality in short duration. Thus this important leafy vegetable is often categorized under highly perishable category of foods. Attempts have been made to process the fenugreek leaves into shelf stable form having maximum possible retention of quality characteristics in its dehydrated form. The dehydration process was subjected in a cabinet drier maintained at the isothermal temperatures ranging from 50 to 90 °C with an interval of 10 °C. The identified time and temperature combination based on the physico-chemical parameters, the combination method of different temperature during dehydration process was recommended. The obtained dehydrated leaves were converted into powdered form before fractionated and characterized on the basis of chemical, physical and optical parameters. As expected the dehydration process was governed by the subjected pretreatment, dehydration temperature and exposure time during dehydration operation. The quality of obtained dehydrated fractional functional fenugreek powder was found better for the fenugreek leaves dehydrated at an initial temperature of 70 °C with finishing temperature of 60 °C with its counterpart. The chlorophyll content has been found to be enhanced by more than seven times in powdered fraction of fenugreek leaf with the loss of merely 12 %. The antioxidant effect on DPPH radical scavenging activity was found to be 377 mg/g. The non-polar solvent extract of fenugreek leaf powder was revealed the presence of various phyto-chemicals having potentially important nutritional, therapeutic and medicinal values. The antimicrobial aspect of fenugreek leaf powder was checked on selected bacterial strains.

Keywords: *Trigonella foenum-graecum*, Fenugreek, Dehydration, Powder characterization, Antimicrobial activity.

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum*) is a self pollinated annual herbaceous legume, belongs to Fabaceae family and popularly known as Greek hay, bird's foot[1] and methi. It is one of the well documented and most ancient recorded medicinal herbs[2] used as major culinary ingredient, since ancient, in India. Fenugreek is supposed to be originated from southeastern Europe and western Asia. Presently, it is extensively cultivated in many parts of the world, including India, northern Africa and United States[3]. Fenugreek leaves and seeds have been used extensively to prepare extracts and powders for medicinal uses[4].

Fresh or dried forms of fenugreek leaves are very popular kitchen herb due to its associated properties of pleasant flavour, powerful antioxidant properties, health promoting effects and antimicrobial activities. Application of fenugreek has been found to be lethal against hazardous bacteria, specifically coli forms, *Pseudomonas spp*., *Shigella dysentiriae* and *Salmonella typhi*[5]. These properties probably make fenugreek a valuable ingredient in food and pharmaceutical applications[5-7].

Clinical studies have demonstrated the beneficial effects of fenugreek in controlling the blood glucose, lipids and platelet aggregations. The defatted portions of the plant is said to be responsible for the anti-diabetic action[8]. Fenugreek as an appetizer[9,10] and lactation stimulant[11,12] is also found to be beneficial in reducing pain, atherosclerosis and rheumatism[13]. Antidiabetic, hypoglycemic activity[14], anticarcinogenic, anti-ulcer[15], antiinfertility, enzymatic pathway modifier, hypo-cholesterolemic activity[16-18], antioxidant[19], fungicide[20] and immunomodulatory effects are the major medicinal properties also associated with fenugreek[5,21].

This plant is known to have organic acids, alcohols, carbonyl compounds, amines, esters and wide variety of heterocyclic and aromatic compounds such as alkaloids[22], flavonoids[23], salicylate[24] and nicotinic acid[25,26] to play major role in improving the acceptability of food items, provide characteristic and medicinal effects on its use. Vitamins, flavonoids, terpenoids,

carotenoids, cumarins, curcumins, lignin, saponin and sterol are the active phytochemicals responsible for the antioxidant properties. High protein and fibre content with the presence of many bioactive compounds make fenugreek a naturally available unique and health promoting major herb[5,6]. Carotenoids as C-40 tetraterpenoids, chlorophyll as porphyrin, flavonoids and betalains are among the natural colorants occurring in foods[27]. Carotenoids have diverse biological functions and actions, the most important of which are provitamin "A" activity, antioxidant, immune function enhancers, UV skin protection and cell communication. Among major colour compounds, chlorophyll is the pigment responsible for green colouration of leaves. Chlorophyll a (blue-green) and b (yellow-green) are occurring in the ratio of (3:1) in higher plants and they differs in the methyl group on C3 being replaced by aldehyde[28,29]. The chlorophyll along with the metabolites, pheophytin, pyropheophytin, pheophorbide and chlorophyllide have found role in antimutagenic and anti-carcinogenic effects against cancer suspects by formation of complexes[28,30,31]. The presence of essential oils and their composition determine the specific aroma of plants and the flavour of the condiment[32].

A considerable amount of fenugreek leaves are unutilized due to lack of post harvest processing facilities in India. Dehydration improves the biomaterial shelf life without altering significantly the chemical proportions and simultaneously reduces both the size of package and the transport costs. Drying of leafy vegetables has long been documented as the cheapest and most abundant potential sources of protein[33,34]. Most of the plants are also traditionally dried and stored until consumption. Compared to fresh fenugreek leaves, which could only be keep afresh for extremely short duration under normal conditions, whereas dehydrated products could be stored for longer durations without any appreciable loss of nutrients. Again, hygroscopic and fine food powders are difficult to use and trade as well. Major hurdles concerned with powders containing fine particles are dusting, lumping, difficulty in reconstitution and inhibition of flow[35]. The addition of small amount of leaf powder not only adds taste to food but also improves the nutritional values[36]. Considering the mentioned importance, the present study was conducted specifically in order to determine the characteristics of developed shelf-stable fenugreek leaf powder so as to use directly in various food formulations.

EXPERIMENTAL

Sample preparation: Fenugreek leaves (Methi Khushbu, KS-15) were harvested with stalk as sold in the local market during early morning from the available local farm nearby Longowal and brought to Pilot Plant, SLIET, Longowal within 0.5 h time in a closed polyethylene bag. Fresh and undamaged leaves were separated; yellow and unwanted leaves as well as firm stems were removed and weighed to calculate the recovery of leaves. The leaves were washed in running tap water at least twice to remove foreign matter such as dust, dirt and chaff. Steam blanching was provided to the leaves for two minutes in the developed precision steam blancher[37]. Drying behaviour of fenugreek leaves were investigated at four different isothermal dehydration temperature (50 to 90 °C) with an interval of 10 °C[38]. The dehydration kinetics and the resultant products were compared and time temperature combination was identified as initial 70 °C for 1 h and rest 2 h at finishing temperature of 60 °C. The manually crushed dehydrated leaves were further powdered using mixer grinder. Sieve shaker in a set of six screens 10-12-16-25-60-85 BSS were used to find out the specific sieve to be used to divide the dehydrated fenugreek leaf powdered mix in order to get the coarse and fine fractions. The screen 60 BSS was thus used to get two fractions as fine rich in phyto-chemical portion and coarse fraction rich in insoluble fiber portions in order to be used for various food products.

Chemical characteristics: Chemical properties such as proximate composition analysis and components of phyto nutrients were determined[29]. In order to get the quantitative estimation of phyto-chemicals gas chromatography and mass spectroscopy (GC-MS), Shimadzu GC-MS 2010 available at Jawahar Lal Nehru University, New Delhi was used. Nitrogen was used as carrier gas at 10 PSI inlet pressure with FID and AB inno-wax column (60 m × 0.25 mm ID, film thickness 0.25 μm). Injector and detector temperatures were 270 and 280 °C, respectively. Column temperature programmed from 60 to 180 °C at 3 °C/min with hold time of 2 min and from 180 to 250 °C at 5 °C/min with hold time 20 min respectively. The flow rate of carrier gas was 1.2 mL/min and split ratio was 80:1. The data were processed on GC solutions software for leaf powder constituents. Helium was used as carrier gas. EI source and mass range were 70 eV and 40-750 amu, respectively. The identitfication of the components was assigned by comparing their GC retention times with those of authentic samples as well as with known components of standard essential leaf powders of the fragmentation pattern with that of the reported in NIST and Wiley computer libraries.

Physical characteristics: Moisture content of leaf powder was measured using hot air oven method[29] and physical properties using standard method as described elsewhere[39]. Gravimetric property (bulk density), frictional characteristics (angle of repose and coefficient of friction) and optical parameters (L a b-values) were evaluated. Water absorption capacity (WAC) and water solubility index (WSI) were determined[38]. Subsequently, the dehydration characteristic as dehydration ratio was assessed[29].

Antimicrobial studies: The isolated and verified bacterial strains of Gram-positive (*Staphylococcus aureus)* and Gram-negative (*E. coli and Pseudomonas aeruginosa)* from the patient at microbiology department of Guru Nanak Dev Dental College and Research Institute, Sunam were sub cultured on nutrient agar (Himedia, Mumbai) and incubated at 37 °C for 24 h. The antibacterial activity of the fenugreek leaf sample was performed as per the guidelines of Clinical and Laboratory Standard Institute using Mueller-Hinton broth[40]. Once the agar was solidified, the microbial suspension was spread on agar surface by using sterile swab. The agar was punched by using sterile cork borer to prepare wells of 6 mm diameter. The wells were filled with 50 μL of the plants aqueous extracts with sterile distilled water as control. The incubated petriplates at 35 °C for 24 h were observed for the zone of inhibition[41].

Statistical analysis: The statistical analysis for the data of obtained at least in triplicates were evaluated with mean separation to determine any statistically significant effects prevailed among them. A multiple comparison of the treatment means was performed by Duncan's Multiple Range Test. Significance of the difference was determined at $p \leq 0.05$[42].

RESULTS AND DISCUSSION

The recovery of fenugreek leaves from the collected harvested bunch was found to be 43.01 ± 1.47% (Table-1). The moisture content of sorted fresh leaf sample used for dehydration was found to be about 87.77 ± 0.23% (wwb) with the chlorophyll and carotene content as 109.65 mg/100 g and 7.595 mg/100 g, respectively (Table-1). The leaf colour in terms of lightness (L value), greenness (negative a value) and yellowness (positive b value) were 62.43 ± 2.11, -8.37 ± 0.66 and 17.58 ± 1.23, respectively, which were found to be in agreement with the reported values elsewhere[43]. The higher negative a values associated with the fenugreek leaves reflect the higher extent of greenness[6,32].

Physical characteristics: Blanching pretreatment with different dehydration temperature as affected the physical, chemical and optical characteristics of dehydrated fenugreek leaf powder are reported in Table-2. The quality of dehydrated fenugreek leaf powder was found to be pretreatment and temperature dependent as per the observed variations[36,38] (Table-2). The increase in subjected temperature during dehydration has led the decrease in moisture content of powder and varied in the range of 2.00-10.89 %. The higher level of final product moisture content was found to be associated with the dried powder subjected either with blanching pretreatment or lower dehydration temperature[44,45]. Blanching as the mild heat treatment affected the leaves to soften and dehydration allows more shriveling and possibly develop a compact structures in the less fibrous portions of the subject. This trend could very well be correlated with the associated change in the dehydration ratio, which has increased with raising temperature and corresponding values are higher for the

TABLE-1
PROPERTIES OF FENUGREEK LEAVES

Parameters	Values
Leaf recovery (%)	43.01 ± 1.47 %
Moisture content (%)	87.77 ± 0.23 % (wwb)
L-value	62.428 ± 2.108
a-value	-8.377 ± 0.661
b-value	17.581 ± 1.229
Chlorophyll total (mg/100 g)	109.651 ± 8.557
β-Carotene (mg/100 g)	7.595 ± 0.175

TABLE-2
TEMPERATURE DEPENDENT PROPERTIES OF FENUGREEK LEAF POWDER

Physical properties		Fenugreek leaf powder				
		50 °C	60 °C	70 °C	80 °C	90 °C
MC, % d.w.b.	(UB)	6.21 ± 1.04	4.52 ± 0.54	3.32 ± 0.11	2.23 ± 0.18	2.00 ± 0.04
	(B)	10.89 ± 1.60	7.84 ± 0.81	4.73 ± 0.69	3.23 ± 0.52	3.00 ± 0.06
BD (kg/m^3)	(UB)	408.67 ± 3.79	457.00 ± 4.58	471.33 ± 9.61	506.33 ± 6.11	501.33 ± 2.31
	(B)	518.67 ± 16.29	538.33 ± 4.51	546.33 ± 32.52	545.67 ± 42.00	551.33 ± 4.80
AOR (degrees)	(UB)	47.44 ± 3.31	46.14 ± 2.39	44.18 ± 2.17	37.09 ± 1.44	37.48 ± 0.78
	(B)	39.53 ± 1.48	39.93 ± 4.20	39.22 ± 1.96	39.53 ± 1.48	39.82 ± 1.62
COF Glass	(UB)	0.32 ± 0.01	0.31 ± 0.00	0.30 ± 0.00	0.30 ± 0.00	0.30 ± 0.00
Plastic board	(UB)	0.34 ± 0.01	0.33 ± 0.01	0.33 ± 0.00	0.30 ± 0.01	0.29 ± 0.00
Steel	(UB)	0.33 ± 0.00	0.32 ± 0.00	0.32 ± 0.00	0.32 ± 0.00	0.32 ± 0.00
Plywood (long.)	(UB)	0.41 ± 0.01	0.40 ± 0.00	0.40 ± 0.01	0.40 ± 0.01	0.40 ± 0.01
Plywood (trans.)	(UB)	0.47 ± 0.02	0.48 ± 0.02	0.46 ± 0.01	0.45 ± 0.03	0.44 ± 0.03
Glass	(B)	0.33 ± 0.00	0.32 ± 0.00	0.31 ± 0.00	0.31 ± 0.00	0.31 ± 0.00
Plastic board	(B)	0.38 ± 0.01	0. 37 ± 0.01	0.35 ± 0.01	0.35 ± 0.01	0.34 ± 0.01
Steel	(B)	0.33 ± 0.01	0.33 ± 0.00	0.32 ± 0.00	0.32 ± 0.00	0.32 ± 0.00
Plywood (long.)	(B)	0.58 ± 0.01	0.57 ± 0.00	0.57 ± 0.00	0.57 ± 0.00	0.57 ± 0.01
Plywood (trans.)	(B)	0.62 ± 0.01	0.62 ± 0.00	0.61 ± 0.00	0.60 ± 0.00	0.61 ± 0.00
L-value	(UB)	54.23 ± 1.36	46.14 ± 0.99	45.99 ± 2.41	41.15 ± 1.40	39.24 ± 0.70
	(B)	42.76 ± 1.44	40.18 ± 0.84	38.15 ± 0.57	33.62 ± 1.34	30.30 ± 0.38
a-value	(UB)	-6.26 ± 0.95	-3.65 ± 0.15	-3.21 ± 0.83	-2.06 ± 0.79	-2.37 ± 0.18
	(B)	-6.35 ± 0.38	-4.81 ± 0.73	-5.49 ± 0.33	-3.77 ± 1.51	-4.32 ± 0.57
b-value	(UB)	20.72 ± 0.18	17.75 ± 0.37	17.03 ± 1.31	14.64 ± 1.75	14.46 ± 0.15
	(B)	18.41 ± 0.71	15.69 ± 0.76	15.32 ± 0.33	11.66 ± 0.52	12.09 ± 1.54
DR	(UB)	7.84 ± 0.18	7.90 ± 0.28	7.87 ± 0.12	8.13 ± 0.05	8.21 ± 0.05
	(B)	7.28 ± 0.15	7.45 ± 0.41	7.73 ± 0.08	7.82 ± 0.06	7.95 ± 0.02
WAC (g/g)	(UB)	2.02 ± 0.02	2.89 ± 0.01	3.49 ± 0.34	3.37 ± 0.01	3.35 ± 0.01
	(B)	2.28 ± 0.28	3.01 ± 0.23	3.51 ± 0.32	3.38 ± 0.10	3.44 ± 0.02
WSI (%)	(UB)	25.00 ± 0.85	28.40 ± 0.56	33.60 ± 0.56	34.80 ± 1.31	35.00 ± 0.28
	(B)	26.40 ± 1.13	30.40 ± 1.70	35.40 ± 0.28	35.40 ± 0.28	35.30 ± 0.14
Chlorophyll total (mg/100g)	(UB)	742.32 ± 51.75	629.50 ± 31.49	612.03 ± 7.33	601.18 ± 11.07	587.86 ± 1.65
	(B)	766.33 ± 12.32	758.72 ± 46.91	663.58 ± 2.42	629.20 ± 36.28	601.38 ± 1.37
β-Carotene (mg/100g)	(UB)	34.38 ± 1.58	32.95 ± 1.67	32.21 ± 2.37	30.47 ± 0.26	25.69 ± 0.70
	(B)	35.00 ± 1.05	30.84 ± 0.44	27.92 ± 0.17	27.49 ± 1.84	24.82 ± 0.53

where, UB- Unblanch, B- Blanch, BD- Bulk density, AOR- Angle of repose, COF- Coefficient of friction, WAC- Water absorption capacity, WSI- Water solubility index

blanched fenugreek leaves in comparison to untreated samples (Table-2).

A relatively low content of water and hygroscopicity are principle characteristics of food powders which differentiate them from other food products. As mentioned the blanching treatment has resulted in a compact mass of resulted powder and thus bulk weight got increased with the increased bulk density (Table-2) as compared to the untreated powder.

Coefficient of friction (COF) as frictional property for the fenugreek powder obtained by dehydrating at various temperatures was assessed and found to be temperature dependent considering the direct effect with decreasing trend as tabulated (Table-2). This may be due to the difference in moisture content, structure of particle and adhesive forces of the particles and that of the studied contact surfaces. The decrease in angle of repose (AOR) for unblanched fenugreek powder with the increase in the dehydration temperature was observed with hardly any effect of temperature on blanched samples (Table-2). Blanched leaf powder exhibited higher degree of cohesiveness and thus the granular materials possess higher frictional characteristics thus coefficient of friction is showing significant variation at different temperatures and surfaces[46].

Optical characteristics: With increase in the temperature of dehydration the L-value was found decreased to 54.23 and 42.76 for unblanched and blanched samples at 50 °C while 39.24 and 30.30 at 90 °C, respectively (Table-2). Thus, revealed that the lightness (L-value) decreased on blanching treatment and drying at higher temperatures[47] (Fig. 1). The pretreatment blanching and dehydration process has adversely affected the green colour as the a value was found to be increased in the finished powder (Table-2). Higher yellowness was associated with the unblanched samples dehydrated at lower temperatures. The pictorial comparison reflects the effect of blanching and dehydration temperature on the powder colour, which supports the findings of objective colour characteristics.

Chemical characteristics: Chlorophyll content decreased with the increase in dehydration temperature and found chlorophyll values slightly higher in blanched samples[48]. β-Carotene a precursor of vitamin A, yield two units[28,43] of it. The colour of which is not visible in plant leaves as the chlorophyll masked entirely. Carotene content found in fresh fenugreek leaves was 7.595 mg/100g. The chlorophyll and carotene content of dehydrated powder obtained at different temperatures are found in agreement with the earlier studies[43,49]. The concentration of carotene also found to be decreased with increasing the dehydration temperature for control as well as the blanched fenugreek leaves.

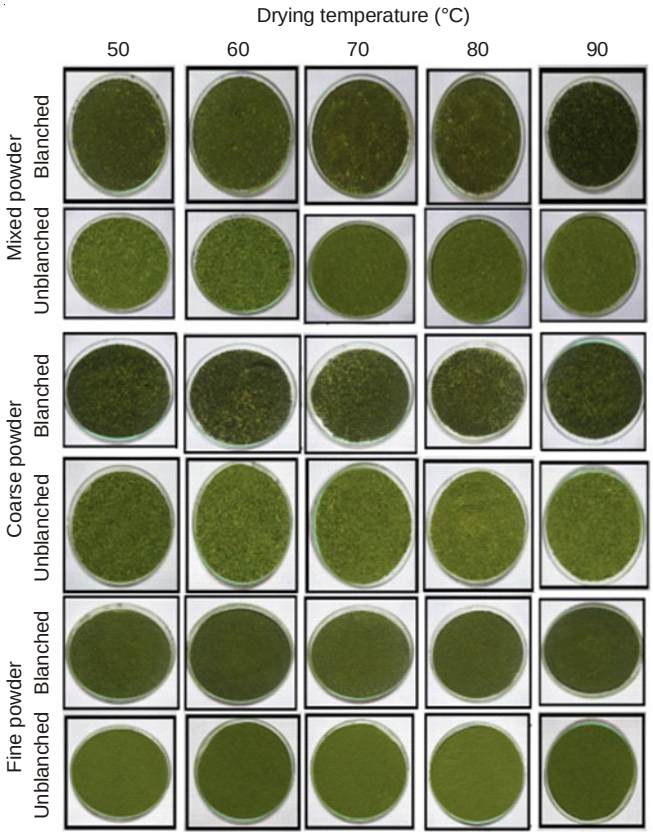

Fig. 1. Effect of sieving and blanching on the powder characteristics

The ground powders (Fig. 1) were analyzed for particle size distribution (Fig. 2) and corresponding size dependent optical characteristics (Fig. 3). It is reflected that the powder obtained at 60 or 70 °C has reflected the acceptable colour characteristics with comparatively better physico-chemical characteristics dealt with (Table-2). The tried combination temperature, 70 °C as initial dehydration temperature with 60 °C as finishing temperature was found to yield a powder (Fig. 4) having better retention of chlorophyll, 788 mg/100 g (Table-3). The fractionated fine powdered fraction having average particle size of 137.13 μm (Fig. 5) further found rich in chlorophyll content (812 mg/100 g) over the mixed powder and the antioxidant capacity of 377 mg/g as the associated functionality apart from nearly 25 % of protein and crude fiber content (Table-3). Crude fiber is considered to be an important and rich component towards human health by improving the gastro intestinal health. Higher content of fiber in the fenugreek powder may improve glucose tolerance by lowering the rate of glucose absorption towards controlling sugar level in blood and also helps in protecting the colon from cancer causing

TABLE-3
CHEMICAL PROPERTIES OF DEHYDRATED FENUGREEK LEAF POWDER

Leaf		Moisture content (%)	Crude fat (%)	Protein (%)	Crude fiber (%)	Ash (%)	Carbohydrate (%)	Chlorophyll (mg/100 g)	Antioxidant (mg/g)
FN	M	4.367 ± 0.081^{b}	2.583 ± 0.172^{a}	26.283 ± 0.8111^{b}	26.983 ± 0.757^{b}	11.245 ± 0.801^{ab}	28.538 ± 2.107^{a}	788.060 ± 61.580^{a}	356.000 ± 6.756^{a}
	C	4.347 ± 0.035^{b}	2.423 ± 0.050^{a}	25.073 ± 0.411^{c}	28.990 ± 0.199^{a}	11.717 ± 0.099^{a}	27.450 ± 0.476^{a}	754.680 ± 37.740^{a}	347.590 ± 1.111^{b}
	F	4.473 ± 0.006^{a}	2.603 ± 0.065^{a}	27.687 ± 0.332^{a}	24.940 ± 0.977^{c}	10.403 ± 0.372^{b}	29.893 ± 1.313^{a}	812.340 ± 7.380^{a}	377.077 ± 3.875^{b}

Means in the same row followed by the different letters are not significantly different ($p > 0.05$).

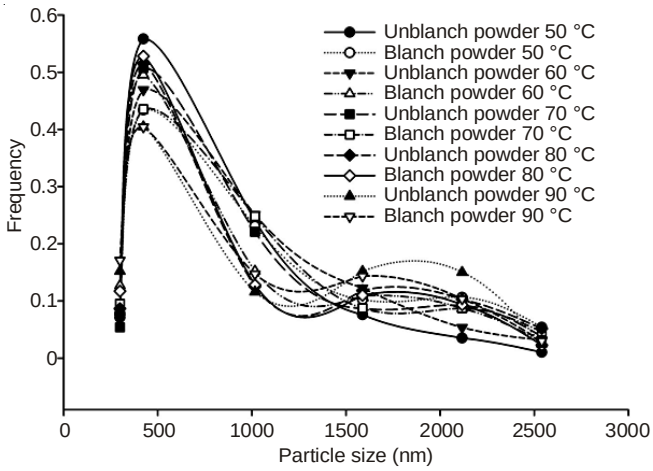

Fig. 2. Pretreatment and temperature dependent particle size distribution of mixed powder

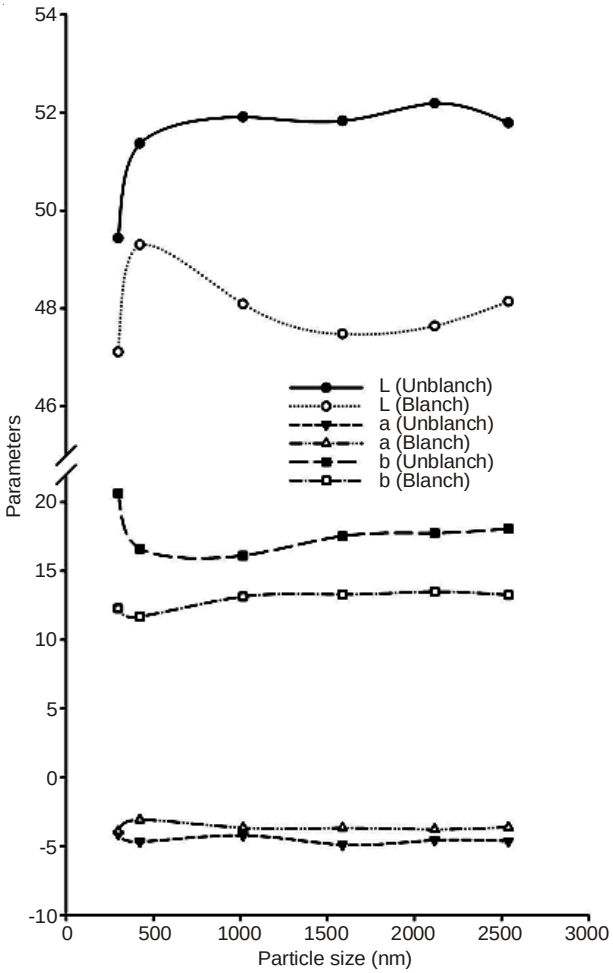

Fig. 3. Pretreatment and size dependent optical characteristics of fenugreek leaf powder

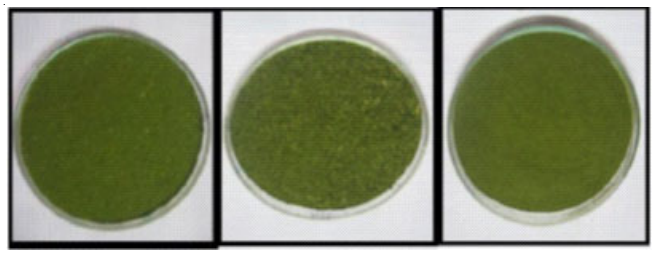

Fig. 4. Fenugreek mix, coarse and fine powder

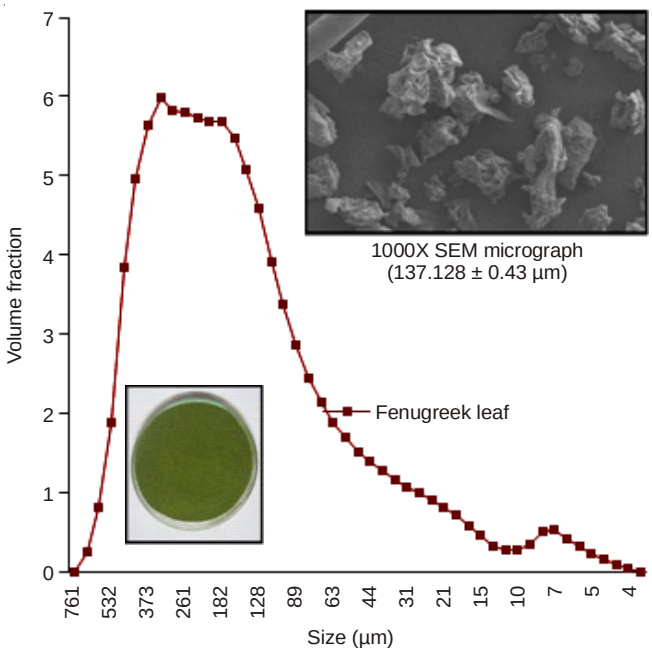

Fig. 5. Particle size distribution and SEM image of fine powder fraction

toxins by binding the toxins present in the food. The absorption of other important constituents of ingested food helps from the risk of cardio vascular disease (CVD) by normalization of blood lipids. It further helps in proper bowel movement to prevent the irritable bowel syndrome (IBS) and constipation in the line of consumption of okra[50-53].

Moisture content and crude protein of fine fraction of fenugreek powder was significantly higher at $p \leq 0.05$ (Table-3). Gravimetric, frictional and rehydration characteristics of fine fraction as compared to the other fractions were also found significantly different at $p \leq 0.05$ (Table-4). Leaf proteins are explored effectively and abundantly for different food applications on nutrition and functional aspects[54].

The role of fenugreek on the persons suffering from ulcer, diabetics and infertility are well documented due to its hypoglycemic and hypo cholesterolemic activity, antioxidant and immuno-modulatory effects apart from the enzymatic pathway modifier associated with this important herb. The fine fraction of fenugreek powder was assessed for the presence of phyto-chemical constituents important for the flavouring, medicinal and therapeutic aspects (Table-5).

The blanched and untreated dried fenugreek leaves in powdered forms were studied for the presence of hexane extractable phyto-chemicals using gas chromatography and mass spectroscopy (GC-MS). Interpretation of obtained mass spectra was compared for revealing the existence of possible chemicals with the database of National Institute of Standard and Technology (NIST) library (Fig. 6). Analysis of fenugreek fraction revealed the presence of alkaloids, flavonoids and saponins, which may be responsible for the hypocholesterolemic, antilipidemic and hypoglycaemic activities to control the person suffering from the life style disorder, the diabetes mellitus (Table-5). The found chemical constituents are in agreement with the studies carried out by the previous researchers[55,56]. Alkaloid is natural bases containing at least one nitrogen atom in its heterocyclic ring are mainly responsible

TABLE-4
PHYSICAL PROPERTIES OF DEHYDRATED FENUGREEK LEAF POWDER

Leaf		BD (kg/m^3)	AOR	COF GLASS	COF STL	COF PLW	WAI (g/g)	WSI (%)
FN	M	457 ± 4.000^b	46.136 ± 2.388^a	0.316 ± 0.002^b	0.334 ± 0.003^b	0.574 ± 0.002^a	2.980 ± 0.117^c	33.533 ± 1.172^a
	C	453 ± 5.000^b	44.482 ± 3.008^a	0.312 ± 0.002^b	0.314 ± 0.000^c	0.533 ± 0.003^c	5.709 ± 0.213^a	30.033 ± 1.834^a
	F	649 ± 30.00^a	46.980 ± 1.319^a	0.350 ± 0.012^a	0.350 ± 0.012^a	0.563 ± 0.014^{ab}	3.666 ± 0.041^b	35.300 ± 4.107^a

where, FN- Fenugreek, M- Mix powder, C- Coarse powder fraction, F- Fine powder fraction, WAC- Water absorption capacity, WSI- Water solubility index
Means in the same row followed by the same letters are not significantly different ($p > 0.05$)

TABLE-5
BIOACTIVE PHYTO COMPONENTS OF *Trigonella foenum-graecum*

Retention time (min)	Name of compound	Nature of compound	Activity/Function [Ref. 55]
19.161	9,12,15-Octadecatrienoic acid, methyl ester	Ester	Antiinflammatory, hypocholesterole, cancer preventive, hepatoprotective
21.591	Phytol	Diterpene	Antimicrobial, anticancer, anti-inflammatory, diuretic
22.25	Menthol	Terpene	Antiallergic, anesthetic, antiasthmatic, antibacterial, antidandruff, antipruritic antirheumatic
24.876	All-*trans*-squalene	Triterpene	Antibacterial, antioxidant, antitumor, cancer preventive, immunostimulant, chemo preventive
25.559	11-Methylsqualene	Triterpene	Antibacterial, antioxidant, antitumor, cancer preventive, immunostimulant, chemo preventive
26.269	Vitamin E acetate	Ester	Antibacterial, antioxidant, antitumor, cancer-preventive, chemopreventive, immunostimulant, immunostimulant, lipoxygenase-inhibitor, perfumery, pesticide, sunscreen
30.11	β-Sitosterol	Steroid	Anticancer, hepatoprotective, antimicrobial, antiasthma, diuretic

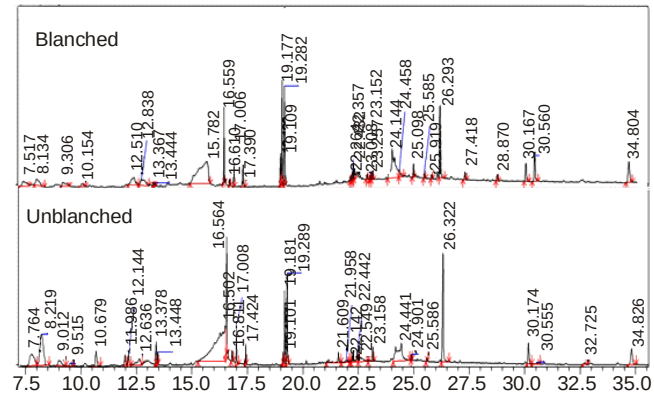

Fig. 6. Gas chromatograph and mass spectroscopy of the fenugreek extract

for the bitter taste. The phenolics and flavonoids are the compounds responsible for the antioxidant effect. The saponin found in fenugreek may act as the starting material for the synthesis of cortisone and progesterone the steroid hormones, which are potentially important in cancer therapy. The presence of various types of terpenes in fenugreek powder further reveals their effect against microorganisms. It is also found that applying the fenugreek paste to scalp in order to control the dandruff problems.

Antibacterial activities: The silver nano was fabricated using the motha (*Cyperus sp*) extract[57] and the antibacterial activity were compared with the fenugreek aqueous extract and the combination of fenugreek extract with antibiotic disc (Fig. 7). The measured antimicrobial activities were observed in terms of zone of microbial inhibition reported as net zone of inhibition[58,59] (Table-6). It is observed that the antibacterial effects of fenugreek leaf extract have great potential as antimicrobial compound against selected pathogens[60]. The synergistic effect of antibiotic with plant extract against resistant

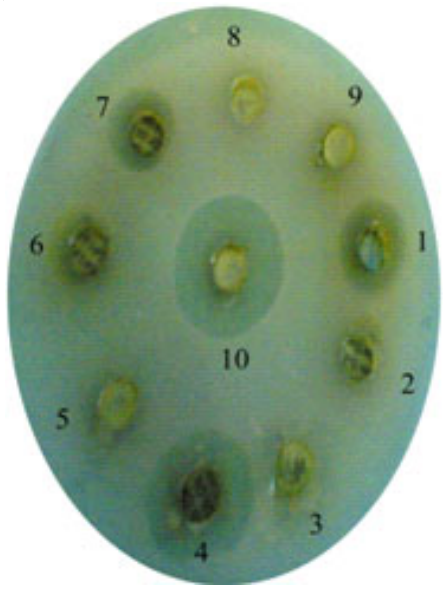

Fig. 7. Effect aqueous fenugreek extract with synergistic effect of antibiotic or silver nano against bacterial strain

TABLE-6
SENSITIVITY PATTERN AGAINST *Staphylococcus aureus*

S. No.	Particulars	Sole effect ZOI (mm)	Synergistic ZOI (mm)
1	Fenugreek extract	7	-
2	Ofloxacin	< 7	7
3	Chloramphenicol	<= 7	8
4	Cefixime	<= 7	10
5	Norfloxacin	< 7	8
6	Amicacin	< 7	8.5
7	Gatifloxacin	< 7	8.5
8	Vancomycin	< 7	7
9	Azithromycin	< 7	7
10	Silver nano	16	-

bacteria may lead to the choice for the treatment of infectious diseases effectively. This synergistic effect enables the use of the respective antibiotic when it is no longer effective by itself during therapeutic treatment.

Conclusion

The dehydration process is governed by the subjected pretreatment, dehydration temperature and time of exposure during dehydration. Blanched powder was found more compact structure with more moisture content as compared to the unblanched leaf powder. The dehydration temperature of 60-70 °C was found suitable for the production of enhanced quality fenugreek powder. The quality of dehydrated fractional functional fenugreek powder is still better for the fenugreek leaves dehydrated at an initial temperature of 70 °C with finishing temperature of 60 °C with its counterpart. The chlorophyll content has been found to be enhanced by more than seven times in powdered fraction of fenugreek leaf with the loss of merely twelve percent. The antioxidant effect on DPPH radical scavenging activity was found to be 377 mg/g. The non-polar solvent extract of fenugreek leaf powder was revealed the presence of various phyto-chemicals having potentially important nutritional, therapeutic and medicinal values. The fenugreek leaf powder is found to have the antimicrobial activity on selected bacterial strains.

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