ORIGINAL ARTICLE

Management of diabetic dyslipidemia with subatmospheric dehydrated barley grass powder

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Diabetes is a chronic, potentially debilitating and often fatal disease. The prevalence of type 2 diabetes is increasing in all populations worldwide. The investigation was carried out to study the impact of barley grass powder (BGP) supplementation on the carbohydrate and lipid metabolism of stable type 2 diabetes mellitus (T2DM) subjects. A total of 59 stable type 2 diabetic subjects were enrolled in the study from pathology laboratories and divided into experimental (n=36) and control groups (n=23). BGP (1.2 g/day) in the form of capsules (n=4) was given to the experimental group subjects for a period of 60 days. Fasting blood sugar (FBS), glycated haemoglobin (HbA1c) and lipid profile levels were monitored at baseline and at 60 days. Paired t test was applied using Microsoft® Office Excel 2003. Supplementation with BGP resulted in a significant decrease in FBS, HbA1c, total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C) and non–high-density lipoprotein cholesterol (Non–HDL-C) and a significant increase in high-density lipoprotein cholesterol (HDL-C) levels. In conclusion, the results obtained suggest that BGP holds promise to be used as a functional food to optimise the health of diabetic subjects.

Key words: Barley grass powder, diabetes, fasting blood sugar, lipid levels

INTRODUCTION

The epidemic nature of diabetes continues to affect ever-increasing numbers of people around the world. In 2010, it is estimated that there will be 285 million people with diabetes in the age group of 20–79 years in the seven regions of the International Diabetes Federation. The number of people with diabetes is expected to rise to 438 million by the year 2030. About 85–95% of all diabetes cases in developed countries are of type 2. According to the Diabetes Atlas 2009, India has the largest number of people with diabetes in the world, with an estimated 50.8 million people diabetic. This figure is slated to rise to 87 million by 2030.[1]

The risk for developing type 2 diabetes mellitus (T2DM) and related metabolic abnormalities is higher among Asian Indians as compared to other ethnic groups. Certain unique clinical and biochemical abnormalities in Indians including increased insulin resistance, greater abdominal adiposity despite lower body mass index, lower adiponectin and increased levels of adipose tissue metabolites make up the "Asian Indian Phenotype".[2-5]

Traditional medicinal plants with various active principles and properties have been used by physicians since ancient times to treat a great variety of human diseases. It has been suggested that compounds present in medicinal plants, either alone or in combination, possess a variety of beneficial activities and have the potential to impart therapeutic effect holistically in complicated disorders like diabetes and its complications.[6-8]

Barley grass (*Hordeum vulgare*) consists of young green leaves of the barley plant. A wide spectrum of vitamins, minerals, amino acids has been isolated from barley grass. Barley grass contains abundant chlorophyll, antioxidants, antioxidant enzymes, and other phytochemicals that neutralise free radicals. Many claims have been made regarding the health benefits of barley grass supplements. Some of the suggested benefits include prevention and cure of cancer, treatment of HIV infection, cholesterol lowering, detoxification of pollutants, protection against solar and other forms of radiation, and boosting energy and immunity.[9] However, there are a few scientific studies supporting these claims. In view of these observations, the effect of barley grass powder (BGP) supplementation on the fasting blood sugar (FBS), glycated haemoglobin (HbA1c) and lipid profile of stable T2DM subjects has been focused upon in the present investigation.

MATERIALS AND METHODS

Preparation of Barley Grass Capsules

Barley grain was procured from the local market and authenticated by botanists from the university. Barley grass was cultivated on a large scale in a farm. The grass was cut when it was around 10–12 inches in height. The entire lot was transported to a food industry where it

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was washed, cut and subjected to cold dehydration (5–10°C) for 24–30 hours. The dried product was then ground into a powder form and nitrogen packed. The powder was then filled in capsules in a local pharmaceutical industry.

Subjects

Fifty-nine stable T2DM subjects who gave verbal consent were enrolled for the study from the pathology laboratories of Vadodara. Based on the willingness to consume BGP capsules, they were then divided into two groups, namely, experimental group and control group. The experimental group consisted of 36 diabetics. The experimental group was given four capsules of BGP daily for a period of 60 days. Each capsule contained 300 mg of BGP, thus amounting to a total of 1.2 g/day. The subjects were asked to take two capsules after lunch and two capsules after dinner. The control group was given no supplementation. During the course of supplementation, no modification in the diet or medication was made. During the study period, none of the subjects took other complementary or alternative medications. The baseline data were collected on general information, anthropometry, medical history and 24 hour dietary recall along with FBS, lipid profile and HbA1c. FBS and lipid profile levels were estimated as per standard procedures using enzymatic kits. HbA1c was estimated using a NycoCard reader. The lipid fractions, low-density lipoprotein cholesterol (LDL-C), very low-density lipoprotein cholesterol (VLDL-C) and non–high-density lipoprotein cholesterol (non–HDL-C), were estimated by calculation. All the parameters were monitored at baseline and at 60 days. The study was approved by the Ethical Committee of the Department of Foods and Nutrition, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat, India (Approval No.: FCSC/FND/ME 35; dated: 25/10/2007).

Statistical Analysis

Results are expressed as mean ± SD. The significance of the data was evaluated using paired *t* test. *P* value of an analysis less than 0.05 was declared to be statistically significant. Confidence interval (CI) limits are specified at 95%. The statistical analysis was carried out using Microsoft® Office Excel 2003.

RESULTS

The mean age of the subjects was 58.1±9.0 years in the control group and 56.9 ± 8.0 years in the group supplemented with BGP. The subjects were categorised as overweight and obese on the basis of the Asia Pacific Classification [body mass index (BMI) ≥ 23 overweight and BMI ≥ 25 obese]. A high percentage of subjects were found to be overweight and obese in the control (69.6%) and experimental groups (83.3%). Waist circumference values were found to be higher than the normal cut-offs (≥90 cm for males and ≥80 cm for females) for both the genders, indicating the presence of abdominal obesity. About 43.5% of subjects in the control group and 52.8% subjects in the experimental group were hypertensive.

Impact of Barley Grass Powder Supplementation on the Fasting Blood Sugar and Glycated Haemoglobin Levels of Type 2 Diabetes Mellitus Subjects

Supplementation of BGP led to a significant fall in the FBS (10.8%) [mean fall = 15.91 mg/dL, CI (0.70–31.12)] and HbA1c (5.2%) [mean fall = 0.45%, CI (0.21–0.70)] values in the experimental group [Table 1]. Such a change was not observed in the control group. FBS and its long-term metabolic control were also studied in relation to the initial FBS values, as initial values are important determinants for the response in supplementation studies. BGP supplementation led to a significant reduction in the FBS (19.2%) [mean fall = 37.1 mg/dL, CI (8.2–66)] and HbA1c (7.3%) [mean fall = 0.68%, CI (0.25–1.11)] values of subjects who had initial FBS greater than 140 mg/dL [Table 2]. In the control group, a marginal but significant reduction was seen with regard to HbA1c levels in subjects having FBS >140 mg/dL (9.4 vs. 9.1%).

Impact of Barley Grass Powder Supplementation on the Lipid Profile of Type 2 Diabetes Mellitus Subjects

The effect of BGP supplementation on the lipid profile of the experimental and control groups is given in Table 3. With supplementation of BGP for a period of 2 months, a significant change was observed in the lipid profile of the diabetic subjects. There was a 5.1% decrease in the total cholesterol (TC) values (195 vs. 185 mg/dL) [mean fall = 9.85 mg/dL, CI (0.96–18.74)]. The atherogenic lipoprotein LDL-C decreased by about 8.2% (122 vs. 112 mg/dL) [mean fall = 9.97 mg/dL, CI (1.05–18.89)]. HDL-C increased by about 5% (40 vs. 42 mg/dL) [mean rise = 2.17 mg/dL, CI (0.62–3.72)]. A 7.7% (155 vs. 143 mg/dL) [mean fall = 12.02 mg/dL, CI (3–21.04)] decrease was found in the non–HDL-C values which represent a mixture of atherogenic

Table 1: Impact of BGP supplementation on the FBS and HbA1c levels of T2DM subjects

	Control (*n* = 23)			Experimental (*n* = 36)		
	Baseline	2 months	*P* value	Baseline	2 months	*P* value
FBS (mg/dL)	154±36	142±49	0.1087	148±56	132±39	0.0478
HbA1c (%)	8.7±1.2	8.6±1.0	0.0638	8.46±1.22	8.02±0.87	0.0009

Data are mean ± SD, BGP = barley grass powder; FBS = fasting blood sugar; HbA1c = glycated haemoglobin lipoproteins. There was a slight nonsignificant reduction in the triglyceride (TG) values as well. In the control group, the lipid profile remained unaltered with an exception of HDL-C which decreased significantly. Thus, BGP supplementation brought about significant reductions in TC and its atherogenic lipoproteins. BGP supplementation also had a significant positive impact on the atherogenic indices, thus lowering the risk of coronary heart disease in the diabetic subjects.

The lipid profile was studied in relation to the initial TC values and is given in Table 4. Diabetic subjects who had TC values ≥200 mg/dL showed a favourable change as compared to those having TC values <200 mg/dL. The fall in

Table 2: Impact of BGP supplementation on the FBS and HbA1c levels of T2DM subjects based on the initial FBS values

	Control			Experimental		
	Baseline	**2 months**	***P* value**	**Baseline**	**2 months**	***P* value**
FBS<140 mg/dL		*n* = 8			*n*=20	
FBS (mg/dL)	117±12	104±19	0.0168	112±24	113±30	0.8464
HbA1c (%)	7.5±0.7	7.6±0.7	0.8263	7.8±1.0	7.54±0.7	0.0586
FBS >140 mg/dL		*n*=15			*n*=16	
FBS (mg/dL)	173±29	162±48	0.3171	193±51	156±35	0.0237
HbA1c (%)	9.4±0.8	9.1±0.8	0.0246	9.3±0.91	8.62±0.66	0.0071

Data are mean ± SD, BGP = barley grass powder; FBS = fasting blood sugar; HbA1c = glycated haemoglobin

Table 3: Impact of BGP supplementation on the lipid profile of T2DM subjects

	Control (*n* = 23)			Experimental (*n* = 36)		
	Baseline	**2 months**	***P* value**	**Baseline**	**2 months**	***P* value**
TG (mg/dL)	148±58	138±29	0.3105	166±88	156±79	0.2673
TC (mg/dL)	190±46	179±31	0.1188	195±44	185±42	0.0366
HDL-C (mg/dL)	46±10	42±6	0.007	40±7	42±6	0.0093
LDL-C (mg/dL)	114±37	109±31	0.3699	122±36	112±37	0.0351
VLDL-C (mg/dL)	30±12	28±6	0.3105	33±18	31±16	0.2673
Non–HDL-C (mg/dL)	144±43	136±30	0.2678	155±44	143±43	0.0131
LDL-C/HDL-C	2.53±0.74	2.59±0.78	0.6492	3.16±1.10	2.73±1.01	0.0025
TC/HDL-C	4.22±1.02	4.26±0.84	0.8283	5.02±1.36	4.49±1.19	0.0009
TG/HDL-C	3.48±1.83	3.35±1.07	0.6328	4.30±2.38	3.81±2.08	0.0743

Data are mean±SD, TG = triglycerides; TC = total cholesterol; HDL-C = high-density lipoprotein-cholesterol; LDL-C = low-density lipoprotein-cholesterol; VLDL-C = very low-density lipoprotein-cholesterol; non–HDL-C = non–high-density lipoprotein-cholesterol

Table 4: Impact of BGP supplementation on the lipid profile of T2DM subjects based on the initial TC values

	Control			Experimental		
	Baseline	**2 months**	***P* value**	**Baseline**	**2 months**	***P* value**
TC<200 mg/dL		*n*=15			*n*=22	
TG (mg/dL)	130±43	136±26	0.5659	135±77	128±42	0.4543
TC (mg/dL)	165±20	165±26	0.9935	167±25	163±34	0.5587
HDL-C (mg/dL)	44±8	41±5	0.0416	39±7	43±6	0.0039
LDL-C (mg/dL)	96±19	97±26	0.8035	100±23	95±34	0.3666
VLDL-C (mg/dL)	26±9	27±5	0.5659	27±15	26±8	0.4543
Non–HDL-C (mg/dL)	122±20	124±26	0.6879	127±24	121±34	0.2702
TC ≥ 200 mg/dL		*n*=8			*n*=14	
TG (mg/dL)	182±70	142±36	0.082	215±83	200±102	0.4308
TC (mg/dL)	236±47	203±26	0.0452	240±28	220±29	0.0093
HDL-C (mg/dL)	51±13	45±6	0.0808	40±7	41±5	0.6564
LDL-C (mg/dL)	148±40	130±29	0.1581	156±26	139±25	0.0343
VLDL-C (mg/dL)	36±14	28±7	0.082	43±17	40±20	0.4307
Non–HDL-C (mg/dL)	185±44	158±26	0.072	199±30	179±29	0.0124

Data are mean±SD, TG = triglycerides; TC = total cholesterol; HDL-C = high-density lipoprotein-cholesterol; LDL-C = low-density lipoprotein-cholesterol; VLDL-C = very low-density lipoprotein-cholesterol; non–HDL-C = non–high-density lipoprotein-cholesterol

TC [mean fall = 19.86 mg/dL, CI (7.08–32.64)], LDL-C [mean fall = 17.39 mg/dL, CI (2.97–31.81)] and non–HDL-C [mean fall = 20.42 mg/dL, CI (6.6–34.24)] values was 8.3, 10.9 and 10.1%, respectively, in subjects having TC value ≥200 mg/dL. A positive point was the significant rise in HDL-C (39 vs. 43 mg/dL) [mean rise = 3.19 mg/dL, CI (1.26–5.12)] among subjects who had TC value <200 mg/dL. On the contrary, in the control group, a fall in HDL-C was seen (44 vs. 41 mg/dL) in subjects having TC value <200 mg/dL.

The impact of BGP supplementation on the lipid profile of the diabetic subjects was also studied in relation to their initial TG values [Table 5]. Hypertriglyceridemic subjects (TG values ≥ 150 mg/dL) showed significant changes in the lipid levels as compared to the normolipidemics. A 16.7% reduction was observed in TG [mean fall = 41.25 mg/dL, CI (6.77–75.73)] values after 2 months of BGP supplementation in experimental hypertriglyceridemic subjects. Concomitantly, a significant reduction in TC (8.8%) [mean fall = 20.26 mg/dL, CI (5.94–34.58)], VLDL-C (16.3%) [mean fall = 8.25 mg/dL, CI (1.35–15.15)] and non–HDL-C (11.7%) [mean fall = 22.23 mg/dL, CI (7.73–36.73)] was also seen in these subjects. In subjects with normolipidemia, an increase in HDL-C was seen which was significant [mean rise = 2.3 mg/dL, CI (0.31–4.29)]. In the control hypertriglyceridemic group, a significant fall in TG and VLDL-C was also noted.

DISCUSSION

BGP supplementation at a level of 1.2 g/day for a period of 60 days in T2DM subjects resulted in significant reductions in FBS, HbA1c, TC, LDL-C and non–HDL-C levels and a significant increase in HDL-C levels.

It has been documented that impaired homeostasis in diabetes mellitus is associated with increased production of reactive oxygen species and depletion of the antioxidant defense systems. Barley grass is purported to be rich in the antioxidant vitamin C. In the EPIC–Norfolk prospective population study, persons in the top quartiles of baseline plasma vitamin C concentrations had a 42% lower risk of stroke as compared to those in the bottom quartile.[10] Another study which examined the relation between vitamin C intake and risk of coronary heart disease in women found users of vitamin C supplements to be at a lower risk for coronary heart disease.[11]

According to the available literature, one of the active ingredients present in barley grass is proanthocyanidin.[12] Proanthocyanidins are secondary plant metabolites having substantial antioxidant activity. Proanthocyanidins are the most abundant polyphenolic compounds in plants and are common constituents of many foods and beverages. Results of various studies support the protective role of proanthocyanidins against diabetes.[13,14] The "French paradox" phenomenon has been linked to the high consumption of red wine which is rich in the complex polyphenols, the proanthocyanidins.[15]

The major flavonoid antioxidants in young green barley leaves are the flavone-C glycosides, saponarin and lutonarin.[16] Saponarin/lutonarin, isolated from young green barley leaves, were examined for their antioxidant activity using cod liver oil, ω-3 fatty acids (eicosapentaenoic acid and docosahexaenoic acid), phospholipids (lecithin I and II), and blood plasma. The saponarin/lutonarin mixture inhibited malonaldehyde formation from cod liver oil,

Table 5: Impact of barley grass powder supplementation on the lipid profile of T2DM subjects based on the initial TG values

	Control			Experimental		
	Baseline	2 months	*P* value	Baseline	2 months	*P* value
TG <150 mg/dL		*n*= 14			*n*=22	
TG (mg/dL)	111±28	125±25	0.15	116±28	126±41	0.2144
TC (mg/dL)	180±26	177±32	0.7023	175±38	172±38	0.5599
HDL-C (mg/dL)	50±9	44±5	0.0001	40±8	43±7	0.0345
LDL-C (mg/dL)	108±22	108±33	0.9240	111±33	104±35	0.2009
VLDL-C (mg/dL)	22±6	25±5	0.15	23±6	25±8	0.2145
Non–HDL-C (mg/dL)	130±23	133±33	0.6215	135±36	129±37	0.3328
TG >150 mg/dL		*n*=9			*n*= 14	
TG (mg/dL)	206±44	158±25	0.0136	245±91	204±99	0.0355
TC (mg/dL)	205±66	181±32	0.0992	227±34	207±42	0.0157
HDL-C (mg/dL)	40±11	40±6	0.9725	39±6	41±4	0.1526
LDL-C (mg/dL)	124±54	109±29	0.1892	139±35	125±39	0.0968
VLDL-C (mg/dL)	41±9	32±5	0.0136	49±18	41±20	0.0355
Non–HDL-C (mg/dL)	165±57	140±27	0.0692	188±36	166±42	0.0101

Data are mean±SD, TG = triglycerides; TC = total cholesterol; HDL-C = high-density lipoprotein-cholesterol; LDL-C = low-density lipoprotein-cholesterol; VLDL-C = very low-density lipoprotein-cholesterol; non–HDL-C = non–high-density lipoprotein-cholesterol ω-3 fatty acids, phospholipids and from blood plasma. The antioxidant activities obtained from the saponarin/lutonarin mixture were comparable to those obtained from α-tocopherol and butylated hydroxy toluene in all the lipids tested.[17]

The cholesterol-lowering effects of barley grass have been attributed to the β-sitosterol fractions of barley leaf extract. β-Sitosterol is a phytosterol or plant sterol. It is mainly known and used for its cholesterol lowering property which is attributed to the inhibition of absorption of cholesterol. It was recognised in the 1950s that plant sterols lower serum concentrations of cholesterol.[18] β-Sitosterol also prevents the oxidation of LDL-C, thereby reducing the risk of atherosclerosis. Previous evidence shows that intake of 2 g/day of stanols or sterols reduced LDL-C by 10%.[19]

Pistachio nuts are rich in monounsaturated fat and phytosterols (199 mg of β-sitosterol/100 g of nuts). Studies conducted to test the cholesterol lowering ability of pistachio nuts have found significant reductions in the ratios of LDL-C:HDL-C and TC:HDL-C.[20,21]

Few studies have reported the beneficial effects of barley grass. Using a rabbit model of atherosclerosis, it was found that the plasma levels of serum triacylglycerol, TC, and LDL-C decreased in rabbits receiving a barley leaf essence supplement (1% w/w) in combination with an atherogenic diet, as compared with animals on the atherogenic diet alone. These findings were supported by histological examination of the thoracic aorta of the rabbits. Atherosclerotic lesions covered 90% of the surface in animals fed only the atherogenic diet compared with 60% in animals receiving barley leaf essence supplement plus an atherogenic diet. Also, the lag phase of low density lipoprotein oxidation increased in the barley leaf essence supplement group compared to the controls.[22]

In a study on type 2 diabetics, supplementation with barley leaf extract (15 g) for 4 weeks reduced the plasma levels of TC and LDL-C, increased the vitamin E contents and lag times of large, buoyant LDL molecules, and small, dense LDL molecules, and decreased lucigenin-chemiluminescence and luminol-chemiluminescence levels in blood. The authors also reported that the response was better with barley leaf extract in combination with antioxidative vitamins C and E than barley leaf extract alone.[23] In another study on hyperlipidaemic subjects, supplementation with 15 g of young barley leaf extract for 4 weeks substantiated the previous observations.[24]

With a control group, none of the subjects being on lipid lowering medication and no significant dietary changes noted before and after supplementation, our data indicate that improvements in lipids may be due to BGP *per se*.

In our study, the subjects consumed 1.2 g of BGP daily, which is equivalent to approximately 11 g of barley grass. Our study findings add to the scientific basis supporting the cardioprotective role of barley leaf extract and/or barley leaves. Since plant foods are natural sources of phytosterols, supplementation of concentrated barley grass powder may be a novel approach to lower cardiovascular risk factors among T2DM subjects.

CONCLUSIONS

We feel that BGP has the potential to be marketed as a neutraceutical product to optimise the health of diabetic subjects. Advocacy measures to promote barley grass cultivation at household level and to incorporate barley grass in various recipes can also be attempted as a health promotion strategy. In depth analysis of the active ingredients of barley grass needs to be carried out to expand the clinical utility of barley grass in other conditions.

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