International Journal of Multidisciplinary and Current Research ISSN: 2321-3124
Research Article Available at: http://ijmcr.com

Protective Effect of Gum Arabic Supplementation for Type 2 Diabetes Mellitus and its Complications

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Accepted 01 April 2016, Available online 06 April 2016, **Vol.4 (March/April 2016 issue)**

Abstract

Background: *Gum arabic (Acacia senegal) is a well known soluble dietary fiber and is regarded as the safest dietary fiber by the United States Food and Drug Administration (US FDA).*
Objective: *To determine the effect of Gum arabic supplementation on human subjects with type-2 diabetes mellitus and its complications by routine hematological and biochemical examinations.*
Materials and Methods: *A clinical trial was conducted in forty participants with a daily supplement of powdered Gum arabic (10g/day), for a period of 16 weeks in a healthy subjects, pre-diabetics, patients with type 2 diabetes mellitus and patients with diabetic nephropathy.*
Results: *All groups showed significant decrease in fasting blood glucose and glycosylated hemoglobin (HbAc1), followed by significant decrease in total protein and uric acid concentration in the blood. Renal function was also improved after Gum arabic supplementation which was clear in all groups with significant decrease in blood urea nitrogen and creatinine concentration in diabetics and diabetic nephropathy patients.*
Conclusion: *All groups recorded overall health improvement. Thus, findings from the study revealed that Gum arabic supplementation had effects on type-2 diabetes mellitus patients and improved the prognosis of the disease.*

Keywords: *Gum arabic, Type-2 Diabetes Mellitus, Diabetic Nephropathy.*

Introduction

Diabetes mellitus (DM) is associated with a significant increased morbidity and mortality resulting from microvascular and macrovascular complications, in particular diabetic nephropathy and cardiovascular disease ([1]. Type 2 diabetes mellitus (T2DM) is much more common, and the vast majority of people with this disorder are associated with a triad of medical disorders, such as obesity, hyperlipidaemia, and hypertension, which have collectively become known as the “metabolic syndrome” or “syndrome X” [2]. The increase in body weight of the general population, a result of high fat, high-calorie diets and a sedentary lifestyle, is the most important factor associated with the increased prevalence of type 2 diabetes [3]. As a result of these complications, particularly cardiovascular disease and diabetic nephropathy, there is an associated significant increase in mortality.

Currently, there are numerous medications that have been proven to improve outcomes in patients with diabetes mellitus (DM) by reducing cardiovascular and renal complications [2]. Treatment of these conditions involves improving diabetic control, reducing blood pressure, and addressing other cardiovascular risk factors. The treatment options for diabetic nephropathy are limited and targeted at reducing the progression of renal disease principally by controlling protein excretion and regulating blood pressure.[4]. Complete treatment of T2DM includes pharmacotherapy and complementary actions, such as a well-balanced diet, physical activity, and generally leading a healthy lifestyle. Numerous data have confirmed that patients suffering from T2DM tend to make dietary mistakes, especially insufficient micronutrient intake [5].

Scientific evidences suggest that high fiber supplementation of dietary intake may have health benefits in T2DM and its complications [6]. Dietary fiber has wide reaching health benefits, including improvement of diabetic control and blood pressure, potentially by alterations in colonic bacterial populations that result in reducing the inflammation and symptoms associated with inflammatory bowel disease, exerting protective effects to prevent colon cancer, enhancing the bioavailability and uptake of minerals such as calcium, magnesium, and possibly iron; lowering some risk factors for cardiovascular disease; as well as promoting satiety,

weight loss and preventing obesity [7]. Also, dietary fiber may play a role in reducing oxidative stress which is associated with reduced insulin dependent glucose disposal and diabetic complications [8]. Guar gum is extracted from Guar bean and is used extensively in the food industry. It is also used as a soluble dietary fiber to reduce post-prandial glucose absorption [9]. Other than its effect on lowering the risk of developing diabetes, several studies have shown that an increase in dietary fiber intake (and foods with a low glycaemic index) lowers post prandial glucose levels and HbA1c in diabetic and non diabetic populations [10].

Gum arabic (GA) is a water-soluble dietary fiber, it is a polysaccharide with branched chains of (21,22,23), linked β-D-galactopyranosyl units containing α- L-arabinofuranosyl, α-L-rhamnopyranosyl, β-Dglucuronopyranosyl, and 4- O-methyl -β-D-glucurono-pyranosyl units. GA is rich in Ca^{2+}, K^{+} and Mg^{2+}. It is produced from the dried gummy exudates of stems and branches of *Acacia senegal* [11]. In the colon, GA is degraded by microorganisms to short chain fatty acids. According to the US Food and Drug Administration, GA is one of the safest dietary fibers and has been an important food 'additive' since ancient times [12]. Supplementation of the diet with GA has been shown to increase fecal nitrogen excretion and lower serum urea nitrogen concentration in patients with chronic renal failure. The data from [3], demonstrate that dietary supplementation with SUPERGUMTM increased serum butyrate, which at least *in vitro* has beneficial effects on renal pro-fibrotic cytokine generation [13].

Earlier studies have yielded evidences for and against the antioxidant effect of GA, as well as the protective effects in experimental hepatic, renal- and cardiac toxicity [14]. GA has been shown to decrease blood pressure [15], to decrease plasma cholesterol concentrations in rats, to foster dental remineralization, to exhibit antimicrobial activity and to stimulate intestinal absorption, thus counteracting diarrhea [16]. In diabetic mice, GA treatment increases urinary Ca^{2+} excretion and decreases plasma phosphate concentration, plasma urea concentration, urinary flow rate, natriuresis, phosphaturia [17], glucosuria, proteinuria as well as blood pressure [18]. The extra-renal effects of GA treatment in mice include the following: decreased expression of intestinal Na^{+} coupled glucose carrier SGLT1 with subsequent delay of electrogenic intestinal glucose transport, glucose induced hyperglycemia, hyperinsulinemia, and body weight gain [19]. Soluble fibers are effective in reducing serum cholesterol by reducing the absorption of fat and cholesterol from the small intestine and absorption of bile acids from the terminal ileum [20].

Although its effects have been extensively studied in animals, there is paucity of data regarding its quantified use in humans. This study investigated the effect of dietary supplementation by using GA on people at risk of developing T2DM, diabetic patients and the consequences of diabetic nephropathy patients under dialysis.

Methods

A clinical trial was conducted with a total of 40 participants from both sexes , they were divided into four groups with a daily supplement of GA (10 g), for a period of 16 weeks. An initial pilot study was conducted in healthy subjects (n=10), followed by test groups of (n=10) patients diagnosed with having T2DM , test group who are at risk of developing T2DM with BMI <30 (the pre-diabetic group), as well as diabetic nephropathy patients (n=10) under regular dialysis periods, received GA (10 g/day) for 16 weeks.

Before the commencement of this study, all participants completed questionnaires about their personal and family history of disease, medication, and lifestyle factors. The fasting blood sugar (FBS) and lipid profile of participants were determined after fasting for at least 8 h. Measurements/samples were obtained at the baseline and after 16 weeks of treatment of Gum arabic. Informed consent was obtained from all participants.

Gum arabic was purchased from Dar Al Savanna Ltd., Sudan and was administered orally after mixing the powder in lukewarm water; one sachet (5 g) before breakfast and another 5 g before going to bed. The sachets were stored at room temperature. The use of GA as a food additive has been approved by the United States Food and Drug Administration (USFDA) [11].

The study was conducted in accordance with the protocol and ethical principles, as approved by the Council of Higher Scientific Research, Taif University, Saudi Arabia Grant No. [1-436-4328].

The assessments included measurement of body mass index (BMI), calculated as the weight (kg) divided by the height squared (m^2). Obesity was defined as a BMI of >30 kg/m and fasting blood glucose for all groups. Blood pressure was measured using a standard mercury manometer in the sitting position after the subject rested for at least 15 min, in accordance with the recommendations of the British Hypertension Society. Hypertension is defined as a systolic blood pressure >140 mmHg and/or diastolic blood pressure >90 mmHg [21].
All other biochemical and hematological parameters measured for the assessment of diabetic complications were done at the baseline and after 16 weeks of GA treatment, according to the manufacturer's instructions [22].

Statistical analysis of differences between means of all parameters was carried out using analysis of the paired and unpaired t-test was used for analysis of pre-treatment and post treatment. A value of $p<0.05$ was taken as a significant and $P<0.0001$ as highly significant probability level. All statistical analysis was performed with GraphPad InStat version 3.00 for Windows 95, GraphPad Software, San Diego California USA, www.graphpad.com.

Table 1*:* The demographic data, body mass index (BMI) and blood pressure for healthy participants and groups of pre-diabetic, diabetic and diabetic nephropathy patients before and after Gum arabic treatment

Parameter	Healthy	Pre-diabetic		Diabetics		Diabetic nephropathy	
		Pre-treatment	Post-treatment	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
n	10	10		10		10	
Body Mass Index (BMI) (kg /m^2)	24.80±1.12	38.53±2.36	36.88±2.42$^{\#}$	30.43±3.02	28.02±2.98*	33.19±3.25	31.62±3.59
Systolic Blood Pressure (mmHg)	122.13±3.93	131.89±2.81	123.00±1.17	140.20±6.65	126.60±5.47$^{\#}$	147.67±5.30	137.33±4.33
Diastolic Blood Pressure (mmHg)	74.56±4.06	82.56±3.18	75.89±2.03	80.20±3.60	74.40±1.69$^{\#}$	89.33±5.21	82.33±1.45

Arithmetic means ± standard error of mean (SEM (n)), that is, number of participants, *indicates significant (P<0.05), $^{\#}$indicates highly significant (P<0.001) difference before the treatment (pre) and after treatment (post) of Gum arabic for 16 weeks.

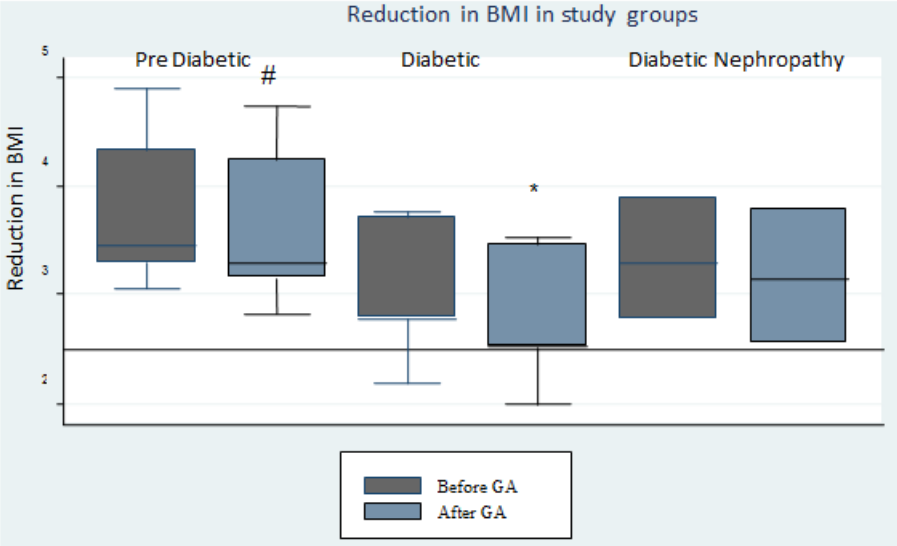

Figure-1: Arithmetic means ± standard error of mean (SEM (n)), that is, number of participants, *indicates significant (P<0.05), $^{\#}$indicates highly significant (P<0.001) difference before the treatment (pre) and after treatment (post) of Gum arabic for 16 weeks

Table-2: Metabolic parameters for the healthy participants and groups of pre-diabetic, diabetic and diabetic nephropathy patients before and after Gum arabic treatment

Parameter	Healthy	Pre-diabetic		Diabetics		Diabetic nephropathy	
		Pre-treatment	Post-treatment	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
Glucose Fasting (mmol/l)	82.80±2.33	113.57±4.24	90.60±1.50$^{\#}$	158.83±13.47	91.93±5.35$^{\#}$	193.89±38.54	112.60±19.54*
HbAc1,(%)	4.57±0.07	5.39±0.12	4.67±0.13*	6.62±0.38	5.21±0.38$^{\#}$	7.68±1.10	5.83±0.87*
Total protein(g/dL)	5.54±0.19	6.84±0.33	5.70±0.30*	7.28±0.33	5.90±0.30*	8.29±0.31	6.53±0.38*
Albumin (g/L)	3.93±0.24	4.44±0.26	4.06±0.27*	3.26±0.14	3.76±0.13*	3.13±0.05	3.83±0.15$^{\#}$
Bilirubin total (mg/dl)	0.40±0.02	0.42±0.03	0.40±0.03	0.54±0.05	0.43±0.16	0.52±0.07	0.36±0.06
Cholesterol (mmol/l)	154.17±10.13	176.33±10.27	152.67±8.69	195.64±22.42	161.07±11.62	210.26±27.00	161.89±7.47
Triglyceriods (mg/dl)	53.40±3.16	145.00±35.53	126.67±30.23	214.82±22.26	174.12±14.98	232.78±32.64	166.81±30.67
Alkaline Phosphatase (U/L)	53.00±3.74	76.33±15.24	54.33±8.11	97.50±8.74	69.93±15.10	164.33±72.66	88.67±18.21
Alanine Aminotransferase (ALT),U/L	20.17±2.72	28.67±3.71	21.33±1.20	16.38±2.79	20.58±2.58	16.82±2.42	18.72±1.87
Aspartate Aminotransferase (AST) ,U/L	18.08±1.91	22.67±0.88	20.33±0.33	14.65±1.06	18.18±3.27	14.70±2.67	17.17±3.55
Uric acid (mg/dL)	3.55±0.18	4.53±0.37	3.30±0.14	7.62±0.63	5.32±0.58	8.65±0.36	5.56±1.15

Arithmetic means ± standard error of mean (SEM (n)), that is, number of participants, *indicates significant (P<0.05), $^{\#}$indicates highly significant (P<0.001) difference before the treatment (pre) and after treatment (post) of Gum arabic for 16 weeks.

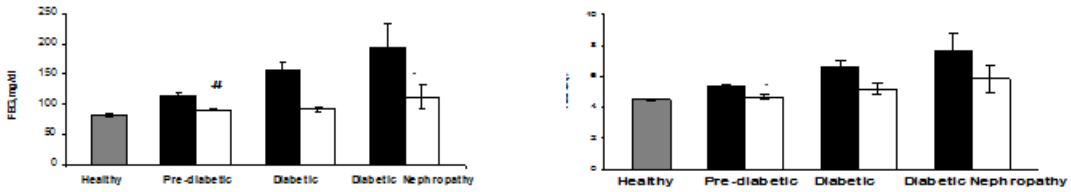

Figure- 2: Effect of gum arabic treatment on fasting blood glucose level (mg/dl, left panel), glycosylated hemoglobin HbAc1 (%, right panel). Arithmetic means ± standard error of mean (SEM), *indicates significant (P<0.05), #indicates highly significant (P<0.001) difference before the treatment (pre) and after treatment (post) of gum arabic for 16 weeks

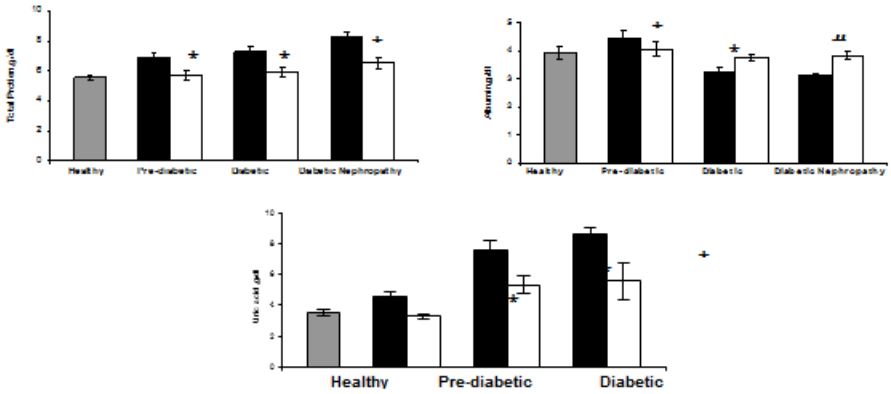

Figure-3: Effect of gum arabic treatment on total protein concentration (g/dl, left panel), albumin concentration (g/dl, middle panel), uric acid concentration (g/dl, below). Arithmetic means ± standard error of mean (SEM), *indicates significant (P<0.05), #indicates highly significant (P<0.001) difference before the treatment (pre) and after treatment (post) of gum arabic for 16 weeks

Table-3: Blood electrolytes and renal functions tests for the healthy participants and groups of pre-diabetic, diabetic and diabetic nephropathy patients before and after Gum arabic treatment

Parameter	Healthy	Pre-diabetic		Diabetics		Diabetic nephropathy	
		Pre-treatment	Post-treatment	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
Blood Urea Nitrogen (mg/dL)	13.40±2.83	25.80±1.39	20.00±1.87*	43.91±9.97	25.08±4.86*	127.67±10.39	82.44±7.74#
Creatinine (mg/dL)	0.54±0.06	0.66±0.07	0.57±0.05	4.57±0.83	3.78±0.63*	8.94±1.34	6.85±1.28*
Calcium (mmol/L)	2.41±0.20	2.60±0.04	2.00±0.29	4.40±1.10	2.08±0.23	4.94±1.05	2.47±0.48*
Phosphorous (mg/dL)	2.27±0.27	1.43±0.23	2.77±0.43	1.57±0.19	2.59±0.20#	1.56±0.30	2.62±0.36*
Sodium (mmol/L)	142.67±0.33	143.33±0.33	142.33±0.88	135.57±1.56	136.17±2.97	135.88±2.66	136.75±1.70
Potassium (mmol/L)	4.24±0.23	4.27±0.15	3.97±0.09	4.53±0.28	3.81±0.38	4.77±0.29	4.30±0.31
Chloride (mmol/L)	97.33±1.76	97.00±3.61	95.67±1.86	99.53±3.94	96.23±3.42	97.54±1.86	95.40±6.50
Magnesium (mg/dL)	1.70±0.06	1.47±0.12	1.58±0.05	1.42±0.50	1.59±0.55	1.09±0.17	1.27±0.20

Arithmetic means ± standard error of mean (SEM (n)), that is, number of participants, *indicates significant (P<0.05), #indicates highly significant (P<0.001) difference before the treatment (pre) and after treatment (post) of gum arabic for 16 weeks.

Results

Forty participants aged between 35 to 60 years, who met the inclusion and exclusion criteria, were enrolled into the study. Out of these, 10 healthy participants were used as control to show the normal values of all biochemical parameters. From all other groups, measurements were taken before (pre) and after (post) the treatment of GA for 16 weeks. Every participant completed the study with no side effects reported after GA ingestion; since the powder of GA (Acacia sengeal) is colorless, tasteless and meets all pharmaceutical standards for preparation.

Pre and post analysis among the study group showed significant reduction in BMI, as shown in Table-1 and Figure-1, following regular intake of 10 g/day GA for 16 weeks. Significant drops in blood pressure were seen in each of the individual groups, especially in the pre-diabetic group (Table 1), which is reported as the antihypotension effect of GA.

Pre and post analysis among the study group showed significant reduction in fasting blood glucose level and HbAc1 (Table- 2 and Figure- 2); this is very important for diabetic patients in long term treatment of diabetic complications.

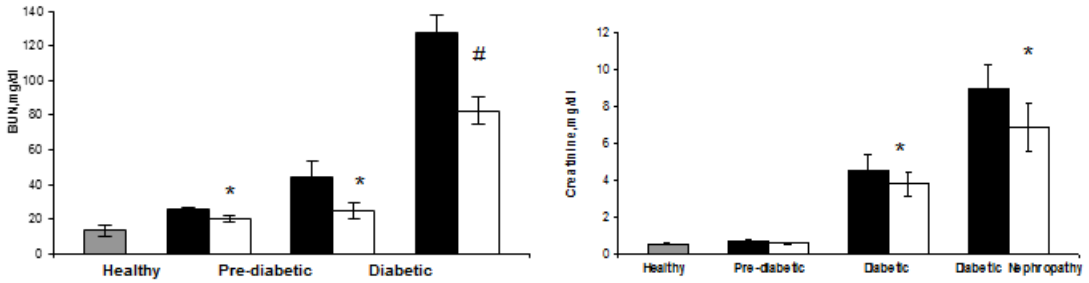

Figure-4: Effect of Gum arabic treatment on blood urea nitrogen concentration (mg/dl, left panel), blood creatinine concentration (mg/dl right panel). Arithmetic means ± standard error of mean (SEM), *indicates significant (P<0.05), #indicates highly significant (P<0.001) difference before the treatment (pre) and after treatment (post) of Gum arabic for 16 weeks

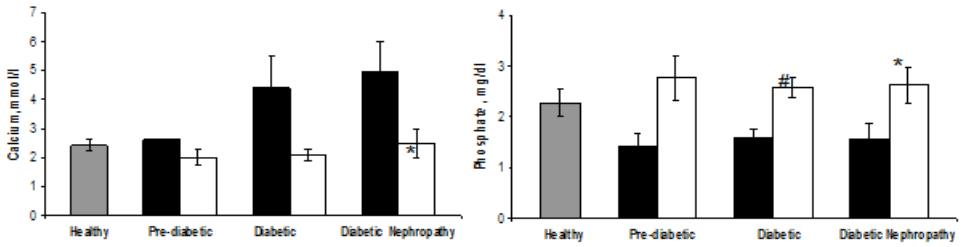

Figure-5: Effect of Gum arabic treatment on blood calcium concentration (mg/dl, left panel), blood phosphate concentration (mg/dl, right panel). Arithmetic means ± standard error of mean (SEM), *indicates significant (P<0.05), #indicates highly significant (P<0.001) difference before the treatment (pre) and after treatment (post) of Gum arabic for 16 weeks

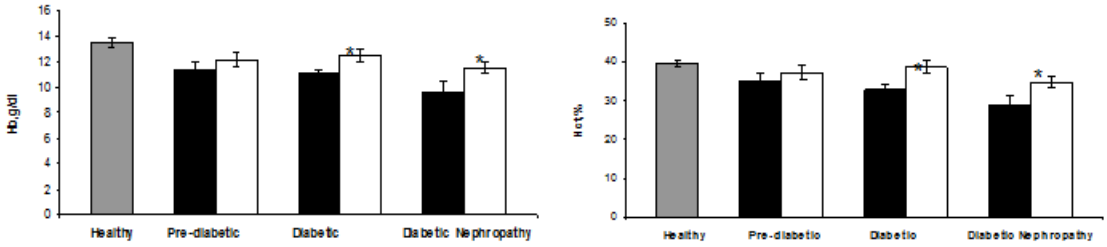

Figure- 6: Effect of Gum arabic treatment on hemoglobulin concentration (g/dl, left panel), packed cell volume (%, right panel). Arithmetic means ± standard error of mean (SEM), *indicates significant (P<0.05), #indicates highly significant (P<0.001) difference before the treatment (pre) and after treatment (pos) of Gum arabic for 16 weeks

This was also followed with significant effect regarding the concentration of total protein and albumin (Table- 2 and Figure- 3). There was remarkable reduction in uric acid concentration for all groups reaching significant difference after GA treatment (Table 2 and Figure 3), showing the protective effect of GA for renal diseases.

A significant drop in blood urea nitrogen (BUN) was recorded in all study groups ,also, blood creatinine concentration reduced significantly in diabetic and diabetic nephropathy patients, after treatment with GA and this could convey some renal protection effect of GA (Table-3 and Figure -4). Calcium concentration was also reduced in all groups, but it was significantly reduced in diabetic nephropathy patients. This was parallel with significantly increased in blood phosphorus concentration, mainly in diabetic and diabetic nephropathy patients showing the characteristic of phosphate biding of GA (Figure-5). It is well-known that GA is rich in Ca^{2+}, K^{+}, and Mg^{2+} salts [27]; however, from the results of this study, no statistically significant change was observed regarding the Na^{+}, K^{+}, and Cl^{+}. But blood calcium and concentration in diabetic nephropathy patients showed a significant reduction, followed by significant increase in blood Mg^{2+} concentration in diabetic nephropathy groups.

After the treatment with GA, the results showed beneficial effect on the hematological parameter; this indicated an improvement of the overall health condition to most of the participants and this was significantly clear with increase in hemoglobin concentration and packed cell volume (Figure-6).

Discussion

Dietary fiber plays an important role in controlling postprandial glycemic and insulin response in diabetic

patients. There is an extensive literature on the influence of fiber on gastric emptying and its inverse relationship with the regulation of postprandial blood glucose responses in response to various fiber rich nutraceuticals [23]. This study revealed the beneficial effects of GA on diabetic, pre-diabetic, and diabetic nephropathy patients regarding the complication of T2DM. These effects are based on the ability to differentially interact with ingested electrolytes and are reflected by complementary changes in the biochemical parameters of the blood. Previous studies on animals have shown that GA can influence the electrolytes secretion and these effects could be favorable for renal and extra-renal functions [19].Although, patients with diabetes are advised to increase the intake of dietary fiber, according to the China National Health and Nutrition Survey (2002), the average daily intake of soluble dietary fiber was found to be only 5.5 g among diabetic patients in China [24]. In 2007, the American Diabetes Association recommended that diabetic patients should consume 14 g/1000 kcal/day of fiber, because a high amount of fiber is necessary to improve glucose control [25].

Soluble dietary fiber promotes beneficial physiological effects such as laxation, reduction in blood cholesterol and postprandial blood glucose modulation. Long term consumption of high soluble fiber diets has been shown to improve glycemic control of diabetic patients, but the overall energy and nutrients content of the diets were not kept constant [23].Baseline biochemical data for the group of healthy individuals and for the incipient nephropaths showed statistically significant decrease, fasting blood glucose and HbAc1. Moreover, GA treatment prevented body weight gain, following 16 weeks of receiving 10 g/day of GA. It has been shown in other studies that a diet rich in dietary fibers is associated with reduced body weight and prevention of metabolism. In patients with T2DM, an increased intake of dietary fiber improved glycemic control and reduced hyperinsulinemia [26]. The proposed explanations for the beneficial effects could be that dietary fibers may delay gastric emptying and this interacts with food intake and body weight through satiety, glycemia and insulinemia, blood lipids, and blood pressure [30].

It is well-known that GA is rich in Ca2+, K+, and Mg2+ salts [27]; however, in our results there was no statistically significant difference regarding Na+ , K+ , and Cl+. An increase in Mg2+ concentration was noticed. Also, GA treatment caused a decrease in Ca2+ concentration, followed by a profound and significant decrease in plasma phosphate concentration. Several positive effects of whole wheat and its byproducts on carbohydrate and insulin metabolism have also been reported; wheat bran and whole wheat products are rich sources of dietary fiber, magnesium (main cofactor of enzymes involved in glucose metabolism and insulin secretion), potassium, phenolic acids, α-tocopherols, carotenoids and antioxidants [28].

The most current evidence reveals that consumption of nuts in type 2 diabetic patients also has beneficial effects on postprandial glycemic response following high-carbohydrate meals, attenuates postprandial oxidative stress and inflammatory processes, normalizes lipid and lipoprotein levels, decreases lipid atherogenicity, and improves insulin resistance [29]. It is believed that the majority of beneficial effects of whole wheat grain are related to bran and germ fractions; wheat bran is a major source of fiber, lignans, phenolic acid, and alkylresorcinol and beyond the health promotion of gastrointestinal tract and weight management, it could improve postprandial glycemic response, glycosylated hemoglobin, lipid disorders and other cardiovascular risk factors in diabetic patients [30]. It seems that a diet enriched with dietary fiber like GA may be an effective strategy to improve glycemic control and prevent renal disease in type 2 diabetic patients.

GA is a large molecular weight polysaccharide and is widely used in the food industry. GA is used in Middle Eastern countries for the treatment of patients with chronic and end-stage kidney disease [31]. Data from an earlier study on animals disclosed some effects of GA treatment, which may be beneficial for T2DM complication; this could be beneficial in delaying the progression of renal disease [19]. The increase in plasma phosphate concentration resulted in a corresponding increase in the plasma concentration of ionized Ca2+, thereby counteracting hyperparathyroidism, a major pathophysiological parameter in advanced renal disease, plus the remarkable decrease in blood urea nitrogen and serum creatinine as observed in this study[19].

Results from the study on humans showed a favorable influence of GA treatment in diabetic nephropathy with clear decrease in BUN and creatinine concentration, which was confirmed in this study as well as in patients suffering from renal failure. GA was found to increase fecal nitrogen excretion, providing an additional approach to lowering serum urea nitrogen [13]. In rat models of acute gentamicin nephrotoxicity, GA modestly ameliorated histological and biochemical parameters [12], an effect attributed to a decreased production of free oxygen radicals.

In most of the hematological parameters, there were no statistically significant differences between all the groups, except the increase in hemoglobin (Hb) and Hematocrite (HCT) . In general, there was little in the way of change in the simple hematological parameters following the ingestion of GA when looking at the group as a whole. The most striking observation was the marked decrease of albumin and uric acid following GA treatment. The decrease in albumin concentration could have been due to a decrease in blood pressure. Moreover, the antihypertensive effect of GA has earlier been demonstrated in humans [15], but in this study, there was no significant change in other lipid parameters as reported in the study of Rima, *et al*. [32].

Conclusions

In conclusion, this study showed that GA supplementation caused an overall improvement in biochemical factors related to T2DM and its complications. These observations have potential implications for the prevention and management of T2DM and its complications.

Acknowledgement

The authors were supported by the Higher Studies Council of Taif University, Saudia Arabia. The authors have no conflict of interest.

References

[1]. Chien-Chang Liao, Chao-Shun Lin, Chun-Chuan Shih, Chun-Chieh Yeh,Yi-Cheng Chang, Yuan-Wen Lee, and Ta-Liang Chen (2014) : Increased risk of fracture and postfracture adverse events in patients with diabetes: two nationwide population-based retrospective cohort studies. Diabetes Care. 37:2246-52. PMID: 24804698 DOI: http://dx.doi.org/10.2337/dc13-2957.

[2]. Glover, David A. (2012): The effects of dietary supplementation with Gum arabic on blood pressure and renal function in subjects with Type 2 diabetes mellitus MD Thesis, Cardiff University

[3]. Kenneth S. Polonsky (2012) :The past 200 years in diabetes.N Engl J Med ;367:1332–134

[4]. Gaede P, Lund-Anderson H, Parving H-H, and Pedersen O.(2008) : Effect of a multifactorial intervention on mortality in type 2 diabetes. N Engl J Med ;358:580-91.

[5]. Franz MJ, Powers MA, Leontos C, Holzmeister LA, Kulkarni K, Monk A, Wedel N, and Gradwell E.(2010) : The evidence for medical nutrition therapy for type 1 and type 2 diabetes in adults. J Am Diet Assoc. ;110:1852-89. doi: 10.1016/j.jada.20 10.09.014.

[6]. Melissa M. Kaczmarczyk, Michael J. Miller, and Gregory G. Freund (2012) :The health benefits of dietary fiber: beyond the usual suspects of type 2 diabetes, cardiovascular disease and colon cancer.Metabolism. August ; 61(8): 1058–1066. doi:10.1016/j.metabol.

[7]. Pineiro, M.; Asp, N.G.; Reid, G.; Macfarlane, S.; Morelli, L.; Brunser, O. and Tuhy, K. (2008) : FAO Technical meeting on prebiotics. J. Clin. Gastroenterol. Vol. 42, S156–S159.

[8]. Brownawell, A.M.; Caers, W.; Gibson, G.R.; Kendall, C.W.C.; Lewis, K.D.; Ringel, Y. and Slavin, J.L.(2012) : Prebiotics and the health benefits of fiber: Current regulatory status, future research, and goals. J. Nutr. Vol. 142, 1–13

[9]. Tiss A, Carriere F, Verger R. (2001) : Effects of gum arabic on lipase interfacial binding and activity. Anal Biochem vol.,294:36-43.

[10]. Van Loo, J.(1995) : Coussement, P.; de Leenheer, L.; Hoebregs, H.; Smits, G.On the presence of inulin and oligofructose as natural ingredients in the western diet. Crit. Rev. Food Sci. Nutr. vol., 35, 525–552.

[11]. Anderson DM. (1986) : Evidence for the safety of gum arabic (Acacia senegal (L.) Willd.) as a food additive--a briefreview. Food Addit Contam ;3:225-230.

[12]. Ali BH, Al Qarawi AA, Haroun EM, and Mousa HM.(2003) : The effect of treatment with gum arabic on gentamicin nephrotoxicity in rats: a preliminary study. Ren Fail 25:15-20.

[13]. Bliss DZ1, Stein TP, Schleifer CR, Settle RG.(1996) : Supplementation with gum arabic fiber increases fecal nitrogen excretion and lowers serum urea nitrogen concentration in chronic renal failure patients consuming a low-protein diet. Am J Clin Nutr 63:392-398.

[14]. Ali BH, Ziada A, and Blunden G. (2009) : Biological effects of gum arabic: a review of some recent research. Food ChemToxicol ;47:1-8.

[15]. Al Mosawi AJ (2002) : The challenge of chronic renal failure in the developing world: possible use of acacia gum. Pediatr Nephrol ;17:390-391.

[16]. Ibrahim MA, Kohn N, and Wapnir RA. (2004) : Proabsorptive effect of gum arabic in isotonic solutions orally administered to rats: effect on zinc and other solutes. J Nutr Biochem 15:185-189.

[17]. Nasir O,Artunc F,Saeed A,Kambal MA,Kalbacher H,Sandulache D,BoiniKM,Jahovic N,Lang F. (2008) :Effect of gum Arabic (Acacia Senegal) on water and electerolyte balance in healthy mice .JRen.Nutr; 18;230-238

[18]. Nasir Omaima, Umbach AT, Rexhepaj R, Ackermann TF, Bhandaru M, Ebrahim A, Artunc F, K``empe DS, Puchchakayala G, Siraskar B, Föller M, Saeed A, Lang F. (2012): Effects of Gum Arabic (Acacia senegal) on Renal Function in Diabetic Mice.Kidney Blood Press Res; Apr 3;35(5):365-372. [Epub ahead of print]PMID:22473073

[19]. Omaima Nasir.(2013) : Renal and Extrarenal Effects of Gum Arabic (Acacia Senegal) – What Can be Learned from Animal Experiments? Kidney Blood Press Res ;37:269-279 DOI: 10.1159/000350152.

[20]. Younes H, Garleb K, Behr S, Remesy C, and Demigne C. (1995) : Fermentable fibers or oligosaccharides reduce urinary nitrogen excretion by increasing urea disposal in the rat cecum. J Nutr; 125:1010-1016.

[21]. American Diabetes Association: Standards of medical care for patients with diabetes mellitus. Diabetes care.(2002) ; 25: S33-S49.

[22]. Russell Warnick, MS, Mary M. Kimberly, Parvin P. Waymack, , Elizabeth T. and Leary, Gary L. Myers. (2008) :Standardization of Measurements for Cholesterol, Triglycerides, and Major Lipoproteins G. LABMEDICINE j Volume 39 Number 8.

[23]. Kang Yu, Mei-Yun Ke, Wen-Hui Li, Shu-Qin Zhang B.S. and Xiu-Cai Fang. (2014) : The impact of soluble dietary fibre on gastric emptying,postprandial blood glucose and insulin in patients with type 2 diabetes. Asia Pac J Clin Nutr ;23(2):210-218

[24]. Wang LD.(2005) : The report of National Health and Nutrition Survey. Beijing: People Medical Publishing House.

[25]. Zheng K, Ke MY, and Wang ZF.(2007) : Liquid nutrient load test in assessment of proximal stomach function in healthy subjects. Basic and Clinical Medicine. ;27:319-23.

[26]. Parvin Mirmiran, Zahra Bahadoran, and Fereidoun Azizi. (2014) : Functional foods-based diet as a novel dietary approach for management of type 2 diabetes and its complications: A review .World J Diabetes , June 15; 5(3): 267-281 ISSN 1948-9358 (online)

[27]. Deckwer WD, Dill B, Eisenbrand E, Bornscheuer U, Pühler A, Heiker FR, Kirschning A, Schreier P, Fugmann B, Pohnert G, Gamse T, and Hulpke H. (2006) : Römpp Online. Georg-Thieme-Verlag; Stuttgart.

[28]. Whent M, Huang H, Xie Z, Lutterodt H, Yu L, Fuerst EP,Morris CF, Yu LL, and Luthria D. (2012) : Phytochemical composition,anti-inflammatory, and antiproliferative activity of whole wheat flour. J Agric Food Chem ; 60: 2129-2135 [PMID: 22321109 DOI: 10.1021/jf203807w].

[29]. Jenkins DJ, Hu FB, Tapsell LC, Josse AR, and Kendall CW.(2008) : Possible benefit of nuts in type 2 diabetes. J Nutr ; 138:1752S-1756S [PMID: 18716181]

[30]. Stevenson L, Phillips F, O'Sullivan K, and Walton J. (2012) : Wheat bran:its composition and benefits to health, a European perspective.Int J Food Sci Nutr ; 63: 1001-1013 [PMID: 22716911 DOI: 10.3109/09637486.2012.687366]

[31]. Al-Majed AA, Mostafa AM, Al-Rikabi AC, and Al-Shabanah OA.(2002) : Protective effects of oral arabic gum administration on gentamicin-induced nephrotoxicity in rats. Pharmacol Res 46:445-451, 2002.

[32]. Rima E. Mohamed, Mohammed O. Gadour, and Ishag Adam . (2015) : The lowering effect of Gum Arabic on hyperlipidemia in Sudanese patients. Front Physiol. ; 6: 160. Published online 2015 May 18. doi: 10.3389/fphys.2015.00160